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Comparison of the efficiency of monofilament and multifilament gillnets in lake Liambezi, Namibia

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Abstract
Lake Liambezi in the Zambezi Region of Namibia, formerly known as the Caprivi Region, is shallow (<6m deep) and characterised by cyclic episodes of filling and drying. A fishery has been established on the lake in 2000 with more than 300 canoes and 120 fishermen using monofilament and multifilament gillnets. Fishing experiments were conducted to determine the catch per unit effort (CPUE) between gillnet types. The CPUEs of monofilament and multifilament gillnets were comparatively investigated between May 2011 and April 2012. Each net type had five nets with stretched mesh sizes of 76 mm, 89, 102, 114, and 127 with a depth of 76 meshes and a hanging ratio of 0.5. The results of this experiment showed that monofilament gillnets catch per unit effort (CPUE) was 2.7 folds higher than that of multifilament gillnets for catching *Oreochromis andersonii, Serranochromis macrocephalus* and *Clarias* spp. *Oreochromis andersonii* comprised over 45% of the overall CPUE for both net types combined indicating the importance of this species in the gillnet fishery on the lake. Based on this study and other relevant studies in the same lake, we recommend that management interventions be put in place to manage the Lake Liambezi fishery by imposing restrictions on effort (number of fishing boats), gear type and mesh sizes and access

Keywords: Lake Liambezi, Monofilament, Multifilament, Mesh size, Gillnet selectivity

1. Introduction

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 [1]. They are widely used in African artisanal fisheries because they are relatively inexpensive and effective. Until recently in Africa, the material used for gillnets was multifilament nylon. More recently however, cheap monofilament nets have replaced multifilament nets in the Zambezi River fisheries [2]. In the Upper Zambezi river system, monofilament gillnets were not available in the Zambezi region until the Zambian authorities allowed the import of monofilament gillnets of stretched mesh size 5” (127 mm) in the 2000s (Zambia Department of Fisheries, pers. comm.). As is the case in many uncontrolled fisheries, the 5” limit was soon disregarded, and by 2012 monofilament gillnets of all mesh sizes had almost entirely replaced multifilament nets in the Upper Zambezi [2]. Monofilament netting is generally more effective than multifilament because monofilament gillnets are less visible and more elastic and are therefore more efficient e.g., [3] [for Lake Malawi fishes]; [4] [for Pacific salmon species]; [5] [for Lake Erie fishes]. Research on the efficiency of monofilament gillnets has mainly been undertaken in the northern hemisphere [3-5] while slight effort has been centered on African aquatic systems [10] [11]. The increased use of this gear in African inland fisheries is therefore of serious concern as it could result in significant effort increase. The widespread and productive use of the new monofilament gillnets by the local communities stimulated interest in evaluating their impact on target species in Lake Liambezi. This assessment contributes to furtherance of our understanding towards the use of these gears in Lake Liambezi and could help in the management of the fish resources. Continued use of both monofilament and multifilament gears could be detrimental to the sustainability of the lake fish resources. The aim of this study was to compare the catch efficiency (CPUE) between monofilament and multifilament gillnets, with emphasis on the most important fishery species and guide management of the Lake Liambezi fishery.

Materials and Methods

The Lake (Fig 1) is about 300km^2 of which 101km^2 is open water with a maximum depth of 6m. A full description of the lake can be accessed in [6]. A paired experiment used five monofilament and five multifilament nets with stretched mesh sizes of 76 mm, 89, 102, 114, and 127, a depth of 76 meshes and a hanging ratio of 0.5. The nets were set on 45 nights during monthly surveys between May 2011 and April 2012. Gillnets were set in three zones (A- C) (Fig 1) at approximately 17h00 and retrieved at 06h00. To minimise the soak time difference, nets were hauled in the order in which they were set. The location of the nets was changed each night to minimise depletion effects. The fish caught in each net were identified to species level and measured to the nearest mm total length and weighed to the nearest gram. Water temperature (ºC), secchi depth (m) and % moon phase were recorded daily during the experimental sampling.

