Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2026; 26(9): 30907-30941 https://doi.org/10.18697/ajfand.156.27670

Date	Submitted	Accepted	Published
	19th June 2026	17th October 2026	19th November 2026

ASSESSMENT OF BIOMASS, MAXIMUM SUSTAINABLE YIELD, SIZE DISTRIBUTION AND BIODIVERSITY OF DEMERSAL LARGE-SCALE FISHERIES IN LAKE MALAWI

Mulumpwa M[1,2]*, Kaunda E[2], Hara M[3] and W Jere[2]



Mexford Mulumpwa

*Corresponding author email: mulumpwa.mexford@gmail.com
ORCiD: https://orcid.org/0000-0003-2522-2737

[1]Senga Bay Capture Fisheries Centre, P. O. Box 316, Salima, Malawi

[2]Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P.O. Box 219, Lilongwe. Malawi

[3]The University of the Western Cape, Institute for Poverty, Land and Agrarian Studies (PLAAS), Private Bag X17, Bellville, 7535, South Africa

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

This study was conducted to assess the fish biomass, biodiversity patterns and sustainable harvesting potential of demersal large-scale fisheries in Lake Malawi. This study aimed to determine appropriate fisheries output management target points (total allowable catch (TAC) and maximum sustainable yield (MSY)). The assessment was conducted in 2024 and was based on fish biomass survey data from 2020, which was conducted on Lake Malawi by the Department of Fisheries. A stern trawler (RV Ndunduma) was fitted with a bottom trawl net with a code-end mesh size of 38 mm. Biomass was estimated using the swept-area method and MSY was estimated using the Beddington and Cooke model. Shannon, Simpson and Pielou's evenness indices were employed to assess biodiversity, while non-parametric statistical tests such as PERMANOVA and Kruskal-Wallis were used to determine differences in fish community composition and fish size distributions across the regions of the lake. The study estimated the total fish biomass and MSY of demersal fisheries in Lake Malawi at 261,297.8 tons and 130,648.9 tons per year, respectively. The southern region of the lake contributed the highest proportion of biomass and MSY, accounting for 55.6% of the total biomass. The study recorded high fish species richness (152), predominantly demersal fish species and very low densities of midwater fish species. The southern part of the lake recorded the highest fish species richness and abundance; however, it also showed a significant regional difference in community composition and fish size distribution. The findings further showed that the following commercially important fish species, *Diplotaxodon*, *Lethrinops*, and *Rhamphochromis*, in the southern part of the lake had smaller mean body sizes than in other regions, suggesting possible excessive fishing effort and growth overexploitation. The study also revealed limitations in the current fish biomass assessment approach, which is biased toward demersal species and may underestimate midwater fish stocks targeted by large-scale fishers. This study demonstrates that sustainable fishery management in Lake Malawi requires region-specific allocation of fishers, improved fish biomass assessment, stricter enforcement of fishery regulations and enhanced conservation measures. This will ensure that fish biodiversity is protected and that there is long-term fishery productivity. The findings provide scientific information for guiding fisheries policy, TAC allocation and ecosystem-based fisheries management in Malawi.

Key words: Trawl fishery, fish biomass assessment, demersal fisheries and fisheries management

Citation: **Mulumpwa M, Kaunda E, Hara M and W Jere** Assessment of Biomass, Maximum Sustainable Yield, Size Distribution and Biodiversity of Demersal Large-scale Fisheries in Lake Malawi. *Afr. J. Food Agric. Nutr. Dev.* 2026; **26(9):** 30907-30941. https://doi.org/10.18697/ajfand.156.27670

CC BY NC ND

Since 2001 ajfand
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

AI Usage Declaration: During the preparation of this manuscript, the authors did not use any AI tools. The authors reviewed and edited the contents as needed and take full responsibility for the contents of the published article.

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

INTRODUCTION

Fisheries resources play a vital role in the socio-economic development and food security of Malawi. Fish is the primary source of animal protein in Malawi. It is also a livelihood for millions of fishing communities as it supports them through fishing, fish processing, transportation and trade [1]. Among the water bodies in Malawi, Lake Malawi is the largest and contributes over 80% of the annual national landings. Lake Malawi is globally recognized as one of the most diverse freshwater ecosystems. It harbors between 800 and 1000 fish species in one place, the majority of which are endemic cichlids [2]. Owing to this exceptional biodiversity, the southern part of the lake has been made into a protected area known as the Lake Malawi National Park, a UNESCO World Heritage Site [3].

Despite their ecological and economic importance, the fishery resources in Lake Malawi are experiencing increased fishing efforts, which usually worsen due to the open access management regime, resulting in overexploitation. Fisheries resources are also experiencing habitat degradation in spawning, nursing grounds and catchment areas, climate change, population increase, which is increasing demand for fish and poor fisheries management structures. Previous studies and fisheries monitoring reports have indicated both declining fish landings and a reduction in fish size, especially in the southern region, where the intensity of fishing effort is the highest [4]. The expansion of both small- and large-scale fishers over the years has increased fishing pressure on fish stocks, threatening the long-term sustainability of the fisheries of Lake Malawi [5]. For this reason, sustainable fishery management requires a management governance system and reliable scientific information on fish stock biomass, biodiversity patterns, fish stock structure and productivity [6].

One of the key strategies for sustainable fishery management is the implementation of output control measures, such as total allowable catch (TAC) and maximum sustainable yield (MSY), that are enforceable not just as fisher allocation tools to fishing areas. These management reference points assist managers in regulating fishing efforts and ensuring that fish exploitation is kept within biologically sustainable limits [7]. However, an efficient determination of TAC and MSY requires a robust fish biomass assessment and an understanding of fishing area differences in fish distribution, abundance, and biodiversity [8].

This study therefore assessed the biomass, biodiversity and sustainable exploitation potential of demersal largescale fisheries in Malawi using fishery-independent demersal trawl survey data collected in 2020. Specifically, the study aimed to: (a) estimate fish biomass and MSY for demersal fisheries of Lake Malawi; (b) assess biodiversity patterns and fish community composition from the southern through the northern regions of Lake Malawi; (c) evaluate regional differences in fish size distribution among dominant species of fish. The overall findings contribute

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

important scientific information for ecosystem-based fisheries management, fisheries conservation and sustainable allocation of fishing effort on Lake Malawi.

Total allowable catch (TAC)

One of the most common output control measures is TAC, which sets an aggregate limit on the total weight or number of fish that can be caught during a specific period. This limit is typically established based on scientific assessments of fish stocks to maintain resource sustainability. For instance, biomass assessment surveys are periodically conducted in Lake Malawi [9]. The effectiveness of TAC systems differs across regions. Ding *et al*. [10] reported that in China, insufficient legal liability, ineffective regulatory control, and multispecies fisheries complexities make the implementation of TAC a challenge. Kane, Ball and Brehmer [9] on the other hand, suggested that game-theoretical approaches can be a great tool for optimizing the sharing of TAC among nations sharing a water body, as illustrated in the Euro-Mauritanian fisheries agreement. The North East Atlantic uses output controls, such as TAC, while Mediterranean fisheries rely more on input controls. This *scenario* highlights regional differences in fishery resource management strategies [11]. In Indonesia, TACs have been found to be inefficient in managing fisheries' sustainability and promoting equity. This has led to the consideration of alternative approaches, such as Individual Non-Transferable Quotas, to allocate catch shares among various fishers while promoting equity in fishery resource utilization [12]. Collectively, these studies emphasize the need for context-specific fishery management policies. These policies should combine different management options, such as input and output controls, to balance resource sustainability, equity, and economic interests [13].

METHODOLOGY

Study area

The study was conducted on Lake Malawi among the large-scale fisheries, which are trawl fisheries in Malawi. The study covered the entire lake from Mangochi in the south to Karonga districts in the north. For analytical purposes, the lake was divided into southern, central and northern regions.

Largescale fishers

In this study, large-scale fishers are defined as those with large investments, technology used, the number of specialized laborers employed, and the output from the fishing industry, and utilize the fish resource primarily for monetary gain. These are also called commercial fishers [14]. Large-scale fishers use large-scale fishing vessels that are mechanized and currently operate trawl nets, while previously they operated purse seines or lift nets. In terms of fishing craft, large-scale fishers operate stern trawlers and pair trawlers. Large-scale fisheries are currently not open access and are effort-controlled through licensing [14, 15].

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Data source and fish biomass survey

The study used fish biomass survey data generated from the 2020 fish biomass assessment survey conducted in Lake Malawi were obtained from the Department of Fisheries (DoF). The survey covered the entire stretch of the lake in Malawi (Figure 1), from Mangochi to the Karonga District in the north.

RV. Ndunduma, a fishing vessel in the Department of Fisheries with a 386 hp engine, was used for sampling. This 17.5m stern trawler was fitted with a Guttorpur bottom trawl net. The trawl net had a 14 m horizontal opening, 4 m vertical openings and a 38 mm code-end. The trawl net headrope length was 23m.

Trawling was conducted along predetermined transects distributed across the lake. Sampling stations were located using an onboard Global Positioning System (GPS), which was complemented by existing maps. Trawling was confined within the stipulated transects, and the trawling duration ranged from 15 to 30 min. The trawling speed was restricted to 2.5 nautical miles per hour as it is a standard fishing speed that has been used in the previous biomass assessment for comparability. A total of 120 sampling sites were covered across Lake Malawi. The total trawled area was 9,647.97 km^2 across all regions (southern, central and northern) on the lake in Malawi.

