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Assessing the Sensitivity of Small-Scale Fishery Groups to Climate Change in Lake Kariba, Zimbabwe

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Abstract: Climate change continues to pose threats to fisheries and fishery-dependent communities globally. Vulnerability to climate change is a function of exposure, sensitivity, and adaptive capacity. Sensitivity is largely determined by the differences in socio-economic conditions among communities, and conflicts over resources often exacerbate this sensitivity. This study aims to understand factors affecting the sensitivity to climate change. The objectives are twofold: first, to develop indicators affecting sensitivity and to determine how they affect sensitivity, second, to compare sensitivity of two small-scale fishing groups (fishing camps and fishing villages). The study used twelve indicators, which are categorized into two; the community characteristics and assets, and threats and conflicts. Results show that fishing camps are less sensitive to climate change than fishing villages since they have more varied livelihood sources, such as crop farming. This allows for more sources of income. Both groups experience conflict with other lake users and wildlife attacks, which amplify their sensitivity through the reduction of fishing grounds and the damaging of fishing gear. It also shows that both climate and non-climate factors affect sensitivity, and understanding this can help to increase adaptive capacity. The findings allow for formulation of policy recommendations to help strengthen the livelihoods of small-scale fisheries.

Keywords: climate change; communities; conflict; fisheries; households; Kariba; sensitivity; vulnerability; wildlife; Zimbabwe

1. Introduction

According to the Food and Agriculture Organization of the United Nations (FAO) guidelines for securing sustainable small-scale fisheries (SSF), SSF are described as "artisanal, characterized by low technology, low capital and fishing practices that are undertaken by individual households and not companies. They tend to be firmly rooted in local communities, traditions and values" [1]. Most of the SSF are self-employed and usually provide fish for direct consumption within their households or communities. Women often play a significant role in post-harvest processing and marketing. In developing countries, inland fisheries are very important for SSF as they form a crucial part of rural livelihoods [2]. SSF in low-income countries are known for their high resource dependency, which may cause resource degradation, poverty, and marginalization [3,4], but communities can self-organize their resource use to prevent tragedy of the commons [5]. There is evidence of the impacts of climate variability and change on aquatic ecosystems, and fishery-dependent livelihoods [6–10]. According to Brander and FAO [11,12], the small-scale fisheries sector will be affected by climate change through fluctuating water levels and flooding events. Increased frequency in wind and storm activity, together with extreme weather events, will affect the productivity, distribution, and abundance of fish species [13]. These changes pose risks to human well-being, assets, and processes throughout the fisheries production chain [14,15], leading to increased economic challenges and missed developmental opportunities for fisheries-dependent communities [16].

The vulnerability concept is fundamental to understanding and responding to socio-ecological system changes, which include climate change and variability [17,18]. Vulnerability encapsulates the potential for damage or harm that may be done by climate change to a system and also its capacity to adapt. It is the degree to which a system is susceptible to adverse effects of climate change, including climate variability and extremes.

Vulnerability can be determined through both top-down quantitative and bottom-up qualitative assessments that do not focus on climatic variability and change alone, but also assess the underlying development issues and underlying community conditions. These assessments consider that social groups in communities are not equally vulnerable and that the differences in vulnerability result from the differences in attributes, such as sex, social class (wealth), education, ethnicity, and health [14–17]. According to Climate Investment Funds (CIF) [18], bottom-up approaches are used in communities' social vulnerability assessments, using qualitative methods, such as focus group discussions and other participatory approaches.

Vulnerability is characterized as a function of exposure, sensitivity, and adaptive capacity [19,20]. Exposure is defined as "the nature and degree to which a system is exposed to significant climatic variations" [21]. Adaptive capacity also is defined as "the degree to which adjustments in practices, processes or structures can moderate or offset potential damages to cope with the consequences" [22].

Each of the three dimensions of vulnerability (exposure, sensitivity, and adaptive capacity) has indicators, which are essential for comprehensive vulnerability assessments. Birkmann [23] described standard criteria for indicator development that include; policy-relevance, statistically sound, and data comparability. Sensitivity indicators usually denote first order effects of stresses [19], and include characteristics such as dependence on climate-sensitive resources for nutrition and income [24]. According to Weis et al. [25], sensitivity has physical, economic, social, environmental, and cultural dimensions. Due to the complexity and multiple factors to consider, FAO [26] recommend consideration of sex, marginalized groups, food security, poverty, globalization, governance and management, post-harvest losses, vessels, and trade as vulnerability indicators in fisheries and aquaculture.

Sensitivity, therefore, encapsulates the inherent characteristics of a community that are likely to influence harm [25]. In this study, sensitivity is determined by evaluating the community characteristics including livelihood assets and the dependence on fisheries, as well as threats and conflicts experienced by SSF. The paper focuses on the sensitivity of small-scale fisheries of Lake Kariba, as the variables assessed are considered to constrain or influence the way in which adaptation to climate change may occur, in livelihood vulnerability assessments [27]. Sensitivity is also believed to reflect the responsiveness of a system to climatic influences, and the extent to which changes in climate may affect it in its current state [28].

Lake Kariba is an artificially created lake (as described later), which is located in Southern Africa and forms a border between Zambia and Zimbabwe. It is an economically significant ecosystem that supports the largest tilapia fish farming area in Africa [29], a commercial fishery that contributes significantly to the economies of Zambia and Zimbabwe, SSF that support local livelihoods, hydropower generation, tourism, sport fishing, crocodile farming, and community aquaculture. According to FAO [30], fish production at Lake Kariba has been on the decline since the 1990s. The artificial nature of the lake makes it sensitive to perturbations in environmental conditions, such as droughts. Climate change research on Lake Kariba indicates that the lake's water temperature has warmed by close to 2 °C, with changes in thermal stratification, increased lake water residence period, decreasing rainfall, and increased evaporation rates decline in phytoplankton and zooplankton abundance [31,32]. Furthermore, hydropower generation, which is non-climatic, has a direct negative impact on the water levels of the lake. However, in Lake Kariba, there are different management regimes from Zambia and Zimbabwe, which have not been well coordinated [30,33].