Statistical analyses

A pair-wise t-test was used to test for statistical differences in total CPUE between the monofilament and multifilament gillnets. The CPUEs of both net types were separately compared for each fish species and season. Difference in CPUE between mesh sizes were determined using the non-parametric Kruskal-Wallis one-way analysis of variance for both net types. Catch per unit effort (CPUE) was defined as the weight of fish caught per canoe.

CPUE was calculated as:

$$CPUE = \frac{Ci}{Ei}$$

where C*i* is the biomass of fish (in kg) and E*i* is the effort expressed per 100 m net. Generalized Additive Mixed Models (GAMMs) using R software, were employed to examine the relationships between the CPUE and the predictor variables, assuming a Tweedie error model [5]. The Tweedie distribution is characterized by a two-parameter power mean-variance function of the form Var (Y) = □□μ^{p}, where □ is the dispersion parameter, □ is the mean and *p* is the power parameter. The optimal power parameter *p* was estimated by maximizing the log-likelihood profile over the range $1 < p < 2$. The full GAMM, evaluated for each species independently, included the categorical variables 'Gear' and 'Mesh size', the smoothing functions for the variables 'Secchi Depth', 'Moon Phase' (% full moon), and 'Month' and a random effect for net night sample *i*, such that:

CPUE ~ exp(□$_0$ + Gear + Mesh size + f_1(Secchi Depth) + f_2(Moon phase) + f_3(Month) + □$_i$)

where □$_0$ is the intercept, $f_{1\text{–}2}$ denote are smoothing functions realized by thin plate spline regression functions, f_3 denotes a cyclic cubic regression spline for the month predictor and □$_i$ is the random effect term for sample night *i*. The lunar phase c alendar was obtained from the link http://home.roadrunner.co m/~davejessie/MoonPhases/calenders/2012 jpg.

As a quantitative way of describing the lunar phase, the fraction of the moon's disk that was illuminated in a day was used. This quantity could take values between 0% (new moon) and 100% (full moon) [7].

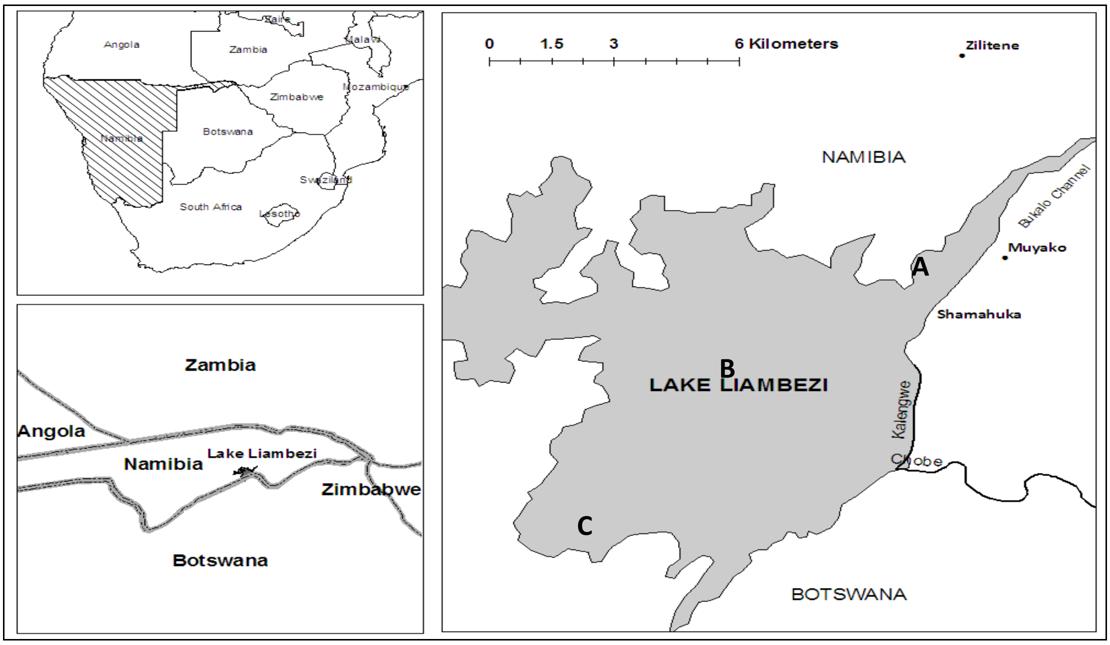

Fig 1 A map of Lake Liambezi, showing gillnet sampling zones (A- C) between May 2011 and April 2012, ArcGIS 9.3.

