



Challenges and possible impacts of artisanal and recreational fisheries on tigerfish *Hydrocynus vittatus* Castelnau 1861 populations in Lake Kariba, Zimbabwe



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ARTICLE INFO

Article history:

Received 20 May 2020

Revised 7 October 2020

Accepted 23 October 2020

Keywords:

Lake Kariba

Tigerfish

Breeding season

Fishing tournament

Hydrocynus vittatus

Socioeconomic factors

Sanyati Basin

ABSTRACT

Increased fishing pressure from artisanal and recreational fishing has led to the collapse of some important fish stocks around the world over the past years. There is currently limited understanding of the impacts of recreational and artisanal fishing on tigerfish *Hydrocynus vittatus* populations in Lake Kariba and the socioeconomic factors behind them. Hence, this study investigated socioeconomic factors that act as drivers of the recreational and artisanal fishery industry and what sort of impact this would likely have on tigerfish *H. vittatus* populations using qualitative approaches. Eight three percent of the artisanal fishers interviewed recorded high catches during the summer season (October–February), which also coincides with the breeding season for tigerfish when it migrates up the rivers. Recreational anglers mainly caught females during the tigerfish tournament which is likely to have a significant effect on the tigerfish population in the long term through changes in tigerfish recruitment and other life history traits. Tigerfish size at sexual maturity and catch per unit effort which are all indicators of overexploitation were found to have decreased over the past years. Results further demonstrated increased fishing activities from artisanal and recreational fishing. It can be implied that the population of tigerfish may inadvertently be affected, but direct evidence that both recreational and artisanal fishing were having impacts on tigerfish populations was limited. It is therefore recommended that effective conservation measures such as preventing fish poaching during the tigerfish breeding season are put in place to protect the population and that of other fishes (i.e. potential prey).

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Introduction

Commercial and recreational fishing can have similar ecological consequences on fished populations [1,6]. Such consequences range from direct impacts on the exploited species (e.g. truncation of the natural age and size structure, loss of genetic diversity and evolutionary changes) to impacts on the aquatic ecosystem itself (changes in trophic cascades and trait-mediated effects). The issues that have led to global fishery concerns (e.g. bycatch and catch-and-release, fisheries-induced selection and trophic changes) are similar in both the commercial and recreational fishery sectors [27].

Recreational fishing is conducted by people primarily for sport with an attainable secondary objective of capturing fish for domestic consumption however not for onward sale [2]. It is an important activity that contributes significantly to national economies. Recreational fisheries have gained increasing attention in European fishery research and management following the introduction of European legislation requiring estimation of recreational catches of designated species [17]. Among 22 European countries there are an estimated 21.3 million anglers, with 10 of the countries having an estimated expenditure of US\$10 billion on recreational fishing [11]. Over the past years, recreational fishing has gained a lot of interest following observations that it could also be having the same impacts as commercial fishing. In West Africa alone, recreational catches brought total annual revenue of US\$152 million to the region [52].

On the other hand, artisanal fishing is conducted on a small scale by fishing households. It always involves the utilisation of low capital and energy with the first objective of native consumption and export. In Africa alone, the artisanal fishing industry employs over 2 million people with the industry being valued at over US\$80 million [18]. Both recreational and artisanal fisheries are beneficial at local and national level. The benefits of recreational fisheries include provision of employment opportunities for the surrounding communities and motivation of a sizable fraction of society to maintain, effectively conserve and manage aquatic ecosystems [46]. In developed countries, recreational fishers act as advocates for the proper exploitation of fisheries resources thereby contributing to their conservation. Artisanal fisheries provide the equivalent of all dietary animal protein for 158 million individuals worldwide [10]. Poor and undernourished populations are particularly reliant on artisanal freshwater fisheries compared with marine or aquaculture sources [40]. In Zimbabwe, the artisanal fishery has been important in periods of decreasing job opportunities, particularly since the mid-1980s when many people had to relocate in search of employment in Zimbabwe [43,44]. When economic problems and unemployment increases, the recruitment of fishers also increases, whilst a good economic climate and good employment opportunities can lead to a decrease in the number of fishers. In other words, exploitation of fisheries resources provides a socioeconomic safety net [13].