The Lake Kariba catchment is one of the primary areas of wilderness and protected areas on the Zimbabwean side. As a result, SSF share space with wild animals, including man-eating crocodiles [34]. In order to promote local livelihoods and encourage community involvement, both the Combination Lakeshore Master Plan and fishery co-management programs were developed in the 1990s. The principle objective of these programs was to improve resource management and encourage the involvement of fishing communities in the management of exclusive fishing zones [35]. The co-management process was accomplished within a policy framework that was parallel to the Communal Area Management Program for Indigenous Resources (CAMPFIRE), which sought to share the benefits from wildlife programs, especially hunting, with communities [36]. However, the above-mentioned policy instruments are not working in the best possible way.

The co-management in Zambia led to dividing the lake into four zones, and each zone was placed under the jurisdiction of traditional leadership authorities, called chiefs. They formed zonal management committees that are responsible for monitoring fishing regulations that were set up by the Department of Fisheries [37]. Zambia emphasizes the social considerations in their management of small-scale fisheries in Lake Kariba, and, as such, the rate of exploitation of fish is considered to be intensive than that is expected. A study on the small-scale fisheries of Lake Kariba conducted both on the Zambian and Zimbabwean side revealed that; unlike the Zimbabwean management regime, Zambian fishery regulatory authorities do not limit the number of nets that a fisher can use [33].

Local communities along Lake Kariba depend on fisheries, yet there has been no empirical study exploring the relationship between livelihoods and climate change impacts. The two groups of SSF in Lake Kariba (fishing camps and fishing villages) differ in the administration and livelihood strategies. This study adopts the bottom-up vulnerability assessment approach to contribute empirical evidence on SSF′ sensitivity to climate change impacts by using socio-economic indicators, as suggested by FAO and GIZ [12,16]. The study aims to understand the first order stressors affecting sensitivity to climate change through identifying (i) SSF community characteristics, including livelihood assets, and (ii) threats to SSF (including conflict with other lake users), all of which may exacerbate sensitivity. The study also explores policy suggestions to reduce exposure, sensitivity, and improve adaptive capacity at the household and community levels.

2. Materials and Methods

2.1. Study Area

Lake Kariba lies between the border of Zambia and Zimbabwe. It was constructed by damming the Zambezi river between 1958 and 1963 (Figure 1) and is the second largest man-made lake by volume in the world. It has a storage capacity of 185 billion m^3, a surface area of 5580 km^2, and a length of approximately 280 km [38]. The lake is divided into five hydrological basins on the Zimbabwean side according to rivers that flow into it.

There are 41 camps and villages along the lake shore, of which six are fishing camps and 35 are fishing villages. The fishing camps are regulated directly by the Zimbabwe Parks and Wildlife Management Authority (ZPWMA), and are registered with the Ministry of Small and Medium Enterprises (SMEs) and Cooperative Development. The regulations only allow for those practicing fishing from fishing camps to fish for limited periods and regularly travel back to their communal areas where their families are based. As they are not supposed to stay permanently in the fishing camps, they are not allowed to build any permanent housing structures. The fishing villages are in communal areas and are regulated by the Rural District Councils (RDCs) through block permits that are received from ZPWMA as part of the co-management requirements. The fishing villages comprise people who were displaced by the construction of Kariba Dam and contain both health and educational facilities. The majority of livelihood sustenance in these areas is from small-scale fishing, as all camps and villages fall within the wildlife safari area and National Park. Farming and livestock rearing are not permitted in the area according to the Statutory Instrument 362 of 1990.

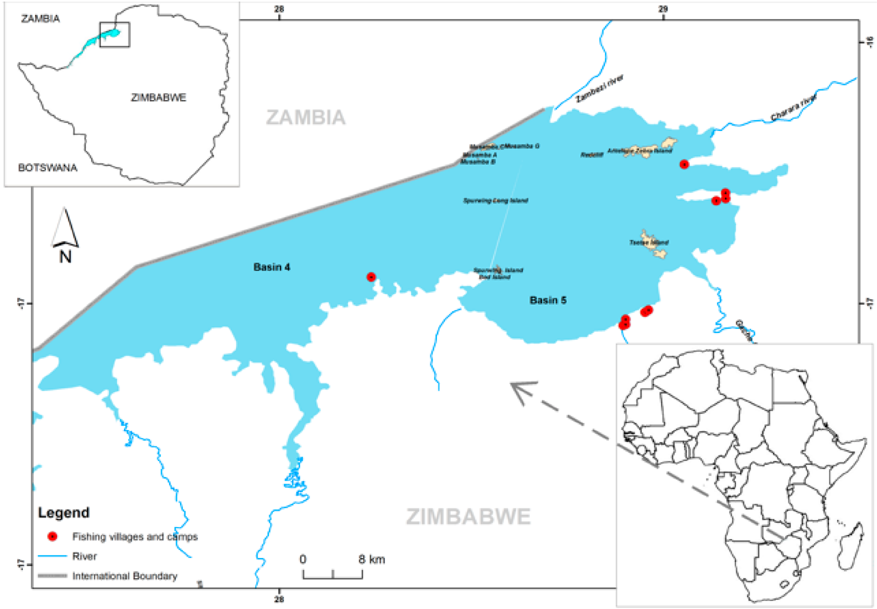

Figure 1. Map showing location of Lake Kariba and study locations.

