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ORIGINAL ARTICLE

Fish diversity and composition of Tugwi Mukosi Dam, Zimbabwe's largest inland reservoir post impoundment

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Abstract

The fish diversity and composition of Tugwi Mukosi Dam, Zimbabwe's largest inland reservoir was investigated in 2019 (post impoundment phase) after the reservoir filled in 2017. The main objective of this study was to determine the status of the fish community in Zimbabwe's largest reservoir post dam impoundment. Nine species belonging to four families were observed from the reservoir. The Cichlidae family with the following species: *Oreochromis niloticus*, *Oreochromis mossambicus*, *Tilapia rendalli*, *Oreochromis macrochir* and *Serranochromis thurmbergi* constituted 66.7% of the sample, the Centrarchidae with species *Micropterus salmoides* constituted 12.7% of the sample and the Cyprinidae family with species *Labeo cylindricus* constituted 2.7% of the sample, which was the least abundant. The *O. niloticus* population, which was introduced in 2017, seemed to have reached the establishment stage' on the introduction–naturalisation–invasion continuum as evidenced by its ability to survive and breed. *Oreochromis mossambicus*, which formerly dominated the riverine catches, appeared to be still dominant in the new environment. *Micropterus salmoides*, *O. niloticus* and *O. mossambicus* had active ripe and ripe-running individuals throughout the year whereas *O. macrochir*, *S. thumbergi* and *L. cylindricus* had no clear trend in terms of breeding. The growth performance indices for *O. mossambicus*, *M. salmoides* and *O. niloticus* ranged from 5.03 to 5.36. The highest mortality rate was 2.81 for *M. salmoides* and the lowest was 1.35 for *O. mossambicus*. There is no pre-impoundment data for the fish community and abundance in Tugwi Mukosi Dam and therefore these results provide baseline data 3 years after impoundment. These results are a benchmark for future studies and new insights into the fish communities of large reservoirs. Future fish studies in Tugwi Mukosi should investigate how this fish community continues to evolve over time.

KEYWORDS
community structure, gillnets, *O. niloticus*, population structure, seine net

1 | INTRODUCTION

In southern Africa alone, the estimated number of water bodies reservoirs ranges from 50 000 to 100 000 (Olagunju et al., 2019). Zimbabwe has about 14 000 small reservoirs, which is 86% of the total in southern Africa, excluding South Africa (Mason et al., 2017). Zimbabwe is a landlocked and semi-arid country located in Southern sub-Saharan Africa. The country is characterised by large variations in annual rainfall with very few perennial rivers and lacks natural lakes. As a result all stored water is held in constructed reservoirs, such as dams and ponds. The

