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Fish Composition, Size Distribution and Fishing Gear Selectivity in Lake Malombe, Malawi

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ABSTRACT: *Lake Malombe is connected to Lake Malawi; the latter is an African Great Lake endowed with the World highest fish species diversity. Thus, fish species of the two lakes are commonly shared and form valuable food resource. The Lake Malombe fishery resources have been exploited to alarming levels by residents and mobile fishermen that use different types of fishing gears; the same has also affected parts of Lake Malawi. This study was conducted on 18 landing sites in eastern and western regions of Lake Malombe on 7-21th July 2017 to provide baseline information on performance and impact of seven fishing gears (Kandwindwi, Nkacha seine, Mosquito net, Gill nets, Fish traps, Handlines and Longlines) on the Lake Malombe fishery. This study: (i) updates the status of artisanal fishing gears, (ii) determines catch rates, (iii) determines the size and species composition, (iv) assesses gear selectivity, and (v) provides recommendations for the management of the fisheries. Species identification, length and weight measurements were done in collaboration with fishing gear owners. Beach name, gear owner, number of crew, craft type, gear type, fish catch, mesh size, fishing times, landing times and fishing ground were recorded using reference manuals on-site to compare morphometric and meristic characters of the fish species. Fish size and length frequency distribution were modelled using the Gamma distribution function to compensate for skewed distribution of the data from seine nets. Size- specific selectivity of the "Nkacha" seine net, being the dominant, was modelled using the logistic model. Overall total catch sample was estimated at 676 kg from 33 gears, the catch per unit effort (CPUE) was 0.1 and 40.1 Kg/trip with an average of 11.3 ±16.3 Kg/trip. Local seine nets known as Kandwindwi and Nkacha, and Gill nets recorded the highest CPUE of 40.1, 28.4 and 8.9 Kg/trip, respectively. Fish traps, Handlines, Mosquito seine nets and longlines were found less effective harvesting 1.1, 0.5, 0.3 and 0.1 Kg/trip, respectively. Fish catches comprised of 19 genera and 28 species classified into four fish families; Cichlidae, Cyprinidae, Claridae and Characidae. Cichlidae recorded highest abundance accounting for more than 77% of the catch followed by Cyprinidae (18%), Claridae (5%) and Characidae (0.003%). Nineteen (19) genera comprising of Nyassachromis (31.8%), Otopharynx (21.2%) and Engraulicypris (16.3%) constituted more than 75% of fish catches. There were over 28 taxa in landings from all fishing gears, the majority of the catches being composed of five species;Nyassachromis argyrosoma (31.8%), Otopharynx argyrosoma stripe*

(17.6%),Engraulicypris sardella (16.3%), Lethrinops lethrinus (6.5%) and Copadichromis chrysonotus (4.8%) making up of more than 75% of the landings. A decline of 60.7% (from 56 taxa to 28 taxa) was recorded among fish catches from Nkacha seines. The size of fish ranged from 17 to 380 mm TL with an average of 69.1±43.2 mm TL and the smallest fish sizes-at-capture observed in all seine nets ranged from 47 to 64.5 mm TL. Meanwhile, the sizes-at-capture for all fishing gears ranged from 47.0 to 124.4 mm TL and 77.3 ±28.1 mm TL was the mean value. Fish sizes-at-capture showed that most fishing gears were unselective, catching mostly juvenile forms. Naturally, this contributed to heavy declines in catches, further confirming why recorded catches were 12,000 tons in 1981-91 and only 3,820 tons in 2016. The intrusion or invasion of Usipa (Engraulicypris sardella) from Lake Malawi into Lake Malombe is a new phenomenon indicating a change in environment and species composition. Removal of illegal gears combined with a Rights-Based system should be considered while refining legal instruments. Above all, political will needs to be galvanised if the fishery is to be restored

KEYWORDS*:* Declining fish catches, Emergence of Usipa, reduced fish species diversity, Lake Malombe, Nkacha and Kandwindwi seines

INTRODUCTION

Lying between latitude 14 31’ to 14 45’south and longitude between 10’ to 35 21’ east (Zwieten et al., 2011), Lake Malombe is connectedto Lake Malawi through the Upper Shire River; it is the third largest lake in Malawi, covering asurface area of 312 Km^2 with an average depth of3.2 m and drains a catchment area of about 133, 600 ha (FAO 2018). According to recent data, 3, 980 tons were produced annually, translating to 3.6% of the country’s annual capture fisheries production (GOM, 2015), a decline from 12,000 tons (FAO 1993, Weyl et al. 2004). This fishery used to support livelihoods of over 2,471 fishers who own about 780 diverse fishing gears (GOM,2015). The dominant fishes include Cichlids (Haplochromine, Tilapiines), Cyprinids and Clariid catfishes. Lake Malombe has been undergoing changes in water levels and is vulnerable to droughts and is reported to have once dried in the 1920-30s.

The high fluctuations in fish in catches are symptomatic of major fundamental changes in fishresources qualifying it to be designated an ecological “hotspot”.Lake Malombe’s fisheries gainedmomentum in the 1970s & 1980s after eradicationof large crocodile population (Tweddle *et al.* 1994)during which time *Oreochromis squamipinnis*, *O. lodoli* and *O. karongae* collectively termed “Chambo” were the main target species.This fishery was later dominated by Kambuzi (Haplochromis) fishery, but for a while both Chambo and Kambuzi fisheries collapsed due to continuing high exploitation rates of juveniles andspawners as well as the removal of important inshore and offshore weed beds by seine nets. Therefore, the Lake Malombe fishery has shown allforms of stress including species succession, recruitment and growth overfishing (King 1995).

Other factors that may have contributed to the fish catch declines include decreasing water levels due to reduced rainfall and increasing silt loads (Banda et al. 2002; van Zwieten et al. 2003, van Zwieten and Njaya 2003; van Zwieten et al. 2011). Climate change appears to be compounding the situation as temperature is reported to increase annually by 0.90C from 1960 to 2006, showing indicative average of 0.210C per decade (FAO & GEF 2017). The “Hot days” have increased by 30.5 per year. Meanwhile, “hot nights” have increased by 41 days according to the general Circulation Models used by IPCC (Intergovernmental Panel on Climate Change). Rainfall in the area is influenced by opposing unpredictable responses to influences of ENSO where the Eastern Equatorial Africa receives above average rainfall during El Nino conditions, and South-eastern Africa experiences of below average rainfall.

This study was conducted as a precursor to the initiative by the Food and Agriculture Organization (FAO/TPC) to provide background to GEF (Global Environmental Fund) in support for Least Developed Countries (LDF) in efforts to rebuild fisheries stocks of Lake Malombe mitigating against impacts of unregulated and illegal fishing, and climate change. Part of the study concentrated on baseline information on the performance and impact of artisanal fishing gears on the fish stocks of Lake Malombe, whose objectives were to: i) obtain an updated status of artisanal fishing gears operating in Lake Malombe, ii) determine catch rates of all artisanal fishing gears operating in Lake Malombe, iii) determine size and species composition in fish landings from artisanal fishing gears operating in Lake Malombe, iv) assess selectivity of all artisanal fishing gears operating in Lake Malombe, and v) offer management options for the fisheries of Lake Malombe.

METHODOLOGY

Study Area

Lake Malombe lies south of Lake Malawi, the twoare joined by Shire River. It is located at 14^{0}40'0" S and 35^{0}15'0" or 14.66667^{0}S joined by the UpperShire River to Lake Malawi in southern Malawi (see Figure 1).