2.2. *Research Design*

2.2.1. Development of Questionnaire to Measure First Order Stressors

Journal articles, gray literature, government reports, and policy documents that are relevant to this study [14,16,39–41] were used to design method and questionnaire. The questionnaire consists of two main sections: (1) personal information and (2) resources and community fisheries and micro-financing. Previous studies, together with local knowledge of the study area, were used to develop indicators [16,23,24,42]. Table 1 shows the literature sources for each indicator that was used in this study.

Table 1. Indicators for sensitivity.

Indicators	Variables	References
	Community characteristics and assets	
Sex	No. of men that were interviewed No. of women that were interviewed	[41,43]
Education	Education level of the interviewee	[44]
Household income from fishing	Average daily catch (kg/day) × fish price ($1.50/kg)	[22,41,45,46]
Livelihood Activities	Dependence on fisheries, fish gear making, aquaculture	[24,41,45,47–49]
Assets	Fishing gear, boats, fishing permit, crop field, livestock (cattle, goats, chicken)	[9,22,40,41,50]
Fishing gear access	Places where fishers go to access fishing gear	[42,51]
Fish processing (post-harvest losses)	Immediate sale of fish Salting and drying Refrigeration	[1,52]
Household diet (Nutrition)	No. of days in a week that people eat fish, meat, and vegetables	[41,47,49,53]
	Threats and conflicts (stressors)	
Events that disrupt fishing	low water levels, winds, storms and wildlife attacks.	[1,40,42,44,47,49,54,55]
Conflicts	Conflicts with other lake users (commercial fishery, aquaculture, tourism, and crocodile farming)	[42,56]
Socio-ecological	Increase in fishing pressure	[40,44]
Financial	Loans/credit access	[23,42,57]

First order stressors were selected based on literature review, together with relevance and applicability to the Lake Kariba small-scale fisheries local situations. The indicators were categorized into two groups in order to determine community characteristics, including livelihood assets, and to determine the threats and conflicts that affect fishers. To capture the conditions at community and household level that influence sensitivity [24], a total of eight indicators were used to determine community characteristics including livelihoods assets. The eight indicators are; sex, education level, household income from fishing, livelihood activities, assets, fishing gear access, fish processing, and household diet. In Zimbabwe, education level categories are: primary school, secondary school, high school, vocational training, college diploma, and university. The highest level of education that was attained by the interviewee was used to measure education. Information on other livelihood activities that fishers are involved in besides fishing was collected. To determine the threats and conflicts that affect fishers, four indicators were used; factors that disrupt fishing, conflicts experienced by fishers, perceptions of fishers regarding both increases in fishing pressure, and difficulty of access to loans. Lack of access to loans/financial resources is known to be an economic stressor to fishers as it limits their ability to purchase new boats, motorize their boats, and to diversify livelihoods [42], hence, it was categorized as a threat in this study. It has to be noted that some non-climatic indicators, such as access to loans/credit, household diet, assets, and livelihood activities are important to understand both sensitivity and adaptive capacity [25,55].

2.2.2. Primary Data Collection and Analysis

Questionnaire data were collected between August and September 2016 in 10 selected communities, including five fishing camps and five fishing villages in basins 4 and 5 of Lake Kariba (which were closest to Kariba town) (Table 2). The fishing camps included Gache-gache, Fothergill, Nyaodza, River range, and King's (Luyando), while the fishing villages included Nematombo, Nyamunga, Dandawa, Mudzimu, and Musambakaruma. To administer the questionnaire at the selected households, each village was first divided into four clusters. An enumerator was then assigned to a cluster and asked to sample households. The target was to sample all of the households, and only the households that had no representatives available during the survey were left out. Due to time constraints, the absent households could not be revisited. A total of 245 questionnaires were collected. In addition to questionnaire data, secondary data on crocodile populations in Lake Kariba was also collected from ZPWMA.

Table 2. The number of households interviewed by group and village.

Group	Village	Total Number of Households	Sampled Households	Sampling Ratio %
Fishing camps	Gache-gache	41	26	63.4
	Fothergill	32	27	84.4
	Nyaodza	39	31	79.5
	River range	5	3	60
	King's camp	27	23	85.2
	Sub-total	144	110	76.4
Fishing villages	Nematombo	56	24	42.9
	Nyamunga	54	26	48.1
	Dandawa	55	29	52.7
	Mudzimu	51	25	49.0
	Musambakaruma	59	31	52.5
	Sub-total	275	135	49.1
	Total	419	245	58.5

To test the difference between fishing camps and fishing villages with regard to indicators that are used in the study, the Mann-Whitney U test (U') and the chi-squared test (X^2) were used. The U' test was applied to income from fishing and household diet data that were continuous but not normally distributed. The chi-squared test (X^2) was used for categorical data, such as sex, education, livelihood activities and assets, fishing gear access, events that disrupt fishing, conflicts, access to loans, and increase in fishing pressure.

3. Results

This section presents the results of the study on indicators that cause SSF sensitivity. The results are divided into two sections. The first section describes the results that are obtained from the assessment of community characteristics, and includes livelihood assets. The second section describes threats and conflicts with other lake users that are experienced by fishers.

3.1. Community Characteristics and Livelihood Assets

This sub-section summarizes the findings from the evaluation of community characteristics and livelihood assets and how they differ between the two groups of SSF in Lake Kariba. Table 3 shows the findings for the eight indicators; sex, education, income from fishing, livelihood activities (both in dry and wet seasons), assets, fishing gear access, fish processing, and household diet.