CC BY NC ND
https://doi.org/10.18697/ajfand.156.27670

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

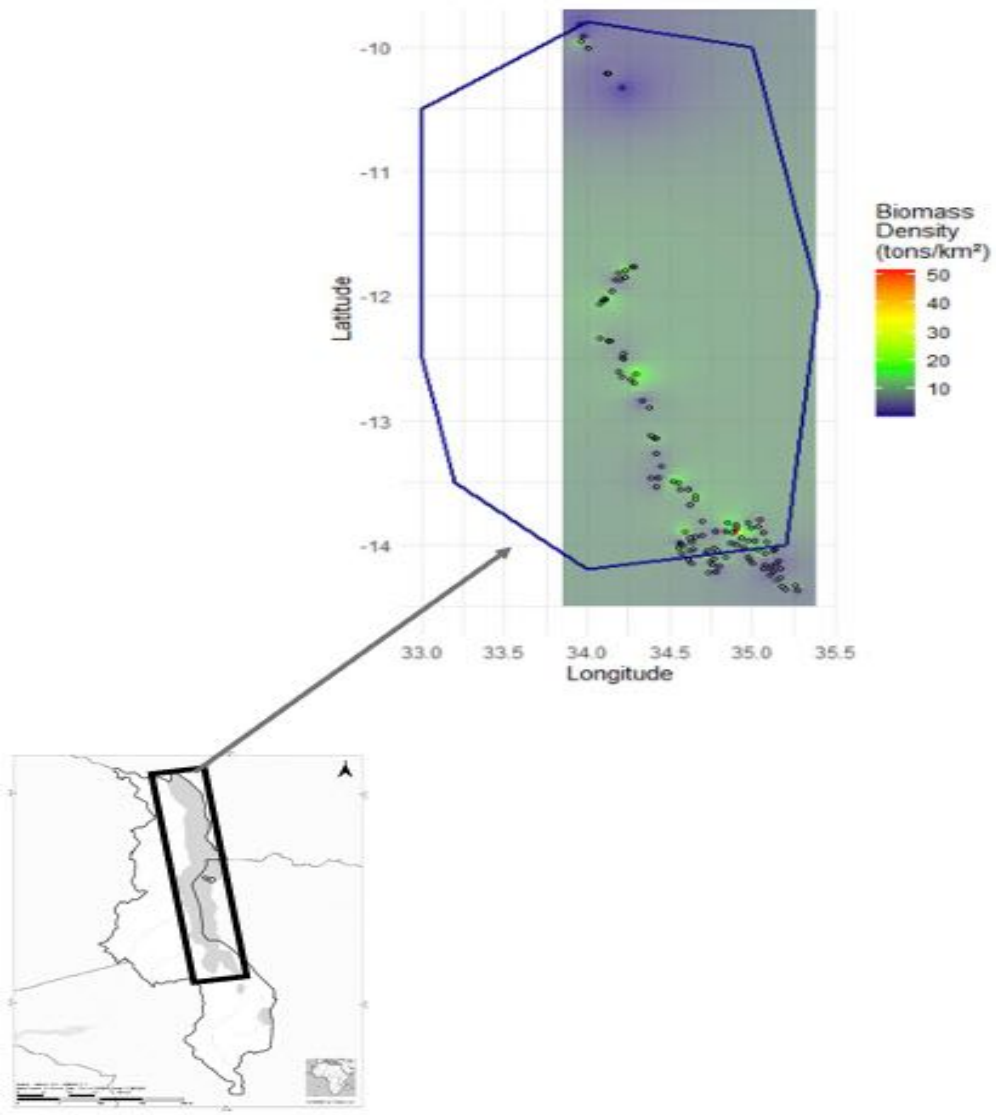


Figure 1: Lake Malawi demersal fish biomass and sampling point distribution/density in Malawi

Fish sampling and biological measurements

A total of 30% of the landed catch at a sampling transect was sampled. In cases where the sample size was too large (> 0.5 ton) to be handled, a sub-sample from the collected sample was used. Individual total length (TL) in mm and weight in g were measured using a stainless-steel ruler and digital weighing scale, respectively, followed by a batch weight of the total sampled fish to establish the total weight where the sample was too large to work with. This sampling protocol was in accordance with the guidelines outlined by Sparre and Venema [17].

CC BY NC ND
https://doi.org/10.18697/ajfand.156.27670

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Biomass estimation

This study employed the swept-area method to determine the biomass of fish in every fishing area allocated to large-scale fishers. The swept-area method is commonly applied in demersal trawl surveys. The swept area for each trawl haul was estimated using the following models (1 and 2):

$$a = D \times L \times \mu \quad (1)$$

Where:

a is swept area (km^2),
D is the distance covered by the gear during trawling,
L is the head-rope length of the trawl net,
μ is the wing spread coefficient,

The distance covered during trawling was calculated as follows:

$$D = V \times t \quad (2)$$

V is the velocity of the trawl net during trawling,
t is the duration of each trawl from start to hauling,

The wing spread coefficient (*μ*) of 0.5 was adopted following the recommendation of previous trawl survey studies, as reported by Shindo [18] and SCSP [19].

The Catch per unit effort (CPUE) was estimated for each sampling station. Since the CPUE data were positively skewed, normality was first assessed using the Shapiro–Wilk test (p= *0.05*). When the data were not normally distributed, a geometric mean (GM) was used to estimate the mean CPUE. The GM was obtained using the model reported by Rosner [20], as shown in Model 3. The total biomass for each region and depth zone was then estimated by extrapolating CPUE values to the corresponding trawlable fishing areas.

$$GM = 10^{\frac{1}{n}\sum_{s=1}^{n}\log(CPUE_{s+1})} - 1 \quad (3)$$

Estimation of Maximum Sustainable Yield (MSY)

MSY was estimated using the Beddington and Cooke [21] model, as shown in Equation 4:

$$MSY = 0.2 * M * B \quad (4)$$

Where:

M is natural mortality.
B is the estimated fish biomass.

Natural mortality was estimated using Pauly's empirical model of 1980 based on the parameters of the von Bertalanffy growth function and mean annual water

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

temperature (T) as stated by Froese, Palomares and Pauly [22] and shown in Model 5.

$$Log\ M = +0.4634\ Log\ T \quad (5)$$

Where:

T is mean annual water temperature in °C

Biodiversity Assessment

Fish biodiversity was assessed using species richness, Shannon diversity index, Simpson diversity index and Pielou's evenness index. The fish species richness was determined as the total number of fish species recorded within each region. The Shannon diversity index was calculated to evaluate species diversity and abundance distribution. The Simpson index was used to assess dominance patterns within fish communities, while Pielou's evenness index was used to determine how evenly individuals were distributed among species. The following models (6, 7, 8 and 9) were used to determine the biodiversity assessment parameters.

a. Species richness

$$S = \sum_{i=1}^{s} 1 \quad (6)$$

Where:

S = species richness
i = species *i*

b. Shannon diversity index

$$H' = -\sum_{i=1}^{s} \text{pi In(pi)} \quad (7)$$

Where:

H' = Shannon diversity index
S = total number of species
p_i = proportion of individuals belonging to species i

c. Simpson diversity index

$$D = \sum_{i=1}^{S} P_i^{\,2} \quad (8)$$

Where:

D = Simpson concentration index
pi = relative abundance of species *i*

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

d. Pielou's evenness can be calculated as follows:

$$J' = \frac{H'}{\ln(S)} \quad (9)$$

Where:

J' = Pielou's evenness
H' = Shannon diversity index
S = species richness

Statistical analysis

The study used R 4.4.2 to analyse the data [23]. To determine whether fish community composition and fish size distributions differed significantly among the northern, central and southern regions of Lake Malawi, statistical analyses were conducted. First, data normality was assessed using the Shapiro–Wilk test. The assumption of conducting a parametric test, such as analysis of variance (ANOVA), is that the data are normally distributed and have equal variances. The Shapiro–Wilk test showed that the data were not normally distributed ($p < 0.001$). In contrast, Levene's test indicated that the variances were not equal across regions ($p < 0.001$). In addition, the Q–Q plots of fish length indicated that the data residuals were not close to zero, as shown in Figure 5. Consequently, non-parametric statistical tests were applied.

Permutational Multivariate Analysis of Variance (PERMANOVA) was used to assess regional differences in fish community composition, which was conducted using 999 permutations. This number of permutations is commonly used in ecological studies because it provides a practical balance between computational efficiency and the resolution of permutation-based significance testing. The permutation (p)-value was calculated using the correction (Model 10):

$$p = \frac{(b+1)}{(N+1)} \quad (10)$$

Where:

where b is the number of permuted test statistics equal to or more extreme than the observed statistic, and N is the total number of permutations. With 999 permutations, the minimum attainable (p-value) was 0.001.

The difference in fish size distribution among regions was evaluated using the Kruskal-Wallis rank-sum test. In scenarios where significant differences were detected, Dunn's post-hoc test was employed. This was done to identify the pairwise regional differences.

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Size structure analysis

The size distribution patterns of dominant fish species were examined using length-frequency distributions. The fish species analyzed included *Diplotaxodon limnothrissa*, *Lethrinops oliveri*, *Rhamphochromis* species, B*athyclarias* species, *Nyassachromis argyrosoma* and *Copadichromis* species.

Haddon [24] reported that the gamma distribution function is a useful simulation tool in fishery science. The probability density functions based on the gamma distribution were fitted to selected fish species length-frequency data [25]. Fish length in mm was the response variable, whereas region (north, central and south) was the grouping factor used to assess regional differences. This was done to evaluate size distribution patterns across the regions. The Model 11 shown below was used.

$$L(x|c,b) = \frac{\frac{x^{c-1}}{b}\, e^{-x/b}}{b\Gamma(c)} \quad (11)$$

Where:

x is the value of the variate,
b is the scale parameter,
c is the shape parameter,
Γ(c) is the gamma function for the parameter c.

RESULTS AND DISCUSSION

Fish biomass and Maximum Sustainable Yield (MSY)

This study provides crucial insights into the biomass status, biodiversity patterns and sustainable exploitation of trawlable demersal fisheries in Lake Malawi. The total biomass of the demersal Lake Malawi fishery was estimated to be 261,297.8 tons, while the corresponding MSY was estimated at 130,648.9 tons per year. At the regional level, south registered 145,216.2 tons representing 55.6% of the total lake biomass with a corresponding MSY of 72,608.1 tons per year. The central region recorded a biomass estimate of 68,339.8 tons and an MSY of 34,169.9 tons per year. The north registered the lowest at 47,741.8 tons with a corresponding MSY of 23,870.9 tons per year (Table 1). Fish remains the highest animal protein source. It provides 28% of animal protein intake in Malawi hence over exploitation of the fisheries resources could have serious nutritional challenges, especially to more vulnerable groups such as under-five children and expectant mothers [21].

The biomass estimates were derived from a bottom-trawl survey and therefore primarily represents fish stocks occurring within the sampled trawlable demersal ecological zones or habitats. As such these results are not estimates of total biomass of all stocks in the Lake Malawi. The Lake Malawi supports ecologically and spatially distinct stocks such as demersal and pelagic fish assemblages. It is consequently

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

important to treat them differently as such by ensuring that their sampling is dependent on fishing gear and survey design and rather than a one-gear-fits-all approach.