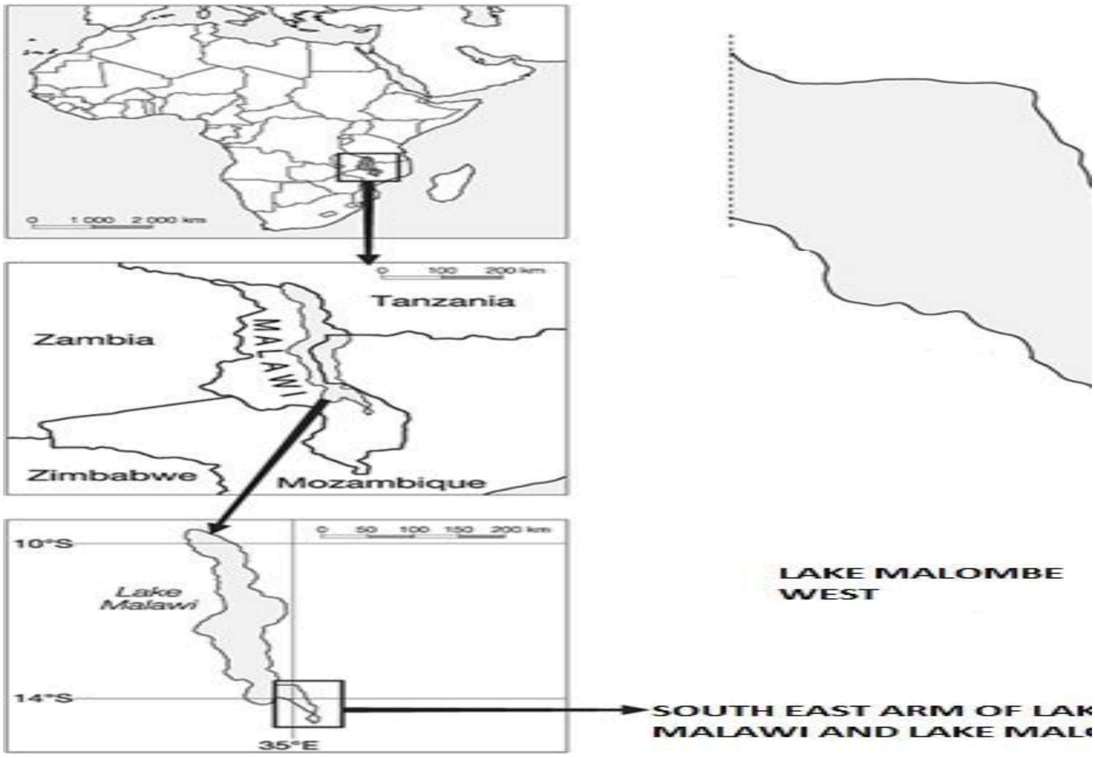

Figure 1. The Location of Lake Malombe.

Collection of fish samples

This research was conducted in 18 fish landing sites distributed along Lake Malombe (Figure 2) during the day and was based on fishsamples collected from seven types of fishing gears used in Lake Malombe for harvesting different types of fish species. The study was conducted for 14 days from 7-21st July 2017.

The gears include three seine nets: Kandwindwi, Nkacha and Mosquito; Gill nets, Fish traps, Handlines and Longlines. The sites were reached out using a motorized steel boatfor remote landing sites and a 4WD vehicle fornearby landing sites.

Upon arrival at the landing sites, the gear owners were contacted and briefed about the objective of the study and the need to collect fish samples following methods outlinedby Sparre *et al.* (1989). Only upon acceptance by the craft and gear owners was the study allowed to proceed. Data collected included: i) particulars of the gear owner, ii) fishing landing site, gear type and specifications, iii) fish landed was separated from snails and any other debris caught and put in separate containers; iv) at least 30% of the sample was collected from the catch and sorted into family, genera and species level; v) the sampled fish were weighed to the nearest 0.01g and counted and their respective total lengths (TL) recorded with a measuring tape in mm, vi) number of crew, fishing times, landing times and the nature of fishing ground

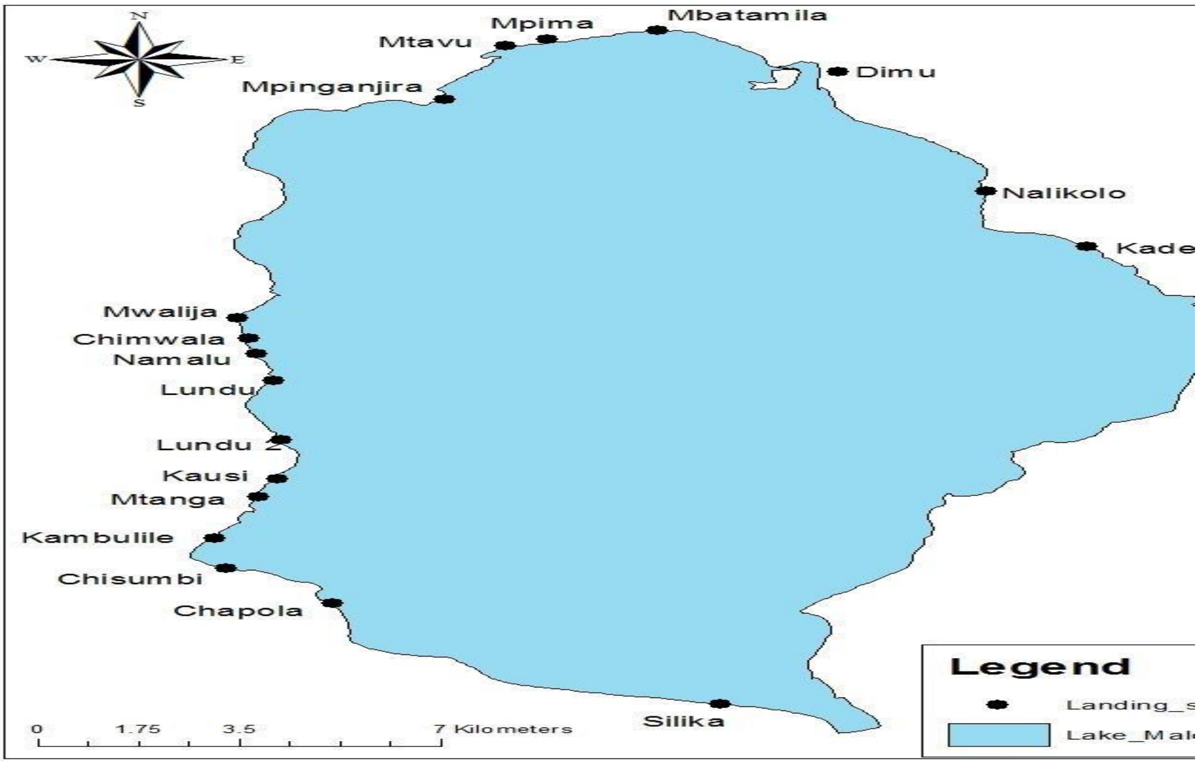

Figure 2: Landing sites covered during the study in Lake Malombe.

Catch per unit effort (CPUE) of seven types of fishing gears was estimated as the quantity (Kg) of fish caught per trip (Kg/trip). CPUE results are presented as average per gear sampled, except when only one gear type was sampled

Size-at-first-capture

The size-at-first-capture is the size at which 50% of fish are retained and the remaining 50% escape through the mesh/gear, or the probability of 50% of the fish being caught (Sparre *et al.*, 1989, King 1995). The size-at-first-capture was obtained by applying the logistic sigmoid function to the total number of fish species caught, irrespective of sex.

Data Processing and Analysis, Size Structure, Distribution and Selectivity

Size and length frequency distribution

The total length (TL) of all fish species caught was measured for individual fish. Size and length frequency distribution were modelled usingthe Gamma distribution function to compensate forthe skewed distribution of data from the seine nets.The gamma probability density function (Malcom, 2001) as described below: `

$$f(x;\alpha,\beta) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-\frac{x}{\beta}}$$

Where x is the value at which the distribution is calculated; α and β are parameters of distribution. The catch data was entered and analyzed in Microsoft Excel 2016 using the in-built Analysis tool pack.

Size specific selectivity

In this study, the size-specific selectivity of Nkacha seine net was modelled using the logistic model suggested and used by Butterworth *et al*. (1989) and Booth and Punt (1998) expressed as:

$$P = \left(1 + \exp^{-(L - L_{50/\delta})}\right)^{-1}$$

where *P* is the selectivity of the gear on a fish of size L, L50 is the size-at-50%-selectivity or the mean length at which 50% of fish are retained in the net (mean length at first capture), and δ is a parameter related to the size range over which the selectivity changes from values near 0 to values near 1. As δ tends to zero, this function approaches knife-edged selection (Butterworth *et al*. 1989)

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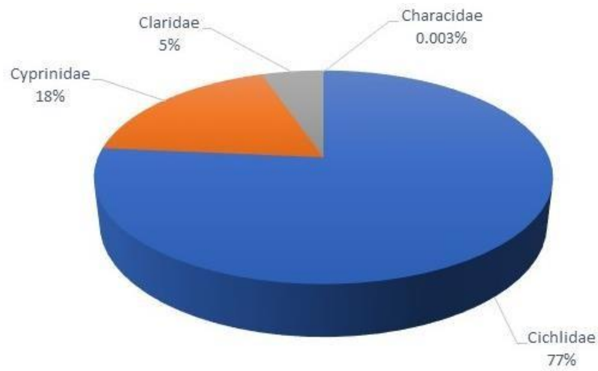
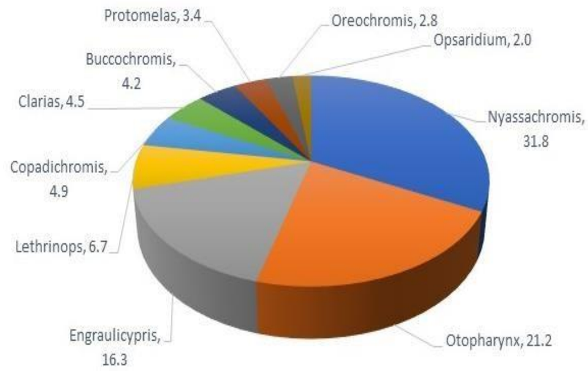
RESULTS

Catch per Unit Effort

The overall total catch amounted to 676 kg estimated from 33 gears sampled is represented in Table 1. The average CPUE ranged from 0.1 to 40.1 Kg/trip with an average of 11.3 ±16.3 Kg/trip (Table 1). Kandwindwi, Nkacha and gill nets realized the highest CPUE of 40.1, 28.4 and 8.9 Kg/trip, respectively, while those of Handlines, Mosquito seine nets and longlines **recorded low CPUEs of** 0.5, 0.3 and 0.1 Kg/trip, respectively (Table 1). Table 1: Total catch and Catch per Unit Effort from seven artisanal fishing gears sampled in Lake Malombe during the study, July 2017.