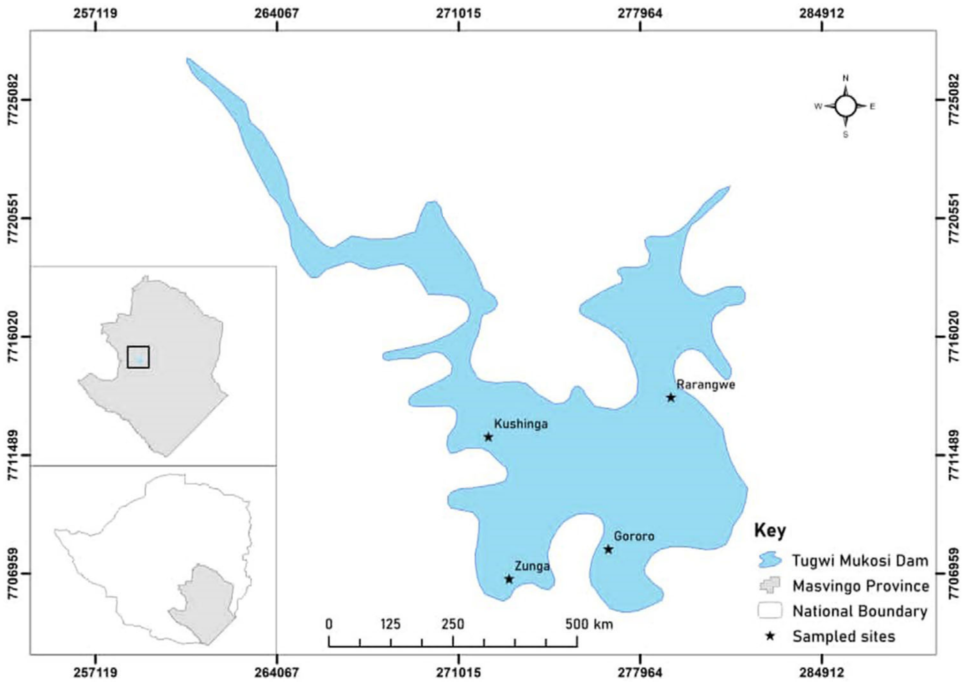

FIGURE 1 The location of Tugwi Mukosi Dam in Masvingo Province, Zimbabwe

major reasons for building dams are to supplement water for irrigation purposes, electricity generation and for supplying water to surrounding communities (Mats, 2011). Most of the dams have now emerged as a source of revenue by supporting commercial and subsistence fishing activities. In Zimbabwe, five reservoirs, namely Kariba, Chivero, Manyame, Mutirikwi and Mazvikadei, are the most important commercial fish stocks exploited by fishers. Fish yield from these reservoirs constitutes a substantial contribution to the country's total domestic fish production (FAO, 2005).

Tugwi Mukosi dam, formerly named Tokwe Mukosi dam, is Zimbabwe's largest dam and is located in the southeastern lowveld of Zimbabwe. The dam is built where two rivers Tugwi and Mukosi converge. Construction of the dam began in 1998 and was completed in December 2016 and the dam was commissioned in May 2017. Consequently, its fish population is made up of mainly riverine species which previously inhabited the Tugwi and Mukosi rivers before dam impoundment. There is no documented data on the fish communities which used to occupy the two rivers (Tugwi and Mukosi) before the Dam was impounded. However, personal communication with the local fishermen have indicated that the two rivers had several fish species, including *Tilapia rendalli*, *Mesobola brevianalis*, *Serranochromis thumbergi*, *Micropterus salmoides*, *Oreochromis macrochir*, *Clarias gariepinus*, *Mormryus longirostris*, *Labeobarbus marequensis*, *Glossogobius giuris*. *Astatotilapia calliptera* and *Oreochromis mossambicus*. *Oreochromis niloticus* was introduced in 2017 in Tugwi Mukosi by the Zimbabwe Parks and Wildlife Management Authority in a bid to boost the fisheries base in the dam and hence increase food security for the local community and region.

According to Mhlanga (et al, 2020) when Tokwe Mukosi dam was sampled in 2017, 7 months after impoundment, the reservoir was

TABLE 1 Tugwi Mukosi dam morphometric parameters

Location	Masvingo and Chivi districts
Geographic coordinates	−20.715169, 30.897233
Altitude	1363 m at USL (1367.86 at high flood level)
Dam height	90.3 m
Surface area	96.4 km^2 at USL
Maximum depth	82.7 m
Minimum depth	3 m
Maximum length	16.8 km
Maximum width	11.1 km
Volume	1 915 000 m^3
Catchment area	7120 km^2

turbid. The trophic state of the reservoir ranged from eutrophic to marginally hypertrophic, with high total phosphorus and total nitrogen concentrations. The distribution and assemblages of fish within a reservoir are driven by physical and ecological factors. Included in these driving factors are a species' physiological and biological tolerance (the ability to live within a specific range of environmental parameters) and behavioural patterns (e.g. feeding preference, shoaling vs. solitary, utilisation of different habitats during the lifecycle) (Skelton, 2001). Therefore, 3 years after impoundment it is important to understand how the fish communities have established and also how *O. niloticus* has established since its introduction. The introduction of non-native fish species often has unintended consequences in water systems, as with the introduction of *O. niloticus* in Lake Kariba and Lake Chivero (Nhiwatiwa, 2012).

Data on fish studies in Zimbabwe is often limited to large dams and/ or lakes, such as Lake Chivero and Lake Kariba (Karenge & Kolding, 1995; Brendonck et al., 2003; Mudzimu, 2013; Muzvondiwa et al., 2013; Chifamba & Videler, 2014). Other fish diversity studies have also been done in other water bodies in the country, namely Insukamini dam and Malilalngwe reservoir (Dube & Kamusoko, 2013; Dalu et al., 2013). However, despite its size, there is no documented study on the fish communities in Tugwi Mukosi, the largest inland dam in Zimbabwe. The ability to accurately track and detect changes in a particular fish community requires an initial estimate to base future comparisons against, as well as a definite understanding of inherent variations in the selected measures of that community. The aim of this study is to determine the fish community composition and abundances in Tugwi Mukosi dam and provide baseline information for fish community composition and growth parameters of different species in the inland reservoir for future studies. The study also sought to investigate size class distributions, growth performance index and mortality of different fish species in the dam.