Tran *et al*. [26] reported that a total of an average landing of 140,500tons/year were exploited from the lake in the years ranging from 2010 to 2022 of which a total of 171,100 tons alone were harvested from Lake Malawi in the year 2022. The reported landings exceeded the sustainable exploitation threshold estimated in this study. The estimated MSY by this study provides a critical reference point for the sustainable management of the surveyed demersal fisheries. However, caution should be taken that this estimated demersal MSY is not directly comparable with total reported fish landings from whole Lake Malawi, comprising both small-scale and large-scale (demersal and midwater) fisheries. To be more specific, the total landings include catches from multiple fisheries, fishing gears, habitats, depths, and species assemblages. The small-scale and pelagic fisheries are not fully represented by the bottom-trawl survey, which is critical to avoid overestimating the exploitation levels of the demersal fisheries. Currently, the demersal management reference points are being overstretched to represent midwater fisheries. This is a management mishap being done by the Department of Fisheries in Malawi.

Nevertheless, the estimated biomass and MSY provide useful evidence for strengthening output-based largescale fisheries management. The use of fisheries management reference points (MSY, precautionary reference points and stock-specific monitoring) has been recognized as an important fisheries management component. Previous assessments of commercial trawl fisheries in the southern part of Lake Malawi have also employed precautionary reference points and standardized catch rates to evaluate the status of stocks and inform fisheries management decisions and policy direction. Therefore, the findings from this study provide an additional scientific basis for developing fisheries management measures that are specific to demersal trawlable fisheries.

Although the relative biomass estimated in the southern region is high, it does not automatically mean that the region can sustain additional effort. The estimated biomass represents the standing stock observed during the survey period. As such, it must be interpreted together with information on fishing mortality, recruitment, fish species composition, fish stock productivity and long-term population time series trends. This is very important in the southern part of the lake, as other studies have documented intensive commercial fishing activity. Fishing effort allocation should be based on multiple stock assessments and precautionary management rather than a single biomass estimate. Although this is very challenging, as a single biomass assessment survey costs a lot and the government usually conducts it with support

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

from other stakeholders. Otherwise, it is usually postponed for a year, resulting in irregular implementation of the survey.

Biomass by depth of Lake Malawi

The fish biomass distribution also varied by depth zones. The 50-100 m depth zone recorded the highest biomass estimate of 133,682.3 tons (accounting for 51.2% for the total estimated biomass) and a corresponding MSY of 66,841.2 tons per year. However, the shallow waters of less than 50m recorded a biomass estimate of 91,478.4 tons with corresponding MSY of 45,739.2 tons per year. On the other hand, the depth greater than 100m recorded the lowest biomass estimate of 36,137.0 tons with corresponding MSY of 18,068.3 tons per year (Table 1).

The aggregation of fish biomass in the intermediate depth zones is broadly consistent with previous experimental demersal trawl studies in the Lake Malawi. For instance, the research conducted in the Southwest Arm showed that the highest biomass occurred approximately between 50m and 125m depths. This is with a biomass peaking at intermediate depths of approximately 75 m to 100m. These findings demonstrate that depth is an important element to determine fish distribution and biomass in Lake Malawi.

These depth-related fish biomass differences may be influenced by several ecological factors namely habitat structure, substrate type, food availability, dissolved oxygen, temperature and species-specific depth preferences. Changes in fish species composition across depth gradients have previously been reported in Lake Malawi. Therefore, the 50-100m depth zone relative high biomass recorded may reflect the ecological suitability of intermediate-depth habitats for several important demersal fish species.

Another substantial fish biomass was supported by the shallow water (50m). this zone is ecologically important as some fish species use shallow water habitat to feed, spawning and nursing young ones. These shallow waters are accessible to many small-scale fishers and may experience more fishing pressure than the deeper waters. Consequently, high fish biomass estimates in shallows waters does not directly mean that there is low exploitation in this region.

The depth of 100m recorded the lowest biomass. This may be as a result of changes in habitat conditions as well as fish species composition with increasing depth. The trawlable habitats are restricted in some deep zones because of ecological limitations such as reduction in dissolve oxygen level and operational limitations of the gears at such depths. It is therefore very import that interpretation of the results considered both ecological and sampling factors to understand depth related fish biomass patterns.

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

The observed depth-related distribution of biomass has important implications for largescale fisheries management of Lake Malawi in Malawi. It is very critical that management interventions put into consideration that fish biomass is not evenly distributed across the lake and different depth zones supports fish assemblages and productivity levels. Additional biomass assessments should continue putting into consideration depth-stratification sampling and integrated habitat information. This is more especially when estimating fish biomass and sustainable exploitation levels.

It should be known that the commercial fishers are demanded to fish from 50m and beyond. The shallow (less than 50m) depth of the water is mostly exploited by the artisan fishers. Most of the artisan fishers do not have capacity to operate offshore. A limited number of the artisan fishers such as those in the purse seine (Chilimira) fishery can both operate inshore and in the offshore beyond 50m of depth, however, they target totally different fishery (Usipa (*Engraulicypris sardella*) fishery) than that of largescale fishers. As such, there is still less significant exploitation of offshore fisheries by artisanal fishers. The artisanal fishers' methods to fish offshore as such they aggregate in shallows. Although recently they have been observed modifying their fishing gears for instance by increasing depth of their fishing gears to enable them fish in offshore successfully. However, since the fish migrate from offshore to inshore in search of food and spawning/nursing grounds, they still encounter artisan fishers in the swallow waters. The artisan fishers land over 90% of the landings from the lake as such this depth is the most exploited and requires more strict fisheries regulation enforcement. The Malawi Fisheries Development Project (Credit No. 2225-MAI) by the World Bank, provided loans to mechanize the artisan fishers to exploit offshore fisheries in 1990s. Two more projects supported small scale fishers to tap into offshore fisheries namely Lake Malawi Artisanal Fisheries Development Project (LMAFDP) supported mainly by the African Development Bank (AfDB) and the Small-Scale Offshore Fishery Technology Development Project (SOFTDP) was a Malawi-Iceland cooperation project supported by the Icelandic International Development Agency (ICEIDA) [26, 27]. Regarding the impact no study has been reported to have assess whether there was a positive impact as anticipated. However, it is known that the fisheries continue to decline thereafter as reported by several studies.

Species biomass distribution

Species-level biomass analysis showed that *Lethrinops oliveri* and *Bathyclarias* species recorded the highest biomass densities (each exceeding 1 ton km^{-2}) of the sampled fish species. Most of the dominant fish species identified during the survey were demersal fish species. Only three (3) primarily midwater fish species (*Diplotaxodon limnothrissa*, *Copadichromis virginalis* and *Copadichromis eucinostomus*) were among the fifteen (15) fish species with the highest biomass

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

densities (Figure 2) as assessment methods of the biomass was done using a demersal trawl net. Understanding that the biomass assessment done is biased towards demersal fisheries as a demersal trawl net was used. It can be concluded that the estimated biomass is demersal as well. As such, it is expected the estimated MSY be used to allocate largescale fishers who target demersal fisheries. This underscores the need to reassess the fish stocks of the Lake Malawi with both midwater and demersal trawl nets.

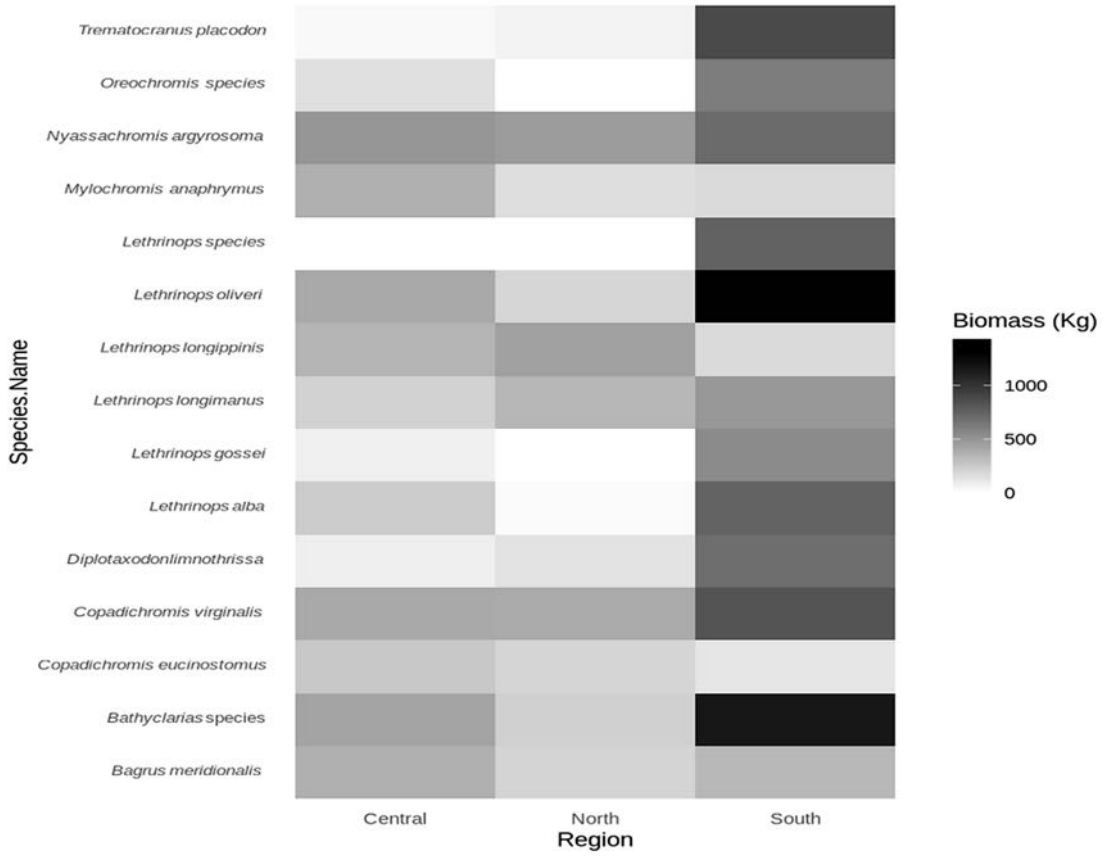


Figure 2: Individual fish species biomass of demersal lake Malawi fisheries in Malawi

Regional biomass patterns

On regional comparisons, the southern region recorded relatively higher species biomass densities than the central and northern regions. Spatial distribution patterns of fish biomass densities indicated that fish abundance was generally highest in the southern part of the lake. The northern region recorded the lowest biomass densities.