Gear Type	No. Gear	Total Catch (Kg)	CPUE (Kg/Trip)
Kandwindwi	5	200.67	40.1 ±
Nkacha seine net	15	425.84	28.4 ±
Gillnet net	5	44.52	8.9 ±
Fish trap	3	3.20	1.1 ±
Handline seine net	3	1.39	0.5 ±
Mosquito sine net	1	0.32	0.3
Longline	1	0.05	0.1
Total	**33**	**676.00**	**11.3**±16.3

Catch composition

The total catch of 676 kg (Table 2) is made outof existing four fish families (Cichlid, Cyprinid, Claridge and Characidae) (Figures 3a), 19 genera (Figure 3 b, c) and 28 species (Figure 3 d) caught by seven gear types in Lake Malombe during the study period.

Catch composition varied as per gear type (Table 1). Of the four fish families, Cichlidae was the most abundant, comprising more than 77% of the catch followed by Cyprinidae (18%), Claridae5%) and 0.003% for Characidae (Figure1 a).

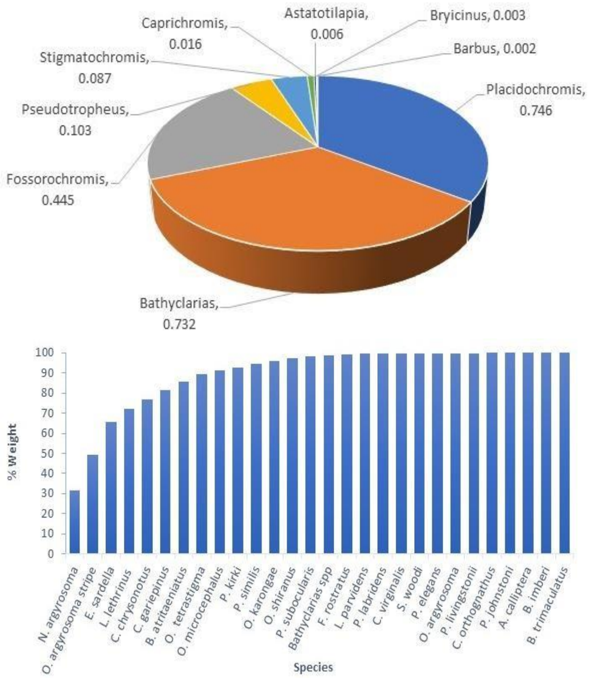


Figure 3: The composition in the catch from seven gear types representing: a) fish families, b) fish genera greaterthan 1%, c) fish genera less than 1% and d) Cumulative percentage of fish species composition.
Fish families and genera from Lake Malombe

.The popularly used Nkacha seines landed catches comprising species from three families; Cichlidae, Cyprinidae and Claridae in the following proportions; 66%, 29% and 5%, respectively. Longlines were the only gear that caught species exclusively from the Cichlid family. Gill nets, Mosquito seine nets, Kandwindwi seine nets and fish traps landed species from only two families of either Cichlidae and Claridae or Cichlidae and Cyprinidae (Table 1).

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The fish genera composition was variableand represented twice, Figure 4 b for genera withcomposition greater than 1% and Figure 4 c for less than 1%. A total of 10 genera comprised of *Nyassachromis* (31.8%), *Otopharynx* (21.2%), and *Engraulicypris* (16.3%) accounted for more than 75% of the catches (Figure 3 b) while *Bathyclarias*, *Fossorochromis*, *Pseudotropheus*, *Caprichromis* and *Brycinus* contributed less than1% (Figure 4 c).

Five fish genera and over seven species from two families, Cichlidae and Claridae comprised of catches from fish traps (Figure 4 a),with the majority of the catch being of the genera*Oreochromis* (85%) and *Clarias* (11%) which together accounted for over 96% of the landings. The other three genera *Caprichromis*, *Protomelas*and *Astatotilapia* accounted for 2%, 1.1% and 0.8%, respectively (Figure 4 a).

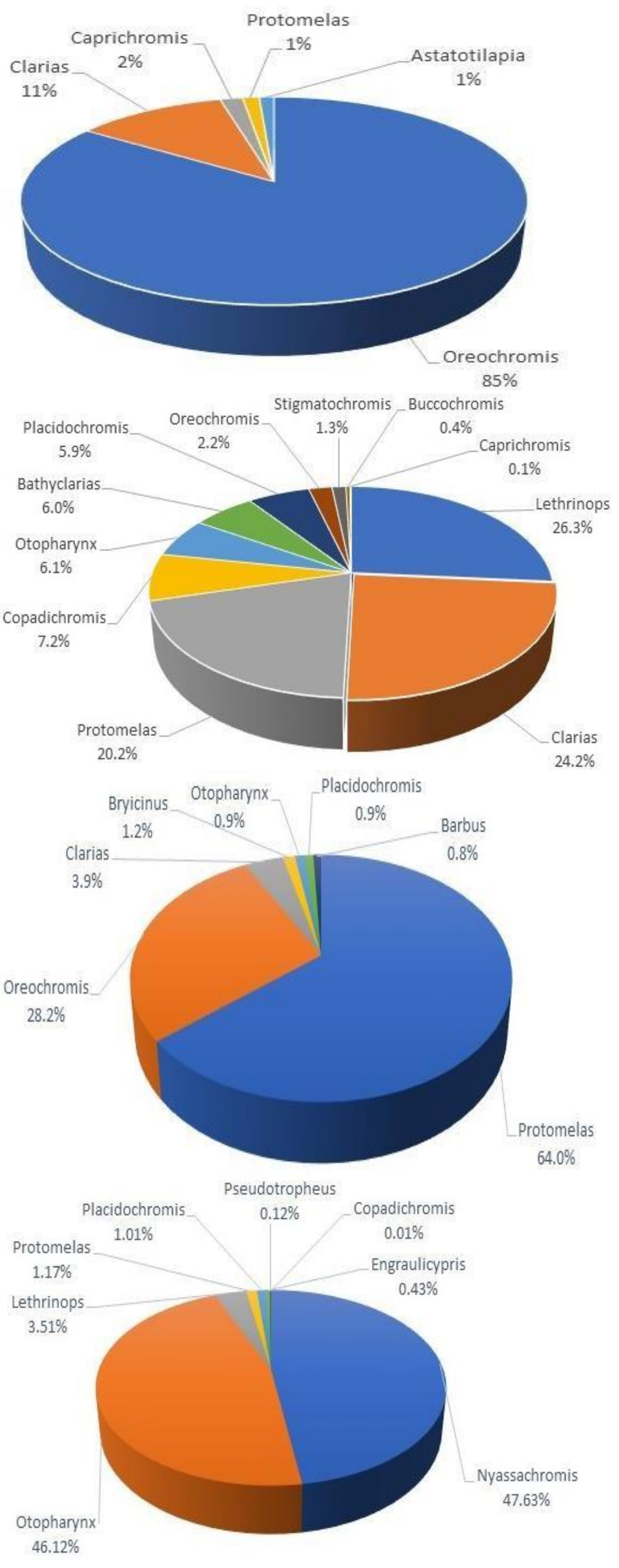
The catch from gill nets comprised 11 genera and over 14 species from two families, Cichlidae and Claridae (Figure 4 b). Cichlids made up morethan 70% of the landings with the rest coming fromClariid catfishes. The majority of the catch in gill nets comprised of three genera *Lethrinops* (26%), *Clarias* (24%) and *Protomelas* (20%) whichtogether accounted for over 70% of the landings. The four least important genera included *Oreochromis* (2.2%), *Stigmatochromis* (1.3%), *Buccochromis* (0.4%) and *Caprichromis* (0.3%).

Over 94% of the hand lines catch wasdominated by the genera Cichlids while Clariids, Characids and Cyprinids made up of 3.9%, 1.2% and 0.8%, respectively (Figure 4 c). The two cichlid genera Protomelas (64%) and Oreochromis (28.2%) were the most important and accounted for over 92% of the catch while the Cyprinid genus Barbus was the least important and contributed less than 0.8% to the catch (Figure 4 c). At genus level, the bulk of the catch originated from two cichlid genera Nyassachromis (47.6%) and Otopharynx (46.1%) which together accounted for over 94% of the landings (Figure 4 d). Other significant forms among contributors to the catch included genera Lethrinops (3.5%), Protomelas (1.2%) and 1.01% for Placidochromis. It is worth noting here that landings from pelagic species such as members of the genera Engraulicypris and Copadichromis were negligible and did not exceed 0.5% (Figure 4 d).