2 | MATERIALS AND METHODS

2.1 | Study area

Tugwi Mukosi Dam is Zimbabwe's largest inland water body and situated in the semi-arid area of the Masvingo province in Chivi District (Figure 1). The area lies in Zimbabwe's agro-ecological Region IV, which has a long-term mean average precipitation of less than 600 mm/year, with the majority of rain falling between October and April, and a precipitation peak reached in February and mean annual temperature is approximately 20°C (Chazireni & Chigonda, 2018). The geology of the area is composed of paragneiss and other high-grade sediments with structural trends, which results in soils that are mainly chromic luvisols with isolated patches of calcaric fluvisols (Table 1). The dam started impounding water in December 2016 and held 210 million cubic metres of water from January 2017 (Maponga, 2017).

2.2 | Fish sampling

Sampling was carried out at four sites namely Zunga, Kushinga, Gororo and Rarangwe (Figure 1). The sampled sites are also fishing grounds for both artisanal and commercial fishermen (areas marked by the ZPWMA for fishing by the local communities for fishing). Sampling was done every month using multifilament gillnets and a seine net between January and November 2019 except for July 2019. Sampling effort was kept constant throughout the study. For the seine netting, 2 hauls at each sampling site were performed using a 50 m net with a mesh size of 12.7 mm in the shallow areas which were less than 1.5 m deep. Multifilament gillnets of varying mesh sizes, ranging from 38.1 to 177.8 mm each with a length of 150 m, were laid in a zigzag pattern in the late afternoon at 1630 h at each sampling site and left overnight. The nets were then pulled out the next morning at 0630 h. All fish caught were identified in the field to the lowest practical taxon using external morphological characteristics and identification keys (Marshall, 2011; Skelton, 2001). The number of fish caught for different species was recorded and the total length (TL) and standard length (SL) of each individual was measured to the nearest 0.1 mm. Weight was measured to the nearest 0.1 g and gonad maturation for each individual was visually evaluated using a simplified scale (Bagenal & Ricker, 1978) as follows:

TABLE 2 Number (*N*) and weight (*W*) of the different fish species recorded in Tugwi Mukosi dam throughout the study period

Family	Species	*N*	*N*%	*W* (kg)	*W* (%)
Centrarchidae	*Micropterus salmoides*	305	12.66	34.13	8.33
Cichlidae	*Oreochromis niloticus*	182	7.55	64.97	15.86
	Oreochromis mossambicus	754	31.29	87.52	21.36
	Tilapia rendalli	461	19.13	74.10	18.09
	Oreochromis macrochir	132	5.48	29.37	7.17
	Serranochromis thurmbergi	77	3.2	19.13	4.67
Claridae	*Clarius gariepinus*	240	9.96	80.12	19.56
Cyprinidae	*Mesobala brevianalis*	196	8.13	4.16	1.02
	Labeo cylindricus	63	2.61	16.15	3.94

- Inactive – immature fish and adults in resting stage with sexual gonads not yet developed, gonads very small and eggs indistinguishable to the naked eye
- Active ripe – eggs distinguishable to the naked eye, testes a pale white colour
- Ripe-running – eggs clearly distinguishable to the naked eye, testes white in colour and sometimes enlarged: sexual products can be discharged in response to light pressure on the fish's belly
- Spent – sexual products have been discharged and gonads appear deflated; ovaries may contain a few eggs and testes some residual sperm.

The catch per unit effort (number of fish per set net) was determined using data from the experimental gillnetting to show changes in the species abundance over the study period.

2.3 | Statistical analyses

FAO-ICLARM Stock Assessment Tool (FiSAT), version 1.2.2, software was used to analyse length frequency data (Gayanilo & Pauly, 1997). The ELEFAN I method in FiSAT was used to estimate the von Bertalanffy parameters (growth performance index and mortality), and the total mortality coefficient (Z) was also determined.