In Zimbabwe, Lake Kariba fishery comprises of the artisanal fishery, kapenta commercial fishery, aquaculture (cage culture) and recreational fishery. The fisheries are managed by the Zimbabwe Parks and Wildlife Management Authority, through Lake Kariba Fisheries Research Institute (LKFRI). Recreational fishing is carried out using mainly the rod and line and spearfishing to a limited extent [36]. The major highlight in this fishery is the annual Kariba Invitational Tigerfish Tournament (KITFT). Catch statistics from this fishery have not been collected systematically apart from angling tournaments. The tournament attracts participants from almost all the continents [36]. The first tigerfish tournament held in 1962 had 400 participants [26], and the number has increased to about 700 participants in 2016 [24]. This demonstrates the consistent and ever-increasing fishing pressure imposed on tigerfish populations in Lake Kariba. Estimations have shown that annual exploitation just from recreational angling alone can reach up to four tonnes ([28] *unpub. data*) and this causes an increase in vulnerability to the apex fish predator within the lake as fishing pressure increases.

The artisanal fishery exploits the riverine mid-Zambezi fish species and the introduced Nile tilapia *Oreochromis niloticus* [37]. The fishery is more intensive in the fishing camps. 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 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 [43]. Entry into this fishery is regulated through a licensing system but the low capital investment required to carry out fishing, coupled with limited enforcement of regulations, makes it easier for unlicensed fishers to harvest the fisheries resource [36]. Fishing effort is regulated whereby each fisher is allowed the nets with mesh sizes of 4-7 inches and a maximum of five fishing nets of varying mesh sizes above the stipulated minimum mesh size [48,49].

The artisanal fishery started in 1962 with only 208 licensed fishers [38]. The estimated number of fishers on the Zimbabwean side of Sanyati Basin has generally increased from 208 fishers in 1962 to 1404 fishers in 1998 [50]. In a survey that was done by the ZPWMA in 2011, the estimated number of fishers was 1540 [37]. It is anticipated that the fishers have increased drastically since then due to the economic downturn in Zimbabwe, with significant implications on resource sustainability. It is therefore expected that the increasing fishing pressure from recreational and artisanal fishery could be having a significant impact on the fishery. According to Ndhlovu et al. [43] there has been an increase in fishing pressure in Lake Kariba due to the increase in human population in fishing villages as well as Kariba town.

For a management regime to ensure that a sufficient number of juveniles reach sexual maturity, usually requires information on the size at first maturity [39]. Sexual maturity has been known to be associated with physiological and behavioural changes [47]. Size at sexual maturity is strongly correlated with growth, maximum size and longevity of a particular fish species [51]. It not only influences how individuals in a population start to reproduce, but also how much they can reproduce because fecundity is often closely associated with body size [20]. Lappalainen et al. [29] highlighted that increased