Two genera comprise the land from Mosquito seines (Figure 4 e), Copadichromis (62.9%) and Engraulicypris (27.3%) were the most important and contributed over 90.2% to the landings with the rest coming from genera Opsaridium (6.4%), Nyassachromis (2.3%), Protomelas (0.7%) and 0.5% for Astatotilapia(Figure 4 e).

Out of the 14 genera, the bulk of the Nkacha catch was comprised these 5 genera (Figure 4 f): Nyassachromis (28%),

Engraulicypris (25.7%), Otopharynx (11.2%), Copadichromis (7%) and Buccochromis (6.6%) which together accounted for over 78% of the landings (Figure 4 f). The least important genera in Nkacha landings were Fossorochromis (0.7%), Bathyclarias (0.5%), Pseudotropheus (0.1%) and Placidochromis with 0.1% (Figure 4f). While Nyassachromis, Placidochromis, Pseudotropheus, Bathyclarias, Fossorochromis accounted for less than 1% (Figure 3 f).



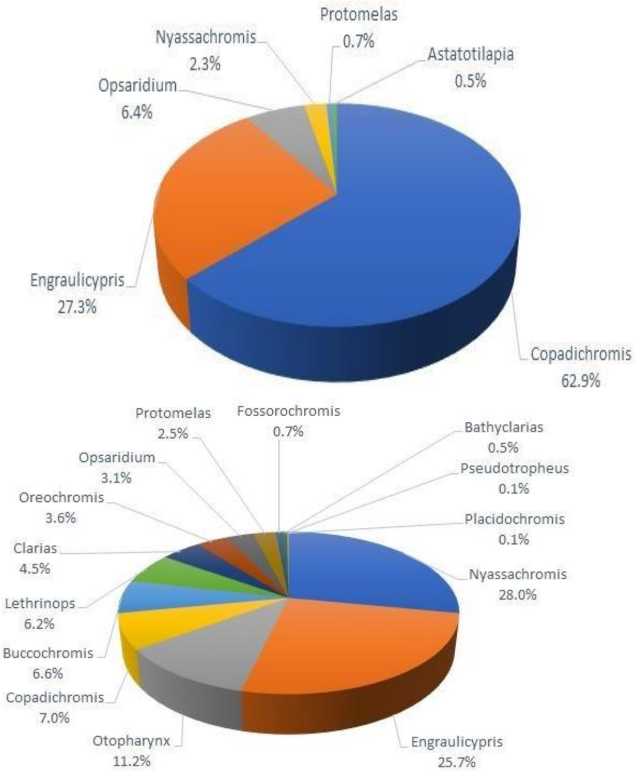


Figure 4: Composition of fish genera: a) Fish traps, b) Gillnets, c) Hand lines, d) Kandwindwi seines, e) Mosquito seines, f) Khacha seines and g) Long line.

3.2.1. Fish species diversity from Lake Malombe

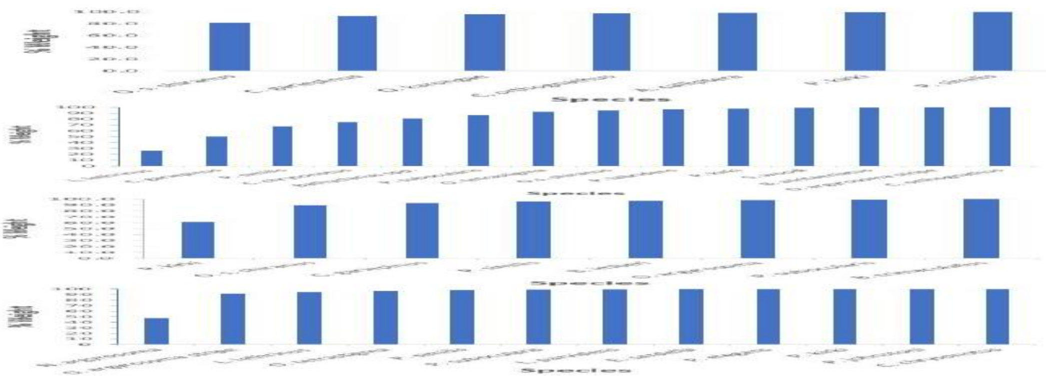
Lake Malombe is species diverse. Collectively, we found 28 fish species (Figure 2 c)from seven gears, with majority comprising of five species *Nyassachromis argyrosoma* (31.8%), *Otopharynx argyrosoma* stripe (17.6%), *Engraulicypris sardella* (16.3%), *Lethrinops lethrinus* (6.5%) and *Copadichromis chrysonotus* (4.8%) which together made up more than 75% oflandings (Figure 2 c). The species that contributedminimally to the landings included *Brycinus imberi* (0.003%), *Barbus trimaculatus* (0,002%), *Astatotilapia calliptera (*0.006%), *Pseudotropheusjohnstoni* (0.01) and

Caprochromis orthognathus (0.02%) among others (Figure 2 c).

Species appearance and dominance were not the same at gear level;, for instance, catches from fish traps were dominated by *Oreochromis shiranus* (82%) and *Clarias gariepinus* (11%) accounting for 93% of the landings with the rest coming from *O. karongae*, *Caprichromis orthognathus*, *Astatotilapia caliptera*, *P. kirki* and *P. similis* (Figure 4 a), while for gill nets, *L. lethrinus* (26.3%), *Clarias gariepinus* (24.2%), *Protomelas similis* (17.1%) and *C. chrysonotus* (7.2%) were the most dominant species and accounted for 75% of the landings while the least important were *Protomelas labridens*, *Protomelaskirki*, *Stigmatochromis woodi*, *Buccochromisatritaeniatus*, *Otopharynx argyrosoma* stripe, and*orthognathus* which made up less than 5% ofthe landings (Figure 4 b).

The bulk of the catch, comprising of over 90% from hand lines (Figure 4 c), came from two species, *P. kirki* and *O. shiranus* in the proportions of 61.4% and 28.2%, respectively. Other species landed in this fishery included *Clarias gariepinus* (3.9%), *P. similis* (2.6%), *Brycinus imberi* (1.2%), *Otopharynx argyrosoma* (0.9%), *Placidochromis subocularis* (0.9%) and 0.8% *Barbus trimaculatus* (Figure 4 c). The bulk of the catch from Kandwindwi consisted of two species, *Nyassachromis argyrosoma* (47.6%) and *Otopharynx argyrososma* (44.1%), which accounted for more 92% of the landings (Figure 4 d). The catch also contained sizeable quantities of *Lethrinops lethrinus* (2.9%), *Otopharynx tetrastigma* (2.0%), *Protomelas similis* (1.1%),

Placidochromis subocularis (1%) and 0.6% of *Lethrinops parvidens*. The catch also contained a peculiar fish of the genus *Pseudotropheus*, *P. elegans* which hides in abandoned shells of dead snails when threateMore than 90% of the fish landings by Mosquito seines (figure 4 e) came from the cichlid*Copadichromis chrysonotus* (62.9%) and the cyprinid *Engraulicypris sardella* (27.3%). Other landings include *Opsaridium microcephalus* (6.4%), *Nyasachromis argyrosoma* (2.3%), *P. similis* (0.65%) and 0.46% for *Astatilapia calliptera* (figure 4 e). The most important fish species in the Nkacha fishery which contributed over 80% to the landings were *N. argyrosoma* (28%), *E. sardella* (25.7%), *O. argyrosoma stripe*(7.1%), *C. chrysontus* (6.9%), *B. atritaeniatus* (6.6%) and *L. lethrinus* (6.2%) while those making negligible contribution included *Pseudotropheus elegans* (0.04%), *P. livingstoni* (0.06), *Placidochromis johnstoni* (0.01%) and 0.08% for *P. subocularis* (Figure 4 f).



