Assessment of catch composition and economic analysis of monofilament and multifilament under-meshed gears (Ngongongo) at Likoma Island, Lake Malawi.

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Abstract

The study was conducted to assess catch composition and economic analysis of monofilament and multifilament under-meshed gillnets (Ngongongo) from March to April 2018 around Likoma Island, Lake Malawi. Catch efficiency for targeted fish species in monofilament gillnets showed that catch per unit effort (CPUE) was three times higher than that of multifilament gillnets for *Copadichromis* spp. (402.2 Kg, 43.3%), *Opsaridium microcephalum* (315.47 Kg, 34.6%), *Rhamphochromis* spp. (26.2 Kg, 2.8%), *Bagrus meridionalis* (21.6 Kg, 2.3%), *Oreochromis karongae* (40.7 Kg, 4.4%), *Bathyclarias* spp. (23.2 Kg, 2.5%), *Dimidiochromis kiwinge* (14.4Kg, 1.6%) among others. Catches for *Copadichromis* spp. comprised of 43% for both gillnet material type combined indicating the importance of this species in gillnet fishery in the district. Monofilament gillnet caught the highest number of fish (7569) while multifilament gillnet caught the least (5427). Again monofilament gillnet has the highest weight of fish (692.87kg) while multifilament has the least (238.22kg). T-test analysis showed that the weight of fish caught by monofilament and multifilament gillnets were significantly different from one another (p=0.001). The profitability performance non-motorized monofilament and multifilament gillnets canoe fisheries in Lake Malawi (Likoma District) recorded profit margins at the end of the first year of operation with the minimum Return on Investment (ROI) of 58.9% and 34.4% respectively. On the other hand, the motorised monofilament and multifilament Gillnets canoe fisheries recorded loss 51.1% and 74.4% ROI. The study results point out to recommend for management interventions be put in place to manage the Lake Malawi fishery by imposing restrictions on effort, gear type and mesh sizes and access to illegal fishing material.

Keywords: Lake Malawi, Fishing gear, Multifilament, Monofilament, Mesh size, Catch per unit effort, Return on investment.

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Introduction

Capture fisheries are a key source of nutrition and employment for millions of people around the world. Food and Agriculture Organisation [1] estimates showed that 800 million people are still malnourished and small-scale fisheries in particular are an important component of efforts to alleviate both hunger and poverty. World over, the fishing industry is passing through a critical situation. New technologies have brought about drastic changes in the management of fisheries that resulted in enhanced access and significant expansion of effort and production [2]. Today, the industry is twice as large as it is required. Technological changes, such as the introduction of motorization and monofilament nets, have enabled fishers to exploit nearshore and offshore fisheries resources more intensively than was ever imagined a few decades ago. These technological advances have led to increased conflicts and overexploitation of some fisheries [3].The unrestrained development resulted in overexploitation consequently depleting certain fish species. A disturbance in the natural ecosystem threatens biodiversity. Weber [4] identified overfishing, destructive fishing practices, pollution and coastal development as the major causes for fish species decline. The inland fisheries in Africa provide a major source of subsistence and income in many countries including Malawi. Fish is recognised as the most important source of animal protein in Malawi and is consumed by many people of all classes regions of the country from the rural poor to the urban rich. In Malawi, the small scale fishery contributes over 90% of total landings in Lake Malawi [5]. Uncontrolled rapid expansion of small-scale fisheries has led to problems of overcapacity and over fishing; hence there is need check the gear efficiency and effectiveness in order to reduce excessive effort. Fisheries productivity has decreased causing poverty among small-scale fishers [6].

Gillnets are among the most selective gears in terms of both species caught and the size range retained and are thus used to target desired species and size of fish. The principles behind gill netting have not changed over the years but equipment and materials have changed. It widely recognized as an efficient and selective type of gear [7]. A multifilament net is a thin braided or twisted twine(very thin rope) where 'strings' or filaments are weaved, making up the net mesh while a monofilament net is one where the net is made of single strands of a synthetic polyethylene material that looks like a stand of modern fishing line. All gill nets that are below the legal minimum mesh size of 95.3 mm are locally known as Ngongongo.

In the period between 2015 and 2016, the number of legal gillnets has declined by 51.5% while the under meshed gillnets (Ngongongo) have decreased by 4.9%. The 2016 fisheries annual frame survey results, further indicated that Likoma registered 14.9% number of legal gillnets [8].

Problem statement

The capture fishery world over is becoming more and more developed even in the small-scale sector. Gillnet fishery is one of the most important fisheries in Malawi. It has been in existence on Lake Malawi as early as 1940 [9]. The number of gillnets has increased tremendously over the years and between 1993 and 1999 there was a three-fold increase in the number of gillnets used in Malawi waters [10]. In contrast, overall catches have remained stable indicating a decline in CPUE. This decline in CPUE has been countered by a decrease in mesh size and the 1999 Frame Survey revealed that over 95% of all gill nets used in Mangochi were below the legal minimum mesh size [10]. These illegal under-meshed gillnets, locally known as (Ngongongo), may be a harvesting strategy targeting juvenile fish and small sized fish species.

