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NINA Report

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2010 - 2018

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Norwegian Institute for Nature Research

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Subsistence gill net fisher © Tor Næsje

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Abstract

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Freshwater fish play an important role in the livelihood of millions of people around Africa. Despite Namibia being classified as semi-arid with very little open water sources compared to other parts of the continent, freshwater fish are vital for communities living along the Kavango, Zambezi, Chobe and Kwando Rivers in North-eastern Namibia. Recent studies have shown a decline in high-value fish species and the commercialisation of the resource that is contrary to the Inland Fisheries Policy of Namibia that states that inland fish should be for subsistence and for the benefit of the local communities. The aim of the project was to record the fishing patterns and catch rates from the fishery through the use of local fishers from the area, to provide the necessary information to manage the fish resource sustainably for the benefit of the local communities for present and future generations. The data set was analysed by dividing the data into two groups. Data were grouped into those collected between 2010 and 2013 (the period where the fisheries reserves had probably not yet had an impact on the resource) and those collected between 2015 and 2018 the period where the protected areas may have had any impact on the resource.

The fishery targets certain fish species, mainly from the family Cichlidae, driven by local and regional markets. This commercialisation resulted in increased fishing effort over the years causing a decline in these targeted fish species. Selective fishing by the fishers was emphasised when comparing the catches from that fishery with those from the survey fishing by the Ministry that are considered to be representative of the fish population in these rivers due to the wide range of mesh size gillnets used. Three species, *Oreochromis andersonii, O. macrochir* and *Coptodon rendalli* dominated the gillnet catches from the fishery contributing 65.3% of the total Index of Relative Importance (IRI). There has been a decline in the collection of data by the fish monitors towards the later stages of the study. The timely follow-up and validation of data received from the fish monitors are recommended to ensure high quality data. The catch per unit effort both in number and in weight declined from the first to the second sampling period, except for Kalimbeza where the catch rate in weight remained the same, perhaps indicating that the establishment of a fishery reserve in the Kalimbeza area had had some beneficial impact in stemming the decline seen in the other areas. The maximum length of selected fish species (of the more important species recorded in the catches) also declined during the study period. It is recommended that the monitoring by the fish monitors continue, but that the quality of the data be regularly evaluated.

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Contents

Foreword

Monitoring of the local subsistence/small scale commercial gillnet fisheries in the Zambezi and Chobe River systems, has been a part of two major research programmes and financed by several institutions. It initially started as part of the NNF/WWF/MFMR funded project "Integrated Co-management of the Zambezi/Chobe Rivers Fisheries Resources Project" (SRM) (2009 – 2012), which aimed to improve the understanding of the fishery in this area and to promote sustainable freshwater fisheries in the region. The SRM project worked closely with stakeholders in Namibia and adjacent countries to achieve these objectives. The project was concerned with the collection and analysis of information (biological, social and economic) to be used in developing long-term management systems for the floodplain areas. At the same time as collecting information for management, the project aimed to develop capacity within the Ministry of Fisheries and Marine Resources (MFMR) to continue the collection of data on the social aspects of the fishery. This project developed a pilot monitoring project, where selected participants from the communities (fish monitors) would record the catches from local fishermen on a weekly basis from the Zambezi and Chobe Rivers. This not only provided a year-round source of data reflecting actual exploitation levels, but also a means of promoting the devolution of powers and functions to the community level. This ensured the cost-effective recording of data on a weekly basis and created a participatory environment for inhabitants in the monitoring and management of a resource that is important to them.

In 2013 the monitoring of the gillnet subsistence/small scale catches was taken over by the EU funded project "Community Conservation Fisheries in KAZA" (2013-present) which aimed to establish a community-based and sustainable management system for the riverine and floodplain fisheries, and thereby improving food security in the area particularly for women, children and the rural poor. This would be achieved through capacity building in fisheries management (local communities and government level/ fisheries ministries). As a result, target groups would benefit from well-managed fisheries.

The collection of fisheries data through the monitoring of artisanal fisheries is labour intensive and best achieved through employment of local monitoring staff. We would like to thank the Development Officers, Messrs K. Sefulo, J. Maezi, M. Mushabati and Ms S. Matengu for assisting the fish monitors and collecting the data from them, and Ms H. Sibanda for entering the data. Furthermore we thank all the local fish monitors who collected the catch data from the different landing sites. This study would not have been possible without their assistance.

We would also like to thank the European Union (EU), the Namibia Nature Foundation (NNF), the World Wide Fund for Nature (WWF), the Norwegian Institute for Nature Research (NINA) and the Ministry of Fisheries and Marine Resources (MFMR) for their financial contributions.

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Clinton J. Hay and Tor F. Næsje

1 Introduction

Fisheries in Africa are probably one of the most underappreciated natural resources on the continent, as the fisheries sector as a whole (i.e. marine artisanal, marine industrial, inland fisheries and aquaculture) contributed U$ 24 billion to the GDP of all African countries with inland fisheries contributing an estimated 0.33 % (i.e. 6.3 U$ billion) (De Graaf and Garibaldi 2014). It is also estimated that the fisheries sector employs about 12.3 million people (De Graaf and Garibaldi 2014). Half of the 12.3 million people employed in the whole fisheries sector are fishers, and half (approximately 4.9 million) of the fishers are employed in inland fisheries (De Graaf and Garibaldi 2014). Furthermore over 200 million, of Africa's 1 billion people, regularly consume fish, with approximately half of this from inland fisheries (UNEP 2010). Inland fish are mostly undervalued and underestimated compared to marine fish globally as marine fisheries contribute more to the GDP of most countries. Inland fisheries are multi-species, complex and dynamic in nature and are usually executed far from political centers. Marine fisheries are mostly for commercial purposes whereas inland fisheries are mainly for subsistence and small scale commercial purposes with uncontrolled landing sites that creates difficulties in calculating catches from unreliable statistics. Estimated yields from African inland fisheries are therefore unreliable. Further reasons for inaccurate data for inland fisheries are the use of an unskilled workforce to collect relevant data, limited financial and manpower resources and the complex nature of the fisheries (Funge-Smith & Bennett 2019). The value of inland fisheries in Namibia is estimated at N$ 109 million, which is five times more valuable than game and trophy hunting on communal lands (Forsythe et al. 2018). In Africa, areas with the highest richness of freshwater biodiversity are usually also associated with the greatest concentration of rural poor, who are directly dependent on healthy fish biodiversity and freshwater ecosystem services (Winemiller et al. 2016). Furthermore, it is estimated that for every African fisherman there is approximately five people who are linked to the fisheries value chain (e.g. via processing, preservation, transport, marketing, production and maintenance of boats and gear) (Tvedten et al. 1994, Welcomme 2011, Youn et al. 2014). Abbott et al. (2015) further showed that the value chain may be largely underestimated due to the lack of monitoring abilities, where fish from small scale artisanal fisheries are directly consumed or sold through informal markets and rarely reported. Although the use of these resources has increased exponentially with the population growth and associated economic development, relatively little information about any aquatic ecosystems in Africa exists, and even less information on the sustainable use or yields of fisheries (Stiassny 1996, Tvedten et al. 1994, Welcomme 2011).

Communities depending on fish resources are, however, threatened by the rapid changing economic and revolutionary shifts, where newer and faster ways to exploit fish and the ecosystems supporting the freshwater resources, are being discovered and unsustainably implemented (Cooke et al. 2016, Lynch et al. 2016, Winemiller et al. 2016). A downward trend of inland fisheries (commercially important species) has recently been reported for numerous southern African countries including Malawi, Zambia, Zimbabwe, Namibia and Botswana (Abbott 2005, Hara 2006, Tweddle et al. 2015). These countries harvest important freshwater resources from the Zambezi River basin including the Barotse, Caprivi and Kafue floodplains, and Lakes Kariba, Malawi and Malombe, where management interventions failed to halt the decline in catches following rapidly increasing fishing effort and the use of environmentally damaging fishing gears (Tweddle et al. 2015, Cooke et al. 2016). The rapid population growth combined with very limited alternative livelihoods in rural areas further forces communities to continue fishing despite low returns (Tweddle et al. 2015). A decline of fish per capita of around 60% was reported for Malawi due to the decline in high-value fish species (Hara & Njaya 2016). Investment-driven growth in fishing effort is the main reason for the decline in high-value fish species as was also the case in Lake Malombe (Hara 2006), although the enormous increase in human population and hence numbers of fishers competing for finite resources is the major driver for over-exploitation. In addition, the population growth in north-eastern Namibia, has caused conflicts between communities, commercial and recreational water users that all have to utilize the same already stressed water resources. These conflicts are increasing in communities that depend on fish for their livelihoods (Tweddle et al. 2015, Cooke et al. 2016). The Zambezi River systems has also experienced encroachment from migrant fishers on its water resources due to a high demand for fish in urban areas in neighbouring Zambia as well as the Democratic Republic of the Congo (DRC) (Abbott et al. 2015, Tweddle et al. 2015, Cooke et al. 2016). These migrant fishers have no interest in long-term sustainability, and they compete with local fishers, who depend on fish for food security as a vital component to their livelihoods (Abbott et al. 2015, Cooke et al. 2016). The destruction caused by a commercialized industry further forced communities to make use of environmentally destructive and unsustainable fishing methods (e.g. drifting gillnets and beach seine netting) in order to account for the declining catches and the need to provide sufficient nutrition for their families (Tweddle et al. 2015). The increased fishing effort using these methods depleted the larger bodied fishes such as tigerfish and cichlids, which are considered both highly important subsistence and recreational species (Marshall 1987, Thorstad et al. 2004, Økland et al. 2005). The depletion of these charismatic species may also have caused changes in food web structures, that could influence the productivity of the waters in the long term. However, this has not yet been explored (Cooke & Cowx 2004).

The inland fishery in the Zambezi Region is important for a number of reasons. It is an important source of protein to both fishing and non-fishing households in the region, and it also provides a crucial source of employment and income for households on and adjacent to the floodplains (Naesje et al. 2002, Purvis 2002, Abbott et al. 2007). Inland fish also have health benefits for communities, e.g. a source of micronutrients such as Vitamin A, B and D and minerals (calcium, zinc, phosphorus and iron). These micronutrients are important during pregnancies and for small children, they lower the risk for cardiovascular diseases, and improve the immune system. Micronutrients can even lower the chances of certain cancer types, prevent some infectious disease and play a role in lowering high blood pressure (Bennet et al. 2018). Another advantage for the poor rural communities is the accessibility and affordability of inland fish compared to other protein sources such as livestock farming and other agriculture (Funge-Smith & Bennett 2019).

The rivers and their associated floodplain habitats are complex ecosystems. During and after the rains, the floodplains are inundated to a varying extent depending on the scale of the annual flood, and the fishes and the people utilizing this resource respond in an adaptive manner (Winemiller & Jepsen 1998, Welcomme 2011). Currently, there is a scarcity of reliable figures depicting the sustainable yields within these rivers and associated floodplains (Hay et al. 2000, Cooke et al. 2016). Tvedten et al. (1994) estimated the yield for the Zambezi region (formerly Caprivi) that include the Zambezi River, the 200 km^2 Lake Liambezi and the Kwando system to be around 1,500 t/year. These figures changed when Lake Liambezi dried up and dropped the total production to around 800-900 t/year (Tvedten et al. 1994). This figure may have been greatly underestimated as Tweddle & Hay (2011) suggested the annual yield to be approximately 5000 t/year in the Zambezi/Chobe system (including floodplains) and Lake Liambezi, although the difference may be partly due to a combination of greatly increased effort coupled with a series of high flood years that boosted recruitment. In addition, trade in fish products is a very important activity to some of the poorer households who have no other resources at their disposal (Purvis 2002, Purvis et al. 2003, Abbott et al. 2015).

The inland fishery in the Zambezi River system is characterised by a large number of small-scale fishers using various gears, targeting a multi-species fish resource (Naesje et al. 2003). Although important, fishing is just one of a number of activities which make up the livelihood strategy adopted by people on the floodplain (Purvis 2002). In a fisher survey in 2002-2003, Naesje et al. (2003) found that fishing intensified between August and November, indicating the period when fishing plays a major part in the communities' daily activities. This may also relate to when fish protein is needed the most. Purvis (2002) emphasized the importance of the involvement of locals and traditional fisheries management systems especially considering there were already some indications that the resource may be overfished. The decline in fisheries was predicted to worsen if the current trends continue (Purvis 2002). Current problems in the agricultural sector may also initiate an increase in fishing activities. If this was not managed, Purvis (2002) stated there was a real possibility of further degradation of the fishery resource. Given the critical economic role of fisheries in the rural livelihood systems of riparian communities, any long-term reduction in profitability or catches was likely to have significant consequences for the security and sustainability of the entire livelihood system (Purvis 2002). The consequence of riparian communities losing livelihood systems is of great concern and motivates the importance for resource users themselves (riparian communities, tourism operators, government institutions etc.) to accept responsibility in co-management of the fisheries resources (Wiederkehr et al. 2019). The concerns expressed by Purvis (2002) were well-founded as the fishery for the large cichlid species collapsed by 2013 (Tweddle et al. 2015). Co-management arrangements have recently been established in the Zambezi River system. The importance of involving riparian communities in a full capacity (i.e. collecting fisheries catch data, disseminating knowledge about the fisheries), to understand the temporal dimension and practical socioeconomic dynamics involved, are the key for community-based interventions to ensure sustainable utilization (Wiederkehr et al. 2019). There are several benefits through the co-management approach. In Lake Chiuta in Malawi, the government and the fishing communities jointly managed the fish resource. Benefits were accrued at several levels. Through this approach patrols became more effective, preventing the use of illegal fishing gear and methods, protecting the habitats and through the recovery process, fish recruitment increased resulting in higher yields that filtered through to the communities. Secondly, co-management gave rise to ownership and higher fish catches due to a more successful implementation of legislation. The government also gained as community patrols reduced operation cost with the government playing mainly a facilitating role (Donda 2017).

The Ministry of Fisheries and Marine Resources has the mandate to manage the Inland Fisheries Resources in Namibia and developed legislation for the different river systems in the country. Scientists from the Ministry have been conducting annual monitoring surveys of the fish resource on the Zambezi and Chobe Rivers since 1997. These annual biological surveys are used to assess the fish stocks, using a wide range of experimental sampling gear, sampling all representative habitats and all fish species and sizes. However, while the biological surveys are most suitable for insight into biodiversity and to a lesser extent stock assessment, they are not so useful to document the exploitation patterns of the catches of the local fishermen (Kolding et al. 2003).

The gillnet surveys of MFMR were standardised with regard to locality (four sites in the Zambezi and Chobe Rivers) and sampling gear (a fleet of multifilament gillnets with stretched mesh sizes varying between 12 and 150mm). A shortcoming of the annual surveys conducted by the Ministry is the sampling frequency as sampling is usually taking place in May and/or September, with no data available during the rest of the year. In addition, the sampling effort varies and is dependent on the general funding situation. Furthermore, fishermen may alter their fishing effort, fishing gear and fishing methods in ways that cannot be captured by standard experimental surveys done by the Ministry. These changes are usually due to the water level of the river, seasonal differences and fish migration patterns. Consequently, policy and legislation emerging to address perceived patterns of overexploitation of fisheries may risk being ineffective or counterproductive if based entirely on the limited knowledge provided by the experimental surveys.

It was, therefore, important that in addition to the standardised, fisheries independent MFMR monitoring programme, information should be collected on the actual catches from the fishery. By involving the local communities in data collection, the communities are given a sense of ownership and involvement in management of these resources. The main purpose of the gillnet monitoring project from 2010 to 2018 was to record the fishing patterns and fishing effort (fishing method, mesh size and gillnet type) and catches of the local fishermen from the Zambezi and Chobe Rivers on a weekly basis. Documenting the exploitation patterns of the local fishery will enable the Ministry to put measures in place necessary to co-manage a multispecies floodplain fishery.

2 Study area

Three study areas were identified on the floodplains. These were Kalimbeza (within the Sikunga Conservancy), Impalila (within the Impalila Conservancy) and Kasika (within the Kasika Conservancy) (Figure 1). The areas were selected based on the importance of local fishing and accessibility to ensure frequent data collection by the fish monitors. These three conservancies were the main focus for the activities of a series of fisheries co-management projects implemented by the Namibia Nature Foundation in the last two decades, which funded the monitoring programmes.

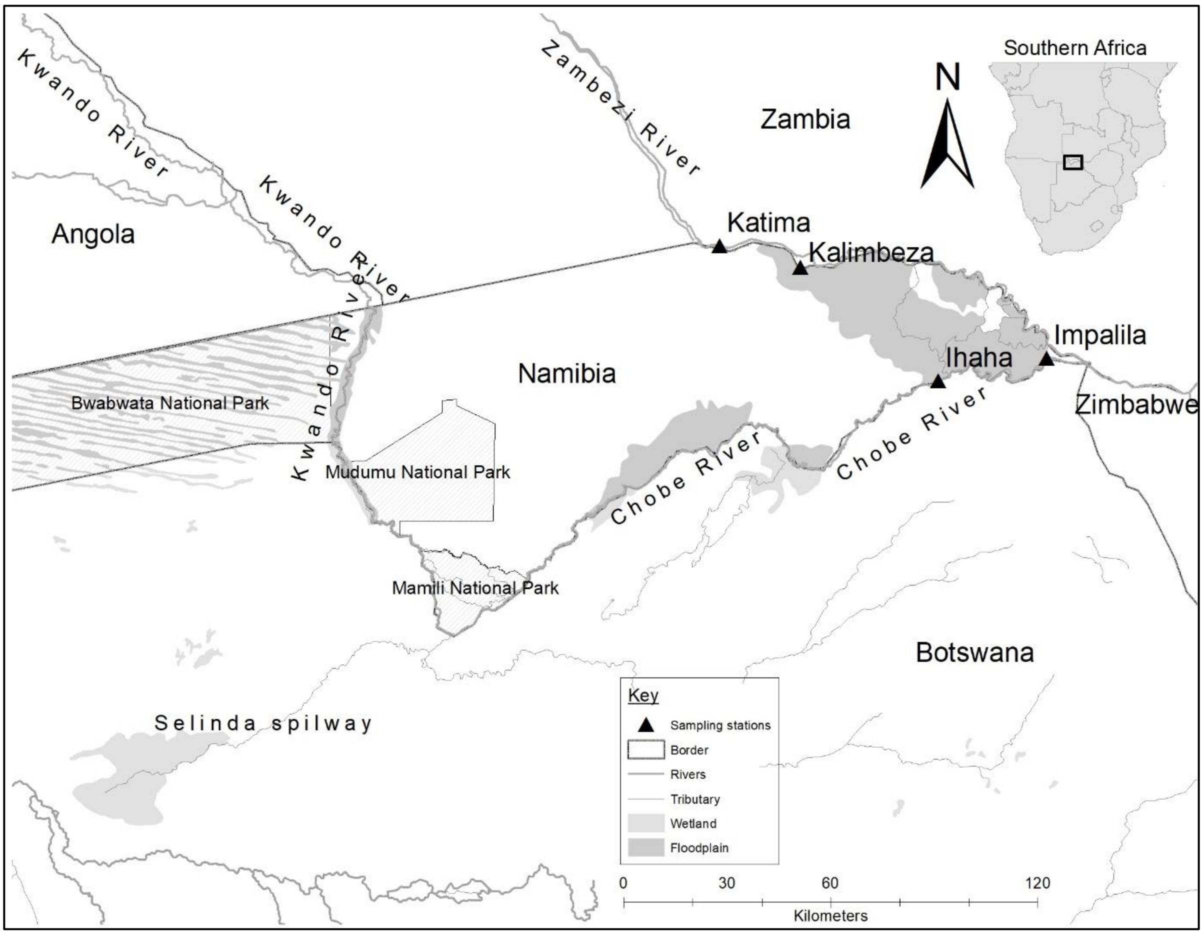

Figure 1: The study area indicating the sampling sites along the Zambezi and Chobe Rivers.