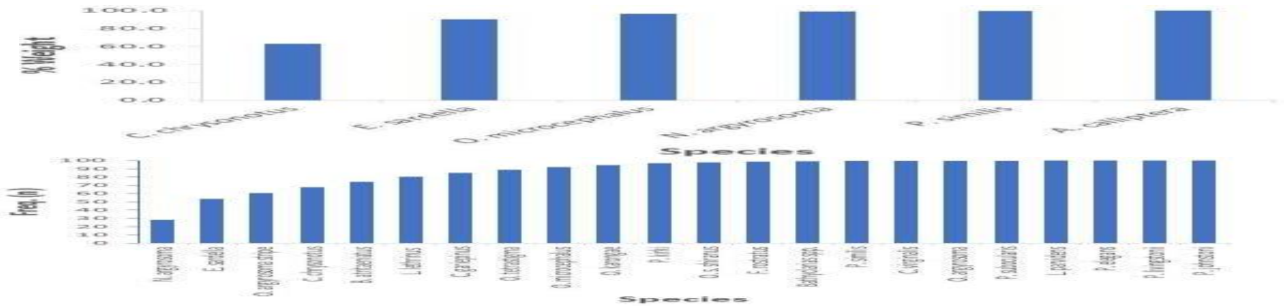
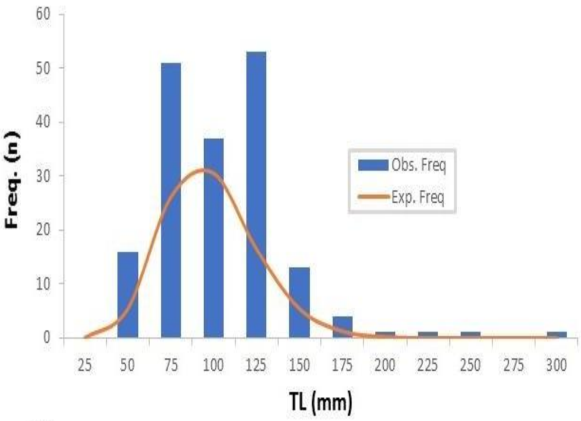


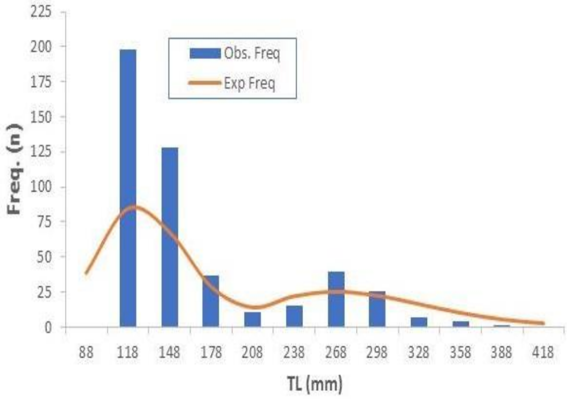
Figure 5: Cumulative percentage contribution of fish speciesper gear type: a) Fish traps, b) Gill nets, c) Hand lines, d) Kandwindwi seines, e) Mosquito seines, f) Khacha seines and g) Long line.

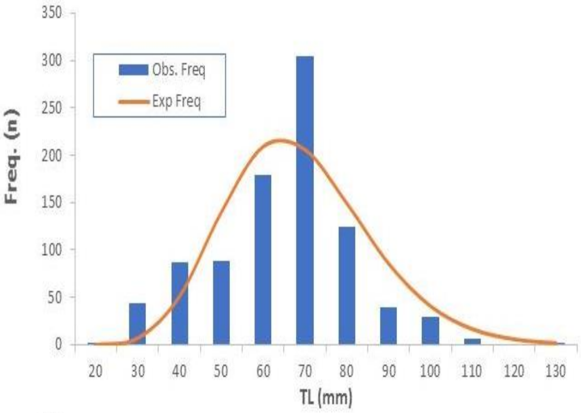
Table 3: Percent composition of landed fish families invarious artisanal fishing gears.*2)*

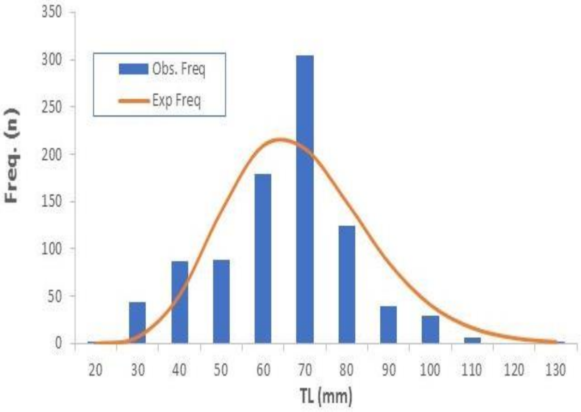
		Family		
Gear Type	Characidae	Cichlidae	Claridae	Cyprinidae
Fish trap		88.4	11.6	
Gillnet		69.8	30.2	
Handline	1.4	94.2	0.6	0.7
Kandwindwi		99.6		0.4
Longline		100.0		
Mosquito Net		65.6		34.4
Nkacha		66.1	5.1	28.8
Overall	0.003	76.5	5.2	18.3

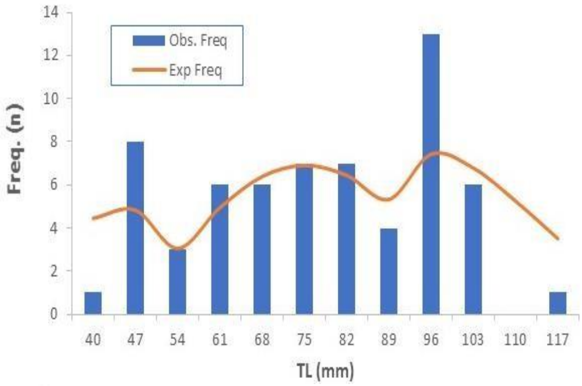
Fish size frequency distribution and size- at-capture Size frequency distribution differed among the used fishing gears (Figure 5); such a difference was also observed on the size-at-first- capture (Figure 6). The size frequency distributionfrom fish traps was from 28 to 280 mm with an average of 91.6±37 mm (Figure 5 a). The size-at- capture for fish traps was estimated at 91.1±27.4 mm (Figure 6 a). For gill nets, size frequencydistribution ranged from 89 to 379 mm with an average of 150±62.06 mm (Figure 5 b) and exhibited a bi-modal frequency distribution with alarge peak around 118 mm and a smaller one at 268mm, respectively (Figure 5 b). The sizes-at-capturewere estimated at 124.4 ±33.2 mm and 268.0 ±61.9mm, respectively, for the two peaks (Figure 6 b). Fish caught by Hand lines had size frequency distribution ranging from 50 to 290 mm with an average of 90±41.1 mm (Figure 5 c) while the size-at-capture on Hand lines was estimated at 80.8 ±22.4 mm (Figure 6 c). Size frequency distribution for the fish caught on Kandwindwi seine nets ranged from 20 to 121 mm with an average of 60.5±41.1 mm withthe expected mean estimated at 60.8 ±16.1 mm (Figure 5 d). The size-at-capture for Kandwindwi seines was estimated at 60.3 ±0.11 mm (Figure 6 d). Mosquito seines caught fish sizes ranging from40 to 112 mm with an average of 74.4±19 mm (Figure 5 e) exhibiting multi-modal distribution with 3 peaks at 47, 75 and 96 mm, respectively (Figure 5 e). The expected mean total lengths were estimated at 47 ±19.5, 75 ±18 and 96 ±16.3 mm, respectively (Figure 5 e). The size at-captureby Mosquito seines was estimated at 74 ±0.08 mm (Figure 6 e). For Nkacha seines, fish size frequency distribution ranged from 17 to 380 mm with an average of 52.8±22.2 mm with expected mean TL estimated at 56.05±15 mm (Figure 5 f).
The size-at-capture for Nkacha seines was estimated at 50 ±0.09 mm (Figure 6 f).











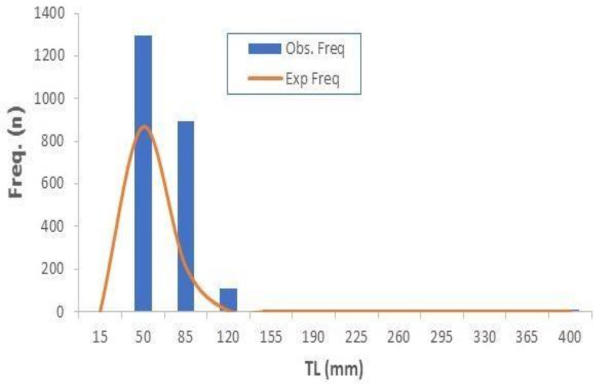


Figure 6: Fish size frequency distribution: a) fish traps, b)
gill nets, c) hand lines, d) Kandwindwi
seines, e) Mosquitoseines, f) Khacha
seines and g) long line.