The biomass across the regions of Lake Malawi (South, Central and North) has shown that the south has the highest biomass (145, 216.2 tons) which is 55.6% of whole Lake Malawi biomass (Table 1) as such will continue accommodating more commercial fishers' allocation than the other regions. This finding is consistent with

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

previous studies that have reported relatively higher biological productivity in the southern basin of Lake Malawi due to its shallower depth with a maximum depth of 400m and greater nutrient availability [26, 27, 28]. However, this has to be done with caution as the region registered the lowest mean sizes of the most targeted midwater fish species (*Diplotaxodon limnothrissa* and *Copadichromis virginalis*) which makeup over 90% of the landings of commercial fishers according to the Department of Fisheries[4, 30, 29]. This could mean that the fisheries of the southern region of the lake maybe rejuvenating and requires strict management strategies to ensure that depleted stocks are restored. Any mismatch that would overwhelm the standing biomass capacity to rejuvenate is very detrimental. The southern region of the lake also recorded the highest fish species richness and fish abundance demonstrating its ecological and fisheries importance within the lake ecosystem. This relatively high productivity in this region may also be associated with the availability of diverse habitats that supports spawning, feeding and nursery grounds for several fish species [26, 31].

The biomass of central region is close to half of the biomass of the south (68,339.8 tons) while the north only registered 47,741.8 tons and there MSY are 34,169.9 and 23,870.9 tons/year respectively. The biomass for northern region of Lake Malawi remains untapped by largescale fishers [34]. There is a need to allocate some of the commercial there to reduce pressure in the southern and central regions. These largescale fishers must be demersal fishers as this assessment remains bias towards such. However, is important to first identify trawlable areas of the northern regions of the Lake as it is very rocky and frequently damage trawl nets even the crafts operating in these areas [30]. This has potential of increasing operation costs among largescale fishers to be operating in these areas leading to reduce returns and protest by the fishers to be allocated to either southern or central regions leading to more fishing pressure in the future. The MSY for the central region part of the Lake is less than half of the MSY for the southern region, however, more largescale fishers are migrating to the central region as it has a higher CPUE than the south. This is exerting excessive pressure on the central region than anticipated.

Patterns of biodiversity of demersal largescale fisheries of Lake Malawi

A total of 152 fish species were recorded during the survey. The southern part of the lake registered the highest fish species richness by 130 fish species. The central registered 114 fish species while the north registered the lowest at 99 fish species. The fish abundance also differed considerably across the regions. In the southern part of the lake, a total of 24, 965 individual fish were sampled while the central and northern region recorded 8,713 and 4,409 individual fish respectively (Table 2).

The diversity indices indicated relatively high biodiversity across all regions of the Lake Malawi. The Shannon diversity index ranged from 3.66 to 3.84 in the northern

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

and central regions respectively. Similarly, the Simpson diversity index values exceeded 0.95 across all the regions of the lake. This indicated relatively high species diversity and low dominance by individual species. On the other hand, the Pielou's evenness index values ranged from 0.79 to 0.81 suggesting that there is a relatively even species distribution within fish communities (Table 2).

The findings are consistent with the recognised biological importance of Lake Malawi as one of the world's major freshwater biodiversity hotspots. However, it is important to understand that the 152 fish species recorded during this study represents species sampled within trawlable demersal habitats. The study was not designed to take into account all other habitats and fish communities across Lake Malawi. This is particular Mbuna species (rock dwelling species), shallow littoral environments and pelagic habitats that cannot be efficiently sampled using the bottom trawl net.

The high number of fish species recorded in the southern region may be influenced by several factors such high productivity, diverse habitats (shallow, intermediate and deeper zones) which may support species with different ecological requirements. The shown spatial differences in habitat heterogeneity and productivity have potential to contribute to variation in fish species richness and abundance.

An analysis of the ten (10) most abundant fish species showed that the southern part of the lake recorded higher species abundance than the central and northern parts of the lake. Across all regions of the lake demersal fish species dominated the fish assemblages relative to midwater fish species (Figure 3). This pattern is consistent with the use of a bottom-trawl survey. It further emphasises that the results primarily describe the structure of trawlable demersal fish communities.

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

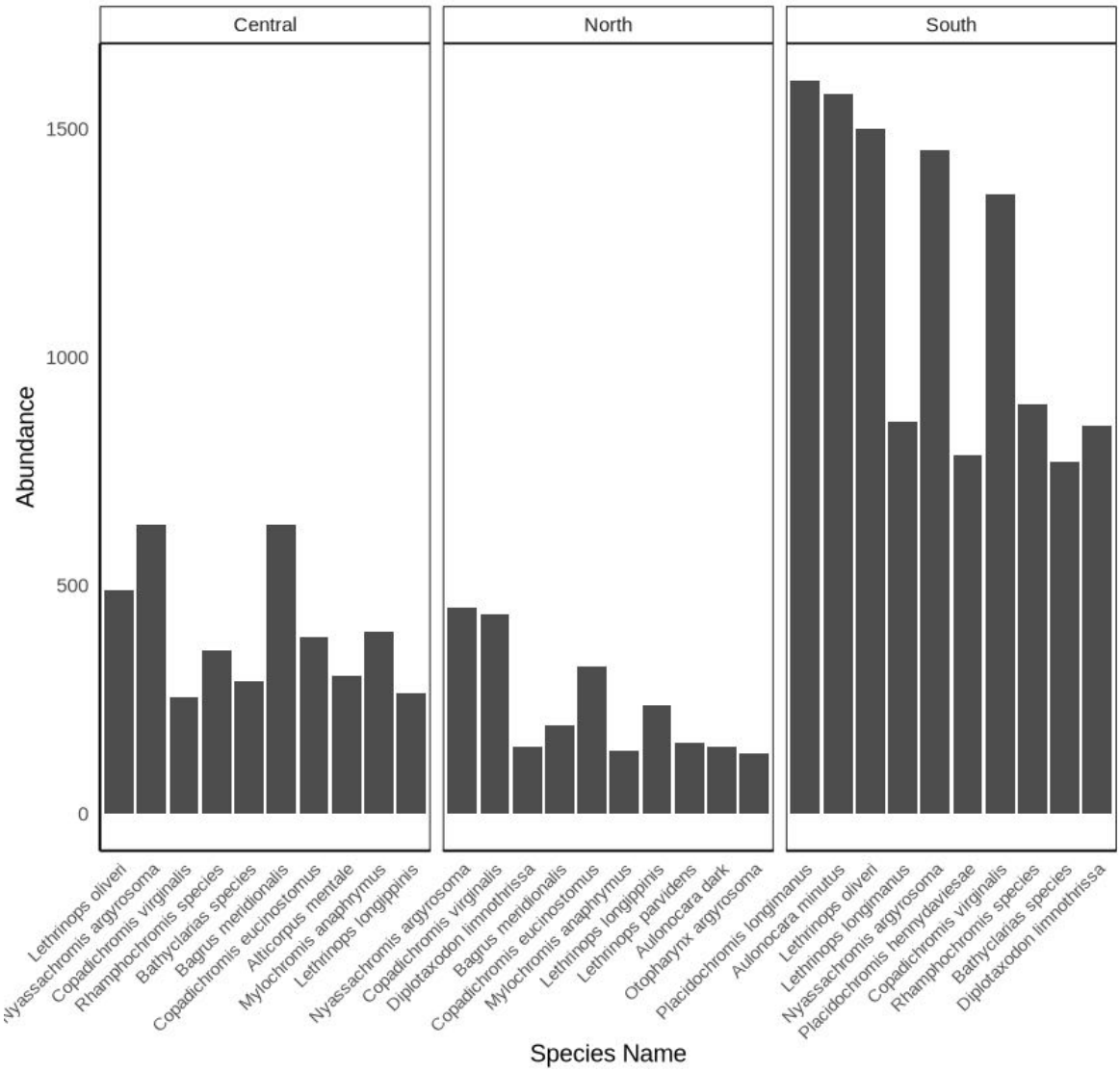


Figure 3: Ten (10) most abundant fish species of Lake Malawi demersal largescale fisheries per region

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

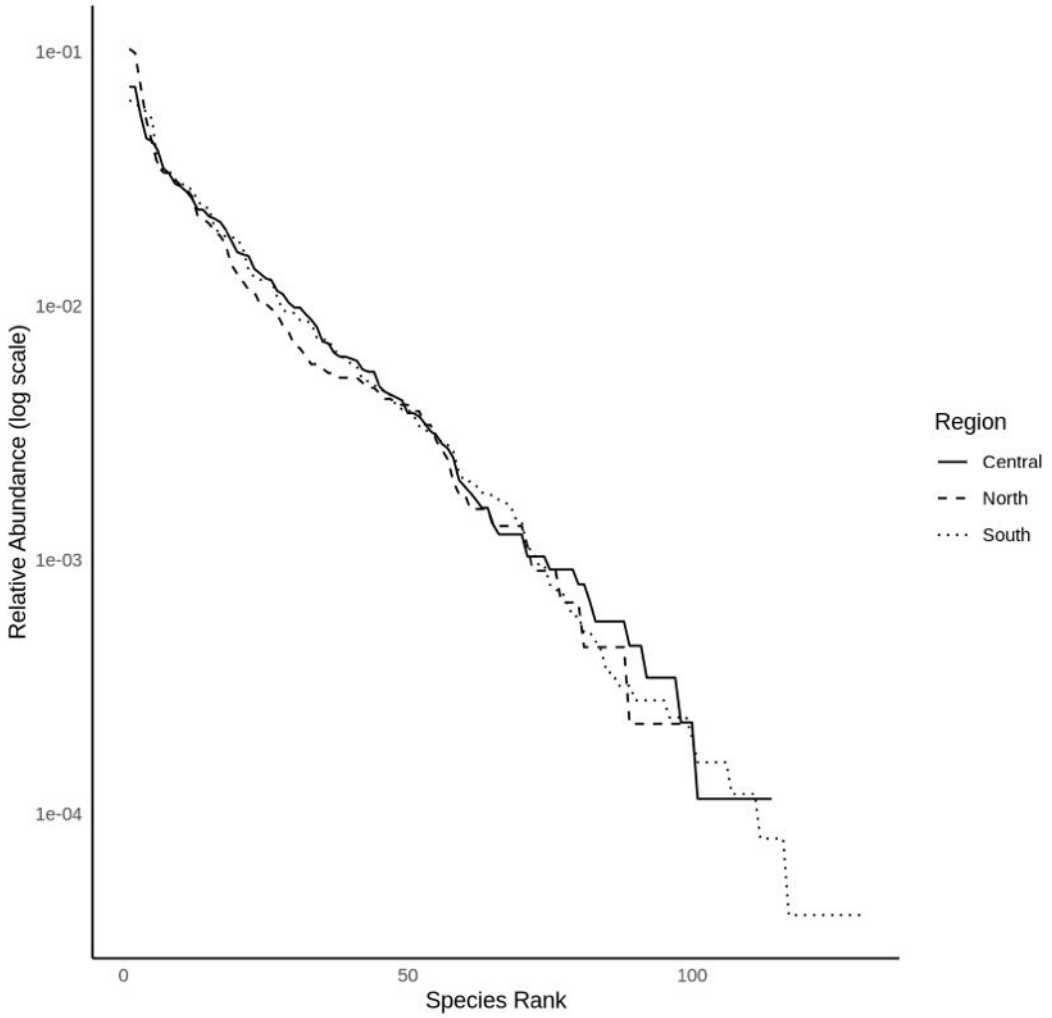


Figure 4: Rank abundance curves by region

The rank-abundance curves further showed similar community structure patterns across regions. This was characterised by a few dominant fish species and many relatively rare species (Figure 4).