Table 3. Community characteristics and livelihood assets.

Indicators	Variables	Fishing Camps	Fishing Villages	Total	X^2/U'
		(n = 110)	(n = 135)	(n = 245)	
Sex	Total men	103 (94%)	111 (82%)	214 (87%)	*
	Total women	7 (6%)	24 (18%)	31 (13%)	
Education	Primary education	39 (36%)	66 (49%)	105 (43%)	*
	Secondary education	64 (58%)	69 (51%)	133 (54%)	
	High School	5 (5%)	0	5 (2%)	
	Vocational training	0	0	0	
	College diploma	1 (1%)	0	1	
	University degree	1 (1%)	0	1	
Household income from fishing	Income	USD16 ± 11.5	USD11 ± 10.6		***
Livelihood activities (Dry season)	Only depend on fishing	91 (83%)	109 (81%)	200 (82%)	
	Aquaculture	0	14 (10%)	14 (6%)	***
	Fishing gear making	6 (6%)	4 (3%)	10 (4%)	
	Fishing gear trading	1 (1%)	0	1	*
	Crops	3 (3%)	2 (2%)	5 (2%)	
Livelihood activities	Only depend on fishing	57 (52%)	100 (74%)	157 (64%)	***
(Wet season)	Aquaculture	0	14 (10%)	14 (6%)	***
	Fishing gear making	5 (5%)	4 (3%)	9 (4%)	
	Fishing gear trading	1 (1%)	0	1	*
	Crops	39 (36%)	12 (9%)	51 (21%)	***
Livelihood Assets	Boats	34 (31%)	48 (36%)	83 (34%)	
	Fishing gear (nets & rods)	66 (60%)	109 (81%)	175 (71%)	***
	Fishing permit	14 (13%)	48 (36%)	62 (25%)	***
	Crop field	52 (47%)	34 (25%)	86 (35%)	***
	Cattle	23 (21%)	7 (5%)	30 (12%)	***
	Goats	24 (22%)	28 (21%)	51 (21%)	
	Chickens (Poultry)	14 (13%)	23 (17%)	36 (15%)	
Fishing gear access	Accessed locally	28 (26%)	75 (56%)	103 (42%)	***
	Capital city	61 (56%)	51 (38%)	112 (46%)	**
	Zambia	15 (14%)	5 (4%)	20 (8%)	*
	Other	8 (7%)	11 (8%)	19 (8%)	
Fish processing	Salting & drying	10 (9%)	36 (23%)	46 (19%)	***
	Refrigeration	3 (3%)	0	3 (1%)	
	Immediate sale	107 (97%)	130 (90%)	237 (97%)	
Household diet	Fish	6.08	5.34	5.67	***
	Meat	0.36	0.19	0.26	*
	Vegetables	3.04	3.45	3.27	*

Significance levels at *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

The survey respondents comprised 94% males and 6% females in the fishing camps, and 82% males and 18% females in the fishing villages (Table 3). Most fishers only attended up to the level of secondary school (58% in fishing camps and 51% in fishing villages), and only two fishers from fishing camps attained post-secondary education. On average, each fisher had an income of US$16 per day in the fishing camps and US$13 per day in the fishing villages. It was observed that household income in the fishing camps was significantly higher than that of the fishing villages. Most households had no other means of income generation except for fishing. Camps are more involved in crops during the wet season, but for subsistence. This corresponded to 83% in the fishing camps and 81% in the fishing villages during the dry season. These figures were slightly reduced during the wet season as a few fishers left fishing to practice crop farming. The majority of those who practiced cropping were found in the fishing camps (36%), while farming practices were limited to 9% in the fishing villages. In the fishing camps, 47% of the households owned crop fields, while only 25% owned crop fields in the fishing villages. Approximately one-third of the households in both groups owned boats (31% in the fishing camps and 36% in the fishing villages). In terms of livestock, data was also collected on cattle, goats, and chickens, which are of dietary and economic importance.

Fishing gear was either accessed locally from fish traders, Harare (capital city of Zimbabwe), Zambia, or other locations, including Mozambique and other towns in Zimbabwe (Table 3). Ninety-seven percent of the households in the fishing camps and 90% in the fishing villages sold their fish immediately on arrival from fishing in the lake. A few fishers preserved their catch through salting and drying or refrigeration. In the fishing camps, the diet of most households depended on the fish eaten on average six days a week, while vegetables were eaten for an average of three days a week. In the fishing villages, people ate fish for an average of five days a week and vegetables for four days a week. Fishers from both groups reported that they had no access to meat.

3.2. Threats Affecting Fishers and Conflicts with Other Lake Users

This sub-section summarizes the findings from the determination of threats and conflicts experienced by fishers, and how they differ between the two groups of SSF in Lake Kariba. Table 4 shows the findings for the four indicators; events that disrupt fishing, conflicts with other lake users, increase in fishing pressure, and a lack of access to loans.

Table 4. Threats and conflicts experienced by fishers.