Gillnets are most important fishing gears in the small-scale fishery in Malawi and they are operated in almost all major water bodies. They are fabricated from either polyethylene monofilament or nylon multifilament and catches from gillnets contribute between 15% and 20% of the total annual fish landings from Lake Malawi [11]. They fishery supports about 13,600 fishers, representing 30% to 35% of people directly fishing industry [10]. However, use of under-meshed multi species fishing gears, excessive fishing effort are the causes of overexploitation of the fisheries resources. Under-meshed fishing gears according to FAO [1] are unselective of which fish they catch. Presently adoption of small mesh sizes for monofilament and multifilament gillnets are common in small-scale fishery mainly aiming to increase by catch targeting juvenile fish. It is assumed that monofilament is more efficient because the gear is not as more visible to fish as compared to multifilament. Continued use of efficient small sized mesh of monofilament could be detrimental to the sustainability of the fisheries resources. It might be unsurprising to note that the abundant fish resources are dramatically reduced. How much will be left once the present mad rush of fisheries has completed its course will depend on how fast mitigation measures are put in place, and especially on how fast we will manage to phase out fishing gears that exploit fish species unsustainably. The small-meshed nets are increasingly becoming popular as result of decreased catch rate of almost all targeted larger sized fish species. This is an indication that the fishery is highly dynamic and whole fishery can shift from one dominant mesh size to another in response to change in population size structure. Kolding and van Zwieten [12] observed that most fishers of African lakes would not follow the recommendations for increasing the mesh sizes of their gears beyond the fish's size at first maturity. This often caused strong conflicts between fishers and the fisheries authorities. The reason for this fishermen behaviour is that their small nets allow for larger catch volumes. Conversely, from a biological point of view change and modification of fishing gears and mesh sizes seem to create unbalanced exploitation (unselective fishing pattern) of both large and small fish species.

The composition of gillnet categories recorded during the 2016 annual frame survey,showed that out of the 58,993 total gillnets recorded, 64.2% were under-meshed gillnets i.e. (Ngongongo). Additionally, the survey also recorded 5.4% of mono-filament gillnets which are also illegal [8]. Currently majority of fishers in the study area are switching from the nylon multifilament gillnets for nylon monofilament gillnets which contravenes the fisheries regulations as nylon monofilament gillnets as strategy to maximise the catches of fish though the latter is considered illegal in Malawi. Unlike Multifilament, when monofilament net or part of it get lost into water body the net keep on ghost fishing for a lengthy time.

However the perception of fishers for polyethylene monofilament is that it is more efficient than nylon multifilament. The net is relatively expensive such that despite low durability of the materials and frequent maintenance, with better catches, costs are recovered and make enough profits to replace the nets easily. The efficiency on the other hand is as a result of the low visibility in the water column when set to fish. In view of the aforementioned, the fish species might face overexploitation within few years from now if the situation is not reversed since many people are more likely going to invest into the fishery considering that both the cost of materials and net mounting and/or construction is cheap and that the net mounting is done by an individual gear owner with the help of very few relatives at no cost. On the other hand, there is danger that on condition that such nets get lost they will continue to catch fish in what is termed as ghost fishing as the materials are not ecological friendly (Not biodegradable).

Although the total number of gillnets has declined by 13.6% from that recorded in 2015 (66,999 total gillnet units) the contribution of under meshed (Ngongongo) has increased by 5.2% in the present survey from that of 2015 [8]. Despite the economic importance to the fishing communities of under meshed gillnets (Ngongongo) but public criticism towards them and, data on their actual efficiency and selectivity are scanty. The data on investment costs and revenues generated by the fishery which is vital to inform fisheries resource management and prospective investors are generally lacking. Such valuable information on comparative analysis of economic operations of the different fisheries should be of interest and be useful to resource managers, entrepreneurs, financial lending institutions and others small micro economic business creditors in the empowerment of the fishermen. The current information on under meshed gillnets (Ngongongo) species catch biodiversity is not available. This gap could be bridged by using catch composition data for similar gillnets until specific under meshed gillnets (Ngongongo) studies are conducted, to provide advice to manage multifilament and monofilament (Ngongongo).

Research justification

The study has enormous significance to both local livelihoods to national economy. In view of the continuous global call to conserve the fisheries resources against the ever growing demand for food to supply the ever increasing general population coupled with environmental threats to fisheries sector. The study contributes to the identification and guidance on the management of gear technology. The generated information is essential in the formulation of nation policies, strategies, plans and programmes of action for sustainable exploitation of fishery resource and conservation of fisheries resource and biodiversity. The use of small meshed nets also results in catching juveniles, especially from shallow waters and intensification of the fishery can deplete fish stocks, alter species composition, leading to loss of biodiversity, fish species extinction and disruption of food webs. Illegal gears continue to be used due to inefficient of enforcement and increased competition for fisheries resources.

The research looked into catch and catch rate thereby comparing the catch composition to reflect biodiversity differences. The assessment the fishing gears will contribute to furtherance of understanding towards the use of these gears in Lake Malawi and could help in the policy guidance and management of the fish resources. The research findings and recommendations will serve as important information in managing the gears.