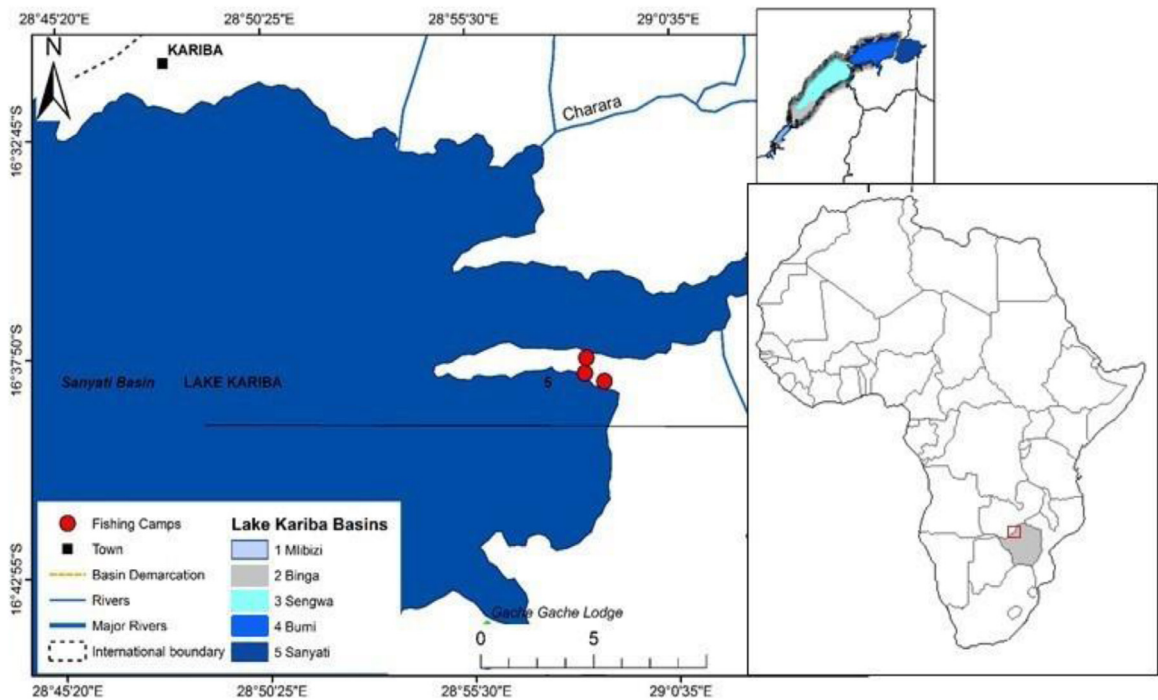


Fig. 1. Location of Nyaodza, Gache gache and Fothergill study fishing camps within Sanyati Basin, Lake Kariba, Zimbabwe.

fishing pressure generally tends to affect the size distribution of adult stock recruited to a fishery by reducing the proportion of large (or target size) individuals. This change in the size structure is generally regarded as unhealthy for fish communities while the opposite situation, with a high frequency of large and sexually mature individuals, is often considered to indicate a healthy structure of fish stocks [21]. Size at maturity and sex ratio are also directly affected by over-exploitation. According to Ojuok et al. [45], fish size at maturity decreases when fish are overexploited over a prolonged period of time. Decreases in fish size at maturity is believed to be offset by an increase in adult mortality hence for fish to ensure survival, they must start reproducing at smaller sizes.

Amongst the fish species exploited by both the recreational and artisanal fishery in Lake Kariba is the tigerfish, *Hydrocynus vittatus* Castelnau, 1861. *Hydrocynus vittatus* is a piscivore belonging to the Alestidae family and popular angling species which can grow up to 70 cm fork length and a weight of 15 kg [32]. *Hydrocynus vittatus* is also a fish of importance in Lake Kariba and local communities along Lake Kariba depend on it for both income and food [33]. The impact of artisanal and recreational sectors on the tigerfish populations has not been investigated despite the importance of the fish in food security, economy, provision of jobs and biodiversity. However, there has been a steady decline in tigerfish catch per unit effort at a sampling site in the Sanyati Basin, Lake Kariba, between 1993 and 2017. This study therefore aims to understand the socioeconomic characteristics of the artisanal fishers in three fishing camps in Sanyati Basin, Lake Kariba (Zimbabwe) and assess the perceptions of anglers on impacts of artisanal and recreational fishing on *H. vittatus* populations. The study also seeks to determine anglers' perceptions on whether there has been changes in catch rates of *H. vittatus*.

Materials and methods

Study area

Lake Kariba is a man-made reservoir along the Zambezi River (Fig. 1) and is shared between Zambia and Zimbabwe (26° 40' E – 29° 3' E). Lake Kariba is 276 km long with a mean width and depth of 19 km and 29.5 m, respectively. The lake has five hydrological basins namely; Mlibizi, Binga, Ume, Sengwa and Sanyati. The Sanyati Basin is close to Kariba town and is where this study was carried out. Surface water temperatures reach 32 °C in October to December and drop to 18 °C between June and August [30]. The mean monthly atmospheric temperature around Lake Kariba is usually above 20 °C with distinct seasonal variation [42]. Three seasons are distinct for Lake Kariba namely; cool-dry (April to August), hot-dry (September to October) and hot-wet (November to March) [30].

The study mainly focused on three fishing camps namely Gache gache, Nyaodza and Fothergill (Fig. 1). The three fishing camps were randomly selected from a total of six fishing camps that are found in Sanyati basin, Lake Kariba, Zimbabwe. The three fishing camps are also located closer to the Nyaodza and Gache gache Rivers which have been identified as tigerfish spawning sites by LKFRI unpublished data. After selecting Nyaodza, Gache gache and Fothergill fishing camps, the

Table 1

Community characteristics of three fishing camps in Sanyati basin, Lake Kariba, Zimbabwe. The values in parenthesis represent the proportion.