Indicators	Variables	Fishing Camps (n = 110)	Fishing Villages (n = 135)	Total (n = 245)	X^2
Events that disrupt fishing	Low water levels	35 (32%)	45 (33%)	80 (33%)	
	Winds	106 (96%)	134 (99%)	140 (98%)	
	Storms	23 (21%)	18 (13%)	41 (17%)	***
	Wildlife attacks	68 (62%)	111 (82%)	179 (73%)	
Conflicts with other lake users	Tourism	23 (21%)	6 (4%)	29 (12%)	***
	Aquaculture	4 (4%)	3 (2%)	7 (3%)	
	Commercial fishery	35 (32%)	48 (36%)	83 (34%)	
	Crocodile farming	3 (3%)	5 (4%)	8 (3%)	
	Other	18 (16%)	30 (22%)	48 (20%)	
Increase in fishing pressure	Yes	69 (63%)	113 (84%)	182(74%)	***
Lack of access to loans	No	107 (97%)	133 (98%)	240 (98%)	

Significance levels at *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

In both groups, one-third of the respondents stated they were affected by low water levels (Table 4). Fishers also reported that their fishing activities were sometimes disrupted by strong winds. This corresponded to 96% of fishers from fishing camps and 99% from fishing villages. Fishers also experienced threats from wildlife, mainly in the form of crocodile and hippopotamus attacks. These threats corresponded to 62% of respondents from fishing camps and 82% from fishing villages. The fishers also experienced conflicts with other lake users, such as tourist house-boat operators and commercial fishery. Fishers from the fishing camp were more affected by tourist activities than those from the fishing villages. Thirty-two percent of fishers from fishing camps and 36% from fishing villages had their nets dragged and damaged by boats from the commercial fishery. Twenty-one percent of fishers from the fishing camps and 4% from fishing villages reported dragging and damage to nets, as well as the disruption of fishing that was caused by tourist houseboat boat operators. Law enforcement patrols conducted by ZPWMA rangers were also identified as a threat to the sustainability of the fishers (16% in fishing camps and 22% in fishing villages). The majority of fishers (63% from fishing camps and 84% from fishing villages) mentioned that fishing pressure had increased from the time that they had started fishing. Almost no fishers had access to loans (97% in fishing camps and 98% in fishing villages).

4. Discussion

In this section, the significance of the sensitivity indicators is critically examined based on an extensive literature review on how each indicator influences sensitivity or how it interacts with other indicators to influence sensitivity. Conflicts between SSF and other lake users and wildlife attacks on fishers are integrated as essential part of sensitivity indicators in this study. Key policy suggestions on how to reduce sensitivity are also proposed.

4.1. Community Characteristics and Livelihood Assets

This sub-section discusses the eight indicators that were used to determine community characteristics and livelihoods assets; sex, education, income from fishing, livelihood activities, assets, fishing gear access, fish processing, and household diet. It particularly shows how these indicators influence sensitivity, how they interact to cause low incomes, and also how these findings compare with other studies.

The findings showed that SSF of Lake Kariba had a low number of women that were associated with them when compared to the number of men, in both camps and villages. This is probably due to the inequality in the allocation of fishing permits by the relevant authorities, as well as traditional barriers that prohibit women from participating in fishing [58]. The low involvement of women in fisheries has also been explained by Choo et al. [59]. Their study focused on developing countries, and found that the fishery sectors are perceived as “male only” domain and offer few opportunities to women, who were instead found to be in the more labor-intensive, but lower paid, positions in the fish supply chain. Women are already poorer, more socio-economically disadvantaged, and more vulnerable than men to nutritional problems and disease outbreaks due to physical, social, economic, and cultural issues that include pregnancy, lactation, and inequitable food distribution within families [60,61]. Climate change impacts on fishing communities can also severely impact women, who are already more sensitive to climate change, thus increasing their overall sensitivity.

The livelihoods of individuals in Lake Kariba SSF largely depend on fishing, with the consequence that fishing is the main source of income (Table 3). A similar situation prevails in the Chilika lagoon, India. Here, 97% of fishing communities depend solely on fishing for income generation [62]. In the fishing camps of Lake Kariba, the average number of livelihood activities in which each household is involved is higher in the wet season (1.7) than in the dry season (1.1). No such seasonal difference in income-generating activities was seen in the fishing villages. According to Adger [41], the reliance on a limited variety of resources leads to social and economic stresses within livelihood systems, thereby exacerbating sensitivity. This is especially true if the resources are climate-dependent. Households and communities that highly depend on fisheries for nutrition, income, and employment are more likely to be impacted by climate change [24]. Diversification of income sources can therefore reduce sensitivity and dependency at the household level, particularly for those that are dependent on fluctuating fishery resources.

Only 34% of the fishers from both groups own boats (Table 3), which could force certain households to resort to inefficient fishing rods or to work as employees of those who own boats. This can have a negative impact as fishers may then be forced to fish in unfavorable weather conditions by boat owners. This observation is similar to the situation prevalent in coastal Bangladesh, where lack of boats and nets was found to affect households' choices on livelihood options [24]. Access to fisheries is obtained through a permit [63], which is therefore an important asset to any fisher. The low number of fishers that are in possession of a permit could be because some of the households that were interviewed constituted employees of permit holders and fish traders. Fishers explained to interviewers that permits were issued back in the 1990s under the co-management program. Since then, the number of permits had never been reviewed to accommodate the fishers who were born after this period. Some of the households interviewed mentioned that they were not able to pay their monthly permit fees (US$10/month), which resulted in the cancellation of permits and definitely affects their access to the fishery. Furthermore, it has been shown that fishers cannot easily access fishing gear locally and some individuals are forced to travel to Harare and Zambia to access the gear. Inadequate boats for fishing communities, lack of permits, and difficulty in accessing fishing gear are multiple stressors [64] that could exacerbate sensitivity to climate change.

The reason why few households own livestock can be attributed to the fact that livestock is prohibited in the areas where the camps and villages are located [65]. The low level of boats and livestock ownership implies high levels of poverty, which is an important indicator of high vulnerability as it is linked to marginalization of communities and lack of access to resources [41]. Livelihood assets can be useful in enhancing community resilience and reducing vulnerability [50]. This is because assets diversify sources of food and services as they can be sold to generate income. Furthermore, assets enable communities to explore alternative resources; for example, in the event of drought, livestock can be sold to generate money for food.