Kalimbeza is situated along the Zambezi River that forms the international border with Zambia. This area consists of backwaters, mainstream habitats and floodplains. Temporary fishing camps are established in the area of Kalimbeza. Zambian fishermen also cross into Namibia as some of the best fishing grounds are on the Namibian side. Impalila is the area where the Zambezi River connects with the Chobe River. Rapids are present at Impalila Island where traditional basket fishing usually takes place during June when the mormyrids migrate downstream. Large floodplains are also present with channels cutting through these floodplains.

Kasika is along the Chobe River with the Chobe National Park in Botswana across the river. Large floodplains with large channels are the main habitats fished.

Two areas were proclaimed as Fisheries Reserves in 2012 and gazetted in 2015. These are the Kalimbeza channel within the Sikunga Conservancy and the Kasaya Channel within the Impalila Conservancy. Since 2012 no fishing was allowed within the borders of these two Fisheries Reserves, except for recreational fishing (catch-and-release). These areas are patrolled by local community members appointed as fish guards.

Pictures: Fisheries monitors recording sub-sistence catches

3 Materials and methods

3.1 Data collection

Collecting catch data from the fishers on the Zambezi-Chobe floodplains is not an easy task and unlikely to be conducted by the Ministry alone, due to manpower shortages as well as limited finances to conduct such surveys effectively. In the three selected areas, local community members were appointed as Development Officers employed by projects administered by the Namibia Nature Foundation, notably the EU funded fisheries project “Community Conservation Fisheries in KAZA”. These Development Officers were instrumental in setting up the fisheries committees in these three areas as well as the appointment and training of the local fish monitors. Monthly visits by the Development Officers to the study areas ensured continuous communication between the fish monitors, communities and project staff. Fish monitors were appointed to record data twice a week from these three areas. However, the data for 2014 were excluded due to poor quality.

Following up and supplementary training of fish monitors were frequently done to ensure that quality data were recorded. These fish monitors visited the landing sites in the three study areas and recorded all catches from the fishers after they gave his or her consent to record their catch. The landing sites changed during the year due to the annual flood cycle which, to some degree, complicated the data collection. The fish monitors recorded the entire catch of the fishers. Individual fish length in millimetres and weight in kilograms were recorded. A subsample of the catch with individual measurements was taken when many fish were landed by the fishers. In such cases the rest of the catch were grouped into species, counted and weighed.

Additional information was recorded such as fishing gear type, gillnet type, net length and mesh size, where the fishing took place and the landing sites (Table 1). Fishers did not always provide all information for various reasons, and the gillnets were not always available for inspection, as they were not always retrieved when removing the fish.

The completed data sheets were collected from the fish monitors by the Development Officers (staff from the NNF/EU project) during their monthly visits and handed in at the regional office of the Ministry of Fisheries and Marine Resources in Katima Mulilo. Data were entered by the staff from the Ministry and validation of the data set was conducted by the report authors.

Gillnet data used in this report are only the catches from monofilament and multifilament gillnets including those where bashing (local name – kutumpula) using a club to beat the water and vegetation to frighten fish out into the nets, took place. Data from the other fishing gear types were used inconsistently with very few catches and were also not used in a standardised matter by the fishers. This makes it very difficult to follow any trends in the fish catches over time.

The data set was analysed by dividing the data into two groups. Data were grouped into those collected between 2010 and 2013 (the period where the fisheries reserves had probably not yet had an impact on the resource) and those collected between 2015 and 2018 (the period where the protected areas may have had any impact on the resource). It is important to note that sampling was not done in the fisheries reserves, but only the areas surrounding the fisheries reserves at Kalimbeza and Impalila.

Table 1: The following fishing gears were recorded during the study period by the local fish monitors used in the Zambezi and Chobe Rivers.

Fishing gear type	**Local name of fishing gear**
Mono- and multifilament gillnets with stretched mesh size range 1 inch to 6 inch	Kanyandi ka mweto (mono-) Kanyandi ka swala (multi-)
Bashing with Mono- and multifilament gillnets with stretched mesh size range 2 inch to 6 inch	Lituwa lakanyandi Ka mweto (bashing mono)/Lituwa lakanyandi kaswala (bashing multi)
Hook and line	Kashuto
Seine net	Ituwa (Lituwa)
Spear	Muwayo
Fish trap	
Fish funnel	Lukuko/Lufula
Fish basket	Katamba
Machete	
Mosquito net	Moskito

3.2 Fishing effort

The number of fisher days recorded by the fish monitors at Kalimbeza, Impalila and Kasika decreased from the first period between 2010 and 2013 compared to the period 2015 to 2018 (Figure 2). This is especially visible at Kalimbeza (Figure 2a). The second period also has months when no recordings were made by the fish monitors.

The number of fish sampled per gillnet also decreased between the period 2010 to 2013 compared to the period 2015 to 2018 (Figure 3).

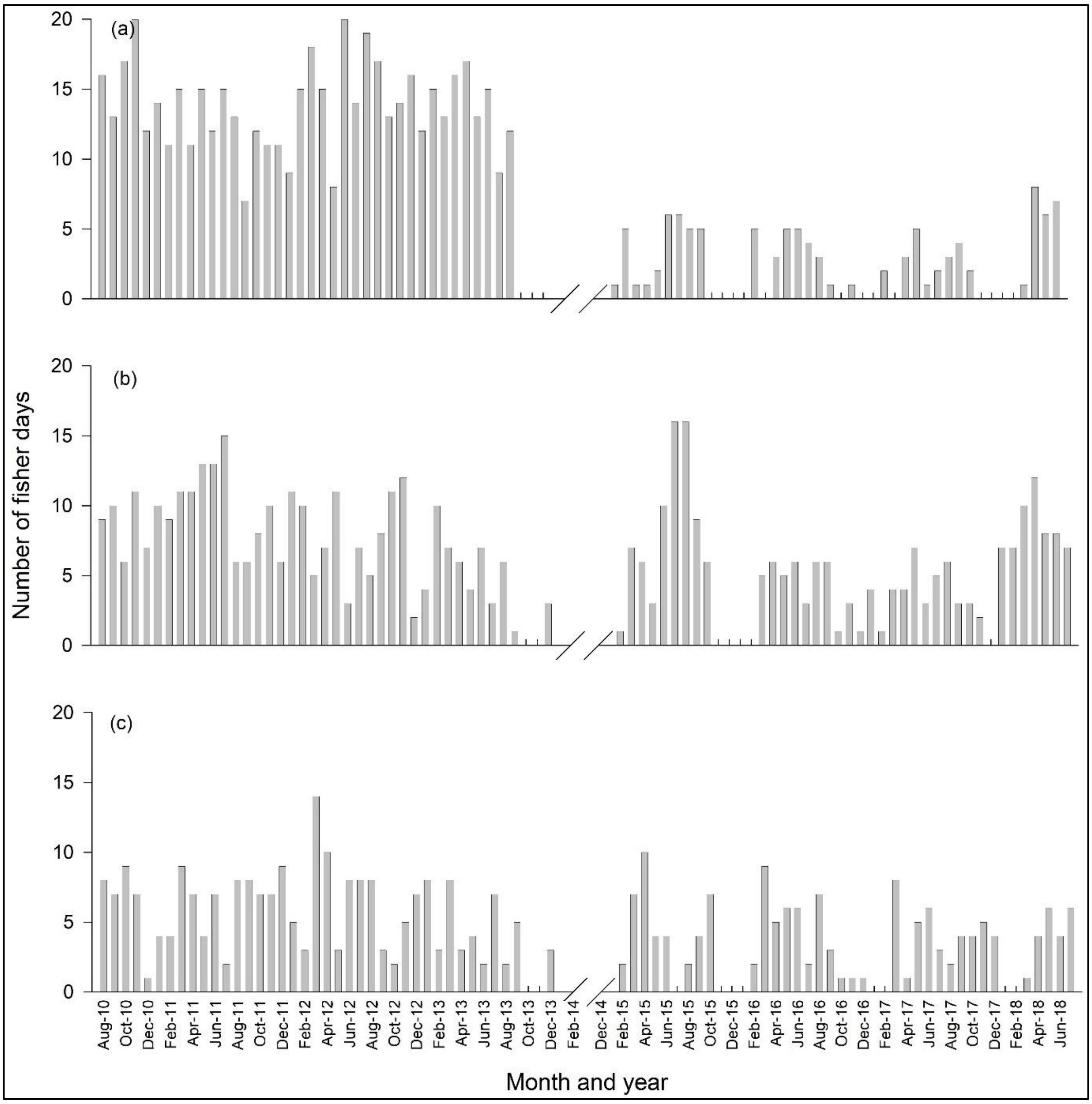

Figure 2: The number of fisher days recorded by the fish monitors per month at Kalimbeza (a), Impalila (b) and Kasika (c) for the period August 2010 to July 2018.

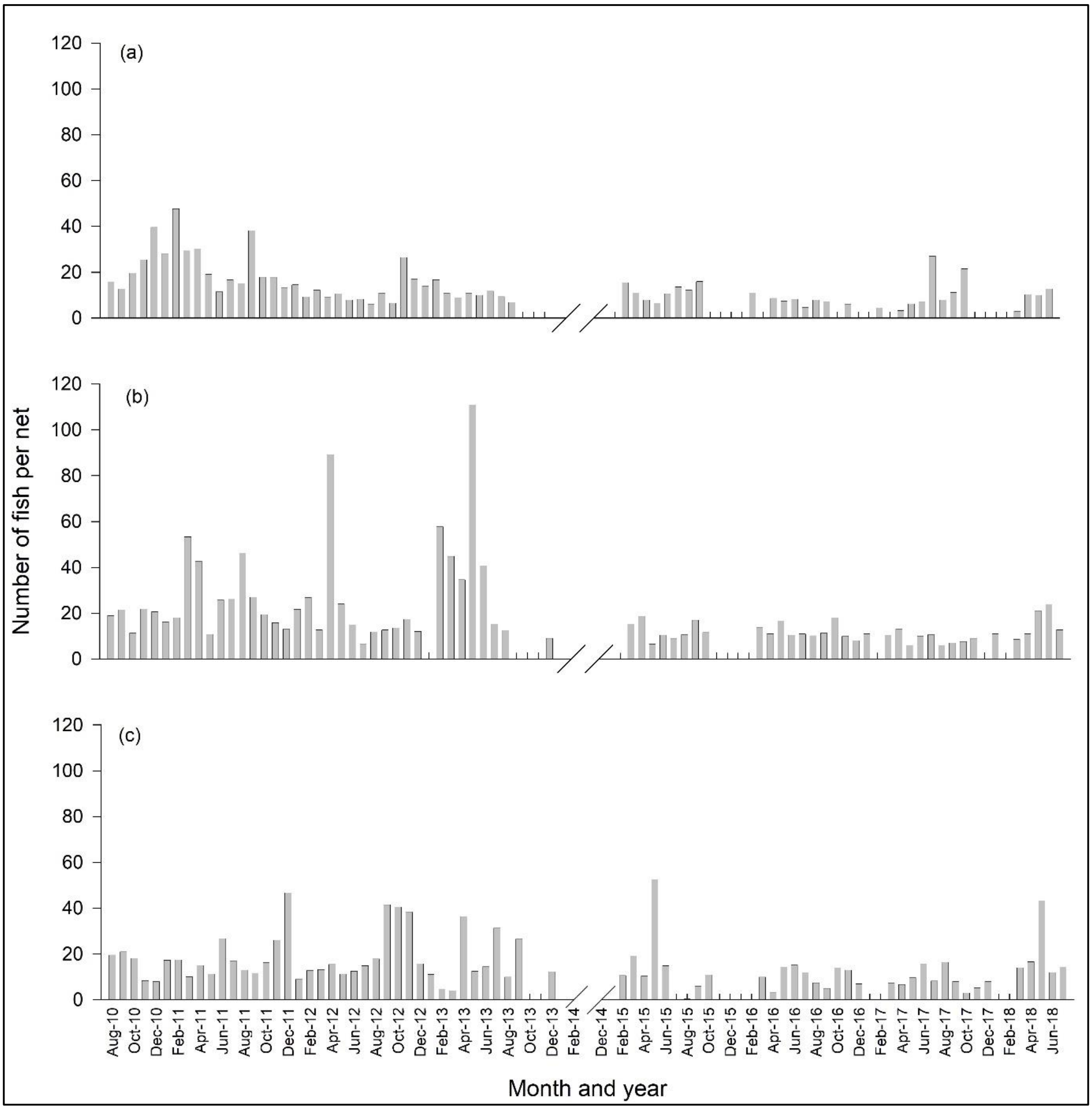

Figure 3: The number of fish per net recorded per month at Kalimbeza (a), Impalila (b) and Kasika (c) for the period August 2010 to July 2018.

3.3 MFMR gillnet surveys

Data were obtained from the annual surveys from the Ministry of Fisheries and Marine Resources between 2010 and 2016. The surveys were usually conducted between April and July of each year. Gillnets were set at sunset (approximately at 18h00) and retrieved at sunrise (approximately 06h00) with a mean fishing time of 12 hrs. Gillnets had multifilament (6 ply) fleets, which comprised of 10 m long × 2 m deep panels with stretched mesh sizes of 12, 16, 22, 28, 35, 45, 57, 73, 93, 118 and 150 mm, resulting in a total net surface area of ~220 m^2. Using the sampling protocol by MFMR, each gillnet fleet was deployed at the same location at each river site during all sampling occasions, but this was also determined by the flood level at that particular site. All fish collected were counted, weighed whole to the nearest 0.1 g and their length measured to the nearest mm fork/total length (L_F) depending on the fish species.

3.4 Data analysis

Data were entered into Microsoft Excel and transferred to Pasgear 2 (Kolding & Skaalevik 2018) (a customised database developed for experimental or artisanal fishery data) for basic analysis. Statistical analyses were performed using PRIMER ver7 with PERMANOVA add on (PRIMER v7: Clarke & Gorley 2015), IBM SPSS Statistics ver. 25 and Microsoft Excel, 2016.

The index of relative importance, (IRI), (1) (Caddy & Sharp 1986, Kolding 1999) was used to find the most important species in the catches from the three different stations, and is calculated as:

$$\mathrm{IRI} = \frac{(\%\mathrm{N}_i + \mathrm{W}_i) \times \mathrm{F}_i}{(\%\mathrm{N}_j + \%\mathrm{W}_j) \times \mathrm{F}_j} \times 100$$

where j = 1–S, $\%N_j$ and $\%W_j$ was the percentage number and weight, respectively, of each species in the total catch, $\%F_j$ was the percentage frequency of occurrence of each species in the total number of settings, and S was the total number of species.

Catch per unit effort in number was used to determine the difference in species composition from the fishermen catches compared to those sampled by the Ministry with experimental gillnets. A dendrogram (hierarchical cluster analysis using the group average linkage method) is presented to show the difference. Bray-Curtis similarity was calculated from the square-root transformed CPUE abundance data. Similarity Percentages (SIMPER) was used to calculate the average dissimilarity between the two sampling groups. A pairwise comparison was performed to compare the sampling groups and to find the average contribution of each fish species to the average Bray-Curtis dissimilarity.

The catch per unit effort was calculated as CPUE = C_i/E_i with C_i the catch of species in number and weight separately and E_i the effort used to obtain $_i$. The catch per unit effort was standardised as number or weight of fish caught per gillnet and expressed as kg or number per gillnet per day. The length of the nets was not taken into account when calculating the CPUE as the nets were not always brought to the landing sites and the information provided by the fishermen could not always be verified.

The catch per unit effort data and mean length do not conform to the conditions for parametric statistical tests. Therefore, non-parametric tests were used to determine whether any significant differences exist between these parameters.

Neither the sex nor the maturity stage could be recorded as the fishermen did not allow the monitors to cut open the fish. Fish are sold whole and any eviscerated fish lost value when sold. The 50% maturity lengths used are from Peel (2012), Hay et al. (2002), Froese & Pauly (2019), and Skelton (1993).

4 Results

4.1 Species composition

4.1.1 Fishers' gillnet catches

A total of 38153 fish weighing 13051 kg was recorded during the study period from all gillnets at all three stations. Over the eight years of the monitoring survey, a large number of fish species were caught in gillnets by the local fishers at the Kalimbeza, Impalila and Kasika study areas. They constituted altogether 29 fish species and species groups (*Synodontis* and *Petrocephalus* spp.) from nine families (Table 2). The Cichlidae family was most diverse, with 13 fish species, nearly half of the species caught, followed by the Mormyridae family with more than four species. The catches were dominated by the larger-sized fish species which are considered to be commercially more valuable (high fish prices at the Katima Mulilo Fish Market, usually in excess of N$65/kg (C. Hay pers. obs.)).

Table 2: Species with scientific, English and local names recorded from the gillnet catches from the local fisheries at Kalimbeza, Impalila and Kasika in the period August 2010 to July 2018.

Family	Scientific name	English name	Local name
Mormyridae	*Cyphomyrus cubangoensis*	Zambezi parrotfish	Sakulo
	Petrocephalus spp.	Churchill	Ninga
	Mormyrus lacerda	Western bottlenose	Ndikusi
	Marcusenius altisambesi	Upper Zambezi bulldog	Nembele
Cyprinidae	*Enteromius poechii*	Dashtail barb	Ijungwe
	Labeo lunatus	Upper Zambezi labeo	Linyonga
Alestidae	*Hydrocynus vittatus*	Tigerfish	Ngweshi
	Brycinus lateralis	Striped robber	Mbala
Hepsetidae	*Hepsetus cuvieri*	Southern African pike	Mulumesi/Mwelu
Clariidae	*Clarias gariepinus*	Sharptooth catfish	Ndombe-Mbunda-musheke/Mangwana
	Clarias ngamensis	Blunttooth catfish	Ndombe-Stama/Nkoma
	Clarias stappersii	Blotched catfish	Lihwetete/Ndombe-Mabbozwa
Claroteidae	*Parauchenoglanis ngamensis*	Zambezi grunter	Siabela
Mochokidae	*Synodontis spp.*	Squeaker	Singongi
	Synodontis nigromaculatis	Spotted squeaker	Singongi
Schilbeidae	*Schilbe intermedius*	Silver catfish	Lubango
Cichlidae	*Oreochromis andersonii*	Threespot tilapia	Njinji
	Oreochromis macrochir	Greenhead tilapia	Imu
	Coptodon rendalli	Rebreast tilapia	Mbufu
	Tilapia sparrmanii	Banded tilapia	Situhu
	Serranochromis macrocephalus	Purpleface largemouth	Ngenga
	Serranochromis altus	Humpback largemouth	Naluca
	Serranochromis angusticeps	Thinface largemouth	Mushuna
	Serranochromis jallae	Nembwe	Nembwe
	Sargochromis giardi	Pink bream	Siyeo
	Sargochromis carlottae	Rainbow bream	Mbuma
	Sargochromis greenwoodi	Green bream	Imbuma
	Pharyngochromis sp	Zambezi river bream	Mpapati
	Hemichromis elongates	Banded jewelfish	Liulyungu

The five most important species recorded according to the Index of Relative Importance (IRI) for the study period contributed 77.9% of the total IRI, 46.6% of the total number and 60.6% of the total weight. The three most important species according to the IRI were *Oreochromis andersonii, Coptodon rendalli* and *Oreochromis macrochir* comprising a total IRI of 65.3% (Table 3).