Factor	Variable	Gache gache n = 30	Nyaodza n = 25	Forthegill n = 25
Fishing camp demographics	Male adults	31 (55 %)	25 (60 %)	21 (51 %)
	Female adults	25(45 %)	17 (40 %)	20 (49 %)
	Children	30	29	48
Number of fishers interviewed	Male	29 (97 %)	21 (84 %)	25 (100 %)
	Female	1 (3 %)	4 (16 %)	0 (0 %)
Education	No education attained	7 (23 %)	11 (44 %)	2 (8 %)
	Primary	18 (60 %)	14 (56 %)	9 (36 %)
	Junior certificate	1 (3 %)		7 (28 %)
	Ordinary level	2 (7 %)		3 (12 %)
	Advanced level			4 (16 %)
	Degree	2 (7 %)		
Challenges faced	Harassment by ZPWMA	15 (50 %)	12 (48 %)	11 (44 %)
	Crocodiles and hippopotamus	9 (30 %)	10 (40 %)	9 (36 %)
	Lack of proper fishing gear	5 (17 %)	3 (12 %)	1 (4 %)
	Weather conditions	1 (3 %)		4 (16 %)

households interviewed for study were randomly selected at each fishing camp. Gache gache which is the closest to Kariba town has a total of 49 households and a population of approximately 157 people. In this fishing camp, 30 households were interviewed. Nyaodza and Fothergill which are located adjacent to each other and a bit further away from Kariba town have 44 (human population 131) and 38 (human population 102) households, respectively. In both Nyaodza and Fothergill, 25 households were each interviewed within the respective fishing camps. In total, 80 households were interviewed across the three fishing camps. The general population demographics of each fishing village are presented in [Table 1](#).

Research sampling methods

The study was approved by the University of Zimbabwe Joint Research Ethics Committee. Initially, informed consent was sought from the fishing camp chairman to conduct the research in his area and also informed consent was also sought from the respondents (i.e. household head) at every household. At each household the respondent was supposed to be the head of the household or the alternative household head in cases where the actual household head was absent. Interviews were only conducted with respondents who were above the age of 18. Furthermore, the interviewers explained to the respondents that their responses would only be used for research purposes only and that they would remain anonymous and no names/house numbers were recorded.

Assessment of the socioeconomic status of the artisanal fishers

A questionnaire survey was used to assess the socioeconomic status of the artisanal fishers and to collect data on catches (see Text S1). The questionnaire interviews were conducted between June and July 2018. The questionnaire had four main thematic areas mainly demographic details, safety net and daily net assessment, income and natural resources access and utilisation. All monetary values are reported in United States dollars (US\$).

Assessment of the potential impacts of the recreational fishing

Recreational fisheries data was collected during the Kariba Invitational Tigerfish Fishing Tournament held in October 2018. The tournament occurs in the Sanyati Basin, Zimbabwe for a period of 5 days every year. A total of 79 teams attended the tournament in 2018 and the teams usually have 5 or 6 team members. Consent to interview the anglers was first sought from the event organisers and also the respondents themselves. During the tournament a total of 56 teams were interviewed and the team captain was interviewed on behalf of the whole team. The questionnaire had 4 thematic areas namely demographic details, catch rates, expenditure on recreational fishing and perceptions about recreational fishing. The statistics of the tournament were also collected during the tournament in October 2018. The statistics that were collected included tonnage of fish caught, sex ratios of the fish caught, fishing effort used, largest fish caught and number of sexually active fish caught. In order to get a better understanding of the contextual factors affecting fishing in the area, the questionnaire was complemented by a brief semi-structured interview at the end of each questionnaire (see Text S2). This semi-structured interview section also corroborated the questionnaire data responses.

Biology and population characteristics

Hydrocynus vittatus specimens were collected from recreational fishers during the KITFT. The total length (TL) and standard length (SL) were measured using a 1 m fish measuring board. The sex of each fish collected was determined by dis-

Table 2
The economic characteristics and livestock assets of the respondents within the three fishing villages.

Factor	Variable	Gache gache <i>n</i> = 30	Nyaodza <i>n</i> = 25	Forthegill <i>n</i> = 25
Average income	US\$	210	233	140
Fishing as a job	Full time	23	19	20
	Part time	7	6	5
Livestock	Chickens	2	3	4
	Goats	1	0	1
	None	27	22	20

secting the fish and its gonad state assessed according to Bagenal and Braum [3] classification: inactive, active, ripe, ripe running, and spent. Size at sexual maturity data was obtained from previous studies on tigerfish in the Sanyati Basin, Lake Kariba, Zimbabwe.

Catch per unit effort

Data from experimental gillnetting was obtained from the Lake Kariba Fisheries Research Institute [28] to show changes in the tigerfish abundances for Sanyati Basin, Zimbabwe from 1993 to 2017. The experimental gillnetting site has been maintained since 1960 to ensure uniformity of data and allow assessment of temporal variation in fish species.