The majority of fishers sell fish immediately right after their arrival from fishing in the lake, to buyers who wait at the landing sites. At King's camp, fishing does not take place if there are no prospective fish buyers, in order to avoid post-harvest losses as the cost of salt for fish preservation is high. Fishers are forced by circumstances, including lack of refrigeration facilities and the high cost of salt, to sell their fish at low prices. These factors, together with the fact that buyers often determine the price that is paid for fish, result in overall low incomes. According to Adger [41], income is an economic indicator of poverty. The household income for the SSF in Lake Kariba is largely determined by fish catches. Fishing villages have lower catches when compared to fishing camps, which is due to the difficulties in controlling the number of people that participate in fishing. This renders fishing villages more sensitive than the fishing camps. In addition to these factors, the impact of climate change on fish productivity may result in low catches and low incomes, thereby exacerbating sensitivity. In a study conducted in the Amazon delta and estuary, Mansur et al. [46] found that the low income of urban dwellers increased their vulnerability to floods. Low incomes affect the ability of communities to invest, mitigate impacts of climate change, and to implement coping mechanisms [41]. However, income from fishing for Lake Kariba SSF was estimated based on the amount of catch per household per day and the average local price of fresh fish, income could be verified by measuring actual catches and sales. This study did not include income from dried fish, which is usually sold at a higher price when compared to fresh fish, as the drying of fish is not regularly practiced. It is only done when there are no buyers for fresh fish. According to the chairperson of the villages fisheries association, the drying of fish is practiced approximately once in two months.

Findings in this study showed that households have limited food options, and are therefore are highly dependent on fish as a principle component of their diet. This is because most households have no access to meat. Furthermore, households are unable to grow their own food as only a few practices cropping during the wet season (Table 3). Some households, especially those from fishing villages, do not get fish for their daily diet. This is because they sometimes sell all of their catch to meet other financial requirements. Limited options for food and protein sources can therefore contribute to low food security. Although the consumption of fish is known to promote health [53], if catches decline due to climate change, as predicted by IPCC [21], and supported by Ndebele-Murisa et al. [32], the availability of fish will diminish and exacerbate SSF sensitivity.

This survey also revealed that the lack of electricity, poor road infrastructure, and intermittent transport availability pose a challenge to fish preservation and market access. There is no access to electricity for the Lake Kariba SSF, even though the inhabitants were displaced during the construction of the Kariba Dam (which was developed for hydropower generation). Lack of access to profitable fish markets is a known stressor to fishing communities [42]. Islam et al. [66] identified lack of access to fish markets as one of the barriers to climate change and variability adaptation in Bangladesh coastal communities.

4.2. Threats Affecting Fishers and Conflicts with Other Lake Users

This sub-section discusses events that disrupt fishing (low water levels, winds, storms, and wildlife attacks), conflict with other lake users, and increase in fishing pressure, how they exacerbate sensitivity and how they compare with findings from other studies. The threats disrupt fishing activities and sometimes also constrain completion of fishing trips.

The low water levels experienced by fishers could be climate-induced. The 2015/16 season had very low lake water levels [67] and was characterized by low rainfall due to an El Niño-induced drought that affected Southern Africa [68]. Low water levels amplify sensitivity as fishers reported that their fishing grounds were reduced as a result. Furthermore, fishers compete with wild animals including hippopotamus and crocodiles for the remaining fishing grounds. This increases the risk of wildlife attacks as well as longer distance to the lake. Fishing activities are also sometimes disrupted by winds, wildlife attacks, and storms. In a study of the SSF in north-eastern Brazil, findings showed that winds and tides could sometimes be favorable to fishing activities and sailing. This is because these factors enhance fish migration and favor fish movements [69]. In Lake Kariba, winds and storms pose a challenge to fishing, as fishers may sometimes go for periods of up to three days without fishing due to technologically poor boats. Fishers explained that the non-motorized boats that they use have a high risk of capsizing when the lake is windy. Raemakers and Sowman [42] also showed that fishers in the Benguela Current Large Marine Ecosystem (BCLME) experience the same challenges from winds, currents, and rough sea conditions, which disrupt fishing. These are some of the underlying challenges that fishers experience, and cause fishers to be sensitive to climate change.

Wildlife attacks exacerbate the sensitivity of the SSF to climate change as they disrupt fishing and result in damage or loss of gear, low catches, human injury, and sometimes, the loss of human life. All of these factors can therefore contribute to low income. Attacks from hippopotamus can cause damage to boats. Although both groups experience this problem, the fishing villages are more negatively impacted than the fishing camps. According to Nyikahadzoi [70], the loss of nets due to destruction by crocodiles is known to have forced some small-scale fishers from Lake Kariba into circumstances where they depend on friends or relatives for support or into employment by larger fishers. McGregor [34] demonstrated that crocodiles are a source of harassment and economic problems for artisanal fishers as they damage nets, particularly in the summer months. Fishers explained that nets are expensive and difficult to replace. Furthermore, given the current economic challenges in Zimbabwe, findings from this survey indicate that some fishers are forced to travel to Zambia to buy nets.