Furthermore, multi species fishing production is an important cross cutting issue and is never exhaustive through a single research. Under-meshed fishing gears according to FAO [1] are indiscriminate of which fish they catch. The reduction of mesh size has resulted into increased catches of juveniles from both the monofilament and multifilament gears. However, fishermen would be reluctant to hear and understand the ecological impacts in this line. The best method for making the fishermen aware about the concern will be presenting the same on economic terms. This study will also be of importance to compare the catch efficiency (CPUE) between monofilament and multifilament gillnets, and the economic implications and fish catch biodiversity to ensure sustainable livelihood opportunities. Therefore, the study serves as one of the reference materials for future researches at the same time promote academic successes through contribution of body knowledge to academics and policy makers.

Catch composition: Species diversity is defined as both the variety and relative abundance of species. Indices used to quantify biological diversity can be used to infer a measure of the health of the fish assemblages in these rivers [13]. It is known that some fish species may exhibit uniform or random distribution which rarely occur in nature, while others may have aggregated and gradient distribution [14], or their size structure, frequency and spatial distribution may reflect human exploitation [15]. Fishing is one of the most important livelihood activities in Lake Malawi particularly among poor riparian communities using low cost fishing gears [16].

Monofilament thickness affected not only the numbers of individuals caught, but also the diversity of the catch as a whole. The thicker diameters of monofilament caught fewer species likely due to the fact that stretchability and flexibility decrease continuously as the twine is made thicker [17], reducing the probability of retention for some species. Similarly, Reis and Pawson [18] found that a monofilament diameter might affect the species-selection of a gillnet, which is strongly related to the species' characteristic morphology.

Gillnets are widely used in small-scale fisheries because they require little investment in labour and equipment, and are effective in catching widely scattered fish populations [19].

McClanahan [20] reported that as catches decline, the gear that extracts the smallest size and most diverse fish resources may be the 'better competitor' and will reduce the catch of other gear types that select larger and more species-specific targets. Kurkilahti and Rask [21] suggest that the slightly different twine diameter and mesh size combination has no effect of catches of roach and perch of different gillnet types.

On the other hand, while Jennings et al. [22] indicated that fishing causes a decrease in not only biomass but also diversity such that those gears with low selectivity will certainly decrease diversity more so than other gears.

Catch per unit effort (CPUE): Balik & Cubuk [23] found that a thin monofilament twine caught significantly larger fish than a thicker twine of the same mesh size, and postulated that this was due to the greater elasticity of the thinner twine. For instance, they found that monofilament trammel nets caught 2.08 times more tench, **(***Tincatinca***)** than multifilament nets in Lake Beysehir. The efficiency of gillnets is largely influenced by the behaviour of fish in relation to the visibility of the gear, which in turn is related to the type of materials selected for its fabrication [24]. As reported by Pravin & Ravindran [25], multifilament gillnets showed better catch efficiency than monofilament gillnets.

Similarly, Njoku [26] observed that multifilament nets captured more fish in terms of total weight. This also concurred with the studies [27,28] found multifilament nets superior to monofilament. Stewart [29] compared the nets used in the United Kingdom for cod and found that multifilament nets captures better than monofilament. The differences can be attributed to how the fish is caught in the net, so monofilament nets captures better by yoking, the multifilament captures and entangling/ suspension because the monofilament nets are more soft and elastic.

Banda [9] pointed out that small-meshed monofilament are increasingly becoming popular as a result of decreased catch rate of target fish species though they are technically illegal.

According to Simasiku, et al. [30] monofilament gillnet Catch per Unit Effort (CPUE) was 2.7 folds higher than that of multifilament.

Concurring with Simasiku et al. [30], Machiels et al. [31] found monofilament nets more effective for zander (*Sander lucioperca*) and multifilament nets effective for bream (*Abramis brama*). This is further in agreement with Henderson and Nepszy [32], found a higher total catch in monofilament nets, but captures a 7 of 23 species was higher in multifilament nets. On the otherhand, Ayaz et al. [33] indicated total catch rates of monofilament gillnets were significantly higher than multifilament gillnets probably due to higher visibility of multifilament nets.

Economic efficiency of the monofilament and multifilament gillnet fishery: Multi-species and multi-fleet fisheries are generally open-access with low operating costs, which make fish resources more susceptible to over fishing [34]. In this setting, one critical point to improve management requires considerable technical changes to the gear to increase its selectivity [35].

In India, specific studies were initiated by Sathiadhas et al. [36], Najmudeen and Sathiadhas [37] and Mohamed, et al. [38] in which they have analysed the economic impact of juvenile fishing in multi -gear multispecies fishery of Kerala.

The study carried by Faife [39], indicate that the monofilament gillnets catch better than multifilament at the same time the catch decreases with increasing number of filament and that this may be related to the visibility or friction of materials.

According to Emmanuel et al. [40] monofilament nylon caught more fish than the multifilament but the multifilament had longer life span than the monofilament.