Data analysis

The data was first coded and entered into Microsoft Excel to obtain descriptive outputs and percentages of the respective responses. All responses were analysed based on the themes that emerged from the responses. To test the difference between the three fishing camps with regard to the variables that were used in the study, the Kruskal–Wallis test was used. The test was applied to income and tonnage of fish caught data that were continuous but not normally distributed. The Mann–Whitney pairwise comparisons using the Kruskal–Wallis multiple comparisons of *p* values for variables among the different fishing camps was used to assess the significant differences indicated by the Kruskal–Wallis test in Paleontological Statistics (PAST) software version 3.14 [19]. To test for differences between recreational fishermen responses the Mann–Whitney U test was used.

Results

The social status of the artisanal fishers

The respondents in the survey comprised of 97 % males; 3 % females in Gache gache, 84 % males; 16 % females in Nyaodza and 100 % males in Fothergill (Table 1). In all fishing camps it was observed that more males compared to females practiced artisanal fishing. The proportion of female respondents who practice artisanal fishing in all three fishing camps was 6 %. More than 50 % of the fishers only attended school up to primary education level whilst only two fishers in the three fishing camps had attained tertiary level education. Education level attained by the respondents in the different camps was significantly different ($H = 0.28$, $p = 0.019$). Nyaodza had the highest proportion of people (44 %) who had not attain any high education. The Mann–Whitney pairwise comparisons revealed that Gache gache vs Nyaodza ($p = 0.034$), Nyaodza vs Fothergill ($p = 0.048$) and Gache gache vs Fothergill ($p = 0.021$) were significantly different with regards to education levels attained by the fishers.

In the three fishing camps, more than 40 % of the respondents mentioned harassment by Zimbabwe Parks and Wildlife Management Authority (ZPWMA) officials as their major challenge faced during their fishing activities. The interviews showed that fishing carries with it lots of risks given the different hazards associated with aquatic environments. These hazards include wild animals e.g. Nile crocodiles (*Crocodylus niloticus*) and hippopotamus (*Hippopotamus amphibious*).

Respondents in Nyaodza fishing camp had the highest average income per month from fishing of US\$233, whilst those in Fothergill had the lowest at US\$140 (Table 2). It was observed that there was significant difference between the average income generated by the fishers in the three camps ($H = 2.00$, $p = 0.016$). With regards to average income, Mann–Whitney pairwise comparisons revealed that Gache gache vs Nyaodza ($p = 0.01$) and Nyaodza vs Fothergill ($p = 0.24$) had significantly different incomes. Less than 20 % of the respondents had livestock in all fishing camps.

Artisanal fisheries sector

About 49 % of the respondents catch between 50 and 100 kg per day (Fig. 2). Twenty percent catch less than 50 kg whilst 31 % catch more than 100 kg of tigerfish per day. The summer season (November to February) is the period when the fishers recorded their highest catches on average 50 kg per day whilst the dry winter period (May to July) is when

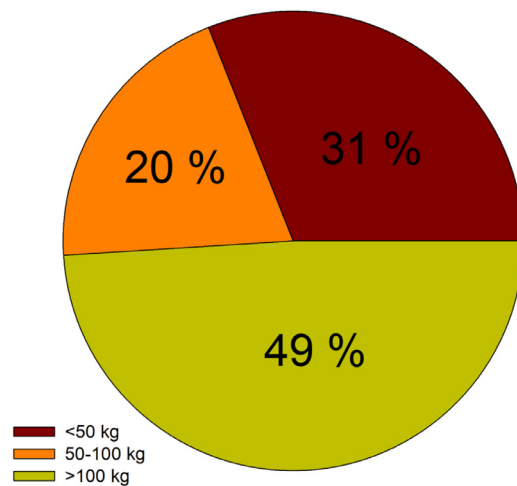


Fig. 2. Perceived average catches per day for *Hydrocynus vittatus* during the summer season (November to February) in Lake Kariba, Zimbabwe.