Table 3: Species composition in number (No), weight (kg), frequency of occurrence (FRQ) and Index of Relative Importance (IRI) recorded from the gillnet catches (all mesh sizes) from all stations for the study period August 2010 to July 2018. [1] *Serranochromis jallae* is treated as a separate species in Fish Base.

Species	No	No %	W kg	W	FRQ	FRQ %	IRI	IRI %
Oreochromis andersonii	6258	16.4	2191.0	16.8	1046	47.2	1567	33.0
Coptodon rendalli	4460	11.7	1822.1	14	855	38.6	990	20.8
Oreochromis macrochir	3460	9.1	1067.2	8.2	703	31.7	547	11.5
Clarias gariepinus	1617	4.2	1712.3	13.1	459	20.7	360	7.6
Hydrocynus vittatus	1973	5.2	1105.9	8.5	386	17.4	238	5.0
Serranochromis macrocephalus	1699	4.5	583.5	4.5	459	20.7	185	3.9
Schilbe intermedius	3444	9	339.9	2.6	311	14	163	3.4
Clarias ngamensis	1259	3.3	1059.8	8.1	253	11.4	130	2.7
Sargochromis giardi	1256	3.3	471.0	3.6	328	14.8	102	2.1
Serranochromis altus	1323	3.5	565.8	4.3	290	13.1	102	2.1
Synodontis spp.	2610	6.8	208.5	1.6	221	10	84	1.8
Marcusenius altisambesi	2704	7.1	201.0	1.5	191	8.6	74	1.6
Serranochromis angusticeps	898	2.4	381.5	2.9	288	13	69	1.4
Mormyrus lacerda	661	1.7	436.2	3.3	208	9.4	48	1.0
Tilapia sparrmanii	1453	3.8	173.2	1.3	148	6.7	34	0.7
Hepsetus cuvieri	641	1.7	235.1	1.8	210	9.5	33	0.7
Sargochromis carlottae	422	1.1	124.0	1	128	5.8	12	0.3
Sargochromis greenwoodi	294	0.8	77.6	0.6	94	4.2	6	0.1
Serranochromis jallae[1]	298	0.8	130.1	1	63	2.8	5	0.1
Brycinus lateralis	868	2.3	36.4	0.3	10	0.5	1	0
Pharyngochromis acuticeps	237	0.6	30.9	0.2	22	1	1	0
Labeo lunatus	116	0.3	37.5	0.3	24	1.1	1	0
Clarias stappersii	51	0.1	40.7	0.3	20	0.9	0	0
Enteromius poechii	76	0.2	0.7	0	3	0.1	0	0
Hemichromis elongatus	29	0.1	2.8	0	6	0.3	0	0
Petrocephalus spp.	27	0.1	0.6	0	3	0.1	0	0
Clarias sp.	4	0	13.3	0.1	1	0	0	0
Synodontis nigromaculatus	8	0	0.7	0	2	0.1	0	0
Parauchenoglanis ngamensis	3	0	0.7	0	3	0.1	0	0
Sargochromis sp.	2	0	0.4	0	2	0.1	0	0
Cyphomyrus cubangoensis	2	0	0.2	0	1	0	0	0
Total	**38153**	**100**	**13051.08**	**100**	**-**	**-**	**4753**	**100**

The Cichlidae dominated the catches with 76.0% of the total IRI, 58.1% of the total number and 58.4% of the total weight recorded (Table 3). The gillnet catches from the fisheries are selective with only 29 species recorded of the approximately 80 fish species listed from the Zambezi/Chobe floodplains (Table 3).

4.1.2 Experimental gillnet catches from the MFMR

A total of 22474 fish weighing 741.2 kg was recorded for the annual surveys by the MFMR between 2010 and 2016 from their experimental gillnets at Kalimbeza, Impalila and Ihaha stations (very close to Kasika) representing 42 species excluding the *Synodontis* group. The five most important species recorded according to the Index of Relative Importance (IRI) for the study period contributed 94.4% of the total IRI, 86.4% of the total number and 80.5% of the total weight. The three most important species according to the IRI were *H. vittatus, B. lateralis* and *S. intermedius* comprising a total IRI of 89.0% (Table 2).

The Cichlidae family contributed very little to the total catch with only 0.5% of the total IRI, 1.8% of the total number and 1.9% of the total weight recorded (Table 4).

Table 2: Species composition in number (No), weight (kg), frequency of occurrence (FRQ) and Index of Relative Importance (IRI) recorded from the experimental gillnet catches from the MFMR annual surveys (mesh sizes 12 to 150mm) at Kalimbeza, Impalila and Kabulabula (close to Kasika) for the period 2010 to 2016.

Species	No	No %	W kg	W %	FRQ	FRQ %	IRI	IRI %
Hydrocynus vittatus	4138	18.4	355.605	48	148	88.1	5849	39
Brycinus lateralis	8956	39.9	92.818	12.5	150	89.3	4676	31.1
Schilbe intermedius	3490	15.5	134.907	18.2	141	83.9	2831	18.9
Petrocephalus spp	1545	6.9	9.938	1.3	82	48.8	401	2.7
Micralestes acutidens	1283	5.7	3.493	0.5	109	64.9	401	2.7
Synodontis spp.	737	3.3	31.278	4.2	64	38.1	286	1.9
Marcusenius altisambesi	851	3.8	13.386	1.8	69	41.1	230	1.5
Clarias gariepinus	29	0.1	52.612	7.1	23	13.7	99	0.7
Pharyngochromis acuticeps	224	1	3.961	0.5	50	29.8	46	0.3
Hepsetus cuvieri	82	0.4	9.744	1.3	44	26.2	44	0.3
Enteromius poechii	207	0.9	1.921	0.3	57	33.9	40	0.3
Tilapia sparrmanii	156	0.7	5.935	0.8	35	20.8	31	0.2
Synodontis nigromaculatus	70	0.3	6.902	0.9	31	18.5	23	0.2
Enteromius radiatus	154	0.7	0.437	0.1	40	23.8	18	0.1
Pollimyrus castelnaui	129	0.6	0.66	0.1	31	18.5	12	0.1
Labeo cylindricus	178	0.8	1	0.1	20	11.9	11	0.1
Clarias ngamensis	6	0	7.487	1	6	3.6	4	0
Labeo lunatus	29	0.1	2.089	0.3	14	8.3	3	0
Enteromius paludinosis	54	0.2	0.154	0	22	13.1	3	0
Cyphomyrus cubangoensis	30	0.1	0.581	0.1	21	12.5	3	0
Serranochromis macrocephalus	15	0.1	0.963	0.1	11	6.5	1	0

Enteromius unitaeniatus	20	0.1	0.128	0	11	6.5	1	0
Serranochromis altus	2	0	2.585	0.3	2	1.2	0	0
Enteromius cf. eutaenia	17	0.1	0.027	0	8	4.8	0	0
Mormyrus lacerda	8	0	0.299	0	5	3	0	0
Coptodon rendalli	5	0	0.343	0	5	3	0	0
Sargochromis carlottae	5	0	0.44	0.1	3	1.8	0	0
Opsaridium zambezense	10	0	0.076	0	4	2.4	0	0
Rhabdalestes maunensis	8	0	0.008	0	5	3	0	0
Oreochromis andersonii	2	0	0.6	0.1	2	1.2	0	0
Serranochromis angusticeps	5	0	0.126	0	4	2.4	0	0
Ctenopoma multispine	5	0	0.121	0	4	2.4	0	0
Enteromius barnardi	6	0	0.008	0	5	3	0	0
Parauchenoglanis ngamensis	2	0	0.291	0	2	1.2	0	0
Pseudocrenilabrus philander	4	0	0.007	0	4	2.4	0	0
Oreochromis macrochir	1	0	0.222	0	1	0.6	0	0
Hippopotamyrus ansorgii	2	0	0.014	0	2	1.2	0	0
Enteromius bifrenatus	2	0	0.004	0	2	1.2	0	0
Enteromius afrovernayi	2	0	0.002	0	2	1.2	0	0
Enteromius eutaenia	1	0	0.004	0	2	1.2	0	0
Enteromius thamalakanensis	2	0	0.003	0	1	0.6	0	0
Enteromius fasciolatus	1	0	0.001	0	1	0.6	0	0
Tilapia ruweti	1	0	0.001	0	1	0.6	0	0
Total	**22474**	**100**	**741.18**	**100**	**-**	**-**	**15014**	**100**

4.1.3 Species composition at the different stations in different periods

4.1.3.1 Kalimbeza fishers' catches

Period: August 2010 to September 2013

A total of 13790 individual fish, weighing 4721.7 kg, representing 25 species were recorded from the gillnets at Kalimbeza from 2010 to 2013.

A total of 25 species, including the *Synodontis* group, with 13790 in total number and 4721.7 kg in total weight were recorded from the gillnets at Kalimbeza from 2010 to 2013. The five most important species recorded according to the Index of Relative Importance (IRI) contributed 87.5% of the total IRI, 55.5% of the total number and 65.3% of the total weight. The three most important species recorded according to the IRI were *O. andersonii, C. rendalli* and *O. macrochir* with a total IRI of 71.9% (Table 5). The Cichlidae dominated the catches with 85.1% of the total IRI, 68.8% of the total number and 67.6% of the total weight (Table 3).

Table 3: Species composition in number (No), weight (kg), frequency of occurrence (FRQ) and Index of Relative Importance (IRI) recorded from the gillnet catches at Kalimbeza for the study period August 2010 to September 2013.

Species	No	No %	W kg	W %	FRQ	FRQ %	IRI	IRI %
Oreochromis andersonii	2681	19.4	882.0	18.7	434	52.1	1986	36.6
Coptodon rendalli	1627	11.8	655.1	13.9	314	37.7	968	17.8
Oreochromis macrochir	1811	13.1	523.5	11.1	327	39.3	951	17.5
Clarias gariepinus	701	5.1	727.4	15.4	204	24.5	502	9.2
Serranochromis macrocephalus	844	6.1	293.7	6.2	233	28.0	345	6.4
Sargochromis giardi	459	3.3	176.3	3.7	131	15.7	111	2.0
Serranochromis altus	510	3.7	236.0	5.0	98	11.8	102	1.9
Serranochromis angusticeps	372	2.7	171.1	3.6	125	15.0	95	1.7
Schilbe intermedius	660	4.8	66.9	1.4	110	13.2	82	1.5
Hepsetus cuvieri	329	2.4	123.4	2.6	112	13.4	67	1.2
Synodontis spp	823	6	37.3	0.8	50	6.0	41	0.7
Clarias ngamensis	270	2	284.6	6.0	36	4.3	35	0.6
Marcusenius altisambesi	510	3.7	49.5	1.0	49	5.9	28	0.5
Sargochromis carlottae	265	1.9	76.7	1.6	64	7.7	27	0.5
Hydrocynus vittatus	148	1.1	99.8	2.1	66	7.9	25	0.5
Mormyrus lacerda	145	1.1	73.7	1.6	63	7.6	20	0.4
Serranochromis jallae	224	1.6	91.4	1.9	34	4.1	15	0.3
Tilapia sparrmanii	388	2.8	42.1	0.9	28	3.4	12	0.2
Sargochromis greenwoodi	134	1	30.0	0.6	46	5.5	9	0.2
Brycinus lateralis	611	4.4	33.9	0.7	8	1.0	5	0.1
Pharyngochromis acuticeps	188	1.4	18.8	0.4	8	1.0	2	0
Labeo lunatus	75	0.5	25.2	0.5	11	1.3	1	0
Clarias stappersii	5	0	2.6	0.1	3	0.4	0	0
Enteromius poechii	6	0	0.3	0	1	0.1	0	0
Petrocephalus spp.	4	0	0.3	0	1	0.1	0	0
Total	**13790**	**100**	**4721.7**	**100**	**-**	**-**	**5428**	**100**

Period: March 2015 to July 2018

A total of 18 species, including the *Synodontis* group, with 1024 fish in total number and 614.6 kg in total weight were recorded from the gillnets at Kalimbeza from 2015 to 2018. The five most important species recorded according to the Index of Relative Importance (IRI) contributed 91.3% of the total IRI, 66.5% of the total number and 79.3% of the total weight. The three most important species recorded according to the IRI were *C. gariepinus*, C*. rendalli* and *O. andersonii* with a total IRI of 80.4% (Table 6). The Cichlidae contributed 45.1% of the total IRI, 60.1% of the total number and 46.1% of the total weight recorded (Table 6). The families Cichlidae and Clariidae dominated the catches with 97.5% of the total IRI, 85.5% of the total number and 92.5% of the total weight (Table 4).

Clarias gariepinus, O. andersonii, O. macrochir, C. rendalli and *S. macrocephalus* were the five most important species (total IRI) recorded during each time period at Kalimbeza. The relative abundance of these species differed over time.

Table 4: Species composition in number (No), weight (kg), frequency of occurrence (FRQ) and Index of Relative Importance (IRI) recorded from the gillnet catches (all mesh sizes) at Kalimbeza for the study period March 2015 to July 2018.

Species	No	No %	W kg	W %	FRQ	FRQ %	IRI	IRI %
Clarias gariepinus	250	24.4	267.3	43.5	67	66.3	4504	52.4
Coptodon rendalli	174	17	108.9	17.7	53	52.5	1822	21.2
Oreochromis andersonii	84	8.2	50.0	8.1	36	35.6	583	6.8
Serranochromis macrocepha-lus	96	9.4	29.3	4.8	34	33.7	476	5.5
Oreochromis macrochir	77	7.5	32.1	5.2	37	36.6	467	5.4
Serranochromis angusticeps	86	8.4	31.0	5	29	28.7	386	4.5
Hydrocynus vittatus	25	2.4	22.2	3.6	15	14.9	90	1
Sargochromis carlottae	32	3.1	7.2	1.2	14	13.9	59	0.7
Serranochromis altus	27	2.6	14.6	2.4	11	10.9	54	0.6
Synodontis spp.	26	2.5	4.6	0.7	12	11.9	39	0.5
Sargochromis giardi	18	1.8	6.0	1	11	10.9	30	0.3
Marcusenius altisambesi	47	4.6	6.0	1	4	4	22	0.3
Mormyrus lacerda	14	1.4	5.7	0.9	9	8.9	20	0.2
Hepsetus cuvieri	16	1.6	5.9	1	8	7.9	20	0.2
Schilbe intermedius	21	2.1	2.3	0.4	6	5.9	14	0.2
Sargochromis greenwoodi	12	1.2	3.0	0.5	5	5	8	0.1
Clarias ngamensis	6	0.6	4.0	0.7	3	3	4	0
Tilapia sparrmanii	8	0.8	1.1	0.2	3	3	3	0
Clarias sp.	4	0.4	13.3	2.2	1	1	3	0
Sargochromis sp.	1	0.1	0.3	0	1	1	0	0
Total	**1024**	**100**	**614.6**	**100**	**-**	**-**	**8604**	**100**

4.1.3.2 Impalila fisher's caches

Period: August 2010 to December 2013

A total of 23 species, including the *Synodontis* group, with 11030 fish in total number and 3084.4 kg in total weight were recorded from the gillnets at Impalila from 2010 to 2013. The five most important species recorded according to the Index of Relative Importance (IRI) contributed 70.9% of the total IRI, 50.3% of the total number and 53.4% of the total weight. The three most important species recorded according to the IRI were *O. andersonii, C. rendalli* and *H. vittatus* with a total IRI of 56.5% (Table 7). The Cichlidae dominated the catches with 66.4% of the total IRI, 47.5% of the total number and 53.9% of the total weight (Table 5).

Table 5: Species composition in number (No), weight (kg), frequency of occurrence (FRQ) and Index of Relative Importance (IRI) recorded from the gillnet catches at Impalila for the study period August 2010 to December 2013.

Species	No	No %	W kg	W %	FRQ	FRQ %	IRI	IRI %
Oreochromis andersonii	1326	12.0	467.5	15.2	188	43.3	1177	24.1
Coptodon rendalli	1182	10.7	452.9	14.7	187	43.1	1094	22.4
Hydrocynus vittatus	822	7.5	369.7	12.0	109	25.1	488	10.0
Oreochromis macrochir	712	6.5	220.4	7.1	125	28.8	392	8.0
Schilbe intermedius	1496	13.6	137.1	4.4	75	17.3	311	6.4
Marcusenius altisambesi	1571	14.2	93.2	3.0	64	14.7	255	5.2
Sargochromis giardi	457	4.1	154.9	5.0	88	20.3	186	3.8
Clarias gariepinus	264	2.4	279.3	9.1	68	15.7	179	3.7
Tilapia sparrmanii	777	7.0	78.9	2.6	79	18.2	175	3.6
Synodontis spp.	955	8.7	84.1	2.7	62	14.3	163	3.3
Mormyrus lacerda	231	2.1	175.3	5.7	63	14.5	113	2.3
Serranochromis altus	312	2.8	117.0	3.8	69	15.9	105	2.2
Serranochromis macrocephalus	315	2.9	105.6	3.4	69	15.9	100	2.0
Clarias ngamensis	218	2.0	208.4	6.8	47	10.8	95	1.9
Hepsetus cuvieri	189	1.7	64.2	2.1	45	10.4	39	0.8
Serranochromis angusticeps	55	0.5	21.6	0.7	19	4.4	5	0.1
Serranochromis jallae	35	0.3	19.9	0.6	13	3.0	3	0.1
Sargochromis carlottae	33	0.3	14.7	0.5	14	3.2	3	0.1
Sargochromis greenwoodi	25	0.2	7.2	0.2	10	2.3	1	0
Labeo lunatus	24	0.2	8.1	0.3	3	0.7	0	0
Hemichromis elongatus	26	0.2	2.6	0.1	4	0.9	0	0
Clarias stappersii	3	0	1.2	0	3	0.7	0	0
Parauchenoglanis ngamensis	2	0	0.4	0	2	0.5	0	0
Total	**11030**	**100**	**3084.4**	**100**	**-**	**-**	**4885**	**100**

Period: March 2015 to July 2018

A total of 26 species, including the *Synodontis* group, with 2459 fish in total number and 1056.2 kg in total weight, were recorded from the gillnets at Impalila from 2015 to 2018. The five most important species recorded according to the Index of Relative Importance (IRI) contributed 85.1% of the total IRI, 53.1% of the total number and 72.4% of the total weight. The three most important species recorded according to the IRI were *C. ngamensis, H. vittatus* and *O. andersonii* with a total IRI of 71.2% (Table 8). The Cichlidae contributed 36.7% of the total IRI, 47.3% of the total number and 39.9% of the total weight recorded (Table 8).