Lake Malawi remains very diverse. Chavula *et al*. [30] reported that fish species of Lake Malawi ranges from 800 to 1000 species. This implies that it is still a key biodiversity area. This is in line with literature that states that Lake Malawi only lake in the whole world with highest fish species diversity in one place. The lake as well has a Lake Malawi National Park in its southern part which is protected under UNESCO as a World Heritage Centre site number 289. This is consistent with Kapute [33]. It is therefore not surprising that the southern part of Lake Malawi recorded the highest species (130) (Table 2). This is in line with what Kapute [33] report that Liwonde National Park acts as breeding and nursery for fish that later migrate to surrounding areas such as Lake Malawi. It is very important to conserve Lake Malawi fish biodiversity as it is offering ecosystem services to the fishing

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

communities and the nation at large. Some of the fish from the lake is exported although not that much as fish imports exceeds fish exports in Malawi [35]. More fish were found in the southern part of the lake as it is known to be more productive than the rest of the lake since it is shallower [29]. The Lake Malawi National Park in the southern part of the lake offers undisturbed spawning and nursery grounds as no fishing is allowed hence acts as fish sanctuary and a fish reservoir. This fish eventually migrates to the immediate part of the lake. Liwonde National Park has been reported to be another spawning and nursery ground for Lake Malawi fish species [33]. The high number of fish sampled in the southern part could as well be attributed to large number sampling stations in the area (Figure 1).

It was observed that demersal fish species were dominant than midwater fish species during the survey. *Diplotaxodon limnothrissa*, a midwater fish species targeted by majority of the largescale fishers is not among the top ten most dominant fish species in the central region. This is very surprising as Department of Fisheries unpublished largescale monitoring reports and logbooks are dominated by the species. This is because over 90% of the largescale fishers in Malawi are midwater fishers (who use midwater trawl net) but the assessment of biomass to allocate to them is done using a gear (bottom trawl net) that is popular among these fishers. The north and southern regions at least registered the *Diplotaxodon limnothrissa* was relatively around half of the most abundant fish species in both of the regions. *Copadichromis virginalis* was significantly abundant in the all the three regions. A biomass assessment with a midwater trawl net could assess these midwater fish species much better. In all the region of the Lake Malawi, among the most ten abundant fish species in the demersal fish biomass assessment only three (3) were midwater fish species (Figure 3). This could be as a result of use of a bottom trawl net during the survey which disadvantaged bioassessment of midwater fisheries. The biomass assessment strategy that the Department of Fisheries is using is not appropriate in assessing midwater fish species. This has serious implication on the management of the midwater fisheries as their true population/biomass size cannot be accurately estimated in this way. It is advisable that when assessing a fish stock for allocation of largescale fishers, a fishing gear that the fishers will be using or a gear more efficient (with higher CPUE) must be used in the assessments so as to have a more accurate fish stock biomass assessed. This will ensure that the fishers are exploiting at all costs below the MSY to ensure sustainable fisheries exploitation

The rank-abundance curves indicated that each was characterised by a relatively small number of abundant fish species and a larger number of relatively uncommon fish species. This pattern is consistent with the biomass assessment surveys that were conducted previously on Lake Malawi. These previous studies found out that

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

a relatively small number of species contributed a large proportion of total catches despite the overall high species richness recorded in the demersal trawl surveys.

The observed variation of species composition demonstrated that Lake Malawi is not a homogeneous fishery and should not be treated as such. The findings also showed that the communities varied spatially which maybe from variations in habitat, depth, substrate, productivity and fishing pressure. As such the management strategy being employed by the Department of Fisheries based on a single lake-wide assumption such as the concept of large-scale closed fishing season may fail to account for important regional differences in fish stock structure.

The findings indicated that several commercially important fish species were not dominant in the bottom trawl survey. This does not imply the species are rare in Lake Malawi rather may reflect the difference in efficiency of the bottom trawl net in sampling midwater fish species or fish species that dwell in rocks and shallows. The underrepresentation of some commercially important midwater fish species in this survey is a methodological limitation of the sampling approach. A midwater trawl survey would provide more accurate distribution and abundance of midwater fisheries.

CC BY NC ND
https://doi.org/10.18697/ajfand.156.27670

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

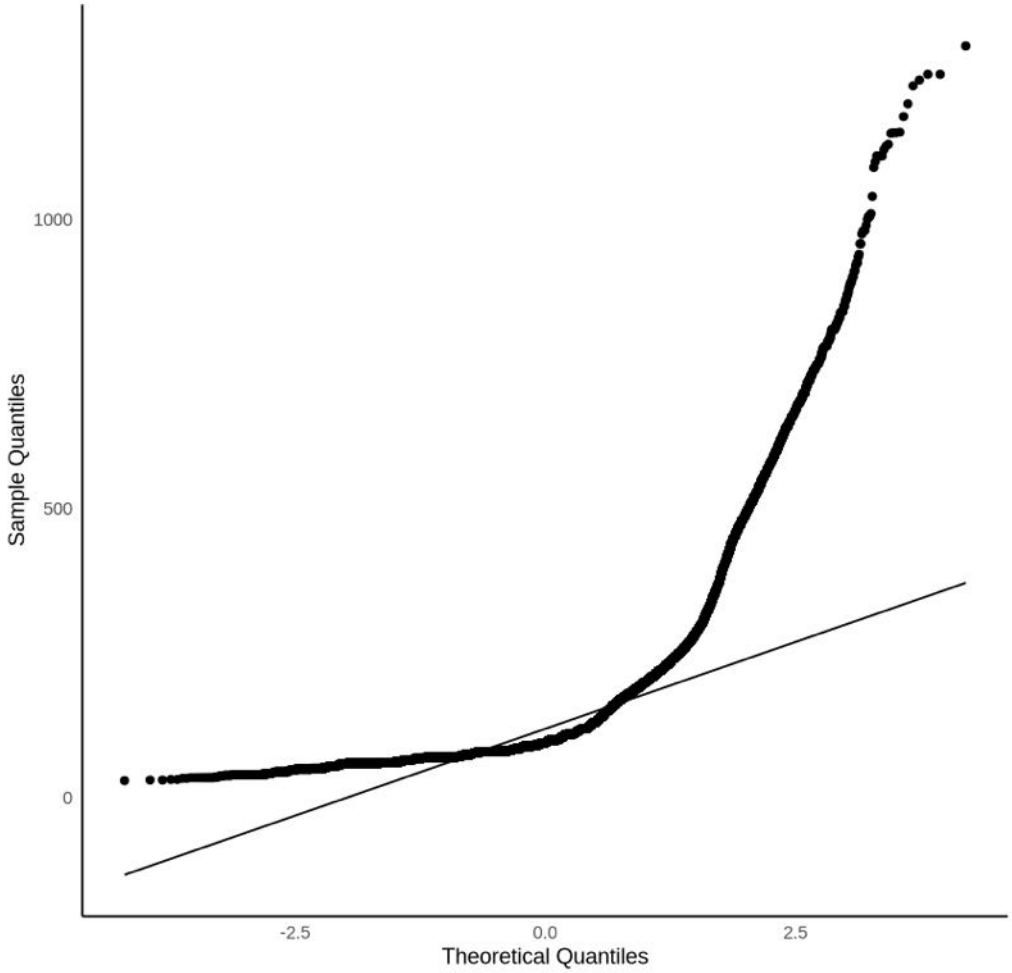


Figure 5: Q-Q Plot of fish lengths of demersal large-scale fisheries of lake Malawi in Malawi

The most appropriate non-parametric statistical tests to statistically test biodiversity patterns across the groups are Kruskal-Wallis and PERMANOVA. The analyses reveal both significant differences in community composition (PERMANOVA) and fish size distributions (Kruskal-Wallis) across regions, with the South region being particularly distinct in terms of fish lengths.

The PERMANOVA results indicated that there is a significant difference in community composition among the regions (p = 0.001), with the model explaining about 94% of the variation (R^2 = 0.93622). The PERMANOVA results were subjected to Monte Carlo simulation with 999 permutations which further confirmed the significance of the observed regional differences.

On the other hand, Kruskal-Wallis rank sum test indicated significant difference in fish size distribution across the regions (p = 0.001). The Dunn's post-hoc test reveals the southern region differed significantly from both central and northern regions (p <

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

0.0001) while there was no significant difference between central and northern regions (p = 0.156).

The Whittaker plots suggest similar community structure patterns across regions. However, the southern region clearly showed a higher species richness followed by those in the central and northern regions in that order (Figure 4). However, the regions showed low evenness implying that a few dominant species are highly abundant and many rare fish species as evident by the steep downward-sloping curve. These few dominant fish species can be concluded to be the bottom dwelling fish species and not mid-water fish species (Figure 3). However, at this point the Figures 3 and 4 cannot portray how significant are fish species richness and evenness across the regions. A statistical test was required to test if there is significant difference in fish biodiversity patterns of Lake Malawi demersal largescale fisheries. However, conducting parametric testing such as analysis of variance (ANOVA) was not possible as the Shapiro-Wilk test showed that the data was not normally distributed ($p < 0.0001$). The Levene's test indicated variances were not equal across regions ($p < 0.0001$) and the Q-Q Plot of fish length indicated that their residuals errors were not close to zero (Figure 5). As such, two non-parametric statistical tests namely Kruskal-Wallis and PERMANOVA were employed to statistically test if there was significant difference in fish size distribution and community composition across the regions. The PERMANOVA with Monte Corle simulation with 999 permutations showed that community compositions are not just different but statistically significantly different at a $p = 0.001$. The model well fitted the data representing it by 94% implying it can be trusted. As such the community compositions can be trusted and adopted as indeed different.