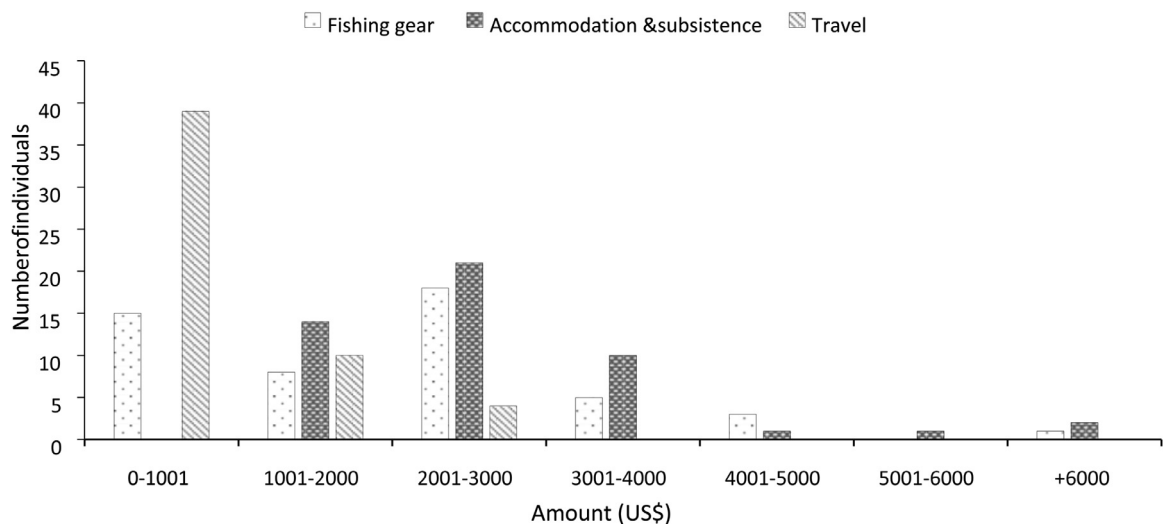


Fig. 3. Expenditure in US\$ of the anglers on fishing gear, accommodation and subsistence during the 2018 Kariba Invitational Tigerfish Fishing Tournament.

the lowest catches are recorded on average 15 kg per day. There were significant differences between tonnage of tigerfish caught in the summer and winter season ($t = 0.20, p = 0.043$).

Recreational fisheries sector

The amount spent on accommodation and subsistence was significantly high ($t = 3.76, p = 0.039$) compared to other expenses. For example, four anglers from London spent more than US\$3000 on travel and accommodation, with the majority of anglers spending less than US\$3000 on travel and accommodation since they will be coming from neighbouring countries and within Zimbabwe (Fig. 3).

Biology and population characteristics

A total of 158 tigerfish were sampled during the tournament. About 68 % of the fish sampled had a total weight of between 1001 g and 2000 g. Ten percent of fish sampled belonged to the 2001–3000 g weight class. It was observed that 59 % of the tigerfish caught during the tournament were females whilst 41 % were males. Of the fish weighing more than 1000g, 68 % were females.

Sixty four percent of the anglers perceived that their catch rates were decreasing whilst 19 % perceived that their catches were increasing (Fig. 4). There was a significant difference between the responses ('decreasing' and 'increasing') given by the respondents ($H = 0.31, p = 0.048$). Forty two percent of the recreational anglers attributed the decrease in catch rates to

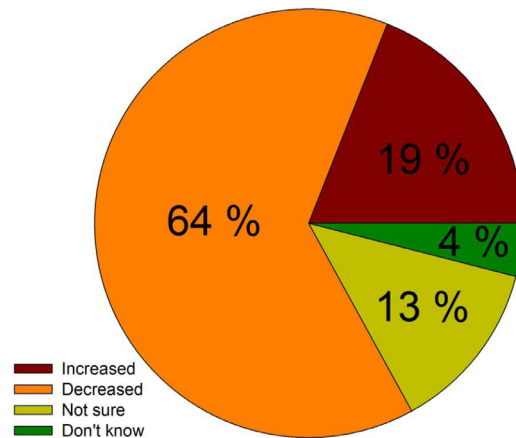


Fig. 4. Perceptions on the state of catch rates of *Hydrocynus vittatus* during the tournament over the past 20 years (1998–2018), Lake Kariba, Zimbabwe.

artisanal fishing in particular the illegal use monofilament gillnets, 49 % due to fish poaching in Nyaodza and Gache gache rivers and 9 % of the recreational anglers attributed the decrease due to the annual KITFT.

The contextual backdrop of fishing in the study area

The fishers in the three fishing camps revealed that they experienced their highest catches of tigerfish during the summer season. According to 83 % of the fishers who were interviewed, they block the passages that the fish use in migrating to their breeding grounds. They cast gillnets across these passages and this results in a lot of fish being caught and being unable to reach the breeding grounds. The respondents raised several challenges that they were facing during their day to day fishing activities during the interview process. According to some of the respondents, they are being continually harassed by ZPWMA rangers who are always extorting money from them. This affects the fishers in a negative way because the little money they sometimes get from legal fishing is spent on bribing the rangers. This then leaves them with no other option but to exercise illegal fishing activities such as fish poaching. Another problem that was highlighted by the respondents was the natural hazards that they face. According to the Zimbabwe National Statistics Association [53] at least 4 fishers die every year from attacks by crocodiles and hippos in Lake Kariba. Other hazards include storms, heavy currents and high tides that expose the fishers to risk of injury and death.