The catches were dominated by the families Cichlidae and Clariidae that contributed 75.7% of the total IRI, 67.4% of the total number and 75.2% of the total weight (Table 6).

Oreochromis andersonii, O. macrochir and *H. vittatus* are listed during both periods within the five most important fish species according to the IRI (Tables 7 & 8). *Schilbe intermedius*, a much smaller species and less valued, is listed as the fifth most important fish species during August 2010 and December 2013, but the twelfth most important species during March 2015 and July 2018.

Table 6: Species composition in number (No), weight (kg), frequency of occurrence (FRQ) and Index of Relative Importance (IRI) recorded from the gillnet catches at Impalila for the study period March 2015 to July 2018.

Species	No	No %	W kg	W %	FRQ	FRQ %	IRI	IRI %
Clarias ngamensis	413	16.8	303.4	28.7	83	40.1	1825	38.1
Hydrocynus vittatus	274	11.1	206.3	19.5	61	29.5	904	18.9
Oreochromis andersonii	276	11.2	114.4	10.8	64	30.9	682	14.2
Serranochromis angusticeps	211	8.6	86.2	8.2	57	27.5	461	9.6
Oreochromis macrochir	134	5.4	55.4	5.2	40	19.3	207	4.3
Coptodon rendalli	138	5.6	55.0	5.2	38	18.4	199	4.1
Marcusenius altisambesi	214	8.7	18.6	1.8	31	15.0	157	3.3
Serranochromis altus	88	3.6	33.6	3.2	23	11.1	75	1.6
Serranochromis macrocephalus	66	2.7	21.0	2.0	21	10.1	47	1.0
Synodontis spp.	84	3.4	7.6	0.7	20	9.7	40	0.8
Clarias gariepinus	55	2.2	53.0	5.0	10	4.8	35	0.7
Schilbe intermedius	85	3.5	4.6	0.4	16	7.7	30	0.6
Tilapia sparrmanii	81	3.3	8.9	0.8	14	6.8	28	0.6
Sargochromis carlottae	42	1.7	11.0	1.0	15	7.2	20	0.4
Mormyrus lacerda	38	1.5	14.1	1.3	13	6.3	18	0.4
Sargochromis greenwoodi	51	2.1	10.9	1.0	12	5.8	18	0.4
Pharyngochromis acuticeps	40	1.6	10.5	1.0	11	5.3	14	0.3
Sargochromis giardi	24	1	8.5	0.8	13	6.3	11	0.2
Clarias stappersii	26	1.1	15.5	1.5	9	4.3	11	0.2
Hepsetus cuvieri	31	1.3	9.4	0.9	10	4.8	10	0.2
Serranochromis jallae	10	0.4	7.1	0.7	3	1.4	2	0
Enteromius poechii	63	2.6	0.1	0	1	0.5	1	0
Labeo lunatus	4	0.2	0.5	0	2	1.0	0	0
Hemichromis elongatus	3	0.1	0.1	0	2	1.0	0	0
Petrocephalus spp.	6	0.2	0.2	0	1	0.5	0	0
Cyphomyrus cubangoensis	2	0.1	0.2	0	1	0.5	0	0
Total	**2459**	**100**	**1056.2**	**100**	**-**	**-**	**4795**	**100**

4.1.3.3 Kasika fishers' catches

Period: August 2010 to December 2013

A total of 24 species, including the *Synodontis* group, with 5883 fish in total number and 2344.8 kg in total weight were recorded from the gillnets at Kasika from 2010 to 2013. The five most important species recorded according to the Index of Relative Importance (IRI) contributed 83.4% of the total IRI, 54.5% of the total number and 66.4% of the total weight. The three most important species recorded according to the IRI were *O. andersonii, C. rendalli* and *H. vittatus* with a total IRI of 72.4% (Table 9). The Cichlidae dominated the catches with 79.7% of the total IRI, 61.2% of the total number and 59.9% of the total weight (Table 7).

Table 7: Species composition in number (No), weight (kg), frequency of occurrence (FRQ) and Index of Relative Importance (IRI) recorded from the gillnet catches at Kasika for the study period August 2010 to December 2013.

Species	No	No %	W kg	W %	FRQ	FRQ %	IRI	IRI %
Oreochromis andersonii	1132	19.2	437.4	18.7	169	49.4	1873	34.6
Coptodon rendalli	1016	17.3	426.5	18.2	159	46.5	1649	30.4
Hydrocynus vittatus	401	6.8	291.6	12.4	71	20.8	400	7.4
Oreochromis macrochir	424	7.2	141.5	6.0	83	24.3	321	5.9
Clarias gariepinus	236	4.0	261.4	11.1	62	18.1	275	5.1
Serranochromis altus	301	5.1	125.5	5.4	58	17.0	178	3.3
Sargochromis giardi	251	4.3	109.9	4.7	67	19.6	175	3.2
Schilbe intermedius	517	8.8	67.0	2.9	48	14.0	163	3.0
Mormyrus lacerda	204	3.5	152.4	6.5	46	13.5	134	2.5
Serranochromis macrocephalus	223	3.8	90.4	3.9	47	13.7	105	1.9
Synodontis spp.	331	5.6	42.4	1.8	32	9.4	70	1.3
Clarias ngamensis	78	1.3	73.9	3.2	20	5.8	26	0.5
Marcusenius altisambesi	217	3.7	20.1	0.9	16	4.7	21	0.4
Tilapia sparrmanii	160	2.7	33.1	1.4	11	3.2	13	0.2
Serranochromis angusticeps	55	0.9	17.4	0.7	19	5.6	9	0.2
Hepsetus cuvieri	21	0.4	9.2	0.4	9	2.6	2	0
Serranochromis jallae	18	0.3	8.7	0.4	7	2.0	1	0
Brycinus lateralis	251	4.3	2.4	0.1	1	0.3	1	0
Sargochromis greenwoodi	15	0.3	10.4	0.4	3	0.9	1	0
Clarias stappersii	13	0.2	18.8	0.8	2	0.6	1	0
Sargochromis carlottae	8	0.1	3.0	0.1	7	2.0	1	0
Synodontis nigromaculatus	8	0.1	0.7	0	2	0.6	0	0
Labeo lunatus	2	0	0.6	0	2	0.6	0	0
Parauchenoglanis ngamensis	1	0	0.3	0	1	0.3	0	0
Total	**5883**	**100**	**2344.8**	**100**	**-**	**-**	**5419**	**100**

Period: February 2015 to July 2018

A total of 25 species, including the *Synodontis* group, with 2502 fish in total number and 636.6 kg in total weight were recorded from the gillnets at Kasika from 2015 to 2018. The five most important species recorded according to the Index of Relative Importance (IRI) contributed 79.6% of the total IRI, 59.7% of the total number and 65.3% of the total weight. The three most important species recorded according to the IRI were *O. andersonii, C. ngamensis* and *S. intermedius* with a total IRI of 52.5% (Table 10). The Cichlidae contributed 46.2% of the total IRI, 35.0% of the total number and 46.0% of the total weight (Table 8). *Oreochromis andersonii, C. rendalli* and *H. vittatus* are listed during both periods within the five most important fish species according to the IRI (Tables 9 & 10). *Schilbe intermedius*, a much smaller species and less-valued is listed as the eighth most important fish species during August 2010 and December 2013, but the third most important species during February 2015 and July 2018.

Table 8: Species composition in number (No), weight (kg), frequency of occurrence (FRQ) and Index of Relative Importance (IRI) recorded from the gillnet catches at Kasika for the study period February 2015 to July 2018.

Species	No	No %	W Kg	W %	FRQ	FRQ %	IRI	IRI %
Oreochromis andersonii	257	10.3	82.1	12.9	79	45.1	1046	21.5
Clarias ngamensis	210	8.4	137.8	21.7	48	27.4	824	17
Schilbe intermedius	595	23.8	43.2	6.8	39	22.3	681	14
Hydrocynus vittatus	260	10.4	83.1	13	50	28.6	670	13.8
Coptodon rendalli	169	6.8	69.3	10.9	64	36.6	646	13.3
Synodontis spp.	351	14	27.2	4.3	31	17.7	324	6.7
Oreochromis macrochir	99	4.0	28.6	4.5	39	22.3	188	3.9
Serranochromis macrocephalus	97	3.9	27.1	4.3	33	18.9	153	3.2
Serranochromis angusticeps	72	2.9	31.2	4.9	23	13.1	102	2.1
Marcusenius altisambesi	114	4.6	8.3	1.3	17	9.7	57	1.2
Clarias gariepinus	25	1.0	22.3	3.5	15	8.6	39	0.8
Serranochromis altus	38	1.5	12.5	2.0	16	9.1	32	0.7
Sargochromis giardi	39	1.6	12.5	2.0	13	7.4	26	0.5
Tilapia sparrmanii	39	1.6	9.1	1.4	13	7.4	22	0.5
Sargochromis greenwoodi	31	1.2	10.4	1.6	9	5.1	15	0.3
Mormyrus lacerda	16	0.6	9.6	1.5	9	5.1	11	0.2
Hepsetus cuvieri	20	0.8	8.0	1.3	9	5.1	11	0.2
Sargochromis carlottae	21	0.8	7.5	1.2	9	5.1	10	0.2
Labeo lunatus	6	0.2	2.1	0.3	5	2.9	2	0
Serranochromis jallae	4	0.2	1.1	0.2	3	1.7	1	0
Clarias stappersii	3	0.1	2.0	0.3	2	1.1	0	0
Petrocephalus spp.	17	0.7	0.1	0	1	0.6	0	0
Pharyngochromis acuticeps	5	0.2	0.9	0.1	2	1.1	0	0
Enteromius poechii	7	0.3	0.2	0	1	0.6	0	0
Brycinus lateralis	6	0.2	0.1	0	1	0.6	0	0
Sargochromis sp.	1	0	0.1	0	1	0.6	0	0
Total	**2502**	**100**	**636.6**	**100**	**-**	**-**	**4861**	**100**

4.2.3. Comparison of species composition between fishers' and MFMR gillnets

The experimental gillnets used by the MFMR have a wide range of different mesh sizes as indicated in the materials and method section. The catches from these gillnets give a sense of the overall species composition of the river system due to the wide range of mesh sizes used, targeting all fish sizes. The fishers' gillnets on the other hand differ considerably from those of the MFMR due to the smaller range of mesh sizes used and also the fact that the methods they use are targeting certain species due to their high value at the local and regional fish markets.

Aggregated fish CPUE per fishing methods were hierarchically grouped into two major clusters. There was an 85.6% dissimilarity at Kalimbeza (Figure 4) between the two fishing methods with *B. lateralis* (17.1%), *H. vittatus* (15.1%), *S. intermedius* (9.8%) and *M. acutidens* (9.2%) contributing 51.2% of the dissimilarity between the two groups.

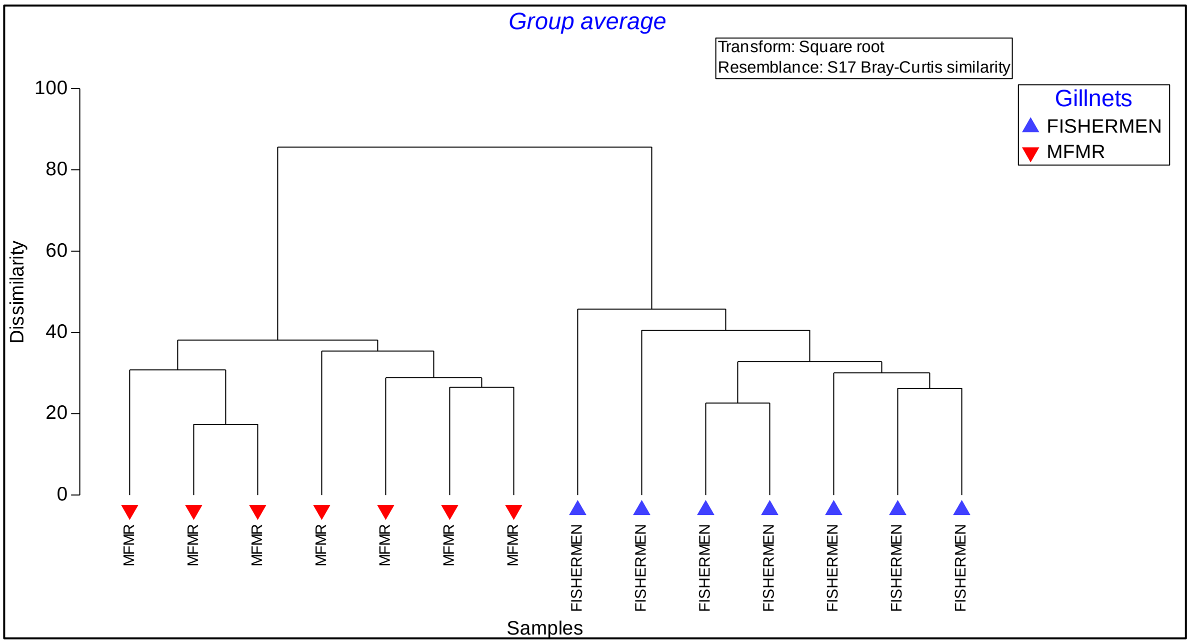

Figure 4: Dendrogram for the hierarchical clustering of the two fishing types (fishers' and experimental gillnets from the MFMR) at Kalimbeza. The dendrogram was produced using the group average linkage method, Bray-Curtis similarities and the CPUE abundance data were square-root transformed.

At Impalila there was a 76.4% dissimilarity between the two fishing methods with *B. lateralis* (15.4%), *M. acutidens* (9.3%) *H. vittatus* (7.6%), *S. intermedius* (7.0%) contributing 39.3% of the dissimilarity between these two groups (Figure5).

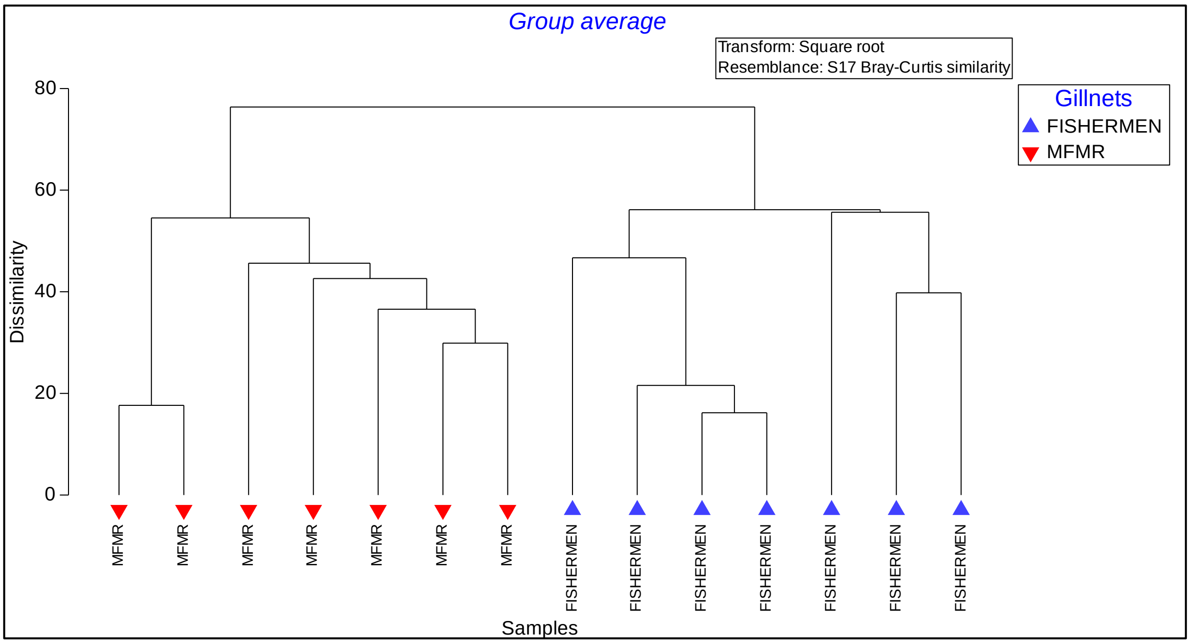

Figure 5: Dendrogram for the hierarchical clustering of the two fishing types (fishers' and experimental gillnets from the MFMR) at Impalila. The dendrogram was produced using the group average linkage method, Bray-Curtis similarities and the CPUE abundance data were square-root transformed.

4.2 Mesh sizes used

4.2.1 Kalimbeza

At Kalimbeza the gillnet mesh sizes used in the local fisheries ranged from 1.0 inch to 5.5 inch Figure6a). Among these, the 3.0-, 3.5- and 4.0 inch were the most frequently used throughout the whole survey period. The 3.0, 3.5, and 4.0 inch mesh sizes contributed 87.2% of the total gillnets used during the period August 2010 to September 2013 and 88.1% during the period March 2015 to July 2018. The most frequently used mesh size was the 3.5 inch, during both periods. The use of the 3.5 inch gillnets increased at Kalimbeza from 35.9% during the first period to 54.5% in the second period.

4.2.2 Impalila

At Impalila the gillnet mesh sizes used ranged from 1.5 inch to 5.0 inchFigure6b). Among these, the 2.5 inch to 4.0 inch were the most frequently used during the period August 2010 to December 2013 and the 3.5 inch during the period March 2015 to July 2018. The 3.0, 3.5 and 4.0 inch gillnets contributed 62.0% of the total gillnets used during the period August 2010 to December 2013 and 84.1% during the period March 2015 to July 2018. The most frequently used mesh size was the 3.5 inch, during both periods. The use of the 3.5 inch gillnets increased at Impalila from 26.2% during the first period to 61.4% in the second period.

4.2.3 Kasika

At Kasika the gillnet mesh sizes ranged from 1.0 to 5.5 inch (Figure6c). Among these the 2.5 inch to 4 inch gillnets were the most frequently used during both periods. The 3, 3.5 and 4 inch gillnets contributed 73.1% of the total gillnets used during the period August 2010 to December 2013 and 75.0% from February 2015 to July 2018. The most frequently used mesh size was the 4 inch during the period August 2010 to December 2013 and the 3.5 inch mesh size during the period February 2015 to July 2018. The use of the 3.5 inch gillnets at Kasika increased from 23.4% during the first period to 50.0% in the second period compared to the rest of the mesh sizes.