The proportion of undersized fishes in total catch is high in a multispecies fishery where various kinds of gear and crafts are competitively employed to target different varieties of fishes [41,42].

In open access marine fisheries, the non-targeted catches in the form of juvenile are detrimental, as this would reduce future yield and subsequent recruitment to the fishery. The proliferating impact of juvenile fishing is much more intense in multi-gear and multi species fishery where intra and inter sectoral conflicts exists [37].

As reported by Diamond et al. [43], growth overfishing occurs when the fishery targets fishes of a size below the optimal harvestable size.

Materials and Methods

The study area

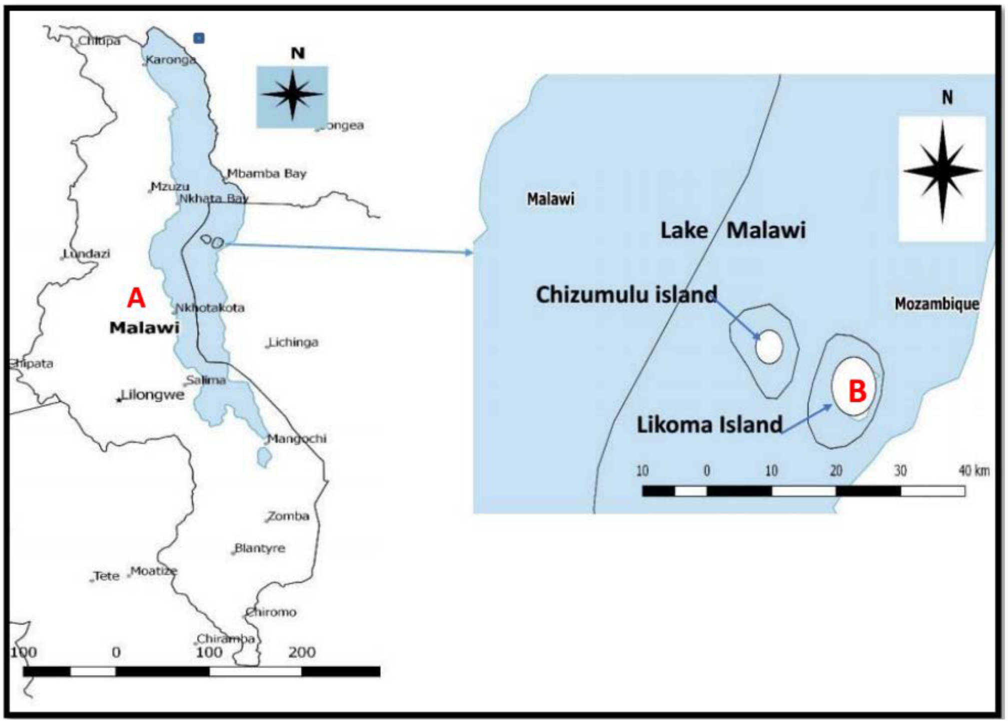
The study was conducted in Likoma District. The District lies between 12°3′55.55S and 034°44′310E in northern Lake Malawi (Figure 1). Sampling was done was in four landing sites namely; Mainja, Likula, Ndunda and Msekwa. The Likoma District has an estimated population of 13,419 in 4,248 households; corresponding to an average density of 84 people per km^2 [44]. Likoma was selected for the study because there was more intense fishing activity than any other part of the lake and harbours many artisanal fishers. The population primarily depends on the lake for their livelihood. The artisanal fishers at the island are using both types of the undermeshed (Ngongongo) gillnets.

Study design

The study involved a sample based survey in which Thirty-six (36) monofilament and multifilament gillnets owners were sampled using simple random during the study period from conducted between from 12th March to 17th April 2018 upon landing in their perspective landing site and data on species composition and total catch was collected. Data on effort (size of fishing gear) was also collected during the survey.

A cross-sectional survey was also conducted in which quantitative data on social economic aspect such as Investment cost, operational cost, average fishing days of a month and total revenue from the catch of the day was collected through a checklist administered in a face to face interview with gear owner using open ended questionnaire. Fifty-one (51) gear owners were interviewed using a questionnaire to assess profitability of small scale gillnet fishery.

Figure 1. *Map of the Study Area, Likoma (B) Longitude: 12°3'55.55S and Latitude 034°44'310E showing its location in Malawi (A).*



Sampling and sample size

A stratified sampling procedure was used to draw the sample, from which a total of 36 gillnet artisanal fishers were drawn using simple random sampling. The sample size was determined using the following formula [45] for monofilament and multifilament gillnets drawn randomly [45]. The estimation of sample size followed [45] using the formula below:

$n=[Z^2 (1-p) p]/e^2$

$=[1.96^2 (1-0.06) 0.06]/0.05^2$

$=86$

Where, n=sample size.

p=percentage proportion of the prevalence of fishers (6%).

z=z-value yielding the desired degree of confidence (1.96).

e=error term (0.05).

Questionnaire pretesting: The questionnaire was pretested for a period of one week (in December 2017). This helped to modify the questionnaire through inclusion of more responses and detection of ambiguities in wording.