Fishers that were interviewed also highlighted that they experience conflicts with other lake users in the form of tourist houseboat operators, activities associated with commercial aquaculture, the commercial fishery, crocodile farming, and ZPWMA (Figure 2). Fishers explained that most houseboat operators do not regard artisanal fishers as legitimate lake users. Houseboat operators sometimes moor their boats along the shoreline, disrupting fishing activities in the process. Tender boats that are used by tourists for game-viewing have propellers, which damage fishers' nets. In terms of aquaculture, small-sale fishers allege that their fishing grounds have been reduced as some were given to Lake Harvest Aquaculture, a commercial tilapia farm. Crocodile egg collection is an important activity for crocodile farming. However, it is during this process that fishers claim that they are often assaulted. The commercial fishery is restricted to fishing in waters more than 20 m deep. Furthermore, it has been alleged that they encroach and fish in shallow waters designated for SSF, which results in conflict. Finally, fishers explained that boats operated by commercial fishers can drag and damage their nets, leading to loss of catches. Damage and loss of fishers' nets and also loss of fish catches result in low incomes, exacerbating sensitivity to climate change.

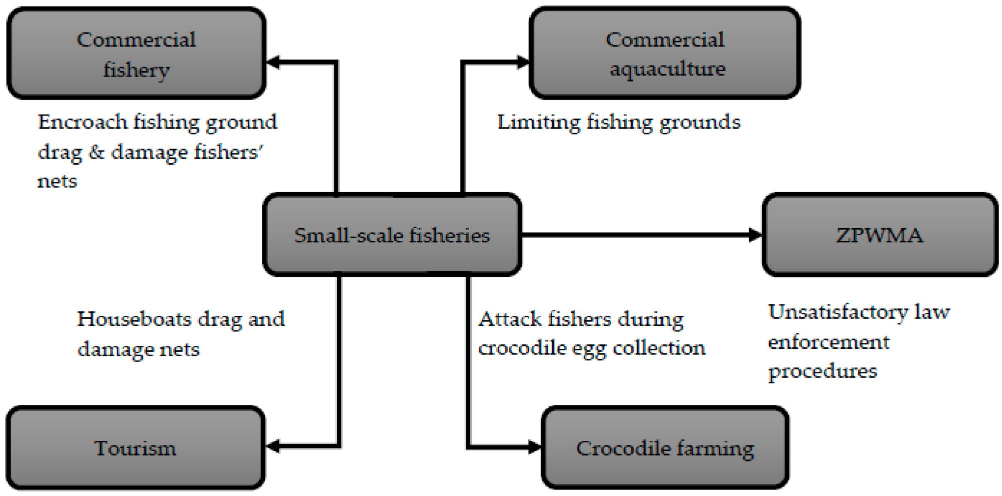

Figure 2. Possible conflicts between small-scale fishers and other lake users.

Fishers expressed disappointment over the way that law enforcement patrols are conducted on the lake. Rangers from ZPWMA conduct patrols to control illegal fishing, but the patrols result in conflicts as rangers are accused of chasing and confiscating fishing boats and nets. They explained that fisheries management regulations in place were unrealistic, and as a result, they always have clashes with ZPWMA rangers. Conflicts are common in many places where fishing is practiced, and when they are reduced [71], sensitivity to climate change is ultimately reduced. Conversely, it is also essential that climate change adaptation and mitigation efforts be designed to manage and reduce conflicts that are experienced by fishing communities [72]. According to Medrad et al. [73], conflicts over appropriation, management, or the use of common property resources can pose a significant challenge for the creation of sustainable management strategies. Climate change can act as a multiplier, by exacerbating existing tensions and environmental stressors, and may also cause new conflicts to emerge [72]. If such conflicts remain; they may lead to marginalization of SSF. Conflicts affect fishing communities' capacity to subsist. Fishers may maximize fishing in the short term, fearing that conflicts will rob them of good opportunities; however, this can become unsustainable in terms of climate resilience with time. The propensity of fishers' sensitivity to climate change is likely to be increased by their continued exposure to conflicts over resource use.

Fishers also reported that there is an increase in fishing pressure due to high unemployment in other parts of the country. This is because many people moved from cities, towns, and adjacent rural areas to fishing camps and villages to earn a living. The unemployment rate in Zimbabwe is currently believed to be more than 80%. Low education levels of the fishers make it difficult for them to compete for the few available jobs. This finding is comparable to that of [74], which is a study of reef fisheries in Kenya. In this investigation, they found that unemployment is one of the socio-economic drivers of poverty and that the low agricultural productivity due to dry climate made people resort to fishing for a livelihood. This increase in fishing pressure was said to cause a decline in catches, particularly in the fishing villages. In this assessment, it was found that almost all of the fishers from both groups had no access to loans. This is because there are no policies and programs in place for credit support. The local and wider scale factors that influence sensitivity to climate change interact in complex ways that limit livelihood diversification. This survey focused on SSF, but it is also important to investigate other fishery-related stakeholders, such as the commercial fishery, crocodile farmers, and regulatory authorities.

4.3. Linking Sensitivity with Exposure and Adaptive Capacity

The known climate conditions affecting the stressors include increasing temperatures and reducing rainfall rates. According Ndebele-Murisa et al. [75], temperatures surrounding Lake Kariba have been rising at a faster rate than the IPCC regional projections for semi-arid regions of Africa. Mahere et al. [76] also assert that between 1986 and 2011, the mean temperature of the lake rose by 0.7 °C, at a rate of 0.03 °C per year. Increases in ambient temperatures around the lake are known to translate into increases in lake water temperatures that have been shown to impact negatively on fish productivity, increasing the evaporation rates, lowering lake water levels, and also decreasing the amount of nutrients that are entering into the lake [31]. These observed and projected changes may affect fish productivity, resulting in low fish catches, lower incomes from fishing, and reduced availability of fish for diet as the sensitivity assessment shows SSF' high dependence on fish for diet. The observed low incomes from fishing will be exaggerated. The resultant low water levels may worsen the human-wildlife conflicts due to an increase to competition for space between fishers and wildlife. They may also exacerbate conflicts among lake users, and new conflicts may emerge.