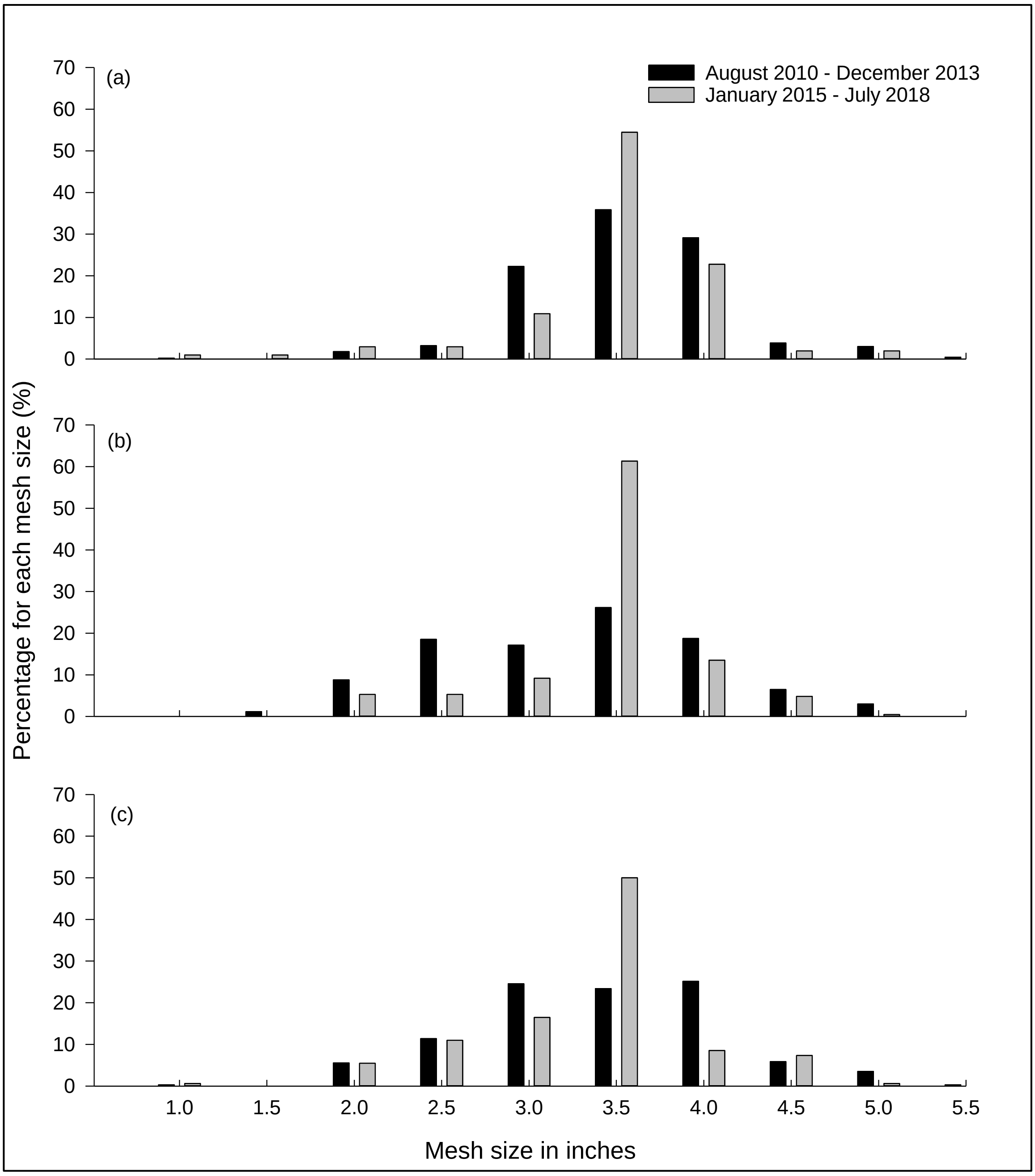

Figure 6: Percentage of the gillnet mesh sizes (1.0 - 5.5 inch) recorded separately at Kalimbeza (a), Impalila (b) and Kasika (c) during each of the two time periods.

The use of 3.5 inch increased in general at all three stations between the first period and the second. The preferred mesh sizes at all three stations were the 3-, 3.5- and 4 inch gillnets. These mesh sizes are all legal according to the Inland Fisheries Resources Act. The smallest mesh size recorded was 1 inch and the largest 5.5 inch.

4.3 Mean size of fish

4.3.1 Kalimbeza

The median fish length increased from 25.5 cm in the period August 2010 – September 2013 (mean length 27.7 cm ± SE 0.11) to 27.6 cm in the period March 2015 – July 2018 (mean length 32.0 cm ± SE 0.39) (Mann-Whitney U = 2823092.5; P < 0.001)Figure 7a).

Accordingly, the mean weight of the fish increased from August 2010 – September 2013, 0.47 kg ± SE 0.01 (median 0.4 kg) increased to the period March 2015 – July 2018, 0.64 kg ± SE 0.02 (median 0.4 kg) (Mann-Whitney U = 3072000.0; P < 0.001)Figure8a).

4.3.2 Impalila

The median fish length increased from 25.0 cm in the period August 2010 – December 2013 (mean length 26.3 cm ± SE 0.121) to 26.9 cm in the period March 2015 – July 2018 (mean length 28.5 cm ± SE 0.24) (Mann-Whitney U = 4838123.5; P < 0.001) Figure7b).

However, the median weight of the fish remained the same from August 2010 – December 2013, 0.3 kg (mean weight 0.43 kg ± SE 0.01) to the period March 2015 – July 2018, 0.4 kg (mean weight 0.44 kg ± SE 0.01) (Mann-Whitney U = 6676557.0; P = 0.226)Figure8b), possibly due to a shift in the species caught.

4.3.3 Kasika

The median fish length remained the same in the period August 2010 – December 2013 (median 25.4 cm, mean length 27.6 cm ± SE 0.15) and in the period February 2015 – July 2018 (median 25.4 cm; mean length 27.9 cm ± SE 0.26) (Mann- Whitney U = 23860430.0; P = 0.984) Figure7c).

However, the fish size in weight (kg) decreased (Mann- Whitney U = 2059848.5; P < 0.001) from the period August 2010 – December 2013 (Median 0.35 kg; mean weight 0.49 kg ± SE 0.01) to the period February 2015 – July 2018 (Median 0.30 kg; mean weight 0.39 kg ± SE 0.01) (Figure8c). As in Impalila, this might possibly be due to a shift in the species caught.

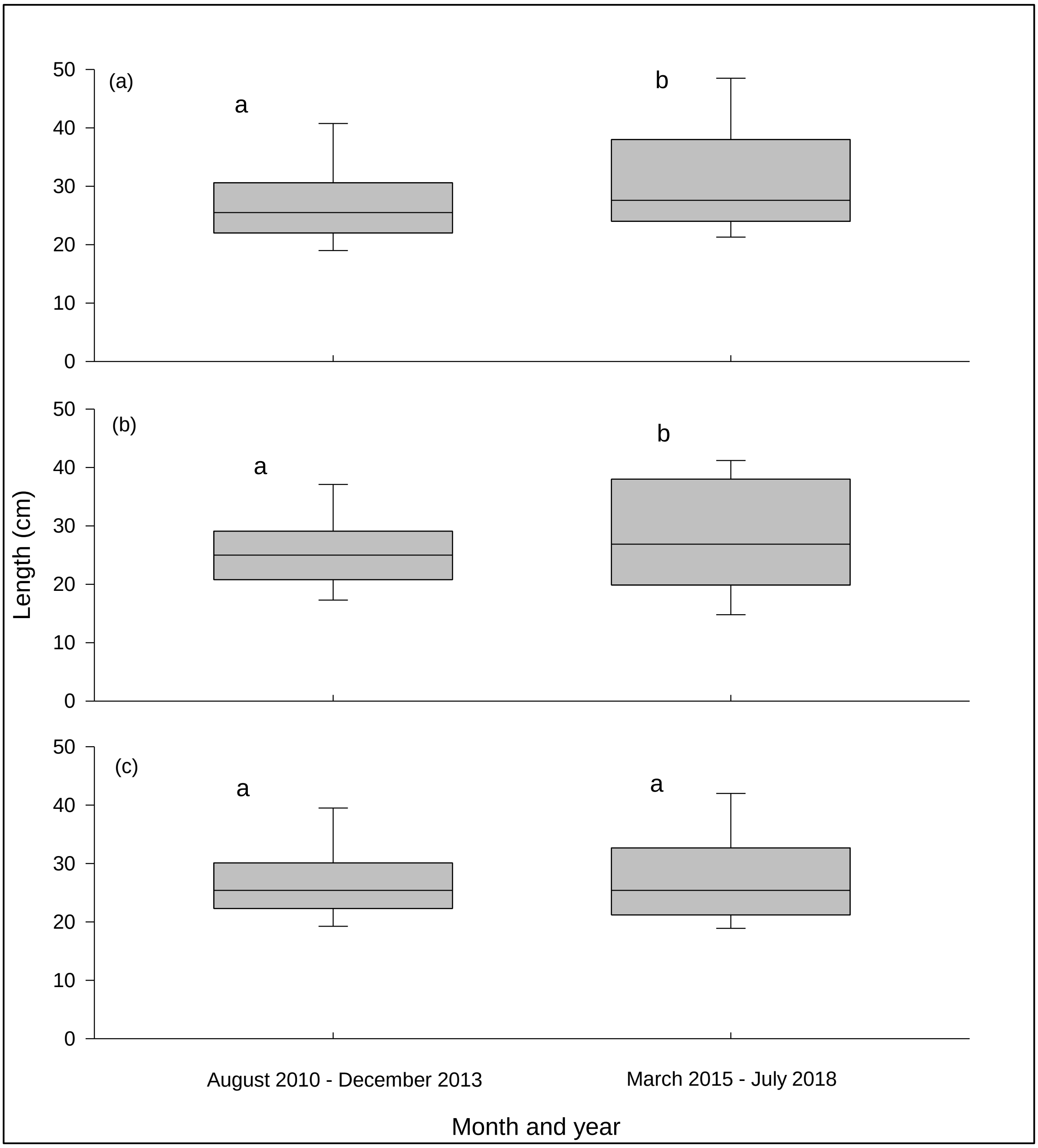

Figure 7: Length of the fish caught with gillnets during August 2010 to September 2013 and March 2015 to July 2018 at Kalimbeza (a), Impalila (b) and Kasika (c). (Box and whisker plots represent the median, upper and lower quartiles and whiskers represent the 5th and 95th percentiles of length). Different superscript above plots denotes significant change.

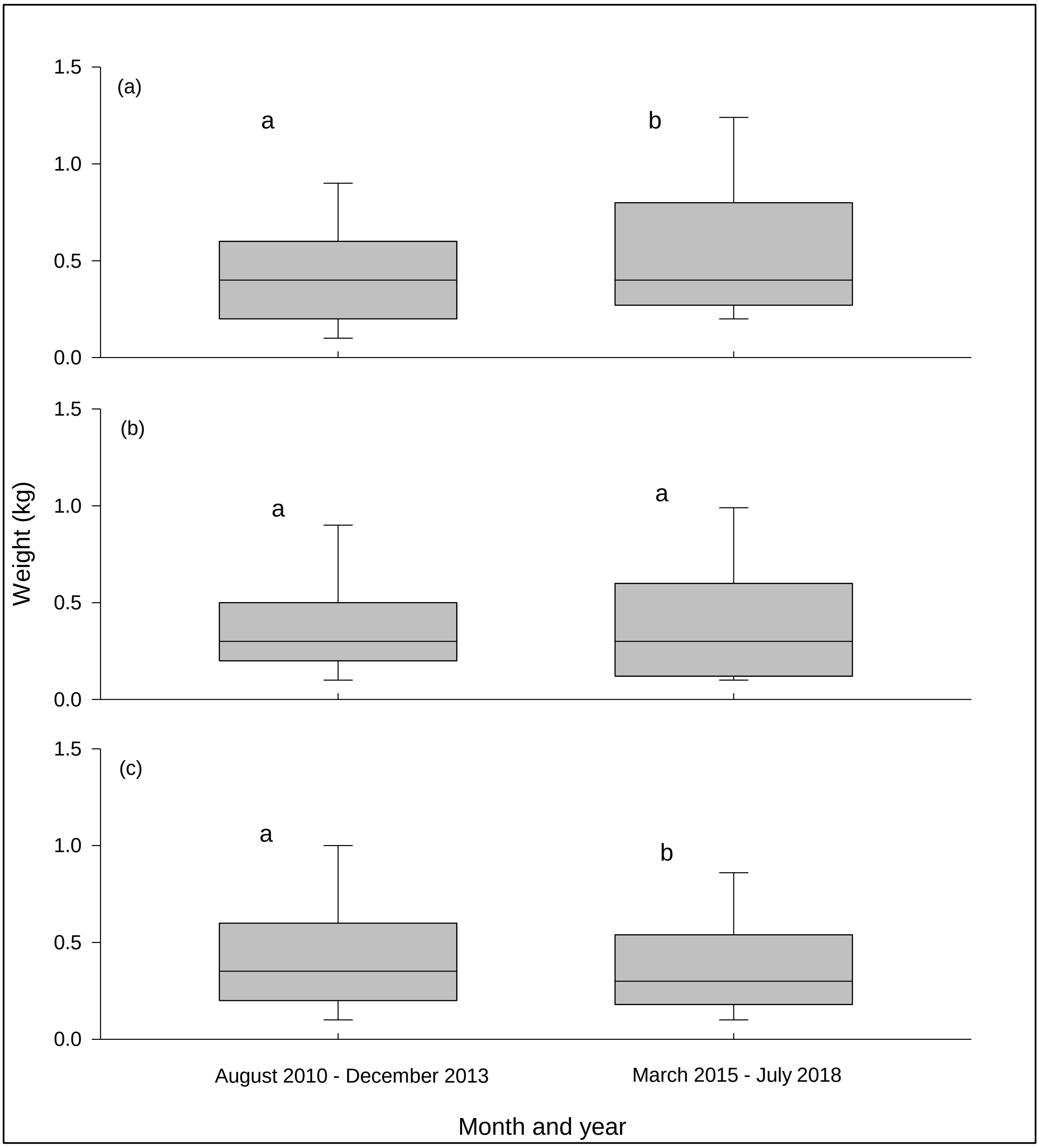

Figure 8: Weight of the fish caught with gillnets during August 2010 to September 2013 and March 2015 to July 2018 at Kalimbeza (a), Impalila (b) and Kasika (c). (Box and whisker plots represent the median, upper and lower quartiles and whiskers represent the 5th and 95th percentiles of length). Different superscript above plots denotes significant change.

4.4 Catch per unit effort

4.4.1 Kalimbeza (all species)

At Kalimbeza the mean catch per unit effort in number of fish per gillnet in the period August 2010 – September 2013 was 16.6 ± SE 0.80 (median 11.0), and decreased to 10.1 ± SE

0.50 (median 9.0) in the period March 2015 – July 2018 (Mann-Whitney U = 34407.0; P < 0.003)Figure9a).

The mean catch per unit effort in weight (kg per gillnet) in the period August 2010 – September 2013 was 5.67 kg ± SE 0.19 (median 4.10 kg), and remained similar in the period March 2015 – July 2018 when it was 6.09 kg ± SE 0.52 (median 4.77 kg) (Mann-Whitney U = 37671.0; P = 0.086) (Figure 10a).

4.4.2 Impalila (all species)

Also at Impalila the mean catch per unit effort in number of fish per gillnet in the period August 2010 – December 2013 was 25.41 ± SE 1.63 (median 15.00) and decreased to 11.88 ± SE 0.60 (median 10.00) in the period March 2015 – July 2018 (Mann-Whitney U = 31295.0; P < 0.001) (Figure9b).

The mean catch per unit effort in weight (kg per gillnet) in the period August 2010 – December 2013 was 7.11 kg ± SE 0.39 (median 4.60 kg) and decreased to 5.10 kg ± SE 0.30 (median 3.60 kg) in the period March 2015 – July 2018 (Mann-Whitney U = 37403.0; P = 0.001) (Figure 10b).

4.4.3 Kasika (all species)

At Kasika the mean catch per unit effort in number of fish per gillnet in the period August 2010 – December 2013 was 17.20 ± SE 1.23 (median 12.00) and decreased to 14.30 ± SE 1.32 (median 10.00) in the period February 2015 – July 2018 (Mann-Whitney U = 24718.5; P = 0.001)Figure9c).

The mean catch per unit effort in weight (kg per gillnet) in the period August 2010 – December 2013 was 6.86 kg ± SE 0.44 (median 4.20 kg) and decreased to 3.64 kg ± SE 0.25 (median 2.62 kg) in the period February 2015 – July (Mann-Whitney U = 21525.0; P < 0.001) (Figure 10c).

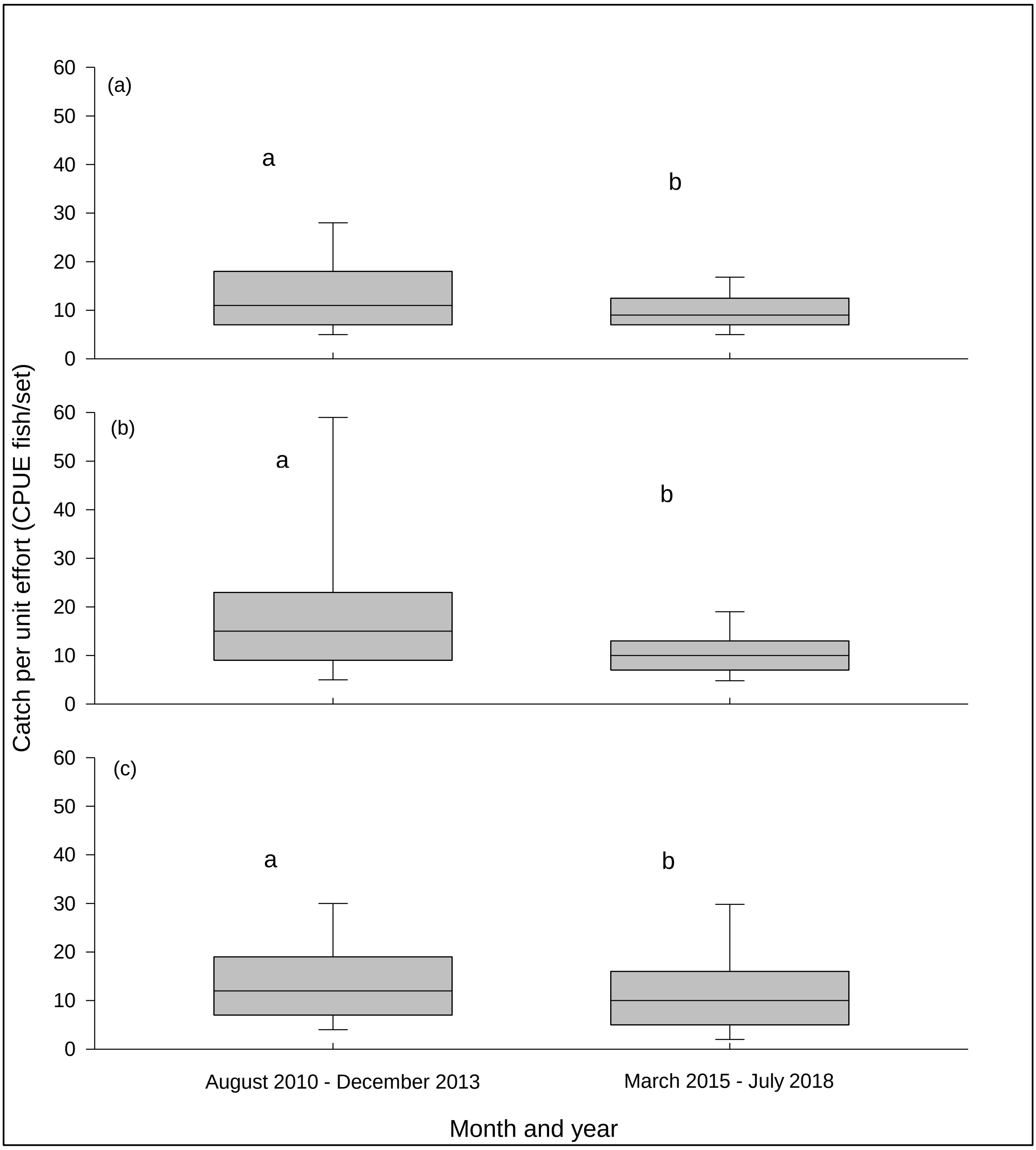

Figure 9: Catch per unit of effort in number per set (CPUE fish/set) of the fish caught with gillnets during August 2010 to September 2013 and March 2015 to July 2018 at Kalimbeza (a), Impalila (b) and Kasika (c). (Box and whisker plots represent the median, upper and lower quartiles and whiskers represent the 5th and 95th percentiles of length). Different superscript above plots denotes significant change.