Data collection

Fish catch and effort data: Primary data was collected from the surveys conducted from 12th March to 17th April 2018. A cross section survey was conducted in four landing sites (Mainja and Likula from Chizumulu, Msekwa and Ndunda from Likoma) in minor stratum using a checklist and data on fish catch and effort collected in their respective fish landing sites for twelve days. A sample based survey conducted to upon landing in the morning was used to collected data on species composition and individual body weight. From the sample based survey, fish species composition data was collected where fish were identified with a close reference to Konings [46] fish taxonomy books. The sampling and recording of the catch closely followed guidelines outlined by Sparre, et al. [47]. All catfishes of the genera *Bathyclarias*, *Clarias* and *Bagrus* as well as large cichlid and non-cichlid species were sorted out of the main catch. Data collection sheet was used to record data for fish samples from each gear category. The primary data were collected through direct measurements, weights and observations, interactions and interview sessions using questionnaires. Data collection was done using a formal survey and substantiated by key informant interviews.

Analytical technique: The sampled fish species was extrapolated to determine fish catch and composition from the total catch for each category. A pair-wise t-test was used to test for statistical differences in total fish catch composition, CPUE, weight between the monofilament and multifilament under-meshed gillnets respectively. Profitability analysis was used to compare economic differences for the monofilament and multifilament gillnets. Annual Return on Investment (ROI) was used in the analysis instead of the linear assessment of depreciation over the years mainly because of the traditional sources of loans which required payment within 1 year of operations.

Data analysis

Index for biodiversity:

Calculating Simpson's biodiversity index (D) is:

$$D=\frac{\sum n_i(n_i-1)}{N(N-1)} \quad (1)$$

Where, N=the total number of all organisms.

n_i=the numbers of individuals of each individual species.

Fishing effort

In this study, fishing effort was size of fishing gear

$$\text{Catch}=\text{CPUE}\times\text{Effort} \quad (2)$$

$$\text{Catch per unit effort (CPUE)}=C_{i/Ei} \quad (3)$$

Where, C_i=biomass of fish (in kg)

E_i=effort expressed per 100 m net.

Estimation of economic return

Gillnets operation was investigated in Likoma between March 2017and April 2017. The catch variation were observed between monofilament and the multifilament under-meshed Gillnets (Ngongongo). The current market prices of fishing inputs, the running costs of the operational methods and retail prices of the fish species were collated for production analysis.

Profitability of the fishery [48]

$$\text{Profit/Loss}=\text{TR}-(\text{TOC}+\text{TIC}) \quad (4)$$

Where, TR=Total revenue (MK/kg)

TOC=Total operation cost (MK)

TIC=Total investment cost (MK)

Return on Investment

$$ROI=\frac{\text{Revenue}-(\text{Initial fixed cost investment}+\text{Operational cost})}{\text{Initial fixed cost investment}+\text{Operational cost}} \quad (5)$$

Results and Discussion

Catch composition

Catch composition by number and weight for each species are presented in (Table 1). In total, 7569 fish weighing 692.87 kg were caught in monofilament gillnets and 5427 fish weighing 238.22 kg in multifilament gillnets. A total of twenty nine (29) fish species were caught and *Copadichromis chrysonotus* was numerically most abundant.

The six most abundant species were *Copadichromis chrysonotus*, *Opsaridium microcephalum*, *Copadichromis quadrimaculatus*, *Dimidiochromis kiwinge*, *Copadichromis viginalis* and *Oreochromis karongae*. More than 43.3% of the total fish catch for both net types combined was *Copadichromis* spp. (Table 1). The present study found that the weight of fish caught by monofilament and multifilament gillnets were significantly different from one another (p=0.000). Species caught in small numbers include *Synodontis njassae*, *Taeniolethrinops furcicauda*, *Fossorochromis rostratus, Lethrinopos longimanus* and others. The species diversity for the monofilament gillnet was slightly higher (D=0.49) than the multifilament gillnet (D=0.56) but no significant difference was observed on catch composition of the two gears (p=0.320). This may be the result because with gillnets is that the nets are indiscriminate of the types of fish it catches and can lead to a high level of species diversity (Table 1). The results obtained in the present study support previous findings [49-51] and fishermen's knowledge, that gillnets of thinner diameter catch more fish. For instance in this study the results revealed that some cichlid species; *Copadichromis spp., Opsaridium microcephalum*, *Dimidiochromis kiwinge* and *Oreochromis karongae* were caught more frequently in monofilament nets, although the catch difference was less pronounced for *Synodontis njassae* and *Bagrus meridionalis*. Similar results were also noted by [9,30,52] showed that some cichlid species were caught more frequently in monofilament than multifilament gillnets. The difference suggests that eyesight is cichlids' primary means of sensory perception and that they are more likely to attempt to swim through the less visible monofilament net than the more visible white multifilament nets used in this study, and hence are at greater risk of getting tangled therein. The results agree with what Reis and Pawson [19] found that gillnets are widely used in small-scale fisheries and are effective in catching widely scattered fish populations. Weyl et al. [53] noted that increased fishing effort due to adoption of new efficient fishing technology and unlimited entry into fishing industry in Lake Malawi has resulted in species changes, depletion of larger, more valuable species in the fishery.