3 | RESULTS

3.1 | Fish communities, diversity and abundance

A total of 2410 individual fish of 9 different species from 4 families were captured during the study period (Table 2). Two species which are found in the Dam but were not caught during this study are

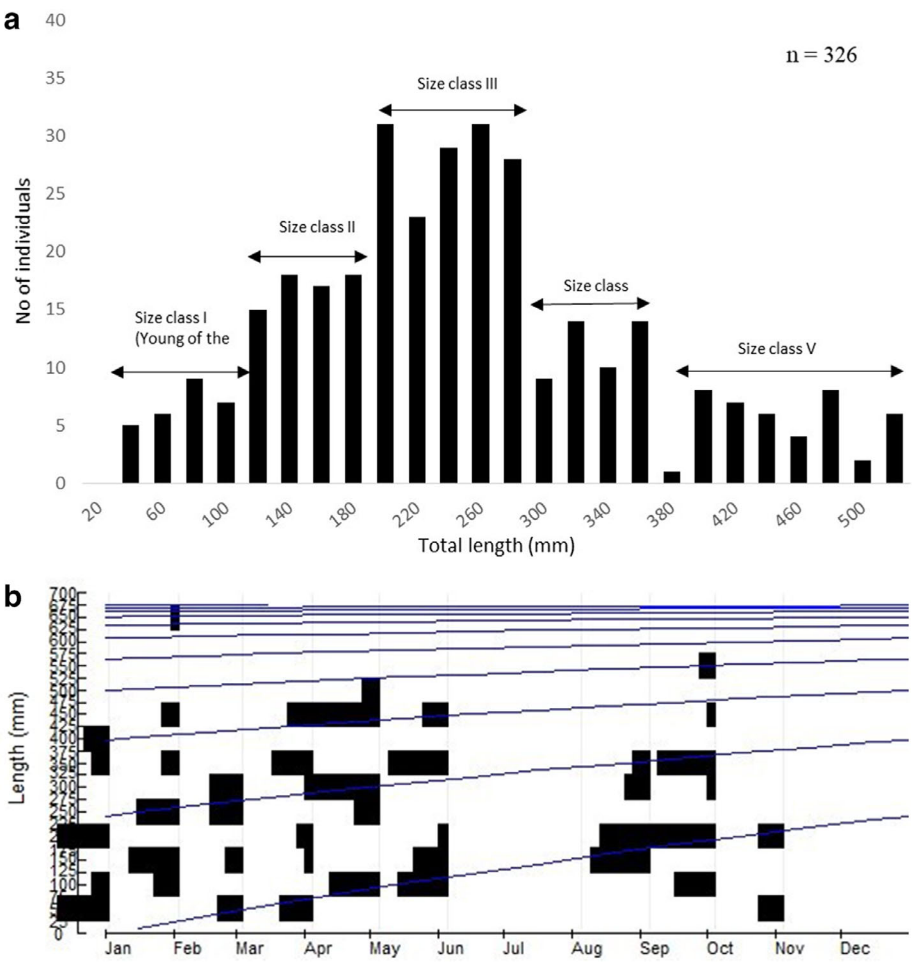

FIGURE 2 (a) Length frequency analysis of male and female *O. niloticus* in Tugwi Mukosi. (b) Growth curve for male and female *O. niloticus* in Tugwi Mukosi

M. longirostris and *S. robustus*. *Clarias gariepinus* was mainly caught during the hot-rainy months (January, October and November). *Serranochromis thurmbergi* was only caught in shallow grounds close to the dam wall while *L. cylindricus* was most abundant in the rocky areas of the reservoir. *Mesobala brevianalis* and most cichlids were evenly distributed in the reservoir.

3.2 | Size distributions analysis of the fish

Length frequency distributions of *O. mossambicus*, *M. salmoides*, *O. niloticus* and *M. brevianalis* were plotted using the length frequency data and analysed with FiSAT. Size classes were clearly distinguishable in *O. niloticus*, *O. mossambicus*, *M. salmoides* and *M. brevianalis*. There were indications of growth for *O. niloticus* and *O. mossambicus* from the length frequency distributions. The size of *O. mossambicus* fish caught throughout the study period were observed to be generally small compared to the common size of specimen normally caught in other dams (Figure 4a). Size classes were not easily identifiable for other fish species.