Results

Catch composition

Catch composition by number and weight for each species are presented in (Table 1). In total, 3741 fish weighing 717 kg were caught in monofilament gillnets and 719 fish weighing 184 kg in multifilament gillnets. The six most abundant species were *Oreochromis andersonii*, *Oreochromis macrochir*, *Coptodon rendalli*, *Serranochromis macrocephalus*, *Schilbe intermedius*, and the two Clarrids combined (*Clarias gariepinus* and *Clarias ngamensis*). More than 45% of the total fish catch for both net types combined was *Oreochromis andersonii*. Species caught in small numbers (<5%) were grouped and categorized as "others" and these were; *Mormyrus lacerda*, *Hepsetus odoe*, *Sargochromis codringtonii*, *Synodontis spp*., *Sargochromis carlottae*, *Tilapia sparrmanii*, *Serranochromis robustus*, *Marcusenius altisambese*, *Serranochromis angusticeps*, *Sargochromis giardia*, *Serranochromis altus*, *Pharyngochromis acuticeps*, and *Brycinus lateralis*.

Table 1: Catch composition in numbers of the commonest species group caught in monofilament and multifilament gillnets from Lake Liambezi, Namibia between May 2011 and April 2012; n = 99 per gillnet set, with effort standardized to 100 m net length. The most dominant species in each net type appears in bold.

	Monofilament		**Multifilament**	
	No	**Kg**	**No**	**Kg**
Oreochromis andersonii	1406	365	156	47.5
Oreochromis macrochir	625	82.2	74	14.5
Coptodon rendalli	181	27.1	22	5.2
Serranochromis macrocephalus	624	85.9	249	55.9
Schilbe intermedius	295	26.2	43	6.6
Clariids	180	81.2	39	20.9
Others	430	49.5	136	33
Total	3741	717	719	184

Relative catch efficiency

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 2.5 for *S. macrocephalus* up to nine times for *O. andersonii* (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 meter net length. Significant differences in catching efficiency of monofilament and multifilament gillnet were found to be significant ($p < 0.05$). Monofilament gillnet efficiency was 2.7 times than multifilament gillnet (Fig 2).