Furthermore, lack of involvement of fishing associations negatively affects artisanal fishers and their relations with ZPWMA who are the custodians of the fish. Their associations such as the Gache gache Fishers Association are not being involved in formulating some of the policies that are being implemented by the responsible authorities. This in turn leads to rejection of the policies by the fishers. In such situation, no one has a clear incentive to keep the harvest within sustainable limits. The number of fishers is fast increasing in the fishing camps as more people are flocking into the area in search of a source of income because of the continued economic meltdown in Zimbabwe. According to Chirume, the fishing camp chairman for Gache gache, “the number of people living at the fishing camps has increased over 10 times from the time when the cooperative was formed. The number of people has increased but the resource is not expanding”. In addition, the increasing population coupled with lack of proper infrastructure such as of toilets and accommodation can lead to a high frequency of diseases such as cholera and typhoid. According to the fishing camp chairman of Nyaodza, they are prohibited from building any permanent structures by ZPWMA because the area is a wildlife area. This law has thus prevented the fishers from building structures despite some of them having lived there for more than 30 years. All these challenges have the potential to reduce the income of these people and thus affect their livelihoods.

Discussion

The livelihoods of individuals in the three fishing largely depend on fishing, with the consequence that fishing is the main source of income. The results showed that the number of women practising artisanal fishing was low compared to that of men (Table 1). This finding may be attributed to the bias in allocating fishing permits to men by the responsible authorities. Traditional barriers may also be a factor in more men participating in fishing than women. According to Choo et al. [5] the artisanal fishing industry is regarded as “male only industry” in developing countries. Women are perceived as people who should stay at home and take care of the household [23].

The average income in all fishing camps was below the poverty datum line as defined by the Zimbabwe Statistical Agency [53] that stood at US\$562.32. This shows that all of the fishers are poor and this is likely further pushing the fishers to practice overfishing and also engage in other illicit activities such as fish poaching so as to survive. The increased fishing pressure combined with fish poaching is detrimental especially to top predator fishes such tigerfish which can ultimately

lead to declining fish stocks and/or even leading to its collapse ([2, 8, 9],b). Declining fish stock is serious and the most common challenge confronting fishing communities across the world and in Africa particularly. Approximately 80 % of the fishers interviewed perceived that their tigerfish catch rates were decreasing. The decline in fish stocks have also been noted in Poland, Guinea and Ghana [4,16].

The summer season in Lake Kariba is around the same period when tigerfish breed because of the flooding of major rivers. Tigerfish spawn for just a few days each year during the summer season, usually in December and January [25]. The artisanal fishers also recorded their lowest catches during the winter period which indicates that temperatures are also an important variable that affects catch rates. According to Marshall [35], most fish species in Zimbabwe are less active during the winter months as a result of low temperatures which affect fish movement. High tigerfish catches are recorded in the Nyaodza area which might indicate fish poaching in the Nyaodza River. According to Kenmuir [25], tigerfish spawn in the Gache gache and Nyaodza Rivers. However, practices such as the casting of twine gillnets have the potential to drastically alter the population of the fish species, as the females are the ones usually caught during this onslaught. The fish caught in this area are the largest and most fecund of the population. Marshall [34], argued that if such fish poaching was to continue in the Sanyati Basin, there would likely be a further reduction in the number of young fish and hence a general decline in tigerfish abundances.

Analysis of previous studies in Kariba revealed that the size at maturity (L_{50}) for both *H. vittatus* male and female has decreased from that recorded by Jackson [22]. According to the fisheries induced evolution theory, fishing can exert strong selective pressures on a stock, causing rapid evolution of key traits and behaviours. Size-selective fishing is typically expected to select for earlier maturation, slower or faster growth, and increased investment to reproduction [15]. Analysis of size at maturity data from previous studies showed that from 1961 to 2017, the size at maturity (L_{50}) value had decreased from 30 cm to 22.1 cm for male tigerfish and 35 cm to 27.8 cm for female tigerfish in the Sanyati Basin, Lake Kariba [33]. According to Karna and Panda (2011), a smaller L_{50} can be an indication of a stressed population due to overharvesting of the females which then forces them to reach sexual maturity earlier in their life stages. This is what has been observed in Lake Kariba where female *H. vittatus* are being poached at very high rates and large quantities during the breeding season.