The VBGF parameters (growth performance index and mortality) of *O. mossambicus*, *M. salmoides* and *O. niloticus* are shown in Table 3. The

TABLE 3 Growth (VBGF parameters) and mortality (*Z*) of three fish species from Tugwi Mukosi dam, January to November 2019. Data obtained using FiSAT

Species	*K*	*Z* (year^{-1})	Loo	Ø[1]
O. mossambicus	0.69	1.35	577.5	5.36
M. salmoides	0.32	2.81	577.5	5.03
O. niloticus	0.44	2.16	682.5	5.31

VBGF parameters (growth performance index and mortality for other fish species could not be determined. The length-based growth curves for *O. niloticus* (Figure 2b) *M. salmoides* (Figure 3b) and *O. mossambicus* (Figure 4b) were determined in FiSAT

3.3 | Reproductive status of the fish

The gonad states active ripe and ripe-running are shown for all species in Table 4. *Micropterus salmoides*, *O. niloticus* and *O. mossambicus* had active ripe and ripe-running individuals throughout the year. There was some indication of seasonality in the males and females of *M.*

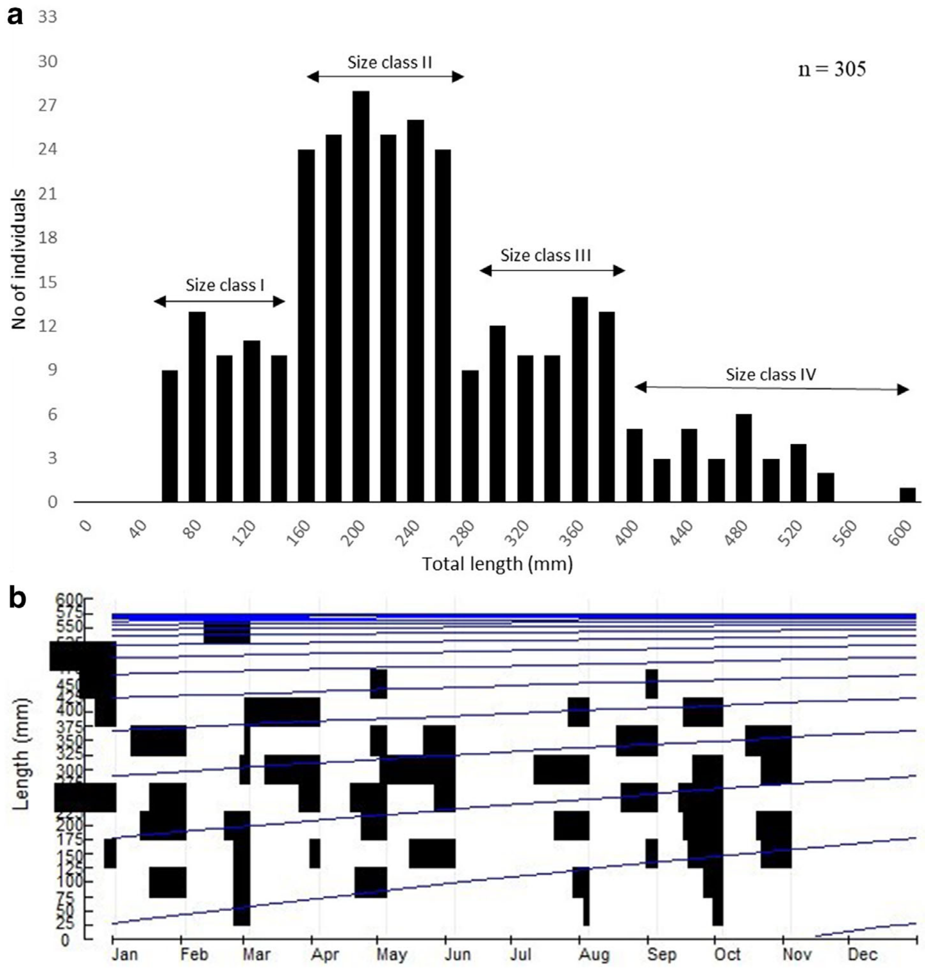

FIGURE 3 (a) Length frequency analysis of male and female *M. salmoides* in Tugwi Mukosi. (b) Growth curve for male and female *M. salmoides* in Tugwi Mukosi

brevianalis. The results indicated that the number of active ripe and ripe running gonads increased towards the hot rainy season (October, November and January). *Oreochromis macrochir*, *S. thumbergi* and *L. cylindricus* had no clear trend in terms of the active ripe and ripe-running gonads found throughout the study period.