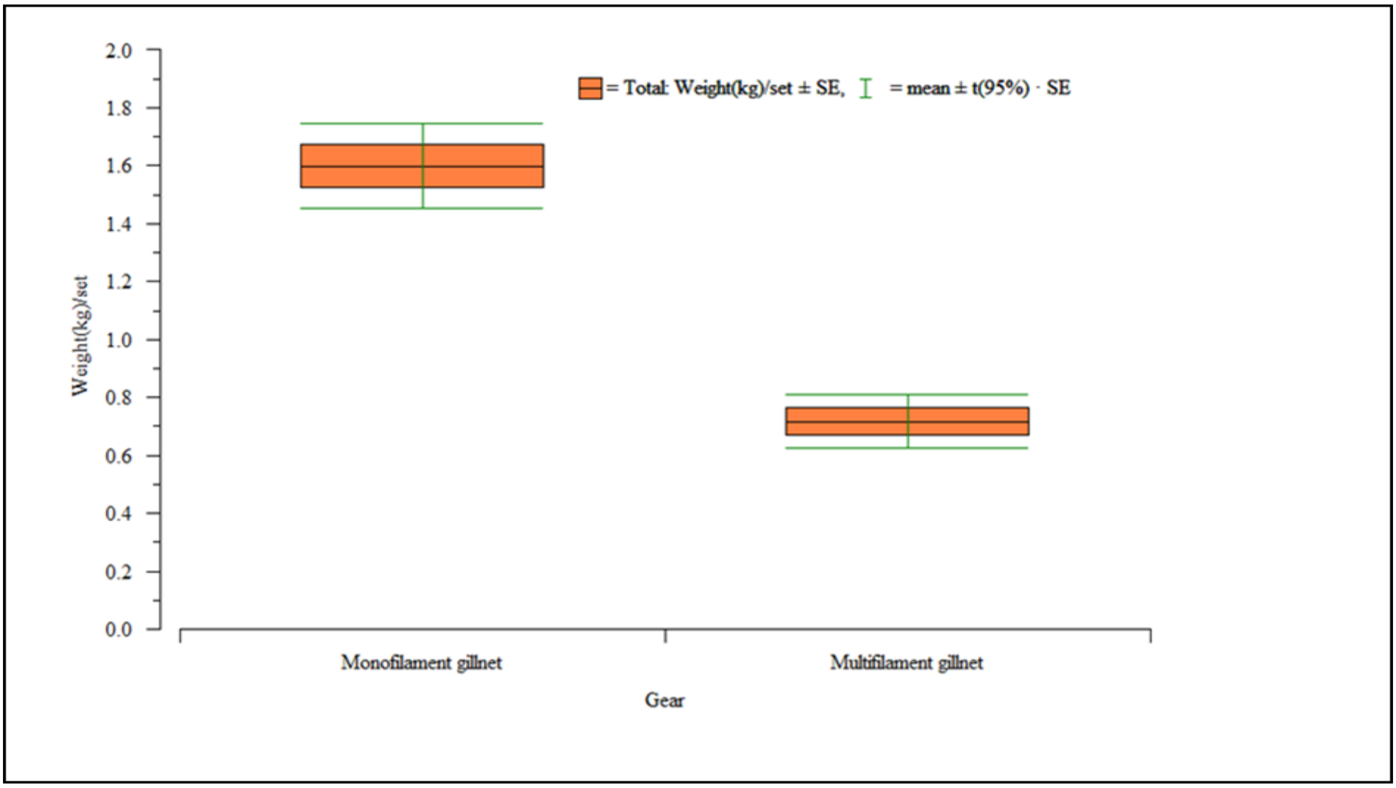

Fig 2: Overall catch per unit effort by weight for all species in each gear type in Lake Liambezi, sampled between May 2011 and April 2012.

Catch per unit effort on selected species

Catch sizes for monofilament gillnets (n = 3741) were substantially higher than for multifilament gillnets (n= 719) (Table 1). Due to the small multifilament gillnets catch sizes, it was only possible to obtain reliable catch per unit effort on three abundant species, viz; *Oreochromis andersonii*, *Serranochromis macrocephalus*, and the two catfishes combined (*Clarias gariepinus* and *C. ngamensis*).

CPUE of *O. andersonii* differed significantly between monofilament and multifilament gillnets ($p < 0.05$) (Fig 3a). Monofilament catches were higher than recorded Multifilament gillnetting catches. A steady drop in CPUE from Monofilament to Multifilament gillnets is evident in (Fig. 3a). Combined CPUE analysis by mesh size for *O. andersonii* differed significantly ($p < 0.05$) between various mesh sizes (76 mm, 89, 102 & 114mm) with a distinctive peak in the larger mesh size of 102 (mm). A steady increase in CPUE with an increase in mesh size is depicted in (Fig. 3b). A smooth decline followed by an increase in CPUE between the sampling months is evident in (Figure 5.2). Lower CPUE was observed during the winter season (June – July) (Fig. 3c). A distinct peak in CPUE was observed during the warmer month between October - February (Fig. 3c). Separate correlations were performed to assess the relationship between CPUE, Secchi depth and Moon phase. An insignificant correlation between CPUE and secchi depth was found ($p > 0.05$) (Fig. 3d). Similarly a negative insignificant correlation between CPUE and lunar phase was also found ($p > 0.5$) Fig. 3e.