Relative catch efficiency: The weight of fish caught in monofilament gillnet were more than those of the fish caught in multifilament gillnet (Table 1). The T-test revealed that the weight of fishes caught with monofilament were not statistically significant to that of multifilament. The efficiency of monofilament gillnets was derived by using the ratio of monofilament mean CPUE to multifilament mean CPUE for each of the compared mesh size. Monofilament versus multifilament catch ratios by number ranged from 2.1for *Opsaridium microcephalum* up 4.7 times for *Copadichromis quadrimaculatus* (Table 1). All catches were adjusted to catch per unit Effort (CPUE) by dividing the catch by the effort. Effort is expressed herein as fish biomass per 100 m net length.

Table 1. *Fish catches weight (Kg) for Likoma for March, 2018.*

Scientific name	Monofilament				Multifilament			
	No	D	W (Kg)	%	No	D	W (Kg)	%
Aulonocara blue orange	1	0	0.9	0.1	0	0	0	0
Bagrus meridionalis	5	0	18.14	2.6	3	0	3.5	1.5
Barbus jonstonii	4	0	4.03	0.6	2	0	8.2	3.4
Bathyclarias gigas	4	0	0.55	0.1	2	0	5.3	2.2
Bathyclarias nyasensis	6	0	4.76	0.7	13	0	12.6	5.3
Copadichromis chrysonotus	5062	0.4472	2609	38.2	3950	0.53	111.6	46.8
Copadichromis quadrimaculatus	138	0.0003	2.26	0.3	29	0	0.2	0.1
Copadichromis viginalis	678	0.008	8.5	1.2	692	0.016	16.3	6.8
Dimidiochromis kiwinge	25	0	12.74	1.8	23	0	1.7	0.7
Fossorochromis rostratus	7	0	1.65	0.2	0	0	0	0
Labeotropheus fuelloborne	36	0	8.5	1.2	5	0	1.4	0.6
Lethrinops longimanus	10	0	2.58	0.4	8	0	7.5	3.1
Lichnochromis auticeps	10	0	6.75	1	0	0	0	0
Meravichromis mollis	-	-	1.7	0.2	1	0	0	0
Mormyrops deliciosus	8	0	2.16	0.3	4	0	1.7	0.7
Mormyrops longirostris	12	0	0.66	0.1	0	0	0	0
Nimbochromis venustus	11	0	29.98	4.3	0	0	8.2	3.4
Opsaridium microcephalum	1381	0.033	275.17	39.7	656	0.015	40.3	169
Oreochromis karongae	28	0	7.16	I.0	20	0	3.7	1.6
Otopharynx nitidus	4	0	0	0	0	0	2.3	1
Otopharynx ovatus	-	-	0.5	0.1	1	0	0	0
Petrotilapia retrognathus	21	0	15.93	2.3	4	0	3.7	1.6
Pheudotropheus elegans	35	0	5.61	0.8	0	0	1.1	0.5
Rhamphochromis ferox	6	0	1	0.1	3	0	3.32	1.4
Rhamphochromis longiceps	13	0	5.35	0.8	0	0	0	0
Rhamphochromis woodi	0	0	0.01	0	1	0	0	0
Rhamphochromis brevis	16	0	1.65	0.2	0	0	5.2	2.2
Synodonotis njassae	33	0	9.44	1.4	10	0	5.2	2.2
Taenolethrops furcicauda	15	0	0.8	0.1	0	0	0	0
Total	**7569**	**0.489**	**692.87**		**5427**	**0.561**	**238.22**	

Value: Mean ± Standard Error 0.017+0.015 24.713+13.144 0.020+0.019 8.508+4.113
Where, N=the total number of fish species found, and n is the number of individuals of each species.
D=Simpson Diversity Index.

The data in Table 1 indicates that the monofilament was more efficient than the multifilament in terms of weight and number of fish species. In terms of catch composition by weight for the fish species the results from this study showed that monofilament Gillnets catches were 2.9 folds higher than that of multifilament Gillnets. The higher catch efficiency of monofilament gillnets compared to multifilament is in agreement with earlier reports. This comparison of monofilament and multifilament gillnets confirmed findings of other investigators that monofilament nets generally outfished those made of multifilament twine [23,39,40]. It is believed that monofilament nets are less visible under certain conditions of water clarity and fish are less likely to detect them and turn away [28,30,54]. These results are in contention with studies [25-27,29] who reported multifilament gillnets showed better catch efficiency than monofilament gillnets.

Comparison of catches: The catch per net of monofilament and multifilament type varied widely from set to set but 27 of 32 comparisons the monofilament net out fished the multifilament. The highest number of individual fish was recorded for monofilament throughout the study period and the lowest number of individuals was observed for multifilament gillnets (Table 1). The weight of fish was higher for monofilament gillnets (692.87 kg) than for multifilament gillnets (238.22 kg). This could be due to the fact that soft monofilament twines usually have very fine diameters and they tend to entangle the fish.