3.3.1 | Catch per unit effort

Catch per unit effort data showed that there was a gradual decrease in the CPUE in the winter months (May–June) in all species. The CPUE increased towards the hot-rainy season months (September to November) (Figure 5). Only *O. mossambicus* had its highest CPUE in January while other species had their highest CPUE in August, September and October.

4 | DISCUSSION

Tugwi Mukosi's fish population is made up of mainly riverine species which previously inhabited the Tugwi and Mukosi rivers before dam impoundment (Mhere *pers.comm*). Only *O. niloticus* was introduced in the Dam. This fish population consists of several species including *Tilapia rendalli*, *Mesobola brevianalis*, *Serranochromis thumbergi*, *Micropterus salmoides*, *Oreochromis macrochir*, *Clarias gariepinus* and *Oreochromis mossambicus*. Our analysis showed that all of these species have established well and were breeding successfully, as evidenced by the numbers recorded and the reproductive states of the fish sampled. *Labeobarbus marequensis*, *Glossogobius giuris* and *Astatotilapia calliptera*, which are said to have been found in the two rivers, Tugwi and Mukosi, were not recorded during the current study.

Apart from these species, *O. niloticus*, which was introduced in 2017 with the aim of boosting the fisheries sector and increasing domestic fish production, is now well advanced into the 'establishment stage' on the introduction–naturalisation–invasion continuum as evidenced by its ability to survive and breed since its introduction into the reservoir. Possible explanations for this include the fact that *O. niloticus* is a highly invasive species with a 'hardy' nature and has a wide range of trophic and ecological adaptations. It can also thrive in disturbed habitats and opportunistically reproduce. It is a fast growing species with high reproductive potential (Chifamba 2019; Welcomme 1992). Tilapia introductions are often associated with severe environmental change,