These results are providing a strong evidence that the sampled fish communities in the regions of Lake Malawi in compositionally different. The significant regional differences in fish communties composition are ecological plausible. This is because the Lake Malawi contains substantial variation on depth, substrate, habitat stracture and productvity. Fishing effort may also contribute to the regional differences by influencing the relative abundance of heavily exploited spcies. The present findings therefore support the need for spatially explicit largescale fisheries management. Management interventions in largescale fisheries should take into account regional differences in fish communties and avoid to assume that a management measure suitable for one part of the Lake is appropriate to the rest of the lake.

Fish size distribution among dominant species

Kruskal-Wallis rank sum test showed that the sizes of the fish at species level across the regions were also significantly different at a p = 0.001. However, there was a need to pinpoint exactly where the significant difference was. In this regard, Dunn' post-hoc test showed that the southern region differs significantly from both central

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

and northern regions ($p < 0.0001$) while there was no significant difference between central and northern regions ($p = 0.156$). In this regard, it is very important to take into consideration these community differences across the region when coming up with conservation interventions of Lake Malawi fish biodiversity. These differences are consistent with previous studies which stated that they may be associated with regional variation in habitat conditions, productivity, depth characteristics and fishing pressure. Intensive fishing pressure may alter fish community structure by reducing the abundance of heavily targeted species and changing species dominance patterns within the ecosystem [36].

Regional differences in fish size distribution were observed among dominant fish species. *Diplotaxodon limnothrissa* recorded relatively lower mean body sizes in the southern region compared to the central and northern regions. However, some larger individuals were also observed in the southern region (Figure 6).

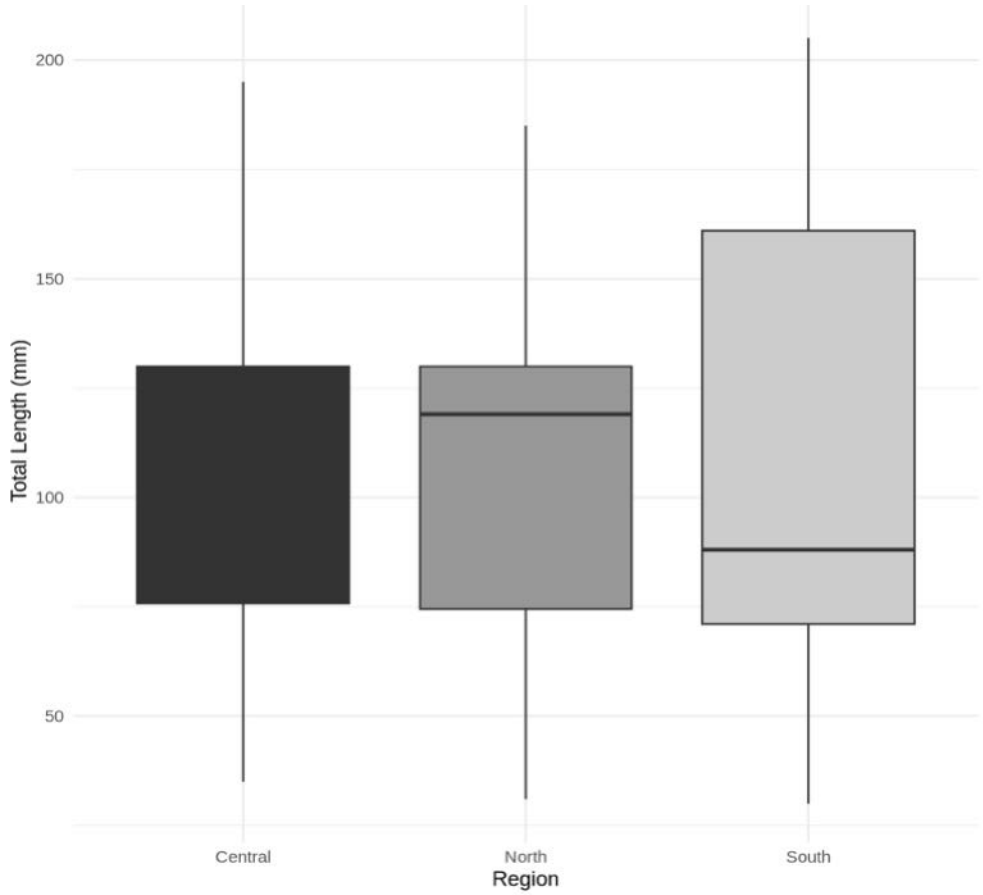


Figure 6: Size distribution of *Diplotaxodon limnothrissa* in Lake Malawi by region

The sizes patterns observed in *Diplotaxodon limnothrissa* are particularly important as this is a species that is commercially significant in the Lake Malawi. Although there was observed large individuals, the lower mean size of the species compared

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

with other regions necessitates continuous monitoring. The previous studies also provide additional evidence that fishing activities have potential to influence population structures.

Lethrinops oliveri showed relatively larger individuals in the southern and northern regions than in the central region of Lake Malawi (Figure 7). Similarly, *Rhamphochromis* species recorded larger individuals in the northern region of the lake. The southern region generally showed lower average fish size (Figure 8).