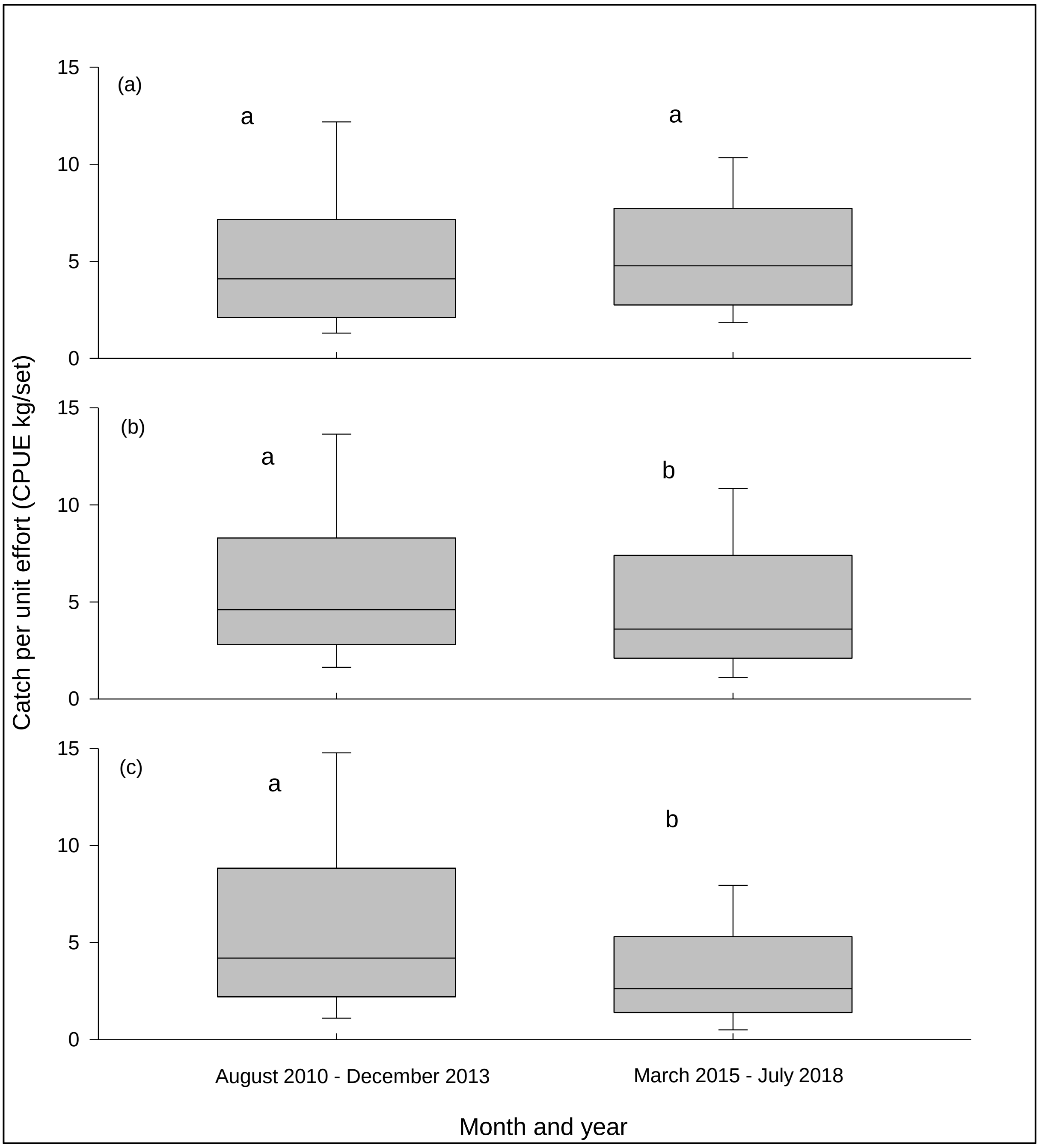

Figure 10: Catch per unit of effort in weight per set (CPUE kg/set) of the fish caught with gillnets during August 2010 to September 2013 and March 2015 to July 2018 at Kalimbeza (a), Impalila (b) and Kasika (c). (Box and whisker plots represent the median, upper and lower quartiles and whiskers represent the 5th and 95th percentiles of length). Different superscript above plots denotes significant change.

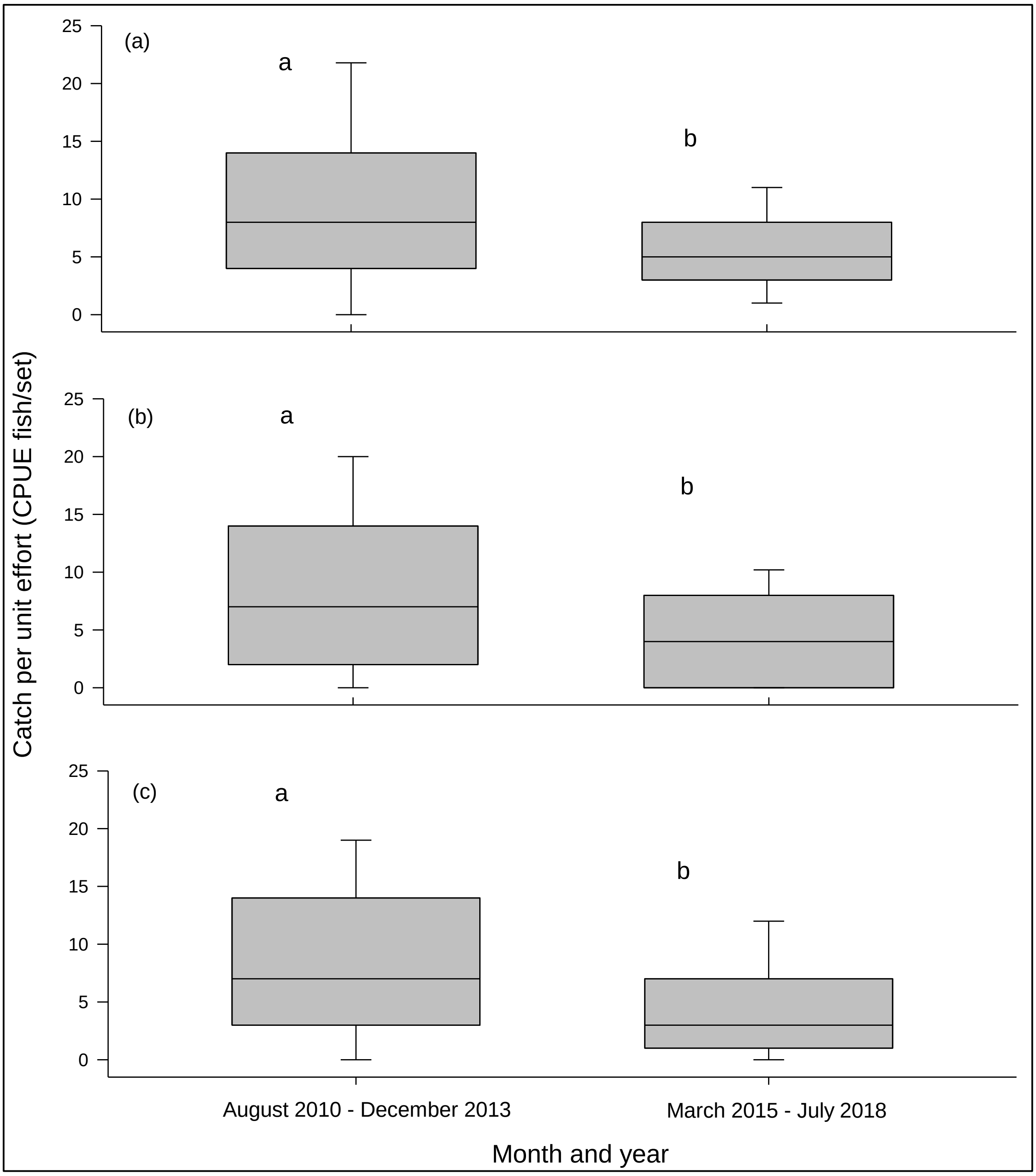

Figure 11: Catch per unit of effort in number per set (CPUE fish/set) of the large cichlids caught with gillnets during August 2010 to September 2013 and March 2015 to July 2018 at Kalimbeza (a), Impalila (b) and Kasika (c). (Box and whisker plots represent the median, upper and lower quartiles and whiskers represent the 5th and 95th percentiles of length). Different superscript above plots denotes significant change.

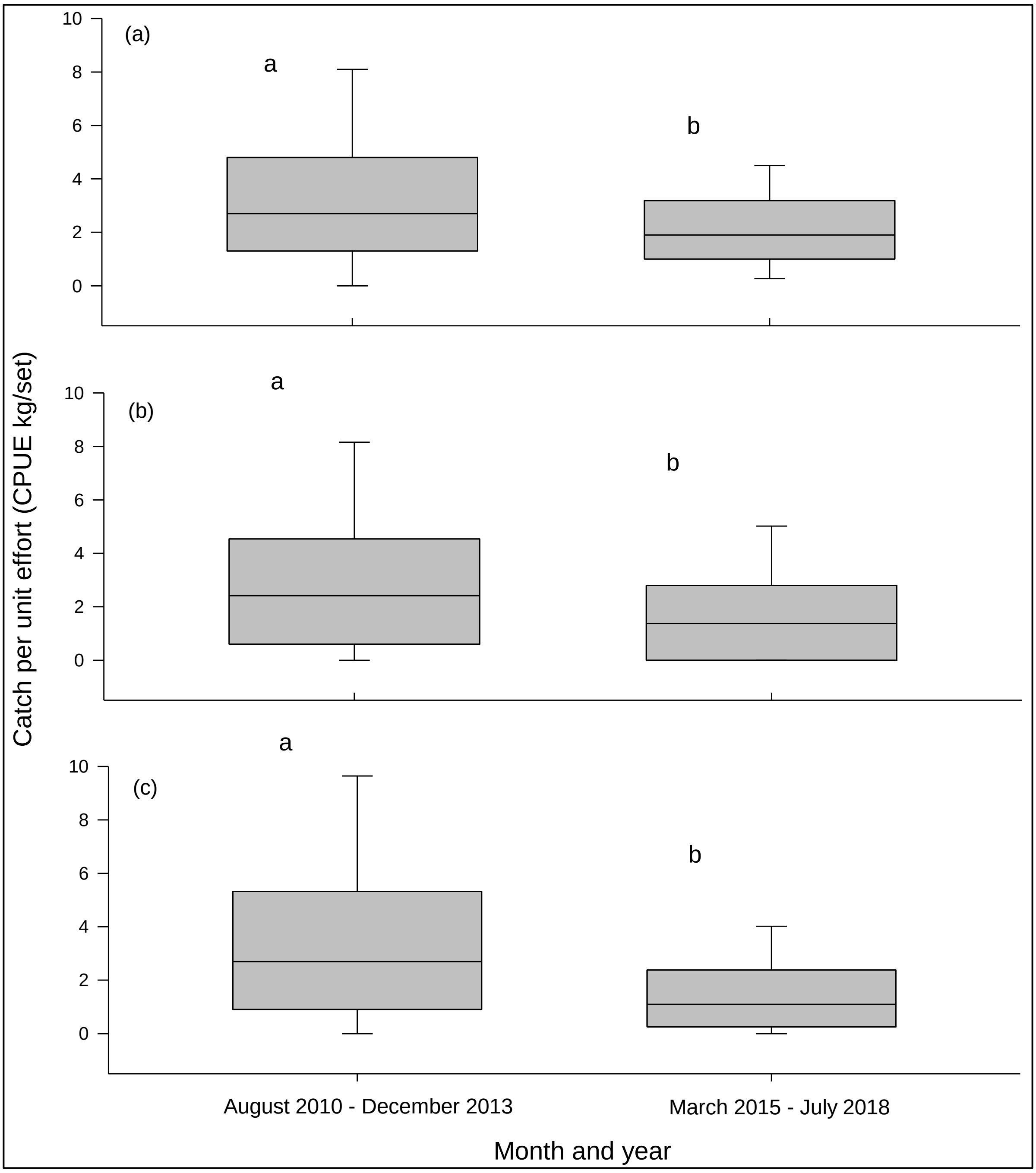

Figure 22: Catch per unit of effort in weight per set (CPUE kg/set) of the large cichlids caught with gillnets during August 2010 to September 2013 and March 2015 to July 2018 at Kalimbeza (a), Impalila (b) and Kasika (c). (Box and whisker plots represent the median, upper and lower quartiles and whiskers represent the 5th and 95th percentiles of length). Different superscript above plots denotes significant change.

4.4.4 Kalimbeza (large cichlids)

At Kalimbeza the mean catch per unit effort in number of fish per gillnet in the period August 2010 – September 2013 was 10.7 ± SE 0.40 (median 8.0), and decreased to 6.0 ± SE 0.42 (median 5.0) in the period March 2015 – July 2018 (Mann- Whitney U = 30040.5.0; P < 0.001) Figure11a).

The mean catch per unit effort in weight (kg per gillnet) in the period August 2010 – September 2013 was 3.77 kg ± SE 0.15 (median 2.7 kg), and decreased in the period March 2015 – July 2018 when it was 2.80 kg ± SE 0.41 (median 1.9 kg) (Mann-Whitney U = 33.631.1; P = 0.001) (Figure 112a).

4.4.5 Impalila (large cichlids)

Also at Impalila the mean catch per unit effort in number of fish per gillnet in the period August 2010 – December 2013 was 10.3 ± SE 0.68 (median 7.0) and decreased to 5.0 ± SE 0.32 (median 4.0) in the period March 2015 – July 2018 (Mann- hitney U = 32332.0 P < 0.001) (Figure11b).

The mean catch per unit effort in weight (kg per gillnet) in the period August 2010 – December 2013 was 3.7 kg ± SE 0.26 (median 2.4 kg) and decreased to 1.9 kg ± SE 0.14 (median 1.4 kg) in the period March 2015 – July 2018 (Mann- hitney U = 34475.5; P < 0.001) (Figure 112b).

4.4.6 Kasika (large cichlids)

At Kasika the mean catch per unit effort in number of fish per gillnet in the period August 2010 – December 2013 was 10.1 ± SE 0.64 (median 7.0) and decreased to 4.8 ± SE 0.38 (median 3.0) in the period February 2015 – July 2018 (Mann-Whitney U = 19592.0; P < 0.001)Figure11c).

The mean catch per unit effort in weight (kg per gillnet) in the period August 2010 – December 2013 was kg 4.0± SE 0.27 (median 2.7 kg) and decreased to 1.6 kg ± SE 0.14 (median 1.1 kg) in the period February 2015 – July (Mann-Whitney U = 19270.5; P < 0.001) (Figure 112c).

4.5 Changes in maximum length over the study period

The maximum length of selected fish species sampled by the fishers' gillnets for each month is documented to determine whether there is any trend visible over the study period.

4.5.1 Kalimbeza

At Kalimbeza, the maximum length declined significantly ($p < 0.05$) over the entire period for *O. andersonii, O. macrochir, C. rendalli, S. macrocephalus, S. giardi* and *S. angusticeps* (Figure 33), while *H. vittatus* and *S. altus* showed no trend during this period. The sharpest decline observed was for *O. andersonii* (b = -0.124), *O. macrochir* (b = -0.102), *C. rendalli* (b = -0.109) and *S. giardi* (-0.126).

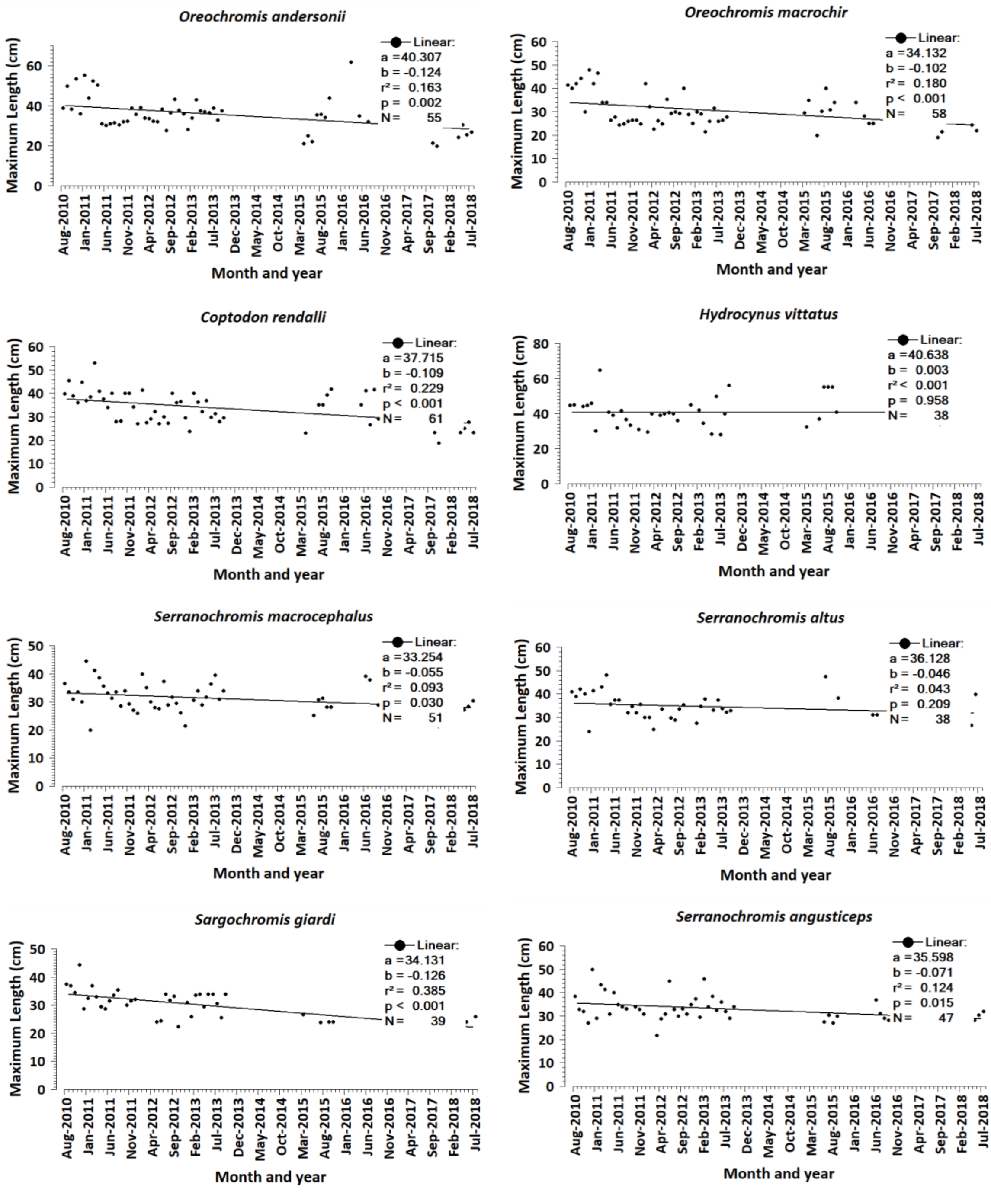

Figure 33: Maximum length (cm) of selected fish species caught by the fishermen using gillnets for each month at Kalimbeza.