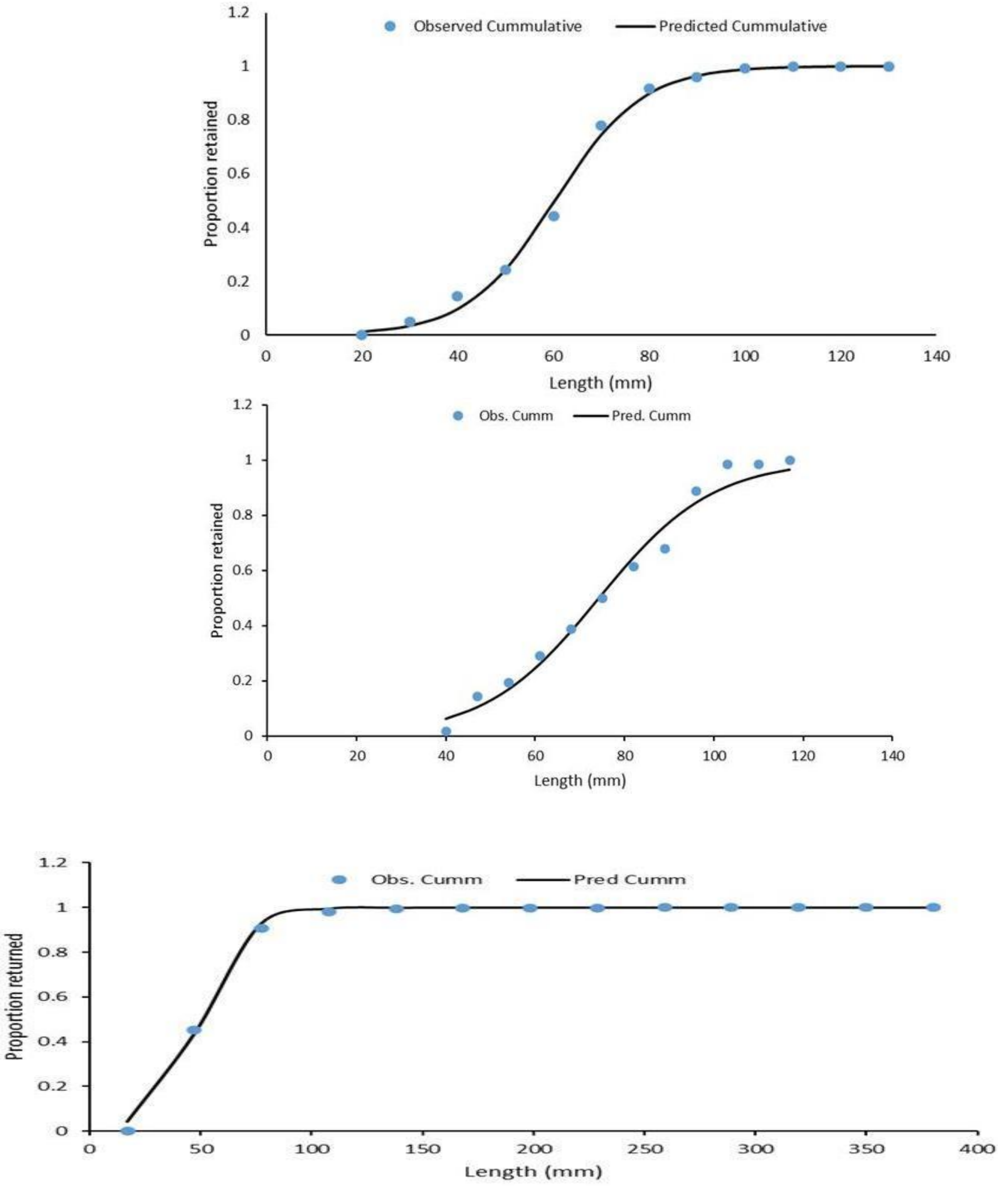


Figure 6: A Logistic selection ogive for fish landed by: a) Kandwindwi seines, b) Mosquito seines, c) Nkacha seines

DISCUSSION

Catch composition

The backbone of the artisanal fisheries of LakeMalombe comprising of 28 fish species and 19 genera is derived from four fish families; Cichlidae, Claridae, Cyprinidae and Characidae as attested by the catch composition in the current study which identified using seven different gear types. The multiplicity of gears is itself a big challenge to the management of the fish resource in such a shallow lake. Among the fish groups, Cichlidae was the most abundant family, comprising more than 77% of the catch followed by Cyprinidae, Claridae and Characidae at 18%, 5% and 0.003%, respectively. Cichlids were harvested by all gears but the composition in the catch varied with gear type. The contribution to landings by cichlids ranged from 66% to 100%, being slightly low in Nkacha (66.1%), Mosquito seine (66.4%) and Gill nets (69.8%). A previous study by Weyl *et al.* (2004) recorded a total of 56 taxa in the Nkacha seine net while this study recorded 28 taxa from 14 genera and 3 families; Cichlidae, Cyprinidae and Claridae, representing adecline of 60.7%. Therefore, these results clearly demonstrated a decline of fish species of Lake Malombe which calls for an effective management of the lake. In fact, this challenge hasbeen recognized for many years.

Catches/gear types

The catch rates from seven fishing gears ranged from 0.1 to 40.1 Kg/trip with an overallaverage of 11.3 ±16.3 Kg/trip, suggesting that gear design and efficiency played a strong influence, for instance, the two seine nets, Kandwindwi and Nkacha recorded the highest catch rates of 40.1 and 28.4 Kg/trip, respectively. This seine nets cover a much bigger area compared to other gear types and this explain why the catches are higher than those of Gill nets (8.9Kg/trip), Hand lines (0.5 Kg/trip), Mosquito seine nets (0.3 Kg/trip) and Longlines (0.1 Kg/trip).

Catches from Gill nets were lower than those of Kandwindwi and Nkacha seine nets, but higherthan the catch rates realized on Hand lines, Fish traps and long lines, most probably due to the fact that they cover a much wider area than the other gears. However, while this is true, an earlierstudy conducted in 2001 by Weyl *et al* (2004) shows a decline in Nkacha seine nets, as it found an average catch rate of 164.5± 8.4kg/trip which is about 5.8 times higher than the current catches representing a decline in catches of 82.7%.

Fish composition

In terms of fish composition per gear type, wefound it high ranging from 89% to 100% in Fish traps, Hand lines, Kandwindwi seines and long lines (Table 2). In comparison with the other gears, Cichlids were more vulnerable to these gears than the other families, for a number of reasons. Firstly, by due to their shape, secondly, cichlids were the most common and abundant species in the fishing grounds. However, regardless of selectivity towards cichlids, their overall contribution in terms of quantities for the Cichlids landed in the lake was low (Figure 7). Therefore, a highly selective gear for a certain species may not necessarily be a major harvestinggear for that species.

The next most important family after cichlidswere the cyprinids contributing about 18.3% of the total landings from four gears; Mosquito seines, Nkacha seines, Hand lines and Kandwindwi seines contributed 33.6%, 28.8%,0.8% and 0.4% of total landings (Table 2). Mosquito and Nkacha seine nets alone made a total making up over 60% of landings of this family in the lake. The high vulnerability of Cyprinids to these gears may be attributed to theirpoor selectivity and the open water fishing grounds frequented by these fishing gears.Generally, Cyprinids prefer open waters, hencethe high probability of capture.

The contribution of Claridae to overall landings in the lake was about 5.2% and unlike the cichlids, these were vulnerable to mostly four gears (Gill nets, Fish traps, Nkacha seines and Hand lines) comprising 30.2%, 11.4%, 5.05% and3.9% of landings, respectively. Gill nets and Fish traps were the major harvesting gears for these fishes although some quantities were also landed in Nkacha (5%) and Hand lines (3.9%). Clariids catfishes were probably more vulnerable in these two gears because Gill nets and Fish traps are normally employed in the vegetated fringes of thelake which are preferred by Clariid catfishes. While previous studies recorded catfishes belonging to Claridae and Bagridae, this study didnot register any landings of Bagrids, particularly the common *Bagrus meridionalis*.

While Characidae are found in abundance in the Lower Shire and Zambezi River systems, the composition in overall landings has been marginal, only about 1.2% was harvested by Handlines probably due to the fact that they generally prefer riverine and weedy habitats.

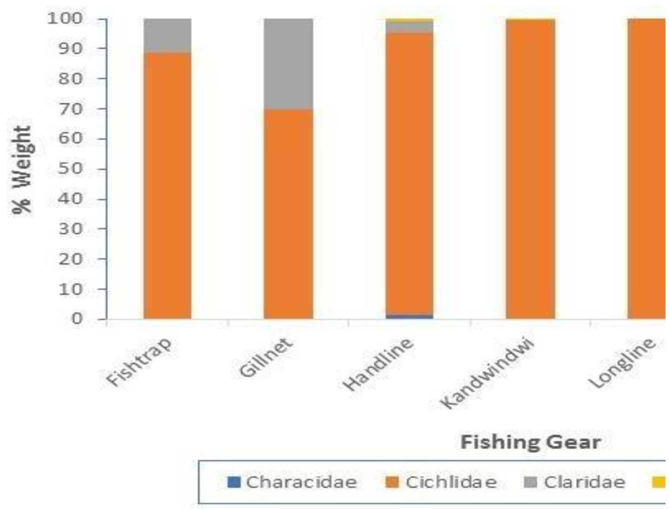


Figure 7: Percentage catch composition at family level byfishing gear type.

There were over 19 fish genera and 28 fishspecies landed in the fisheries of Lake Malombe, but only a handful are of economic importance. Thebulk of the catch comprised only five genera and five species *N. argyrosoma* (31.8%), *O. argyrosoma* stripe (17.6%), *E. sardella* (16.3%), *L.lethrinus* (6.5%) and *C. chrysonotus* (4.8%) whichaltogether formed more than 77% of the landings.