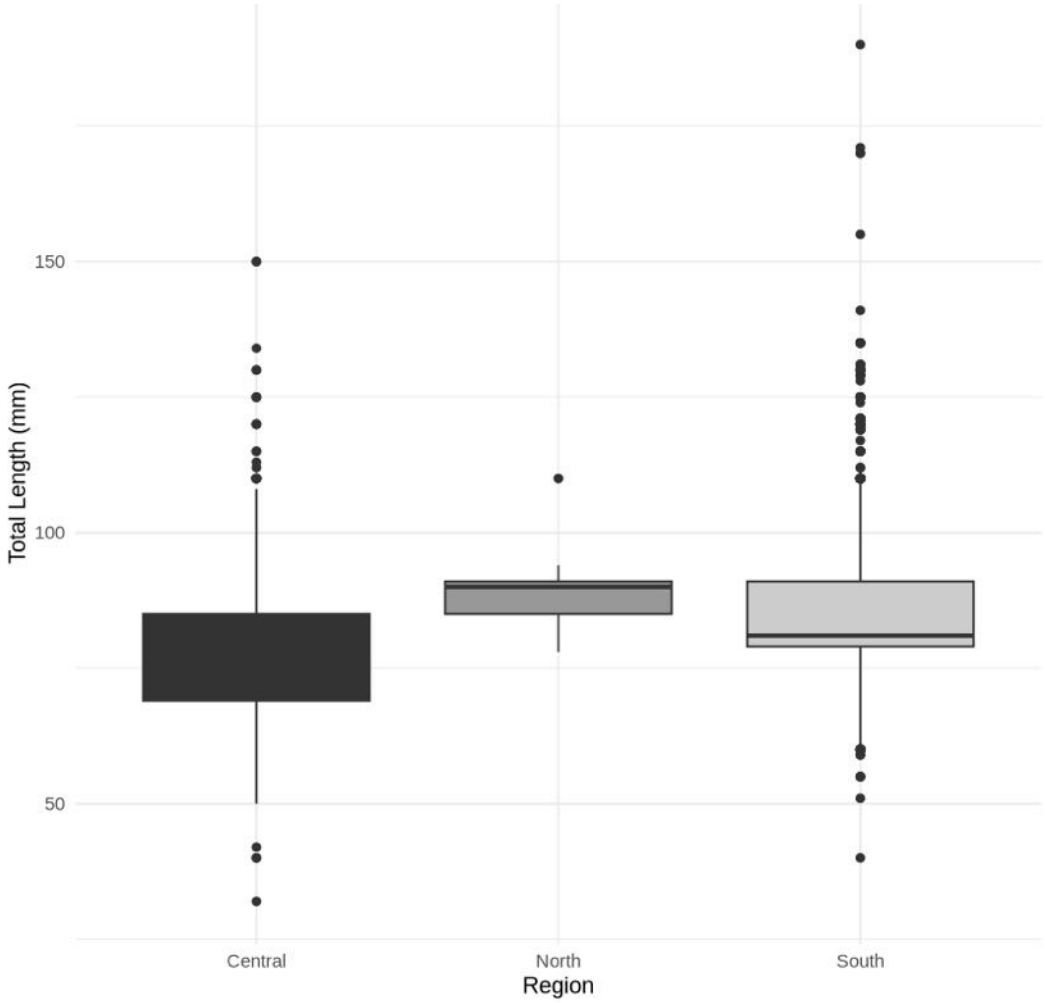


Figure 7: Size distribution of *Lethrinops oliveri* in Lake Malawi by region

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

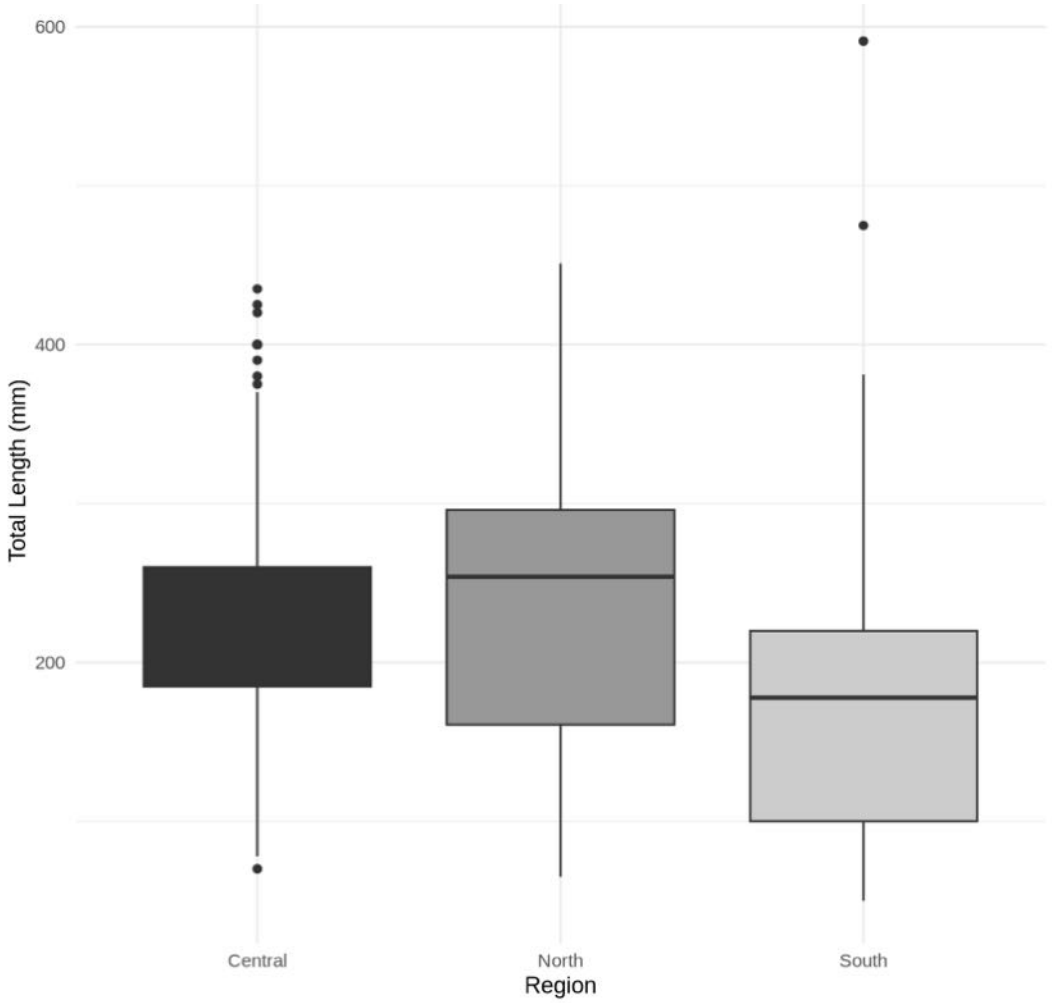


Figure 8: Size distribution of *Rhamphochromis* species in Lake Malawi by region

Regarding size distribution of a rock dwelling (Mbuna) species called *Aulonocara minutus*, it was observed that the species were only recorded in the south and central regions. Largest individual specimens were observed in the central, however, more relatively larger and smallest individuals were observed in the south. The size distribution of *Bargus meridionalis* showed relatively similar sizes in the southern and northern regions. The central region recorded comparatively smaller average sizes despite recording several large individual specimens. Eight (8) large individuals of the species were recorded in the central region unlike two (2) each from the south and northern regions. The *Bathyclarias* species were observed to be relatively having the similar size distribution across the regions, however, north and southern regions registered larger individuals above 1000 mm in length. The study also recorded *Nyassachromis argyrosoma* across the regions. The northern region registered a higher average size of the species. However, the central region registered the largest individuals of the two (2) regions. Higher mean sizes of

CC BY NC ND
https://doi.org/10.18697/ajfand.156.27670

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Copadichromis virginalis in the north and central regions than the southern region. The central region was the only region that registered larger individuals above 200 mm of the species. Overall, the study has found out that several commercially important fish species recorded smaller mean body sizes in the southern region than the central and northern parts of the lake.

The size distribution of the most abundant individual demersal species of Lake Malawi revealed that the species had varying distribution across the regions. This scenario shows where the species are under more pressure which is more likely fishing pressure. The regions with smaller fish sizes could be under more fishing pressure than where the species have larger sizes [26, 35]. For instance, regarding size distribution of *Diplotaxodon limnothrissa* (mid-water fish species), the southern region recorded the largest sizes of the species (Figure 6) which is consistent with the fact that the region is more productive hence offers better environment for fish growth. However, the region recorded the lowest mean length/size of the species as compared to the north and central regions of the lake. This is consistent with the studies that have recorded that there is a lot of fishing activities in the southern region than in the rest of the lake [28, 30]. Many of illegal fishers are found in the southern region of Lake Malawi [35, 32]. The Department of Fisheries has allocated more large-scale fishers in the southern region of the Lake than the population of the fishers in the central region. This explains why the *Diplotaxodon limnothrissa* highly targeted by commercial midwater trawl fishers has small mean size of fish in the south than the rest of the lake.

A general observation on sizes of the top eight (8) abundant fish species among demersal sampling of the Lake Malawi biomass in Figures 6 to 8 have shown that the southern region means sizes are lowest than northern and central regions. This is not surprising as the southern region of the lake has more fishers both commercial/largescale and artisan fishers. The northern region part of the lake recorded highest size of the sampled fish species signifying how healthier the fisheries are in the region. The central region shows that it is slowly succumbing to the fishing pressure that has now been introduced to Nkhotakota District as largescale fishers. The region records second largest number of small-scale fishers from southern region of the Lake. Crafting fisheries management strategies for Lake Malawi must take into considerations this key observation. On the other hand, enforcement of fisheries regulation may as well take into consideration these findings to ensure their efficiency.

The results raise important concerns as several important species showed smaller mean body sizes in the southern region. Previous studies have reported intensive fishing pressure in the southern part of Lake Malawi. As such the present findings are consistent with the possibility that fishing pressure is having a bearing on fish

CC BY NC ND

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

population structures. However, the presence of some large individuals in the southern region demonstrates that fishing pressure may not be the only factor influencing fish size distributions among demersal fishers. Spatial variation in growth, habitat use, recruitment and environmental conditions may also contribute to differences among regions.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The Malawi government through the Department of Fisheries (DoF) should establish and enforce a TAC and MSY based on whether the largescale fishers target demersal or midwater fisheries. The MSY estimated in tons for the central region is 34,169.9, north region is 23,870.9 and southern region is 72,608.1 with their regional fish biomass in tons as 68,339.8, 47,741.8 and 145,216.2 for central, north and southern regions respectively. The estimated MSY by depth are 68,339.8 (>100m), 47,741.8 (50-100m), 145,216.2 (<50m) tons with their corresponding biomass of 36,137.0 tons, 133,682.3 tons and 91,478.4 tons, respectively.

Among the southern, central and northern regions of the lake, the southern region was found to have the highest fish species richness and biomass hence relatively very productive. The southern region of the lake also provided a smaller mean size of several commercially important fish species. This scenario shows that the fish populations in the region are under intense fishing pressure. In sharp contrast, the northern part of the Lake Malawi recorded larger fish sizes and relatively lower fishing pressure. This indicates that the northern region of the lake can be considered to allocate some fishers in the southern region of the lake to reduce excessive fishing pressure in the region. Although this is the case the northern region of the lake has very limited trawlable areas hence fishers allocation will be challenging.

The study further showed that demersal fish species dominated the biomass estimates made. The midwater fish species could be underrepresented due to depth trawled by the bottom trawl net used in this study. In this regard, the significant difference in fish community composition and size distribution across regions and depth necessitate fisheries managers to not consider Lake Malawi large-scale fishery as a single fishery. They should take into account regional ecological characteristics and fishing pressure.

The biodiversity analyses indicated that Lake Malawi remains one of the most diverse inland fresh water biodiversity hotspots that necessitate strengthening of its conservation and sustainable management measures. The lake registered high species richness and diversity across all regions (southern, central and northern). An efficient fisheries management of the lake should include improved biomass assessment methods, stricter enforcement of fisheries regulations, ecosystem-

CC BY NC ND

based fisheries management approaches and a balanced allocation of fishing effort to sustainably exploit the vulnerable fish stocks such as fisheries of southern part of the lake.

The study has provided a strong basis for determining TAC and fishing effort allocation strategies among largescale fishers on Lake Malawi in Malawi. It also highlights the urgent need for an adaptive fisheries management intervention so as to sustainably exploit and conserve the fisheries of Lake Malawi.

The Malawi government through the Department of Fisheries (DoF) should establish and enforce a TAC and MSY based on whether the largescale fishers target demersal or midwater fisheries.

The DoF should identify trawlable fishing areas in the northern region of the Lake Malawi to allocate largescale fishers and reduce the excessive fishing pressure in the southern region. As the study has shown that the northern region has relatively lowest fishing pressure than the rest of the lake.

The DoF should strengthen enforcement of fisheries regulations more especially in the southern region of Lake Malawi where the fishing effort is very excessive as there is evidence of declining fish sizes.

ACKNOWLEDGEMENTS

We thank Department of Fisheries under Malawi Government for providing catch and effort data used in this study.

FUNDING

German Government through the DAAD In-country Scholarship funded my PhD studies which this paper forms part of at the Lilongwe University of Agriculture and Natural Resources (LUANAR).

CONFLICT OF INTEREST

There is no potential conflict of interest relevant to this article that was reported.

DATA AVAILABILITY STATEMENT

Data will be made available on request. For requesting data, please write to the corresponding author who will refer you to the responsible officer at the Department of Fisheries of Malawi Government who are the custodian of the data.

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: MSY and biomass of Lake Malawi demersal commercial/largescale fisheries in Malawi

		MSY (tons/year)	MSY%	Biomass (tons)	Biomass %
	Lake Malawi (whole)	130,648.9		261,297.8	
Region	Central	34,169.9	26.2	68,339.8	26.2
	North	23,870.9	18.3	47,741.8	18.3
	South	72,608.1	55.6	145,216.2	55.6
Depth Zone	Deep (>100m)	18,068.5	13.8	36,137.0	13.8
	Medium (50-100m)	66,841.2	51.2	133,682.3	51.2
	Shallow (<50m)	45,739.2	35	91,478.4	35

Table 2: Lake Malawi demersal largescale fisheries diversity and evenness

Region	Species Count	Total Individual count	Shannon	Simpson	Pielou's evenness index
Central	114	8713	3.8376	0.9	0.8103
North	99	4409	3.6612	0.9580	0.7968
South	130	24965	3.8261	0.9686	0.7861

CC BY NC ND
https://doi.org/10.18697/ajfand.156.27670

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

REFERENCES

1. **Kapute F** Chasing Malawi Fish: The Irony of Local Fish Scarcity vs Exports, *African J. Food, Agric. Nutr. Dev.*, 2021; **21(5)**: 1–5.

2. **Palmer-newton AF and WRT Darwall** *Conservation priorities for freshwater biodiversity in the Lake Malawi/Nyasa/Niassa Catchment*. Cambridge: IUCN Cambridge, UK in collaboration with IUCN Gland, Switzerland, 2019. https://doi.org/10.2305/IUCN.CH.2019.RA.1.en

3. **Phiri M, Bello FG, Lambulira M and I Manuel** Examining the Contribution of Protected Area-Based Tourism to Sustainable Development Goals, *J. Environ. Manag. andTourism*, 2025; **7(4)**: 139–153.