Catch per unit effort (CPUE)

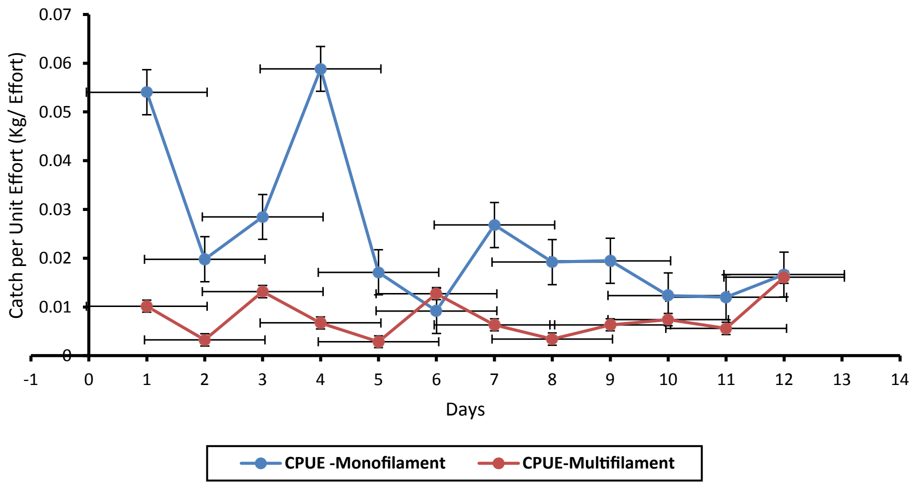
Catch sizes for monofilament gillnets (n=7569) were substantially higher than for multifilament gillnets (n=5427) (Table 1). Monofilament catches were higher than recorded multifilament gillnetting catches. In all the comparisons the monofilament CPUE was 2.9 times as effective in catching fish species such as *Copadichromis* spp., *Opsaridium microcephualum*, *Oreochromis karongae* etc. as the multifilament. Significant differences in catching efficiency of monofilament and multifilament gillnet were found to be significant (p=0.00104). Catch sizes for monofilament gillnets (692.87 Kg) were substantially higher than for multifilament gillnets (238.22 Kg).

The findings of this study revealed that monofilament gillnet Catch per Unit Effort (CPUE) was 2.9 folds higher than multifilament gillnets for catching *Copadichromis* spp., *Opsaridium microcephalum*, *Dimidiochromis kiwinge* and *Oreochromis karongae* and other fish species in the study area. The recorded catch per unit effort (CPUE) agrees with what was earlier reported by Simasiku et al. [30] that CPUE for monofilament gillnets was 2.7 higher than multifilament Gillnets. The results obtained in the present study also support previous findings [23,33,55], that monofilament gillnet catch more fish than multifilament gillnet. Hamley [17] suggested that nets of thinner twine are less visible, easier to stretch, and more flexible; therefore, they should tangle more fish. The result of increased CPUE from the Monofilament gillnets has also positively affected fisher's perception from the Island towards the technology as more and more are adopting the new technology and registering new entry into the fishery at Likoma Island (Figure 2).

Profitability of monofilament and multifilament gillnet fishery

The current market values and cost of fish were used in the analysis of annual production costs and revenues from the small-scale fishery in Likoma Island in 2018 (Table 2). The findings of this study revealed that the initial capital costs for motorized canoe fisheries amounted to MK 2,071,382.47 for multifilament gillnet, MK 2,119,047.62 for monofilament Gillnet fishery. The yearly costs of maintenance and repairs were based on information provided by experience data and documented reports from various sources including Emmanuel et al. [40] and Solarin & Kusemiju [48]. The corresponding maintenance and repair costs were 32%, 5.3% and 5.9% of

Figure 2. *Catch per Unit Effort (CPUE) by gear.*



the initial costs of canoe, outboard engine and the gear/net respectively. The operational costs ranged between MK 1,702, 911.99 for monofilament under-meshed Gillnet fishery and MK 1,084,508.27 for operating the multifilament Gillnets (Table 2). The labour cost was the monetary (locally known as Bhoko) value of fish given to the fisherman.

As shown in Table 2, the total annual revenue from fish sales was lowest at MK 1,160,438.40 for non-motorised multifilament under-meshed gillnet fishery and highest at MK 2,757,506.20 non-motorised monofilament under-meshed gillnets. The Return on Investment (ROI) ranged between 59% monofilament under-meshed gillnet fishery with non-motorised canoe and 34% for multifilament under-meshed gillnet fishery. As indicated in Table 2, monofilament under-meshed gillnet motorised canoe fishery recorded in the first year an initial loss of MK 2,236,410.20 or 55% ROI relative to the sum of capital and operational costs. Motorised multifilament canoe fishery recorded a deficit of MK 2,680,154.47 or 74% ROI was due to the high initial capital investment especially the cost of outboard engine as well as the operational cost incurred in the buying of fuel and lubrication oil (Table 2).