As previously stated, the two seine nets, Nkacha and Kandwindwi, are the main harvesting gears (Figure 33) while *N. argyrosoma* was the most important species, landed in almost equalproportions in both Kandwindwi (44.5%) and Nkacha (55.5%). About three-quarters of *O.argyrosoma* stripe (74.4%), being the second abundant species, was landed by Kandwindwi andthe rest was found in Nkacha.

Fish Species

Records of *E. sardella* were surprising given its absence in historical fish data so far compiled for Lake Malombe. Nkacha was the major harvesting gear for *E. sardella* (99.1%), becoming the third most important species in the lake, while less than1% came from Kandwindwi. The fourth most important species was *L. Lethrinus* harvested by atleast three gears. Over 60% of the landings for this fish came from Nkacha while Gill nets and Kandwindwi accounted for 26.8% and 13.2%, respectively. The species *C. chrysonotus* was the fifth most important species harvested by Nkacha (89.5%) while about 10% was landed in Gill nets and less than 1% was landed by Kandwindwi. As indicated in Figure 4, Nkacha seines also contributed significantly to landings of *Oreochromis* species (99%) and O. *shiranus* was landed by three gears; Nkacha (54%), Fish traps (30%), Gill nets (10%) and Hand lines (< 6%). Nkacha seines landed the highest number of taxa (14 genera and 22 species) comprising almost 50% of all taxa sampled. Catches of other gears (Gill nets, Kandwindwi and Hand lines) were alsodiverse with respect to taxa, however, Fish traps and Long lines landed the least diverse catches (Figure 4). A previous study by Weyl *et al.* (2004) recorded a total of 56 taxa in the Nkacha seine net fishery while this study recorded 28 taxa from 14 genera and 3 families; Cichlidae, Cyprinidae and Claridae, representing a decline of 60.7%.

The overall contribution of cichlids to total landings has not changed. Cichlids made up over 66% of the catch while in 2001 cichlids comprised60.7%, reflecting a slight increase of 8.7% as compared to the previous results found by (Ref.). The five cichlid species *N. argyrosoma*, *O. argyrosoma stripe*, *C. chrysonotus*, *B. atritaeniatus* and *L. lethrinus* and the cyprinid *E. sardella* contributed to over 78% of the catch.

Weyl *et al* (2004) found that 60% of the landings in Nkacha seines came from the five cichlid species *C. chrysonotus*, *C. virginalis*, *L. turneri*, *O. argyrosoma* sp. 'red' and *O. tetrastigma.* Therefore, it can be concluded that in the past 15 years, the Nkacha fishery in Lake Malombe has undergone drastic changes in species composition. Some species such as *C. virginalis*. *L. turneri* and *O. tetrastigma* have decreased in abundance andimportance while the small cyprinid *E. sardella* and the cichlid *B. atritaeniatus* have become increasingly important. Other species such as *N. argyrosoma*, *O. argyrosoma stripe* and *C. chrysonotus* have maintained their dominance inthe Nkacha fisher

Size structure and distribution

Irrespective of the gear type, the TL of fish sizes caught ranged from 17 to 380 mm with an average TL of 69.1±43.2 mm (Figures 8). The minimum and maximum TL of 17 and 380 mm were found in Nkacha seine nets. (Figure 8). The average minimum size was estimated at 45.1 mm and the fishing gears which landed fishes falling below the minimum average of 45.1 mm were seine nets (Nkacha, Kandwindwi and Mosquito) and fish traps (Figure 8). Other fishing gears including hand lines, long lines and gill nets landed fishes of minimum sizes above the average size of 45.1 mm (Figure 8), suggesting that these last gears are passive as attested by catching larger sizes compared Khacha, Kandwindwi and Mosquito seines and fish traps.

Sizes-at-first-capture

The sizes-at-capture for all gears ranged from 47.0 to 124.4 mm with an average of 77.3 ±28.1 mm (Figure 6). The three seine nets (Nkacha, Kandwindwi and Mosquito) recorded sizes-at-capture below the average (77.3 ±28.1 mm). In addition, landings from the three seine nets had sizes-at-capture below average minimum sizes of long lines and gill nets of between 72 and 89 mm, respectively. Manase (2001) estimated the mean total length for C. virginalis, O. argyrosoma and L. pinkhead landed in Nkacha seine nets of 70.8, 64.7 and 67.8 mm, respectively. These fish sizes were well above the mean total length of 56.0 mm estimated for all fish landed in Nkacha seines. The seven gear types studied have been used for many years. Continuous use of these unselective gears that remove small fish sizes in Lake Malombe over the years, have contributed negatively to the fishery. This is not only detrimental to the fishery, it has led to consistent reported declines in fish catches from 12,000 tons in 1981-1992 to 3, 820 tons in 2015 (GoM 2015, 2016), unfortunately, the scenario continues to deteriorate. While the variations in minimum sizes of fish landed can be attributed in part to differences in gear selectivity, the fishing grounds also seem to have contributed to the sizes of fish landed. Seine nets mostly target the heavily fished open waters species of the lake while gill nets, fish traps, long lines and hand lines were generally set up to catch fish within the less disturbed vegetated fringes of the lake compared to gears catching fish in less disturbed by fishing activities than the open waters, they harbour healthier fish populations than open waters, hence the fish landed here are generally of larger size, thus the study suggests that fish size structure and distribution were influenced by gear selectivity aswell as type of fishing grounds.

The analysis revealed that the majority of the fish retained in Hand lines, Fish traps and Gill nets ranged between 80 and 124 mm with an average of 98.5 ±23.1 mm (Figure 9 a). Meanwhile,seine nets caught fish varying between 47 and 64.5mm with an average of 55.9 ±8.8 mm (Figure 9 b).The majority of the fish which were retained in theseine nets (55.9 mm) were almost half the size of those retained in the other gears (at average size of98 mm TL (Figure 9 b). Seine nets used in Lake Malombe seem to have been deliberately designedto target juvenile and small-size fish. This might have resulted owing to the decline of the fisheries which is currently dominated by small sized fish inan open access lake to fishing.

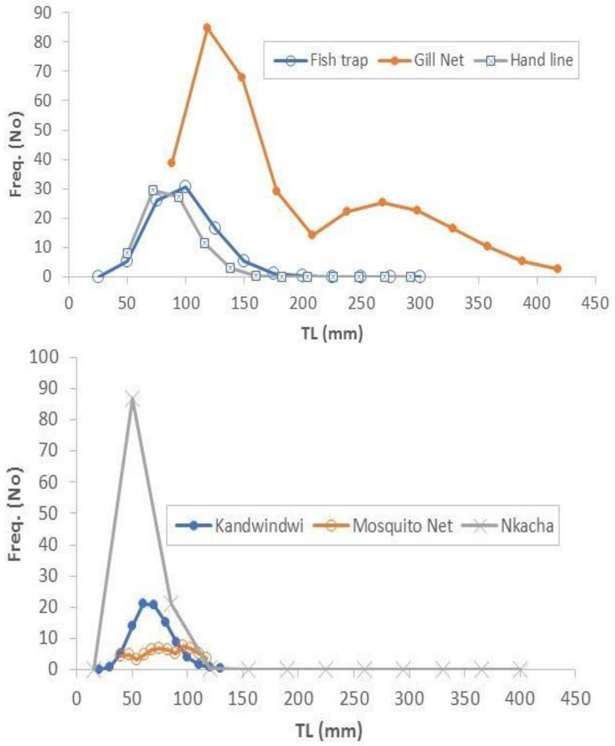


Figure 9: Comparison of fish size structure and distributionin: a) Fish traps, Gill nets and Hand lines and b) Nkacha, Mosquito and Kandwindwi operating in Lake Malombe.

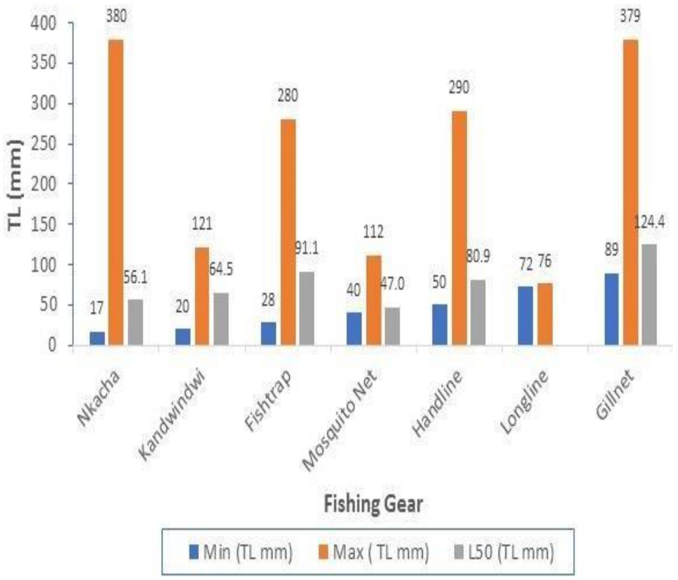


Figure 8: Comparison of Size-at-capture, minimum andmaximum sizes of fish by fishing gear.