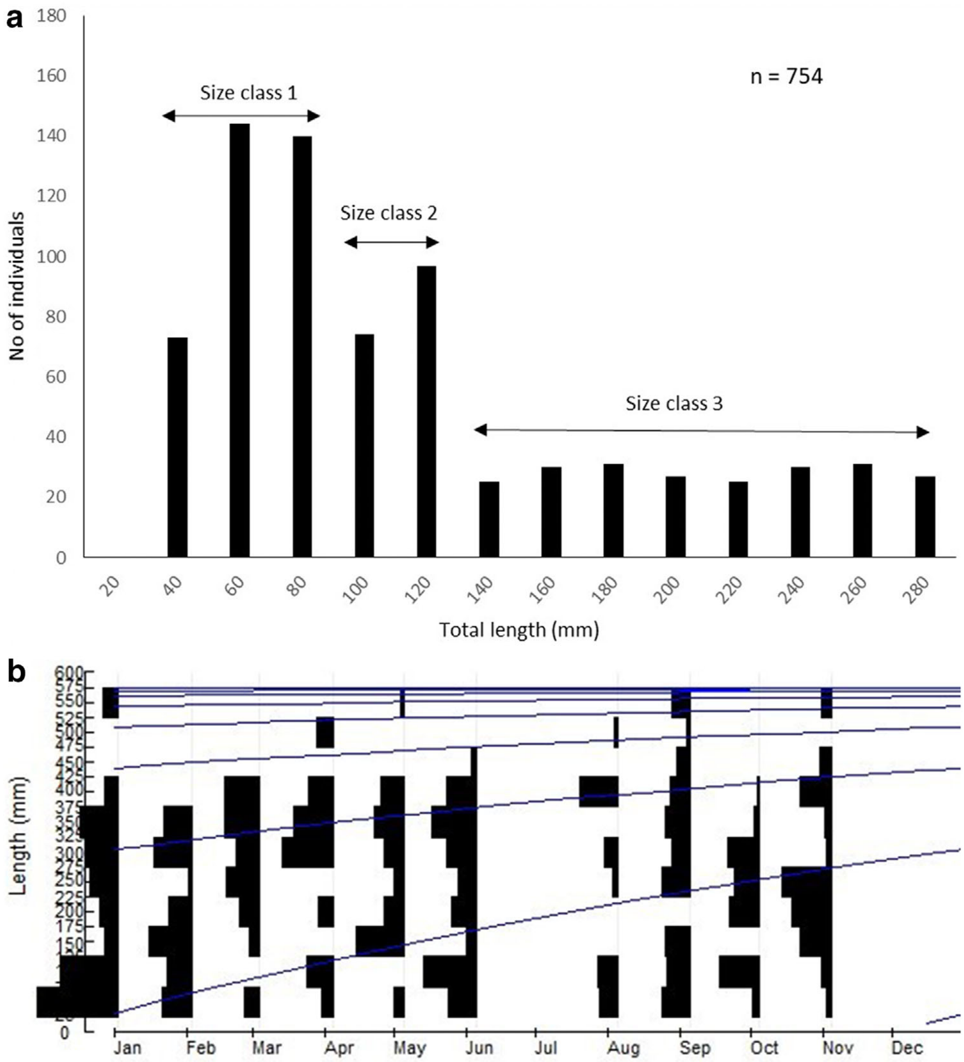

FIGURE 4 (a) Length frequency analysis of male and female *O. mossambicus* in Tugwi Mukosi Dam. (b) Growth curve for male and female *O. mossambicus* in Tugwi Mukosi

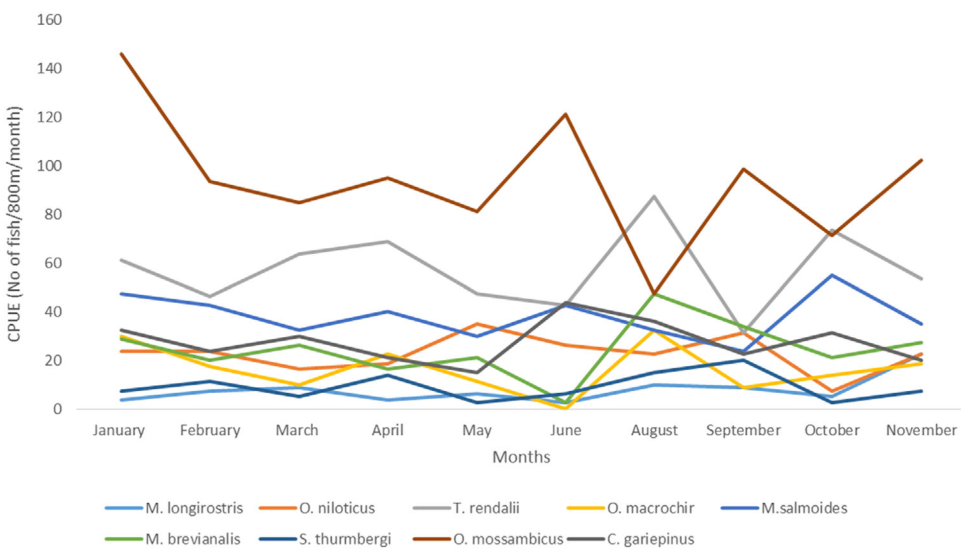

FIGURE 5 Catch per unit effort of the nine species recorded in Tugwi Mukosi over the study period

TABLE 4 Number of fish with gonad states which were observed to be active ripe and ripe-running in Tugwi Mukosi dam for the study period

Species	Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
M. salmoides	Male	22	14	5	2	0	20	0	7	37	12	22
	Female	17	3	7	9	14	9	0	2	8	18	29
O. niloticus	Male	2	14	19	15	2	0	0	21	3	11	9
	Female	0	12	3	5	6	1	0	2	13	16	21
O. mossambicus	Male	27	32	29	33	21	0	0	38	44	46	15
	Female	22	25	31	22	0	0	0	26	30	44	21
T. rendalli	Male	0	0	0	3	12	5	0	21	3	14	19
	Female	26	31	4	7	1	9	0	11	17	38	23
O. macrochir	Male	0	0	0	0	0	9	0	0	7	11	17
	Female	2	0	0	0	0	22	0	17	0	0	4
S. thurmbergi	Male	0	0	0	0	0	0	0	0	3	16	4
	Female	2	0	1	0	0	0	0	4	1	5	6
L. cylindricus	Male	0	0	3	1	0	0	0	1	4	0	5
	Female	0	5	2	0	0	0	0	2	6	1	3
C. gariepinus	Male	1	3	1	0	14	1	9	22	2	1	0
	Female	0	7	0	1	12	8	0	1	0	11	3
M. brevianalis	Male	2	5	12	7	0	0	0	26	41	29	31
	Female	0	0	2	6	12	3	0	11	14	16	2

especially after construction of reservoirs. Many populations of tilapia are now so well established; they are a permanent part of the fish community. This was also the case with Tugwi Mukosi dam, as shown by the wide extent of occurrence of *O. niloticus* throughout the dam during sampling. *Oreochromis macrochir* was also present in Tugwi Mukosi dam but its abundance was lower than that of *O. niloticus*. This may be due to diet overlap between these two species, with both *O. niloticus* and *O. macrochir* feeding mostly on blue-green algae (>50%), in all size classes (Zengeya & Marshall, 2008).