Population characteristics data for tigerfish also revealed a gradual decrease of the catch per unit effort (CPUE) from 1997 to 2017 when the lowest CPUE recorded was 3.7 individuals/set. Marshall [34] showed that tigerfish CPUE for commercial fishing decreased from 48.7 to 19.1 kg/km between 1975 and 1984. In the same study period CPUE for tigerfish at the Lakeside sampling station decreased from 24.18 to 9.62 kg/km. The Kariba Invitational Tigerfish Tournament saw a decrease from 6.22 to 5.50 kg/angler of tigerfish caught. CPUE of tigerfish has been fluctuating but a constant decrease was noted since 1997 and it could be attributed to increased fishing pressure from artisanal and recreational fisheries and possible climate change due to dwindling food sources [31,41]. The decrease in CPUE as noted is in line with the perceptions of fishermen investigated in this study who perceived that catch rates for tigerfish were decreasing.

The data from the tigerfish tournament shows that fish caught were dominated by females of >1 kg. Female tigerfish were substantially larger than the males, which made them prone to capture by anglers and artisanal fishers as they need to forage more for food. This likely affects the tigerfish population sex ratio and demonstrates the existing fishing pressure on females and potential threat to tigerfish population structure. Most anglers perceived that catches were decreasing (Fig. 4) and they attributed this decrease to the netting by artisanal fishers. This is consistent with what the artisanal fishers mentioned about casting twine nets across the Nyaodza and Gache gache Rivers so as to harvest as much fish as possible during the breeding season (i.e. summer) of *H. vittatus*. There is therefore need for the responsible institutions to implement effective management tools so as to protect the *H. vittatus* especially during their breeding season.

However, a small proportion of the anglers attributed the decline in tigerfish catches to recreational fishing. The Kariba Invitational Tigerfish Tournament does not practice catch and release and because of this, the anglers can harvest as many fish as one can during the tournament times. Catch and release is a conservation practice developed to stop the overharvesting of fish stocks, increasing fishing pressure and increasingly effective fishing gear and techniques [12,48].

Recreational fishing plays an important role in African tourism industry and has the potential to be a million-dollar industry if properly managed [7,14]. For examples, the data on expenditure revealed that on average the anglers spend US\$5000 during the 3 day tigerfish tournament in Lake Kariba and this has huge economic implications considering the number of people who come for the tournament. Recreational fisheries in Africa and Zimbabwe in particular must be given adequate attention which has been lacking over the past years. There is a pressing need for the global statistics of the Food and Agriculture Organization (FAO) to gather more information and statistics on recreational and artisanal fisheries participation and harvest rates, particularly for the developing countries. However, a major challenge in collecting such statistics is that many management agencies are poorly equipped to acquire and capture such records.

Conclusions

This analysis showed that Lake Kariba's tigerfish *H. vittatus* stocks are possibly under threat from increased fishing pressure and fish poaching from artisanal fishers, and that fish catch rates have been decreasing over the past years. Decreasing catch rates have forced the fishers to resort to fish poaching so as to catch enough fish to sustain their livelihood. Our analysis and interpretation of the study results show that recreational fishing is also responsible for the decline in fish catch rates as indicated by the number female tigerfish that are caught during the fishing tournament. As the threat of increased fishing pressure from artisanal and recreational fisheries continue to grow globally, conducting sensitivity assessments at

the local level, such as this study, can help to identify effective adaptive measures for exploited fisheries. It is recommended that the ZPWMA improves its monitoring and law enforcement activities especially in the rivers during the summer season when tigerfish are breeding. The continued tigerfish poaching during this period is likely to have detrimental effects if it goes uncorrected over a period of time. Fishing associations should also be involved in the decision making policies so that the decisions made are not met with rejection. Directives from above, and which run against the interests of those who are supposed to carry them out, are likely either to be sabotaged or to be interpreted contrary to their purpose. A better way to accomplish centrally framed objectives would be to build upon a system of incentives that makes individual interests consistent with those objectives. Lastly, to ensure the sustainability of recreational fishing and sport fishing tournaments in Zimbabwe, the catch and release method should be adopted.

Declaration of Competing Interest

All authors have declared no competing interests.

Acknowledgements

The research was funded by the University Lake Kariba Station ([University of Zimbabwe](#)). We would like to thank Elmon Dhlomo and his ULKRS team for their assistance during this study. Any opinions, results or recommendations expressed in this study are that of the authors and the ULKRS does not take liability in this regard. TD acknowledges funding from the [National Research Foundation](#) of South Africa Thuthuka grant (UID: 117700).

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