4. **M'balaka M, Kaunda E, Kanyerere GZ, Jamu D and A Msukwa** Changes in fish species diversity, size structure and distribution in the trawlable demersal zones of Lake Malawi, Malawi, *Environ. Dev. Sustain.*, 2025; **27(7)**: 17239–17259. https://doi.org/10.1007/s10668-024-04649-8

5. **Hara M, Donda S and F Njaya** Lessons from Existing Modes of Governance in Malawi 's Small-Scale Fisheries, in *Interactive Governance for Small-Scale Fisheries*, 2015, 135–155. https://doi.org/10.1007/978-3-319-17034-3_8

6. **Zimmermann F and K Enberg** Managing Biological and Ecological Systems, in *Managing Biological and Ecological Systems*, 2nd ed., B. D. Fath and S. E. Jorgensen, Eds., Boca Raton: CRC Press, 2020, ch. Sustainable: 14. https://doi.org/10.1201/9780429346170

7. **Liu OR, Thomas LR, Clemence M, Fujita R, Kritzer JP, McDonald G and S Cody** An evaluation of harvest control methods for fishery management, *Rev. Fish. Sci. Aquac.*, 2016; **24(3)**: 44–263. https://doi.org/10.1080/23308249.2016.1161002

8. **Blanchard JL, Andersen KH, Scott F, Hintzen NT, Piet G and S Jennings** Evaluating targets and trade-offs among fisheries and conservation objectives using a multispecies size spectrum model, *J. Appl. Ecol.*, 2014; **51(3)**; 612–622. https://doi.org/10.1111/1365-2664.12238

9. **Kane EA, Ball AC and P Brehmer** Dilemma of total allowable catch (TACs) allocated as shareable quotas: Applying a bio-economic game-theoretical approach to euro-mauritanian fisheries agreements, *Aquac. Fish.*, 2024; **9(4)**: 674–681. https://doi.org/10.1016/j.aaf.2022.02.008

CC BY NC ND

10. **Ding Q, Shan X, Jin X, Gorfine H, Guan L and T Yang** Evolution of China's Total Allowable Catch (TAC) system: Review and way forward, *Mar. Policy*, 2023; **147**: 105390. https://doi.org/10.1016/j.marpol.2022.105390

11. **Bellido JM, Sumaila UR, Sánchez-Lizaso JL, Palomares ML and D Pauly** Input versus output controls as instruments for fisheries management with a focus on Mediterranean fisheries, *Mar. Policy*, 2020; **118**: 1–8. https://doi.org/10.1016/j.marpol.2019.103786

12. **Narwati E and MT Kumala** Determination of Fishing Rights Allocation as a Strategy for Sustainable Fisheries Management Realisation in Indonesia, *World J. Entrep. Manag. Sustain. Dev.*, 2023; **19(1-2)**: 27–38, 2023. https://doi.org/10.47556/J.WJEMSD.19.1-2.2023.3

13. **Pope J** Input and out controls: The practice of fishing effort and catch management in responsible fisheries, in *A Fishery Manager's Guidebook*, Second., K. L. Cochrane and S. M. Garcia, Eds., Rome, Italy: Food and Agriculture Organization of the United Nations and Wiley-Blackwell, 2009; **9**: 1–20. https://doi.org/10.1002/9781444316315.ch9

14. **Kanyerere GZ, Kaonga D, Mponda O, Nkhoma B and E Ngulande** Status of the large-scale commercial trawl fisheries in southern Lake Malawi, *Aquat. Ecosyst. Heal. Manag.*, 2018; **21(2)**: 121–131. https://doi.org/10.1080/14634988.2018.1457388

15. **Banda M, Jamu D, Njaya F, Makuwila M and A Maluwa** The Chambo Restoration Strategic Plan, in *The Chambo Restoration Strategic Plan*, M. Banda, D. Jamu, F. Njaya, M. Makuwila, and A. Maluwa, Eds., Penang, Malaysia: WorldFish Center, 2005; 113.

16. **Government of Malawi.** The Master Plan Study on Aquaculture Development in Malawi Working Papers National Aquaculture Strategic Plan (NASP) 2006-2015 July 2005 The Master Plan Study on Aquaculture Development in Malawi Working Papers National Aquaculture Strategic Plan (NASP), 2005.

17. **Sparre P and SC Venema** Introduction to tropical fish stock assessment, *FAO, Rome, Italy*, 1998.

18. **Shindo S** General review of the trawl fishery and the demersal fish stocks of the South China Sea, Rome, Italy, 1973; 120.

CC BY NC ND

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

19. **SCSP.** Report on the workshop on the demersal resources of the Sunda Shelf, part 1., *SCSP (South China Sea Dev.*, vol. SCS/GEN/77, 1978; **12**: 44.

20. **Rosner B** *Fundamentals of Biostatistics*, 4th Editio. Belmont, Calif: Duxbury Press, 1995.

21. **Beddington JR and JG Cooke** The Potential Yield Of Fish Stocks, Rome, Italy, 1983.

22. **Froese R, Palomares MLD and D Pauly** Estimation of life history key facts, in : *FishBase 2000: Concepts, Design and Data Sources*, R. Froese and D. Pauly, Eds., Los Ban˜ os, Laguna, Philippines: ICLARM, 2000, pp. 167–175. [Online]. Available: https://www.sealifebase.org/manual/key%20facts.htm? *Accessed March 2026.*

23. **R Core Team.** R: A Language and Environment for Statistical Computing., R Foundation for Statistical Computing, 2024. [Online]. Available: https://www.r-project.org/ *Accessed July 2024.*

24. **Haddon M** *Modelling and Quantitative Methods in Fisheries*, 2nd ed. New York: Chapman and Hall/CRC, 2011. https://doi.org/10.1201/9781439894170

25. **Hastings NAJ and JB Peacock** *Statistical Distributions: A Handbook for Students and Practitioners*, First. Wiley, 1975.

26. **Tran N, Peart J, Rodriguez UPE, Yee Chan C, Hoong Y, Siamudaala V, Njaya F and R Kafakoma** The future of fish supply-demand in Malawi and its implications for nutrition security and poverty reduction The future of fish supply-demand in Malawi and its implications for nutrition security and poverty reduction, Penang, Malaysia, 2022; **21**. Available: https://digitalarchive.worldfishcenter.org/bitstreams/21ee1c93-5c17-4229-a7e5-e7306d7e95d7/download *Accessed February 2026.*

27. **Agboma PC, Coompson JA, Kufakwandi SF, Pitamber S, Soliman W and N Toure** APPRAISAL REPORT: ARTISANAL FISHERIES DEVELOPMENT PROJECT, Abidjan, Ivory Coast., 2002. Available: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Malawi_Lake_Malawi_Artisanal_Fisheries_Development_Project_-_Appraisal_Report.pdf *Accessed March 2026.*

CC BY NC ND

28. **Ágústa, Árni H, Ásdís, Drífa HK, Dulce M, Geir OGG, Guevara G, Pálsson G, Þorkelsson G, Stefánsson GV, Salvarsson G, Þórðarson G, Hauksson H, Pálsson J, Kolbeinsdóttir LD, (RKÍ/IRC), Nína H, Björgvinsson S, Hafstein S, Kristmannsson S, Samúelsdóttir S, Tómasson T, Söebech P, Sigurðardóttir P and V Wiium** ANNUAL REPORT 2008, Reykjavík, Iceland, 2008. Available: https://www.stjornarradid.is/library/03-verkefni/utanrikismal/throunarsamvinna/arsskyrslur-thssi/ICE_030409_arsskyrsla2008.pdf *Accessed February 2026.*

29. **Ngochera MJ and HA Bootsma** Spatial and temporal dynamics of pCO 2 and CO 2 flux in tropical Lake Malawi, *Limnol. Oceanogr.*, 2020; **65**: 1594–1607. https://doi.org/10.1002/lno.11408

30. **Chavula GMS, Mwamad SM, Gondwe E, Ngochera M, Banda D, Muyumbana N, Lawrence TJ, Ajode MZ, Smith S, Jonasse C, Kanyerere GZ and BP Ngatunga.**.Lake Malawi / Niassa / Nyasa basin : Status , challenges , and research needs, *J. Great Lakes Res.*, 2023; **49(2022)**: 1–11. https://doi.org/10.1016/j.jglr.2023.102241

31. **Stone JR, Westover KS and AS Cohen** Late Pleistocene paleohydrography and diatom paleoecology of the central basin of Lake Malawi , Africa, 2011; **303**: 51–70. https://doi.org/10.1016/j.palaeo.2010.01.012

.32. **Weyl OL, M'balaka MS, Sharma R, Cope J and D Kafumbata** Modelling the current status of Lake Malawi fish stocks, an inland lake in East Africa, *Aquat. Ecosyst. Health Manag.*, 2024; **26(3)**: 26–39, https://doi.org/10.14321/aehm.026.03.26

33. **Kapute F** The role of the Liwonde National Park in conserving fish species diversity in the upper Shire The role of the Liwonde National Park in conserving fish species diversity in the upper Shire River , Malawi, *Aquat. Ecosyst. Health Manag.*, 2018; **21(2)**: 132–138. https://doi.org/10.1080/14634988.2018.1457389

34. **Thompson AB and EH Allison** Potential yield estimates of unexploited pelagic fish stocks in Lake Malawi Potential yield estimates of unexploited pelagic fish stocks in Lake Malawi, *Fish. Manag. Ecol.*, 1997; **4**: 31–48: https://doi.org/10.1046/j.1365-2400.1997.00103.x

CC BY NC ND

35. **Mussa H, Kaunda E, Chimatiro S, Kakwasha K, Banda L and J Nyengere** Assessment of Informal Cross-Border Fish Trade in the Southern Africa Region: A Case of Malawi and Zambia, 2017; **7**: 358–366. https://doi.org/10.17265/2161-6264/2017.05.009

36. **Weyl OLF, Ribbink AJ and D Tweddlel** Lake Malawi: Fishes, fisheries, biodiversity, health and habitat, *Aquat. Ecosyst. Heal. Manag.*, 2010; **13(3)**: 241–254. https://doi.org/10.1080/14634988.2010.504695

CC BY NC ND