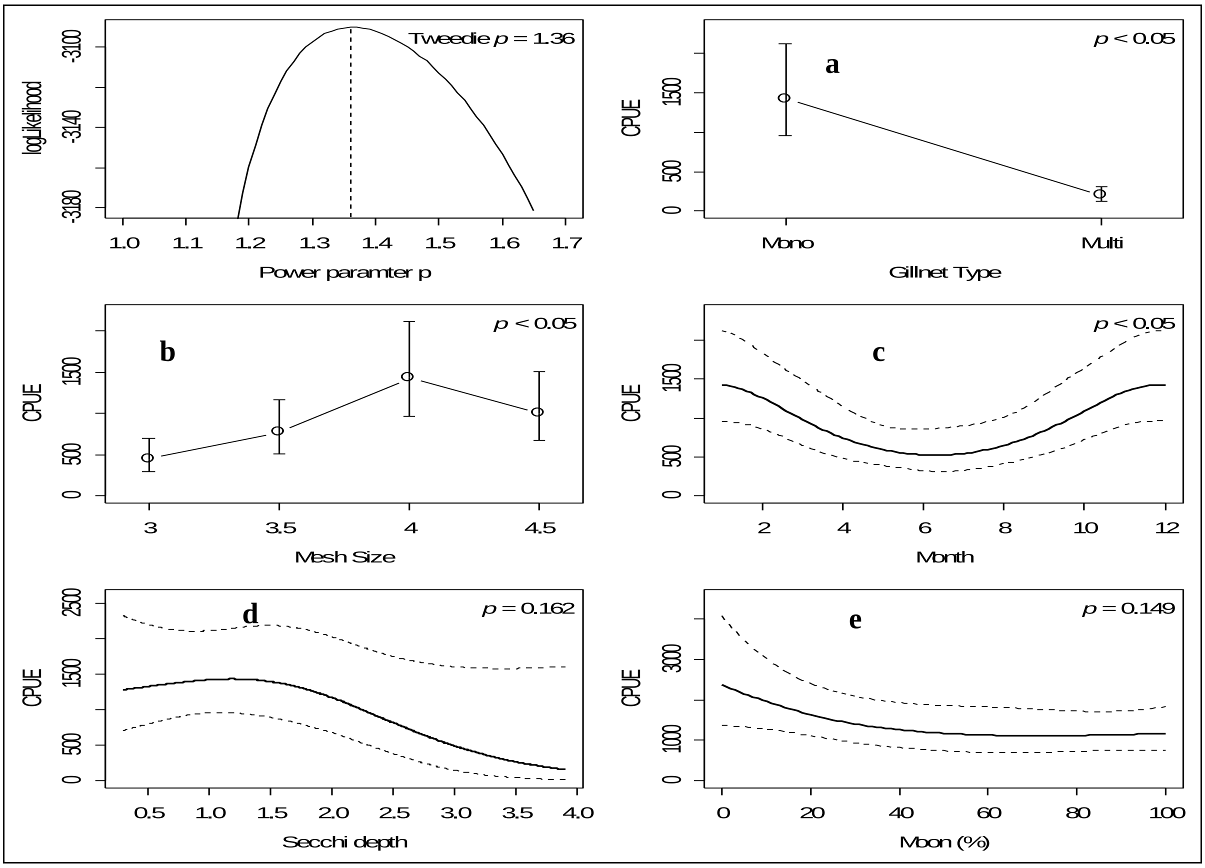

Fig 3: *Oreochromis andersonii*, *p*-values denotes the significance level of the predictor variable based on sequential F-tests

CPUE of *S. macrocephalus* differed significantly between Monofilament and Multifilament gillnets (*p*< 0.05) (Fig 4). Monofilament catches were higher than recorded Multifilament gillnetting catches. A steady drop in CPUE from Monofilament to Multifilament gillnets is depicted in (Fig 4a). Combined CPUE analysis by mesh size for *S. macrocephalus* differed significantly (*p* < 0.05) between various mesh sizes (76 mm, 89, 102 & 114mm) with a distinctive peak in the smaller mesh size of 76 (mm). A steady drop in CPUE with an increase in mesh size is depicted in (Fig. 4b). There is no trend in CPUE between the sampling months (Fig 4c). A significant correlation between CPUE and secchi depth was found (*P*<0.05) with a distinct peak on the intermediary secchi levels of 2.0 (m) (Fig 4d). Similarly a significant correlation between CPUE and lunar phase was also found (*P*<0.05) with a distinct peaks at half-moon (Fig 4e).