4.5.2 Impalila

At Impalila, the maximum length declined significantly ($p < 0.05$) over the entire period for *C. rendalli* and *S. giardi* while it increased for *H. vittatus*. The rest of the species showed no trend during this period (Figure 44). *Coptodon rendalli* (b = -0.088) had the sharpest decline (Figure 14).

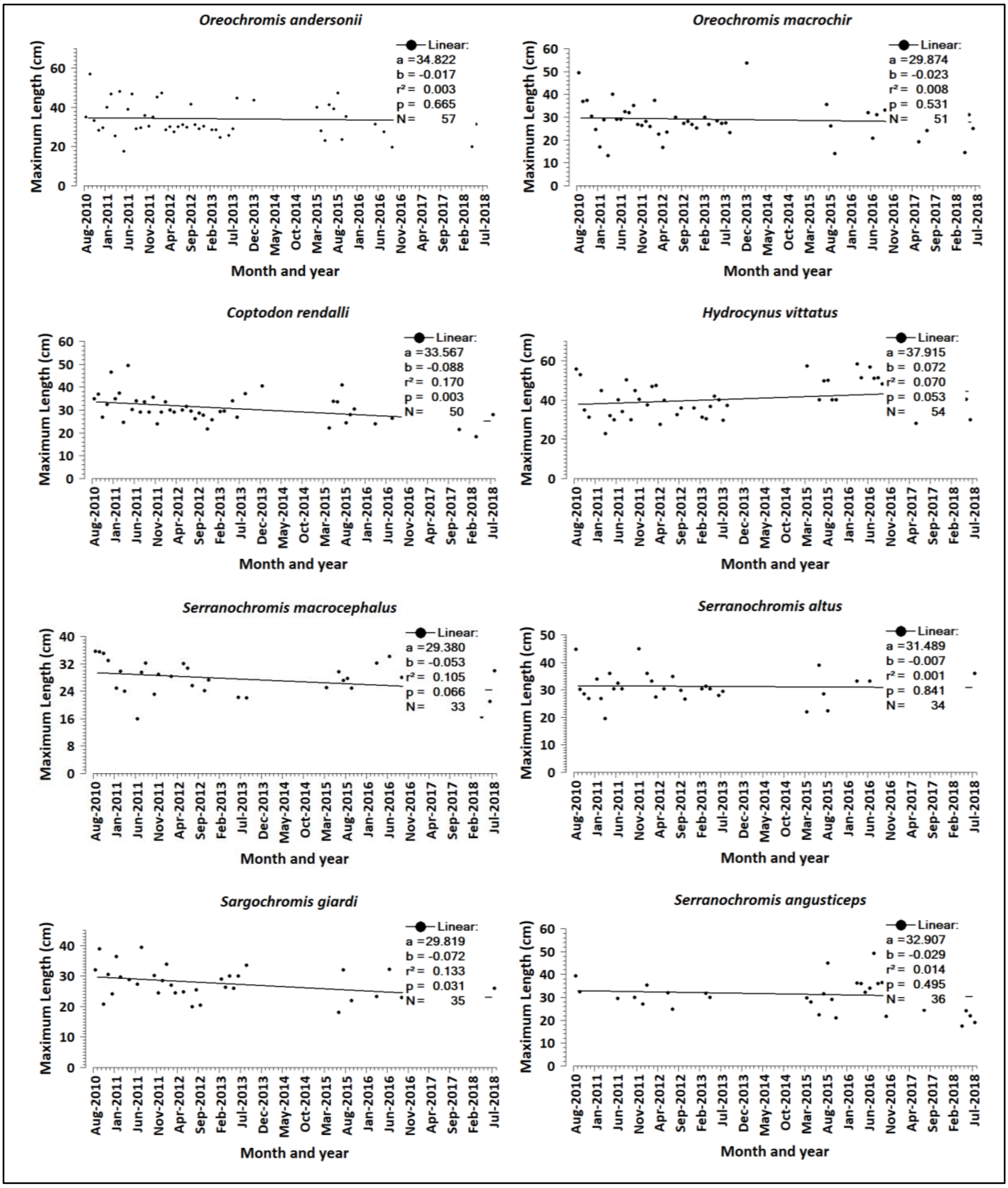

Figure 44: Maximum length (cm) of selected fish species caught by the fishermen using gillnets for each month at Impalila.

4.5.3 Kasika

At Kasika, the maximum length declined significantly ($p < 0.05$) over the entire period for *O. andersonii* and *O. macrochir* while the rest of the species showed no trend during this period (Figure 55).

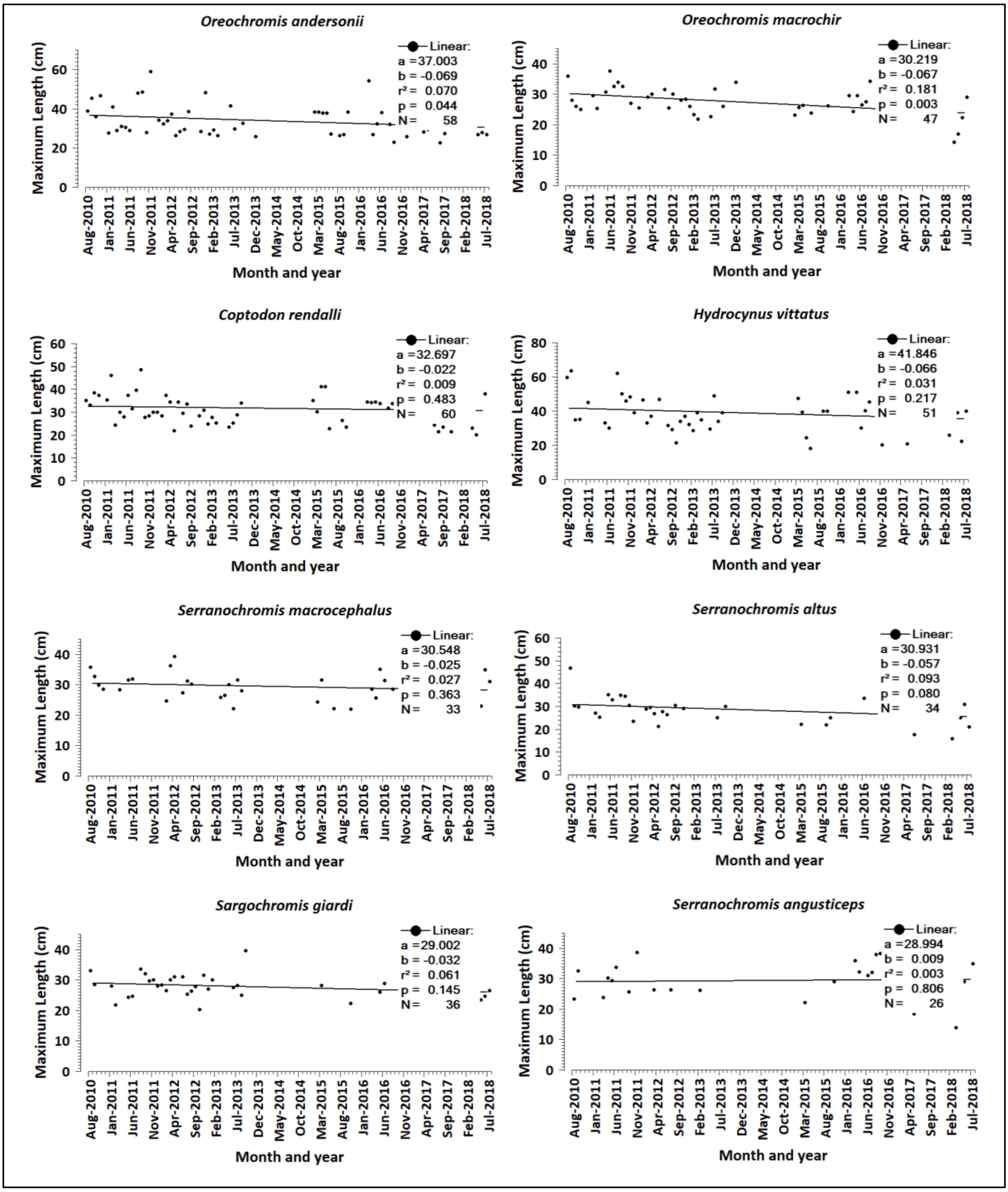

Figure 55: Maximum length (cm) of selected fish species caught by the fishermen using gillnets for each month at Kasika.

4.6 Proportion of mature fish caught

4.6.1 All stations combined

At all three locations combined, in the fisher's gillnet catches, the majority of specimens of the following species were sexually immature: *O. macrochir* (73.5%), *S. altus* (66.7%), and *S. jallae* (60.3%) (Table 9).

*Table 9: Percentage immature (total number in brackets) fish caught per species by the fishermen using gillnets at all stations. All mesh sizes are combined. (50% maturity length, * Peel (2012), ** Hay et al. (2002), *** Froese & Pauly (2019), # Skelton (1993).*

Species	Maturity length (mm)	Percentage immature fish caught		
		August 2010 to September 2013	March 2015 to July 2018	Total
O. andersonii	240*	38.0 (3365)	38.6 (643)	38.0 (4308)
O. macrochir	254*	76.2 (1941)	58.0 (343)	73.5 (2284)
C. rendalli	214*	18.0 (2593)	24.4 (501)	19.0 (3094)
S. intermedius	180#	31.5 (928)	35.8 (159)	32.1 (1087)
M. altisambesi	130**	3.1 (445)	29.2 (202)	11.3 (647)
H. vittatus	300**	37.8 (699)	22.7 (471)	31.7 (1170)
S. macrocephalus	230***	16.4 (1273)	29.9 (268)	18.8 (1541)
S. altus	300***	67.3 (695)	64.5 (186)	66.7 (881)
S. giardi	170#	2.2 (685)	1.2 (84)	2.1 (769)
S. angusticeps	240***	17.7 (418)	21.2 (405)	19.4 (823)
S. jallae	280***	59.8 (127)	64.3 (14)	60.3 (141)

4.6.2 Kalimbeza

At Kalimbeza, in the fisher's gillnet catches, the majority of specimens of the following species were sexually immature: *O. macrochir* (75.1% in total), *S. altus* (53.1%), and *S. jallae* (63.9%) at Kalimbeza using gillnets (Table 10).

*Table 10: Percentage immature (total number in brackets) fish caught per species by the fishermen using gillnets at Kalimbeza. All mesh sizes are combined. (50% maturity length, * Peel (2012), ** Hay et al. (2002), *** Froese & Pauly (2019), # Skelton (1993).*

Species	Maturity length (mm)	Percentage immature fish caught		
		August 2010 to September 2013	March 2015 to July 2018	Total
O. andersonii	240*	37.9 (1667)	22.6 (84)	37.2 (1751)
O. macrochir	254*	76.8 (1016)	50.0 (66)	75.1 (1082)
C. rendalli	214*	19.7 (1169)	12.6 (167)	18.8 (1336)
S. intermedius	180#	41.6 (334)	0 (8)	40.6 (342)
M. altisambesi	130**	1.4 (140)	0 (10)	1.3 (150)
H. vittatus	300**	32.4 (145)	28.0 (25)	31.8 (170)
S. macrocephalus	230***	16.3 (731)	20.8 (96)	16.8 (827)
S. altus	300***	51.3 (263)	70.4 (27)	53.1 (290)
S. giardi	170#	0.6 (359)	0 (18)	0.5 (377)
S. angusticeps	240***	14.0 (322)	7.0 (86)	12.5 (408)
S. jallae	280***	63.9 (83)	-	63.9 (83)

4.6.3 Impalila

At Impalila, in the fisher's gillnet catches, the majority of specimens of the following species were sexually immature: *O. macrochir* (69.9%) and *S. altus* (68.4%) at Impalila using gillnets (Table 11).

*Table 11: Percentage immature (total number in brackets) fish caught per species by the fishermen using gillnets at Impalila. All mesh sizes are combined. (50% maturity length, * Peel (2012), ** Hay et al. (2002), *** Froese & Pauly (2019), # Skelton (1993).*

Species	Maturity length (mm)	Percentage immature fish caught		
		August 2010 to December 2013	March 2015 to July 2018	Total
O. andersonii	240*	40.4 (940)	40.6 (261)	40.5 (1201)
O. macrochir	254*	73.3 (544)	56.0 (134)	69.9 (678)
C. rendalli	214*	19.6 (710)	33.6 (128)	21.7 (838)
S. intermedius	180#	27.0 (274)	72.4 (58)	34.9 (332)
M. altisambesi	130**	4.8 (229)	32.3 (167)	16.4 (396)
H. vittatus	300**	46.9 (294)	16.8 (274)	32.4 (568)
S. macrocephalus	230***	24.3 (300)	37.9 (66)	20.8 (366)
S. altus	300***	71.1 (194)	62.5 (88)	68.4 (282)
S. giardi	170#	6.7 (179)	4.2 (24)	6.4 (203)
S. angusticeps	240***	10.6 (47)	28.9 (204)	25.5 (251)
S. jallae	280***	42.9 (21)	60.0 (10)	48.4 (31)

4.6.4 Kasika

At Kasika, in the fisher's gillnet catches, the majority of specimens of the following species were sexually immature: *O. macrochir* (76.8%), *S. altus* (80.9%), and *S. jallae* (54.5%). (Table 12). In the first period (August 2010 - December 2013) the majority of S. *angusticeps* (51.1%) in the catches caught was immature.

*Table 12: Percentage immature (total number in brackets) fish caught per species by the fishermen using gillnets at Kasika. All mesh sizes are combined. (50% maturity length, * Peel (2012), ** Hay et al. (2002), *** Froese & Pauly (2019), # Skelton (1993).*

Species	Maturity length (mm)	Percentage immature fish caught		
		August 2010 to December 2013	February 2015 to July 2018	Total
O. andersonii	240*	39.4 (796)	42.7 (253)	40.2 (1049)
O. macrochir	254*	76.8 (284)	76.8 (99)	76.8 (383)
C. rendalli	214*	13.1 (656)	29.4 (163)	16.4 (819)
S. intermedius	180#	23.4 (291)	11.5 (78)	20.9 (369)
M. altisambesi	130**	1.7 (60)	10.0 (10)	2.9 (70)
H. vittatus	300**	30.4 (260)	38.8 (129)	33.2 (389)
S. macrocephalus	230***	15.0 (213)	34.7 (95)	21.1 (308)
S. altus	300***	82.6 (224)	71.1 (38)	80.9 (262)
S. giardi	170#	0.7 (144)	0 (37)	0.6 (181)
S. angusticeps	240***	51.1 (45)	20.8 (72)	32.5 (117)
S. jallae	280***	50.0 (18)	75 (4)	54.5 (22)

5 Discussion

5.1 Selective fishing by the local fishery

The experimental gillnets (with a wide range of mesh sizes) used by the MFMR give an overview of the fish stocks of these river systems in species richness as well as in relative abundance. Although some bias is still present in the catches as e.g. not all habitats are sampled, and small species are under-represented, the results give a reasonably representative overview of the fish populations in the river system.

There is a marked difference between the species composition in the catches collected with the MFMR experimental gillnets and the species caught by the fishers' gillnets. The five most important fish species (IRI) sampled with these two gear types are all different except for *H. vittatus* that is the most important species sampled with the experimental gillnets and the fifth most important with the fishers' gillnets. The most pronounced difference between the two gear types is the catches of species in the family Cichlidae (the breams). The IRI of the Cichlidae from the experimental gillnets is 0.5% compared to 76% of the fishers' gillnets. Fishers target this family of fishes according to the market demand, with high prices obtained at the fish market in Katima Mulilo and an export market to neighbouring Zambia and the Democratic Republic of the Congo. This targeted fishing is probably the main reason for the decline in these species (as shown in this report), further underlined by legislation that only allows larger mesh sizes above a certain minimum mesh size. This legislation is such that it mainly targets these larger bream species, preventing the utilization of the larger portion of the fish population in the river system that is mainly small-sized species. One of the earliest reports on the fish stocks in Namibia recommended that all gillnet mesh sizes be allowed for a balanced fishery targeting all species of all sizes (Hay et al. 2000).

The two dendrograms of catches at Kalimbeza and Impalila (Figure 2 andFigure3) showed a dissimilarity of more than 70% between the fishers' catches and those from the experimental gillnets. At both stations, it was the smaller fish species that contributed the most to these differences, namely *B. lateralis, S. intermedius* and *M. acutidens*. The only large-sized fish species that influenced this difference, was *H. vittatus*. These results indicate the importance to collect data from fishers' catches as the experimental gillnets used by the MFMR cannot be used to assess the catches from the local fishers.

Oreochromis andersonii, O. macrochir and *C. rendalli were* the three most important fish species sampled by the fishers on the Zambezi and Chobe rivers and floodplains in Namibia. These three species were also the three most important species sampled by the commercial fishers using gillnets from the Okavango Delta (Mosepele, et al., 2019) with a total IRI of 79,6% compared to 65.3% for the Zambezi and Chobe fisheries in Namibia. *Clarias* spp. were also sampled in high numbers in both systems by the gillnet fisheries. *Hydrocynus vittatus*, however, does not play an important role in the commercial fishery of the delta (0.7% IRI) compared to the Zambezi and Chobe Rivers (5.0% IRI) in Namibia. The habitat difference between the delta and the Zambezi and Chobe Rivers is probably the reason for this. The number of species sampled by the gillnet fisheries between the two systems was also very similar with 29 species sampled in the Zambezi and Chobe Rivers and 30 species in the delta when grouping the *Synodontis* spp.

Selective fishing in Africa is common and the fishery targeting high-value fish species is usually at commercial scale that results in a decline in the catch rates of these high-value species. Similarly in Lake Malombe, the fishery of these high-value species collapsed due to increased fishing effort and mainly investment-driven efforts (Nunan et al. 2015, Hara 2006). This situation was exacerbated by an increase in more efficient and destructive gears of monofilament gillnets in the Zambezi and Chobe Rivers. As a result, monofilament gillnets were recently banned in Namibian waters due to their associated high catching rates and further destruction in form of ghost fishing nets.

5.2 Species composition at the different stations in different periods

The sampling results are divided into two periods, one before the establishment of fisheries reserves and the second period after the fisheries reserves were in place, managed by the local communities and effectively patrolled. However, it must be stressed that the sampling was not done inside, but adjacent to the fisheries reserves. Only areas at Kalimbeza and Impalila are currently proclaimed as fisheries reserves with negotiations still ongoing at Kasika to establish a fisheries reserve.