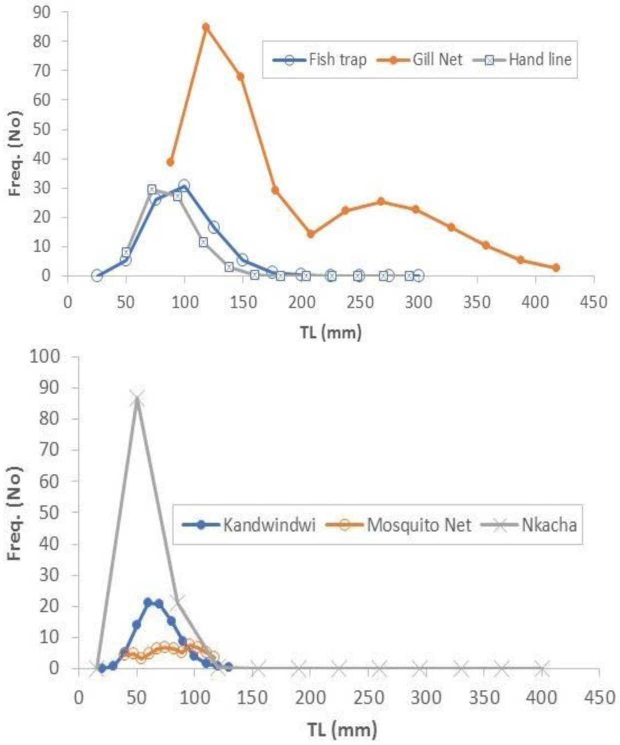


Figure 9: Comparison of fish size structure and distributionin: a) Fish traps, Gill nets and Hand lines and b) Nkacha, Mosquito and Kandwindwi operating in Lake Malombe.

The artisanal fisheries of Lake Malombe isprecariously compromised owing to the use of active fishing gears broadly categorized into seinenets (Nkacha, Kandwindwi and Mosquito), gill net type (multifilament), long line (with multifilament snoods), two hand-line types (pole mounted & without pole) and fish traps, such a variety of fishing leads to indiscriminate fish harvests where very few fish escape capture; this compounded by the fact that the lake is so shallowat average of 3-4 meters deep (FAO 2018), increases the efficiency of some fishing gears, especially the Kandwindwi, Nkacha and gill nets. The use of different fishing gears resulted in: (i)Different catch rates, (ii) Rich species composition, (iii) Wide length frequency distribution, (iv) various sizes-at-first-capture owing to gear selectivity.

Based on these findings, it can be concluded that the most economically important fish species in the artisanal fisheries of Lake Malombe during the period of study were the two Kambuzi species *Nyassachromis argyrosoma* and *O. argyrosoma,* Usipa *(Engraulicypris sardella*), Mbaba (*Lethrinops lethrinus)* and Utaka or Chamwamba (*C. chrysonotus*). The study also revealed that *E. sardella* is now the third most important fish in the lake while *C. chrysonotus* is increasingly become an important contributor to fish landings. Compared to findings reported by Weyl (2004), there has been a considerable reduction in sizes of fish landed in the fishery overthe years. Current results suggest that the seine nets used in Lake Malombe are highly unselectiveand harvest mostly juvenile and small fish, hence the sizes-at-capture ranging between 47 and 64.5 mm are lower compared to the overall estimate of 77.3 ±28.1 mm.

Although there are over seven types of fishing gears being used in the lake, the seine nets Nkacha and Kandwindwi are the most important fishing gears with respect to both quantities of fishlanded and catch rates. These seine nets are also major harvesting gears for the previous economically important species of *O. shiranus* and *O.* (Chambo). Due to their poor selectivity, these seines are also the most destructive fishing gears in the lake as they target mostly juvenile andsmall fish, thereby greatly contributing towards growth and recruitment overfishing (Weyl *et al.*, 2004). This fishery has undergone all forms of stress and survives partially from recruits from Lake Malawi. Further evidence of this is the recent appearance of Usipa among the catches.

RECOMMENDATIONS

The continued destructiveness of seine nets to the fishery in Lake Malombe has once more been highlighted, thus it is recommended that these gears should be removed from the fishery or in some way be modified to minimize their harmful effects on the fishery and the ecosystem. If it were practical, it would be better to ban out-right the use of seine nets in Lake Malombe. Alternatively, allowing use of limited numbers of less destructivefishing gears such as multi filament Gill nets, Handlines and Fish traps might offer temporary relief to the fishery. This fishery could most easily recover if these measures are implemented as which is composed of small short-life cycle species. Elsewhere, the practice of buying out gears considered to be destructive has been used and the banning illegal fishing gears has proved useful considering that the fishery **i**s currently unsustainable. Alternatively, introduction of a Rights-based quota system as happened on high seas in countries like Namibia is a viable option. In Namibia, the fish resource recovered dramatically from fish catches of <50,000 in the 1960sincreasing to 800,000 tons in 1970s and slumping to 100,000-200,000. Currently fish catches are around 400,000 after TAC was introduced (A. vander Westhuizen 2001). However, there will be need for legal framework and political will to achieve fishery recovery. Since Lake Malombe is shallow, cage culture is not a good option consideration for pen culture is being suggested because the benthic fauna and flora is relatively rich from studies conducted under the same FAO/TCP program (Kamtambe *et al* 2019).

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References

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Booth AJ and Punt AE. Evidence for rebuilding inthe Panga stock on the Agulhas Bank, South Africa. Fish. Res., 1998: 34: 103-121.

Butterworth DS, Punt AE, Borchers DL, Pugh JG.,and Hughes GS. A manual of Mathematical techniques for line fish assessment. S.Afr. Natl. Sci.Pro. Rep., 160, 1989: 89 pp.

FAO Report of the Bathymetry Survey of Lake Malombe. Prepared by Gift Chagona and Orton Msiska for FAO Project TCP/MLW/3504, 2018.

FAO/GEF. Building Climate Change Resilience in the Fisheries Sector in Malawi. GCP/MLW/053/LDF Project DocumentAnnotated, 2017.

FAO. Fisheries management in south-east LakeMalawi, the Upper Shire River and Lake Malombe,with particular reference to the fisheries onChambo (*Oreochromis* spp.). CIFA Tech. Pap. 21 1993: Rome FAO. 113p.

FAO. Fisheries Management in the South East Arm of Lake Malawi, the Upper Shire and Lake Malombe. *CIFA Technical paper*, Vol. 21 1992: GOM/FAO/UNDP Chambo Fisheries Research Project.

GoM. Government of Malawi. Annual EconomicReport, Ministry of Finance, Lilongwe, Malawi, 2015.

GoM. Government of Malawi. Annual FrameSurvey report for all water bodies in Malawi,2015.

Manase MM. The Nkacha fishery in Lake Malombe and south eaJ Bandast arm of Lake Malawi. In Lake Malawi Fisheries Management Symposium- Proceedings 4th-9th June 2001. *In* Weyl OLF and Weyl MV (Eds.) NARMAP, Department of Fisheries, Lilongwe: 156-162.

Kamtambe K, J, Banda, B. Kaphuka, and O.V Msiska.2019. The abundance, distribution and diversity of benthic invertebrates of Lake Malombe, Malawi. International Journal of Fisheries and Aquaculture Vol. 11 (2), pp13-22.

King M. Fisheries Biology, Assessment andManagement. Fishing News Books, 1995: Osney Mead, Oxford, London

Sparre P, Ursin E and Venema SC. Introduction toTropical Fish Stock Assessment. Part 1- Manual. FAO, Fisheries Technical Paper No. 306/1, 1989: 337pp.

Van Zwieten PAM, Banda M, Kolding J. SelectingIndicators to Assess the Fisheries of Lake Malawi and Lake Malombe: Knowledge base and Evaluative Capacity. J. Great Lakes Res., 2011:37, 26-44, DOI: 10.1016/j.jglr.2010.11.001

Van Zwieten, P.A.M, F. Njaya. Effort developmentand the collapse of the fisheries of Lake Malombe: Does environmental variability matter? *In* Editors (Eyolf Jul-Larsen, Jeppe Kolding, Ragnhild, Overa, Jasper Raakjaer Nielsen, Paul A.M. Van Zwieten). Management, Co-Management or NoManagement major dilemmas in Southern AfricanFreshwater Fisheries. 2. Case Studies. FAO Fisheries Technical Paper 426/2, 2003: Rome, Italy.

Malcolm H. Modelling and Quantitative Methods in Fisheries, 2001. Chapman and Hall, Boca Raton, 406 pp.

Weyl O, Mwakiyongo KR and Mandere DS. AnAssessment of the Nkacha net Fishery of Lake Malombe, Malawi, Afr. J. Aqua. Sci., 2004: 29:1, 47-55.