Significant differences were however found between operation cost of non-motorised monofilament and multifilament gillnets (p=0.004). On the other hand the operation cost analysis motorised monofilament and multifilament gillnet showed no significant difference (p=0.211). Similarly revenue for non-motorised monofilament and multifilament gillnets registered significantly different (p=0.035). Again revenue for motorised monofilament and multifilament gillnets revealed significantly different (p=0.001).

The present study revealed that non-motorised monofilament gillnets fishery recorded 59% return on investment over a period of 12 months or 1 year. The results agree with Emmanuel et al. [40] who found that non-motorised canoes gillnet fishery recorded 125.1% return on investment over a period of one year. The initial loss or deficit recorded in the first year of operation by the motorised gillnet fishery was due to the high capital investment or cost of outboard engine. This is further in agreement with Solarin and Kusemiju [48] who reported that non-motorised canoe fisheries recorded profit margins at the end of the first year of operation with the minimum return on investment of 45.70% for gillnet used in non-motorised boats gillnet fishery. Motorised gillnet fishery canoe fishery recorded a deficit of 58.6% ROI. The loss recorded by motorized gillnet fishery in the first one year of operation (with a 15-horsepower out board engine which can last for eleven to fourteen years) should be regained in the subsequent operational years. According to Brainerd [56] a fisherman has to cover the average variable costs in order to operate in the short run. It is also imperative to cover the average total costs in order to replace the equipment and operate in the long run.

A fisherman has to cover the average variable costs in order to operate in the short run. It is also imperative to cover the average total costs in order to replace the equipment and operate in the long run (pers. discussions and obs., December, 2018) as Chimu Club in Likoma were able to pay back the loan to Small Enterprise Development of Malawi (SEDOM) in time within one-half years. With only one year's data, the overall economic performance of the gillnet fishery is not certain to determine.

Conclusions

There were no significant differences in catch composition between monofilament and multifilament under-meshed gillnets (Ngongongo).

The species diversity for the monofilament gillnet was slightly higher (D=0.49) than the multifilament gillnet (D=0.56) but no significance was observed (p=0.032). This may be the result because with gill nets the nets are indiscriminate of the types of fish it catches and can lead to a high level of species diversity. Furthermore, gillnets also restricted to certain habitants which also influence the species selectivity of these gears.

CPUE analysed from the catch and effort data showed that monofilament gillnets had a higher CPUE than multifilament gillnets. These results indicate that the catch decreases with increasing number of filament and that this may be related to the visibility or friction of materials.

Furthermore, on the objective of assessing profitability the study categorized the gillnet fishery operators into two; those motorized and non-motorized operators being practice Non-motorised canoes monofilament and multifilament gillnet fishery recorded 59% and 34% respectively return on investment over a period of 12 months or 1 year. The loss recorded by motorized monofilament and multifilament gillnet fishery in the first one year of operation (with a 15-horsepower out board engine which

Table 2. *Estimates of Annual Production Costs and Revenues of Small-Scale Gillnet Fishery at Likoma Island in 2017/2018.*

	NON MOTORISED GILLNET			MOTORISED GILLNET		
Cost and Revenue	Monofilament	Multifilament	t-test P-Value	Monofilament	Multifilament	t-test P-Value
A. CAPITAL INVESTMENT (MK)	2,68,833.33	2,21,168.18	0.247	21,19,047.62	20,71,382.47	0.451
B. OPERATION COSTS (MK)	14,66,729.39	6,42,052.53	0.005	19,39,094.58	15,26,964.00	0.211
C. ANNUAL REVENUE (MK)	27,57,506.40	11,60,438.40	0.035	18,21,732.00	9,18,192.00	0.001
PROFIT (if any) or LOSS (C-A-B)	10,21,943.68	2,97,217.69	0.04	-22,36,410.20	-26,80,154.47	0.283
Return on Investment (ROI)	**59%**	**34%**		**-0.55 or 55 %(loss)**	**-0.74 or 74 % (loss)**	

U$1=730.00 Malawi Kwacha (MK) on August, 2018 Exchange rate.

can last for eleven to fourteen years) should be regained in the subsequent operational years.

The study results demonstrated that both monofilament and multifilament gillnets pose the equal threats to fish biodiversity as evident in fish species catch composition hence should be treated the same items of restrictions.

Stringent management measures should be instituted to ensure the withdrawal of the gears (monofilament) as it has resulted in increasing the CPUE by a factor of three than that of multifilament hence proved to be more destructive.

Furthermore the study recommends monofilaments to be more profit making than multifilament. Stringent measures should be taken to control the entry into the fishery as this will attract fishers to use this type of gear.

More and detailed research mainly in terms of sizes caught should carried out in order to establish the degree of impact of the gillnet fishery on the fisheries resources. Knowledge on the catching efficiency of gillnets and its application in the development of passive fishing gears such as monofilament gillnets is fairly important for fisheries management and for improving commercial fishing. In Lake Malawi the introduction of monofilament nets has intensified the exploitation rates for *Copadichromis* spp. With the increase in fishing effort through the use of more efficient gear, control of effort through increased minimum mesh size and a ban on the use of destructive gillnets such as monofilament are vital management interventions.

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