The sensitivity assessment findings are useful for improving adaptive capacity [27]. Findings show that the low education levels that are attained by the majority of SSF and limited livelihood assets, especially as fishing-related assets are an indicator of low adaptive capacity [50,74]. This is comparable to findings by Tschakert et al. [15], who stated that unbalanced sets of assets and socially differential access to rights and decision-making processes leads to vulnerability. The findings can be used to initiate relevant policies for adapting to climate change [77], for SSF. For example, the diversification of livelihood activities, and facilitation of access to fishing permits and other fishing-related assets can be considered to improve adaptive capacity of SSF in the study area [15].

4.4. Policy Suggestions to Reduce Sensitivity

This study identified key indicators of first order stressors for the SSF of Lake Kariba, including a high dependence on fishing, limited livelihood assets, wind and climate conditions, wildlife attacks (mainly due to crocodiles and hippopotamus), conflict, and a lack of access to loans. Besides fishing, there are no sound alternative economic opportunities for fishing communities to support themselves, particularly in the fishing villages. Priorities for action to address these challenges that exacerbate sensitivity to climate change are recommended.

To address the high level of dependence on fishing and lack of other income-generating activities, Zimbabwe Parks and Wildlife Management Authority (ZPWMA) and Rural District Councils (RDCs) may consider promoting the aquaculture of tilapia. There is already an EC-funded small-scale tilapia aquaculture program in the fishing villages, which is coordinated by World Vision Zimbabwe [30]. The relevant authorities can consider upscaling the program through capacity building and fish stock supply. They can also facilitate the involvement of SSF in the Zimbabwe Command Livestock Program with the aim of improving the livestock assets of SSF. This program was launched in May 2017 as part of the Zimbabwe Agenda for Sustainable Socio-economic Transformation (ZIMASSET), and was spearheaded by the Ministry of Agriculture, Mechanization and Irrigation Development. This program targets beef, dairy, and poultry, and would be particularly important for the fishing camps who have the option of keeping livestock.

ZPWMA and RDCs can consider organizing training in boat making or establishing a standard boat building yard for the construction of strong boats that can be used in windy conditions and resist damage from hippopotamus attacks. An example of such an intervention is the improvement in local boat building techniques conducted during the post-tsunami period by FAO in Banda Aceh, Indonesia [78]. This will improve the efficiency of fishers, improve fish catches, and reduce the sensitivity to climate change. The standard boat building yard may also create new employment opportunities in the communities, which have the potential to increase incomes and capacity to cope with adverse conditions [79].

To mitigate the damage that is caused by wildlife attacks, the government can consider introducing insurance for wildlife-induced damage. One example is the community-based insurance system that was implemented in Namibia [80]. Another example of human-wildlife conflict mitigation is in the Akagera National Park, Rwanda, where the park officials collaborate with fishing communities that fish along the Akegara River [81]. The resuscitation and involvement of Lake Kariba fishing communities in the CAMPFIRE and co-management programs will ensure that hunting revenue will help local fishing communities. Ecotourism projects that are owned and operated by fishing communities can provide additional job opportunities, thereby reducing the sensitivity to climate change.

ZPWMA can consider improving the enforcement of regulations on fishing boundaries to reduce the conflict between SSF fisheries and commercial fishery. This can be achieved by increasing patrol efforts and the installation of fishing vessel tracking systems on commercial fishing vessels e.g., [82,83]. During the survey, remarks from fishers indicated that the process of installing tracking devices on fishing vessels has been initiated, and it involved the lake navigation authority, mobile company operators, and ZPWMA. The commercial fishers are restricted to fish in waters with a depth exceeding 20 m and these tracking systems will enable this restriction to be effectively enforced, thereby limiting the encroachment of SSF's fishing grounds by the commercial fishers.

In order to reduce conflict between the crocodile industry and SSF, ZPWMA can consider advising fishers prior to egg-collection procedures. Furthermore, individuals that are associated with the crocodile farming industry must agree to avoid the disruption of fishing activities. ZPWMA can also consider establishing a mechanism for effective collaboration and public participation among all lake users and stakeholders through open dialogue meetings [84]. This will have the overall effect of reducing conflict and result in sustainable fishery management. A reduction in conflicts will also reduce SSF sensitivity to climate change. Implementing the FAO voluntary guidelines for securing a sustainable SSF (with modifications to suit local conditions) will further contribute to reducing SSF sensitivity, as its guiding principles have provisions to address conflicts and threats [1]. Policies and programs for credit support to fishers must be established to improve networking and link SSF to formal financial institutions.

5. Conclusions

This analysis showed that Lake Kariba's SSF are sensitive to climate change due to several factors, including low income from fishing, increased fishing pressure due to population increase in fishing villages, declining catches as described by fishers in the area and also reported by FAO, lack of adequate fishing equipment (low numbers of boats and difficulties in accessing nets), and heavy dependence on fishing for a livelihood. It was found that the fishing villages are more sensitive than the fishing camps. This approach provided a means to understand the key processes in the Lake Kariba SSF and how the different sensitivity indicators vary between the two groups of fishers. The different sensitivity indicators suggest specific policy actions, such as facilitating SSF involvement in national livestock programs, effective collaboration among all of the lake users, and the introduction of insurance to cover wildlife damage. As the threat of climate change to fisheries and demand for fish continue to grow globally, conducting sensitivity assessments at the local level, such as this study, can help to identify effective adaptive measures for SSF communities with different socio-economic characteristics.

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