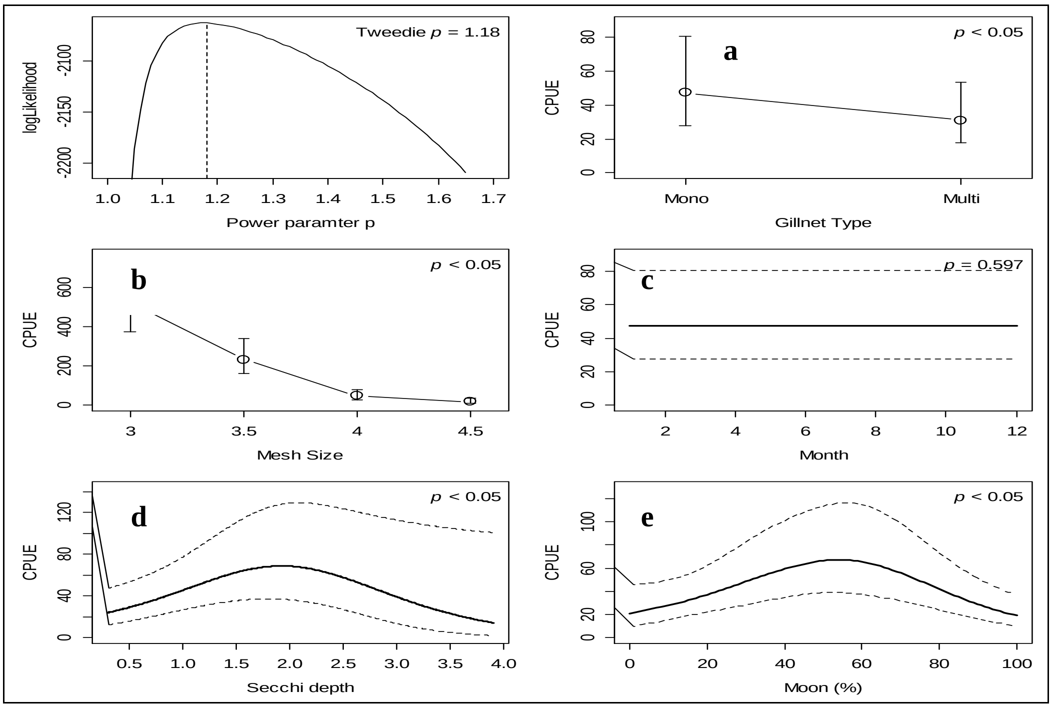

Fig 4: *Serranochromis macrocephalus*, *p*-values denotes the significance level of the predictor variable based on sequential F-test.

A pooled sample of the catfish species by weight differed significantly between Monofilament and Multifilament gillnets ($p<0.05$) (Fig 5a). Monofilament catches were generally higher than recorded Multifilament gillnetting catches. A steady drop in (CPUE) from Monofilament to Multifilament gillnets is depicted in (Fig 5a). Combined CPUE analysis by mesh size for catfish also differed significantly ($p < 0.05$) between various mesh sizes (76 mm, 89, 102 & 114mm) with a distinctive peak in mesh size 76 (mm) (Fig 5b). A steady decline in CPUE with an increase in mesh size is evident in (Fig 5b). Fluctuations in CPUE across the sampling month is also depicted in (Fig 5c). Lower CPUE was observed during the rising water level (February – April) and draw down (Septembers – December). Distinct peak in CPUE was observed during the winter month in June (Figure 5c). Separate correlations were performed to assess the relationship between CPUE, Secchi depth and Moon phase. A significant ($P<0.05$) but negative correlation between CPUE and secchi depth can be observed in (Fig 5d). Similarly a negative but significant correlation between CPUE and lunar phase ($P<0.05$) can be observed in (Fig 5e).