Oreochromis mossambicus had the highest abundance by number and weight in Tugwi Mukosi reservoir. It is a remarkably robust and fecund fish, readily adapting to available food sources and breeding under suboptimal conditions. Due to their robust nature, Mozambique tilapias often over-colonise their habitat, eventually becoming the most abundant species. When over-crowding happens and resources get scarce, adults will sometimes cannibalise the young for more nutrients. Mozambique tilapia are opportunistic omnivores and will feed on algae, plant matter, organic particles, small invertebrates and other fish (Skelton, 2001). There was also a high abundance of *T. rendalli*, a forage fish, and this can be attributed to the good water quality observed in Tugwi Mukosi dam; as these fish are primarily herbivorous, they prefer feeding on submerged vegetation and, at times, on algae, detritus, aquatic invertebrates and small fish. (Skelton, 2001).

The presence of predatory species, such as *M salmoides* and the riverine sardine *M. brevianalis*, may be a result of the good water quality of Tugwi Mukosi, as it features high transparency levels and these species mainly predate by sight (Davis & Lock, 1997).

The reproductive status of fish species in Tugwi Mukosi dam was low during the winter months of the cool-dry season (May, June, July), as they breed with the first rains. This was true for most of the observed species in Tugwi Mukosi, which had inactive gonads during the winter period, namely *O. niloticus*, *O. mossambicus*, *T. rendalli*, *O. macrochir*, *S. thumbergi*, *L. cylindricus*, *C. gariepinus* and *M. brevianalis*. However, *M. salmoides* did not follow this trend as there was a high number of fish which were breeding in May and June. *M. salmoides* had high breeding activity during the winter season and this deviates from the normal breeding patterns of Zimbabwe fish. A number of individuals were observed to have active ripe and ripe-running gonads, for both males and females, during the winter period. According to Marshall (2011), most native fish species in Zimbabwe do not breed during the winter period; they start breeding during the hot-rainy period (November, December, January and February).

Distinct size classes were evident for *O. mossambicus*, *O. niloticus* and *M. brevianalis* in this study. The presence of three size classes for *O. mossambicus* and *O. niloticus* may be due to regular recruitment as a result of breeding during the hot wet season (Marshall 2011). Growth and population parameters were estimated for three species, namely, *O. mossambicus*, *O. niloticus* and *M. brevianalis*. It should be noted that these estimations are not validated but are only indicative. Mortality rates (Z) for *M. salmoides* and *O. niloticus* were high compared with those from other water bodies, for example, *M. salmoides* $Z = 1.27$ (Lake Chicamba, Mozambique), *O. niloticus* $Z = 1.84$ (Lake Chivero) and *O. niloticus* $Z = 1.47$ (Lake Koka, Ethiopia) (Tesfaye & Wolff, 2015; Tiki & Nhiwatiwa, 2016; Weyl & Hecht, 1999). *Micropterus salmoides* is mainly targeted by both artisanal and recreational fishermen.

There is no pre-impoundment data for Tugwi Mukosi dam and therefore this case study provides baseline data 3 years after impoundment, a benchmark for future studies and new insights into the fish communities of large reservoirs.

5 | CONCLUSION

The current fish population at Tugwi Mukosi dam has been shaped by community interactions and human interventions such as fish introductions. Future assessments should investigate how this fish community continues to evolve over time.

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AUTHOR CONTRIBUTIONS

Terence Magqina designed this research. Terence Magqina, Chipo Mungenge and Kuzivakwashe A. Mawoyo carried out the field research, analysed the data and prepared the manuscript. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICS APPROVAL STATEMENT

The study was approved by the University of Zimbabwe Research Ethics Board.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/aff2.24.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author, Magqina, T.

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