Catch composition by sampling station was quite similar between stations and the Cichlidae being most dominant with only one smaller species recorded among the five most important species sampled. This was *S. intermedius* at Impalila during the first period and at Kasika during the second period. One noticeable trait is the increase in the importance of *C. gariepinus* (9.2% to 52.4% IRI) during the second period at Kalimbeza and the increase in *C. ngamensis* (1.9% to 38.1% IRI) during the second period at Impalila. It is important to note that the *Clarias* spp in the Zambezi Region are not as highly valued as the Cichlidae, as it has a much lower market price (N$25kg for *Clarias* spp. vs. N$65/kg for *O. andersonii*, at the Katima Mulilo Fish Market, C. Hay pers. obs.). It is hypothesized that the catches of these two species are considered by-catch and unlikely to be targeted by the fishers. No major changes could be detected in the species composition between the two sampling periods. This, however, is expected due to the short period that the fisheries reserves had been in place and also the fact that the areas sampled were adjacent to the fisheries reserves and not actually within these protected areas. It was shown in Tasmania that marine protected areas can play a role in the increase in species richness of large fish species and that it can also be beneficial for sensitive species to increase in abundance in protected areas (Barrett et al. 2007).

5.3 Mesh sizes used

The use of the 3.5 inch gillnet increased in general at all three stations between the first time period and the second compared to the other mesh sizes. The preferred mesh sizes at all three stations were the 3, 3.5 and 4 inch gillnets indicating that the fishers have not yet changed to the smaller mesh sizes, although smaller mesh sizes are in use. The smallest mesh size recorded was 1 inch and the largest 5.5 inch. According to the Inland Fisheries Resources Act, the minimum mesh size allowed is 76mm (stretched mesh) that translates to the 3 inch mesh size. This shows that the majority of the gillnets used in this fishery is legal There was a change in fish length between the two sampling periods at Kalimbeza and Impalila that may be caused by the increased use of 3.5 inch gillnets. It seems that the fishers have been following the fish stock dynamics by changing mesh size to optimize their catches.

5.4 Mean size of fish

The fish size in length increased from the first to the second sampling period, except for Kasika where it remained the same. The weight per fish, however, increased at Kalimbeza from the first to the second sampling period, remained the same at Impalila and decreased at Kasika. This might be caused by differences in the species composition and variations in their condition factor (relationship between body length and body mass). The increase in *Clarias* spp. during the second period (see previous section) at Kalimbeza may explain the increase in fish length. This result strengthens the statement made that the fishers may change the mesh sizes to optimize their catches following the dynamics of the fish stocks. This emphasizes the importance to monitor fishing gear used by the fishers to follow the trends.

5.5 Catch per unit effort

All catch per unit effort (all fish species) in number per gillnet decreased from the first period to the second period at all the stations, with a similar trend for the catch per unit effort in kg per gillnet except for Kalimbeza where it remained the same. It is expected that the catch rates will continue to decrease with time if effort remains unsustainably high, as is currently the case in this region. This is clear with the change to monofilament gillnets exacerbated by the influx of foreign fishers, some from Zambia fishing in Namibian waters where the best and the majority of the fishing grounds are. Commercialization is, therefore, the biggest contributor to this decline of high-value fish species. This is further emphasised by the decline in large cichlids that are the preferred species by the fishers. This scenario is witnessed across African fisheries in lakes and floodplain rivers (Nunan et al. 2015, Hara 2006, Hara & Njaya 2016). The minimum mesh size allowed according to the legislation targets the larger sized fish species, leading to a decline in the large, high-value fish. So, it became a question of maximising the profit for the short-term or have fish on the table for the long-term (Allegretti 2019). The problem is that people no longer fish for their livelihood but rather to sustain a lifestyle. This sentiment is clearly seen in Lake Victoria where fishers have the saying, “let’s go make some money” when they are off to the fishing grounds. Many of them also do not want to be hired by someone, they want to hire people to work for them, which strengthen the impression that it is all about money (Allegretti 2019).

5.6 Changes in maximum length of selected fish species

A trend analysis was done for the maximum length recorded for each month of selected fish species. The maximum length recorded at Kalimbeza, declined for six of the eight selected fish species, while the maximum length of two species declined at Impalila and Kasika. Only for *Hydrocynus vittatus* at Impalila did the maximum length increase. *Oreochromis andersonii, O. macrochir* and *C. rendalli* declined at two of the three stations. These are also the three species most targeted by the fisheries. However, it is expected that the size of these high-value fish species would continue to decrease in future, especially if legislation is such that it allows fishers to target these sizes (Kolding et al. 2014). The only way to prevent large individuals to disappear is to have a maximum mesh size rather than a minimum mesh size for management purposes.

5.7 Proportion of mature fish caught

A large percentage of immature individuals of *O. macrochir, S. altus* and *S. jallae* was consistently sampled by the gillnet fishery. Also around 40% of the *O. andersonii* individuals sampled was immature. Peel (2012) recommended that the current minimum mesh size (3 inch or 76mm) stipulated by legislation in the Zambezi River is too small and should be increased to 89mm (3.5 inch) to prevent the sampling of large numbers of immature cichlids. However, the 3 inch mesh was optimum for the second most important species sampled by the fishery, *C. rendalli*. The most common mesh size used by the local fishers during the second period monitored was the 3.5 inch that should target mainly mature cichlids.

6 Conclusion

The results obtained highlight the importance of using local community fishers to record fish catches from the local fishery. Comparing these with the experimental gillnet surveys done by the Ministry illustrates the difference in species composition between the two fishing methods. While the experimental gillnet surveys can identify trends in the entire fish population, catches from the local fishery done by fish monitors is the only method to provide a clear picture of the fishing patterns and the potential impact this may have on the high-value fish species. The experimental gillnet surveys cannot provide this information and cannot replace the data collected by the fish monitors.

It is clear from the study that the high-value species declined although the perception from the local headmen and lodges at the two fisheries reserves is that the protected area did benefit the fish stocks. According to these informants, fish stocks increased within the reserves (C. Hay pers. obs.). However, surveys within the reserves still need to be conducted to verify this.

Currently the larger part of the fish population is not utilized by the fishery as legislation on gill net mesh sizes prevent fishers to target the small-sized fish species. Traditional fishing gears do target the small size species but are currently not much in use. The minimum gillnet mesh size stipulated in legislation will cause that the large cichlids will be targeted, putting further pressure on the spawning stock of these species.

The presence of the alien fish species, *Oreochromis niloticus* in the upper Zambezi in Zambia is a serious threat to the biodiversity of this system and may impact negatively on the local fisheries. It was found in the Kafue River System in Zambia that the introduced *O. niloticus* hybridise with the native *O. andersonii* and that it is not always possible to visually distinguish these hybrids from the parental species. Furthermore, the local fishers stated that since the introduction of *O. niloticus*, the catches of this species increased while they observed a decline in the catches of the native tilapias (Bbole et al. 2014). This could lead to a decline in the biodiversity of this river system and with the predicted impact from climate change in this region, put the livelihoods of the poor fishing communities are under threat that mainly fish for subsistence compared to foreign or migrant fishermen that fish for commercial purposes. Some individuals with formal incomes hire poor fishermen from the area and provide them with gillnets to fish for them. These fishermen are paid low wages or are given some of the catch. This is purely for commercial purposes and is in direct conflict with Namibian legislation.

The introduction of any non-indigenous fish species into this system needs to be carefully considered due to the undesirable impacts these have on the ecosystem (Canonico et al. 2005). Fish species in this system are extremely diverse impacting on all levels of the aquatic food web. The reduction of any of these fish species will ultimately impact on the food web. That is why it is important not to selectively fish, but to ensure a well-balanced harvesting approach. This however it not easy to implement due to the preference for certain fish species either for taste, size or financial gain.

Change is inevitable and the management strategies of these fish resources will have to be altered especially with the onslaught of climate change. The rate of change in weather patterns is likely to be sudden in a geological perspective and communities may not have the resilience to quickly adapt to these sudden changes. It is critical that these local communities be assisted to cope with these changes. One aspect would be to study their impact they have on the fish resource and to use local people to assist in this research process.

Pictures. Fishers gill net catches being recorded.

7 Recommendations

1. The data recorded from the local fishery are critical for management purposes as they provide information on the actual fishery target species, whereas the experimental gillnets used by the MFMR are designed to facilitate assessment of the status of the whole fish fauna and they do not specifically target knowledge on the fishery species.
2. The use of fish monitors should continue as present (but see recommendation 8 below) as this is a cost-effective way of collecting fishery data from across the floodplains on a frequent basis.
3. Data must be validated on a monthly basis and feedback must be provided to the fish monitors to ensure high-quality data.
4. Data must be analysed at six-month intervals to closely monitor the fishing patterns and catch rates.
5. Regular training must be provided to new as well as experienced fish monitors.
6. Exchange visits must be arranged between fish monitors to discuss challenges.
7. Sufficient funds must be made available for the continuation of this data collection.
8. While the present report emphasises the need to continue recording through community monitors at present, it must be recognised that the data gathering and quality needs to be improved in future. The system needs to be developed further to ensure that the data have statistical validity to resent accurate estimates of yields, rather than the general trends presented in this report. Namibia is committed to the FAO code of conduct for responsible fisheries, which calls for participating countries to collect and share statistical data on fisheries. To do this, MFMR needs to invest in developing a recording system. This system should incorporate the community participatory element of the present system.
9. No alien aquatic organisms should be introduced into this system.
10. Management of the fish resource should be decentralized and include the participation of the local fishing community representatives.
11. Gender equity must be an important consideration in all management and monitoring activities.
12. The entire ecosystem needs protection to ensure optimum and sustainable utilization of these natural resources.
13. Legislation should be enacted and implemented in such a way as to protect the high-value fish species and their spawning stocks while allowing the utilization of the under-utilized small-sized fish species.

8 References

Abbott J., 2005. *Fishing for a living: Subsistence and income uses of a common property resource in the Upper Zambezi floodplains.* Nicholas School of the Environment and Earth Sciences, Duke University, PhD dissertation 257 pp.

Abbott J.G., Campbell C., Hay C.J., Naesje T.F. & Purvis J. 2007. Market-resource links and fish vendor livelihoods in the upper Zambezi river floodplains. Human Ecology, Volume 35, 559-574.

Abbott J.G., Hay C.J., Naesje T.F., Tweddle D. & van der Waal B.C.W. 2015. Rain and Copper: The Evolution of a Fish Marketing Channel in a Rapidly Changing Region of Southern Africa. Journal of Southern African Studies, Volume 41, 29-45.

Allegretti A., 2019. "We are here to make money": New terrains of identity and community in small-scale fisheries in Lake Victoria, Tanzania. Journal of Rural Studies, Volume 70, 49-57.

Barrett N., Edgar G., Buxton C. & Haddon M. 2007. Changes in fish assemblages following 10 years of protection in Tasmanian marine protected areas. Journal of Experimental Marine Biology and Ecology, 345(2), 141-157.

Bennet A., Patil P., Kleisner K., Rader D., Virdin J. & Basurto X. 2018. *Contribution of fisheries to food and nutrition security: Current knowledge, policy and research.* Report 18-02. Durham, NC: Duke Uiversity, 46, pp.

Caddy J. & Sharp G., 1986. *An ecological framework for marine fishery investigations,* FAO Fisheries Technical Paper no. 283, 151 pp.

Clarke K. & Gorley R., 2015. *Getting started with PRIMER v7,* s.l.: PRIMER-E Ltd, 20 pp.

Cooke S.J., Nguven V.M., Dettmers J.M., Arlinghaus R, Quist M.C., Tweddle D., Weyl O.L., Raghavan R., Portocarrero-aya M. & Cordoba E.A. 2016. Sustainable inland fisheries-Perspectives from the recreational, commercial and subsistence sectors from around the globe. In: G. Closs, M. Krkosek & J. Olden, eds. *Conservation of Freshwater Fishes.* Cambridge University Press Conservation Biology, 20: 467-505.

de Graaf G. & Garibaldi L., 2014. The value of African fisheries. FAO Fisheries and Aquaculture Circular. No. 1093. Rome, FAO. 76 pp.

Donda S., 2017. Who benefits from fisheries co-management? A case study in Lake Chiuta, Malawi. Marine Policy, Volume 80, 147-153.

Forsythe K., Letley G. & Turpie J., 2018. *Namibia TEEB study: The development to maintain and enhance the protection services in Namibia's state, communal and freehold lands. Vol. A national assessment of Namibia's Ecosystem Services,* Windhoek: Anchor Environmental and Namibia Nature Foundation Draft Report. 104 pp.

Froese R. & Pauly D., 2019. *World Wide Web electronic publication.* [Online] Available at: http://www.fishbase.org.version (08/2019) [Accessed 1 August 2019]

Funge-Smith S. & Bennett A., 2019. *Fish and Fisheries, Wiley.* [Online] Available at:https://onlinelibrary.wiley.com/doi/full/10.1111/faf.12403 [Accessed 28 September 2019].

Hara M., 2006. Restoring the chambo in Southern Malawi: Learning from the past or re-inventing the wheel?. Aquatic Ecosystem Health and Management, 9(4),419-432.

Hara M. & Njaya F., 2016. Between a rock and a hard place: The need for and challenges to implementation of Rights Based Fisheries Management in small-scale fisheries of southern Lake Malawi. Fisheries Research, Volume 174, 10-18.

Hay C. J., Naesje T.F., Breistein J., Harsaker J., Kolding J., Sandlund O.T. & van Zyl B.J. 2000. *Fish populations, gillnet selectivity and artisanal fisheries in the Okavango River, Namibia. Recommendations for a sustainable fishery.,* Windhoek: NINA-NIKU Project Report No. 010, 108 pp.

Hay C.J., Naesje T.F., Kapirika S., Koekemoer J., Strand R. Thorstad E.B. & Harsaker K. 2002. *Fish populations, gill net catches and gill net selectivity in the Zambezi and Chobe Rivers, Namibia, from 1997 to 2000,* Norwegian Institute for Nature Research, 89 pp.

Kolding J., 1999. *PASGEAR. A data base package for experimental or artisanal data from passive gears. A short introductory manual,* s.l.: University of Bergen, Department of Fisheries and Marine Biology.

Kolding J., Bene C. & Bavinck M., 2014. Small-scale fisheries-importance, vulnerability, and deficient knowledge. In: S. Garcia J. Rice & A. Charles eds. Governance for Marine Fisheries and Biodiversity Conservation. Interaction and co-evolution.Wiley-Blackwell, 317-331.

Kolding J. & Skaalevik A., 2018. *Pasgear 2 Version 2.11 A database program for experimental or artisanal fishery data.* s.l.:University of Bergen. URL: www.imr.no/forskning/bistandarbeid/pasgear_2/en.

Kolding J., Ticheler H. & Chanda B., 2003. The Banweulu swamps - A balanced small-scale multispecies fishery. In: *Management, co-management or no management? Major dilemmas in southern African freshwater fisjeries 2. Case studies.* Rome: Food and Agriculture Organization of the United Nations, 275 pp.

Lynch A., Cooke S.J., Deines A.M, Bower S.D, Bunnel D.B., Cowx I.G., Nguyen V.M., Nohner J., Phouthavong K. & Riley B., 2016. The social economic and environmental importance of inland fish and fisheries. Environmental Reviews, Volume 24, 1-7.

Mosepele K., Kolding J. & Bokhutlo T., 2019. Fish stock asessment in inland floodplain fisheries: the case of the Okavango Delta submitted International Journal of Limnology. In: K. Mosepele, ed. *Dynamics of the seasonal floodplain fishery of the Okavango Delta, Botswana.* Bergen: PhD thesis, University of Bergen, Norway, 184 pp.

Naesje T., Strand R., Hay C., Purvis J., Thorstad E., Abbott J. & Nickanor N., 2002. *Shared resource management on the Zambezi/Chobe systems in northeast Namibia: Current practices and future opportunities river survey February-August 2002.,* Norwegian Institute for Nature Research, 24 pp.

Naesje T.F., Strand R., Hay C.J., Purvis J., Thorstad E.B., Abbott J.G. & Nickanor N. 2003. *Shared resource management on the Zambezi/Chobe systems in northeast Namibia: Current practices and future opportunities. River fisheries study: February 2002- February 2003,* Norwegian Institute for Nature Resource, 52 pp.

Neiland A. & Bene C., 2008. Review of River Fisheries Valuation in West and Central Africa. In: A. Neiland & C. Bene eds. *Tropical river fisheries valuation: background papers to a global synthesis.*The WorldFish Center, Penang, Malaysia, 290 pp.

Nunan F., Hara M. & Onyango P., 2015. Institutions and Co-Management in East African Inland and Malawi Fisheries: A Critical Perspective. *World Development,* Volume 70, 203-214.

Peel R. A., 2012. *The biology and abundance of three cuchlid species from the Kavango and Caprivi regions, Namibia,* Windhoek: MSc thesis, University of Namibia, 169 pp.

Purvis J., 2002. *Fish and Livelihoods: Fisheries on the eastern floodplains, Caprivi,* Directorate of Environmental Affairs, Ministry of Environment and Tourism, 49 pp.

Purvis J., Abbott J., Naesje T. & Hay C., 2003. *Shared resource management on the Zambezi/Chobe systems in northeast Namibia: Current practices and future opportunities; Existing fishery management systems and implications for future management,* Upublished Report to LIFE-WWF, 31 pp.

Skelton P., 1993. *A Complete Guide to the Freshwater Fishes of Southern Africa.* First edition ed. Soouthern Book Publishers (Pty) Ltd .

Stiassny M., 1996. An overview of freshwater biodiversity with some lessons from African fishes. *Fisheries,* Volume 21, 7-13.

Tvedten I., Girvan L., Masdoorp M., Pomuti A. &Van Rooy G., 1994. *Freshwater fisheries and fish management in Namibia: A socio-economic background study,* Windhoek: Social Sciences Division, University of Namibia, 199 pp.

Tweddle D., Cowx I., Peel R. & Weyl O., 2015. Challenges in fisheries management in the Zambezi, one of the great rivers of Africa. Fisheries Managament and Ecology, Volume 22, 99-111.

Tweddle D. & Hay C. J., 2011. *Data collection analysis: Report on workshop conducted from 26-27 October 2011,* s.l.: Field Document no. MFMR/NNF/WWF/Phase II/5, Namibia Nature Foundation, 16 pp.

Welcomme R. L., 2011. An overview of global catch statistics for inland fish. ICES Journal of Marine Science, 68(8), 1751-1756.

Wiederkehr C., Berghofer A. & Otsuki K., 2019. Ostrom's Governance Principles and Sustainable Financing of Fish Reserves. Human Ecology, 47(1), 13-25.

Winemiller K. & Jepsen D., 1998. Effects of seasonality and fish movement on tropical river food webs. Journal of Fish Biology, Volume 53, 267-296.

Winemiller K., McIntyre P., Castello L., Fluet-Chouinard E., Giarrizzo T., Nam S., Baird I., Darwall W., Lujan N. & Harrison I. 2016. Balancing hydropower and biodiversity in the Amazon, Congo and Mekong. *Science,* Volume 351, 128-129.

Youn S.J., Taylor W.W., Lynch A.J., Cowz I.G., Beard T.D., Bartley D. & Wu F. 2014. Inland capture fishery contributions to global food security and threats to their future. Global Food security, Volume 3, 142-148.

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1791

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