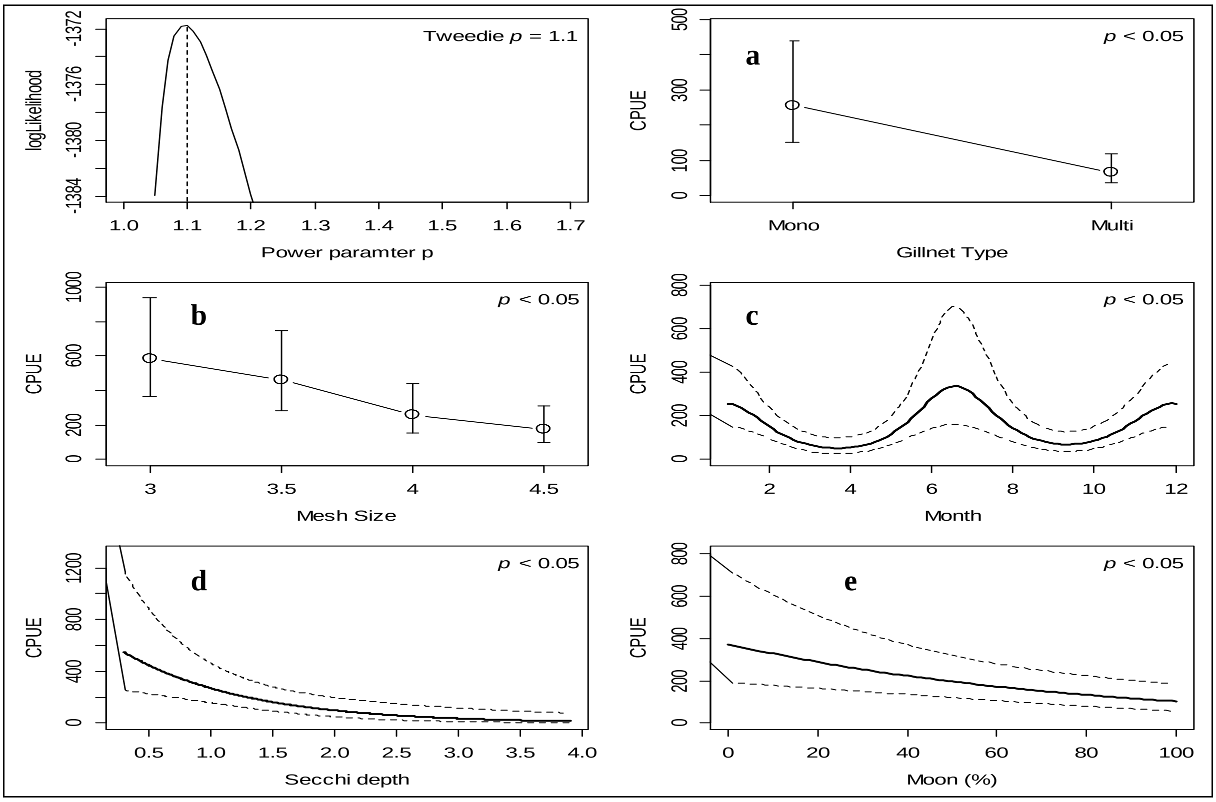

Fig 5: Catfish, *p*-values denotes the significance level of the predictor variable based on sequential F-tests.

Discussion

The results of this study were in agreement with other studies worldwide, where all studies showed that monofilament gillnets were more effective than multifilament nets. For instance Balik & Cubuk, (2000) [8] found that monofilament trammel nets caught 2.08 times more tench, (*Tinca tinca*) than multifilament nets in Lake Beysehir. Washington, (1973) [4] observed monofilament nets being 2.2 efficient than multifilament for catching salmon. Similarly, Collins, (1979) [9] reported that monofilament was 1.8 times more efficient than multifilament nets for catching lake white fish (*Coregonus clupeaformis*) in Lake Huron. Observed differences in CPUE between any two net types may be explained by the differences in visibility of the net in water [10, 11], nets with low visibility in water being more effective. Although fish are known to be myopic, they can see up to 10 m distance at 20 m depth [8]. Multifilament netting, irrespective of colour, is more visible than almost transparent monofilament nets. Thus the catching efficiency of the less visible monofilament nets is higher than multifilament nets. In the present study, all cichlid species; *O. andersonii*, *O. macrochir*, *C. rendalli* and *S. macrocephalus* were caught more frequently in monofilament nets, although the catch difference was less pronounced for *S. macrocephalus*. 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. Tweddle & Bodington, (1988) [10] suggested that for multifilament nets it was not the invisibility of a net that makes it an efficient catcher of fish but the nature of the visibility of the net, with some net colors making the fish more wary and discouraging them from attempting to force a way through the netting and thus making such nets less effective.

In the present study, there were significant differences in species numbers caught between gear types. Generally, the catchability of *O. andersonii*, *O. macrochir*, and *S. macrocephalus* decreased with increasing mesh sizes for both net types. While selectivity acts upon fish size and shape, net perception and net avoidance responses could change with age [12]. Visual acuity may have improved as fish grows and increase in size because the density of cones in its eye declines less rapidly than the image area increases [13]. Steinberg, (1964) [14] found that more visible nets caught a smaller proportion of large perch and postulated that larger, older fish approached nets more cautiously because they were better able to see the nets. The best overall catch rates were achieved with 102 mm mesh monofilament and 76 mm mesh multifilament gillnets.

Target species caught in monofilament nets were on average slightly larger than those caught in multifilament nets of the same mesh size, probably due to twine elasticity. These results are in contention with Larkins, (1963) [15] who reported larger mean length of red Chun and the pink Salmon in monofilament nets than the corresponding multifilament net of the same mesh size in the Pacific Ocean. It was observed that, the net diameter of the multifilament gillnets used in this study was thicker than that of the monofilament nets. Balik & Cubuk, (2000) [8] 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. Meshes of a more elastic and flexible twine can be stretched to be larger size by a struggling fish [12]. This could explain the large fish caught in similar mesh sizes in monofilament nets than multifilament nets.

Visibility of the net can also be affected by weather conditions, turbidity and the depth of the lake water [8]. Turbidity imposes a considerable environmental constraint with a potential to affect whole fish communities [16]. Increased turbidity influences visually-oriented fish by decreasing their visual range and ability to avoid visible nets in the water [14]. However, a distinct peak of *S. macrocephalus,* a visually oriented species at half moon is an unexpected result. If net visibility is the primary factor, catches should have declined during half-moon to full moon due to an increase in illumination of nets in water. The only exception to these observations would be determined by the predatory behavior of this species which might have risked it to be caught at half-moon in the attempt to feed on other entangled small fish species. Predatory fish are better adapted to locate prey in the moonlight [7]. Alternatively, overcast at half-moon might have contributed to these observations. showed that, These observations agrees with (Lewis & Tweddle, 1990) in Simasiku *et al.,* (2017)[7] who pointed out that weather conditions influence catches during the rainy season, and concluded that overcast conditions would create good fishing conditions during periods of full moon. A significant correlation between catch rates of the catfish and turbidity was also an unexpected result. Catfish are non-visually oriented species but rely on their sensory circum-oral barbels for navigation in water. Hence one would expect them not to be influenced by the visibility of the net type in water. *O. andersonii* was not influenced by neither moonlight nor water transparency in Lake Liambezi. This implies that other factors rather than moon light and secchi levels may have shaped the distribution and abundance of cichlids in Lake Liambezi. 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 Liambezi the introduction of monofilament nets has intensified the exploitation rates for *O. andersonii*. 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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