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Full Length Research Paper

Selectivity and fish catches of gillnets in stratum VII (Yeji sector) of Lake Volta for sustainable management

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The study was conducted in Stratum VII (Yeji sector) of Lake Volta where commercial fishermen arbitrarily use gillnets, from June, 2009 to March, 2010. The catches of monofilament gillnets, the most dominant gear used in Stratum VII were investigated for dominant fish species composition and selectivity parameters. The study revealed the dominance of two fish species (*Synodontis membranaceus* and *Schilbe mystus*) which together contributed about 45% by number of gillnet catches. The optimum selection length (total length) of the 5 cm mesh size gillnet for *S. membranaceus* was 19.7 cm and *S. mystus* was 18.2 cm. The result showed that using monofilament gillnets with mesh sizes 3 and 5 cm could have increase pressure on juvenile population. The mean monthly catch for the study period was estimated to be in the range of 0.3961×10^{-3} – 3.2427×10^{-3} (standard deviation, δ=1003.9) metric tonnes. With reference to precautionary approach to fisheries management, a legal minimum mesh size of gillnets of 8 cm may be appropriate for conservation and sustainable exploitation in Stratum VII.

Key words: Catch, gillnet, management, selectivity, species.

INTRODUCTION

Ghana has a long tradition of a very active fishing industry. Ghana's fishing industry has made tremendous strides over the years, developing from a predominantly traditional canoe fleet to a mix of traditional and modern fleet (Agyenin-Boateng, 1989). Fish provides the Ghanaian consumer with about 60% of animal protein needs (FAO, 2008). According to Ghana's 2007 Budget Statement, the country's total annual fish requirement is estimated at 720,000 metric tonnes (mt), while annual production averages 400,000 mt (Atta-Kesson and Atugba, 2008). This leaves an annual deficit of 320,000 mt which is made up through the importation of US$200 million worth of fish into the country yearly. Lake Volta contributes between 80 and 90% of fish catches from the inland fisheries of Ghana (Ofori-Danson, 2002). In order to meet the needs of consumers, maintenance of the quality, diversity and availability of fish in sufficient quantities must be promoted.

The use of inappropriate fishing methods and techniques accompanied with free access of fishermen into Lake Volta pose inverse effects on fish catches (Braimah, 1998). It is observed that over a decade now no significant research work has been undertaken on changes of the fish stocks at Yeji of Lake Volta. As a result, information on the status of the present fish stocks is lacking. To obtain an insight into the potential for increased production and management purposes of the lake, a reliable estimate of the total annual fish catch of the major fishing gear would be necessary. In the light of the above, this study primarily sought to assess fish catch and effects of gillnet selection at Stratum VII (Yeji Sector) of Lake Volta.

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MATERIALS AND METHODS

Stratum VII (Figure 1) of Lake Volta lies between longitudes 0°10' and 1°05'W and latitudes 8° 8' and 8° 20'N and extends for about 60 km south 50 km north of Yeji . Stratum VII is chosen because it is currently one of the areas with the highest fishing activities and boasts of the largest fish market centre at Yeji.

For the purpose of sampling, two landing sites namely Jaklai and Site Area as shown in Figure 1 were selected. Jaklai and Site Area

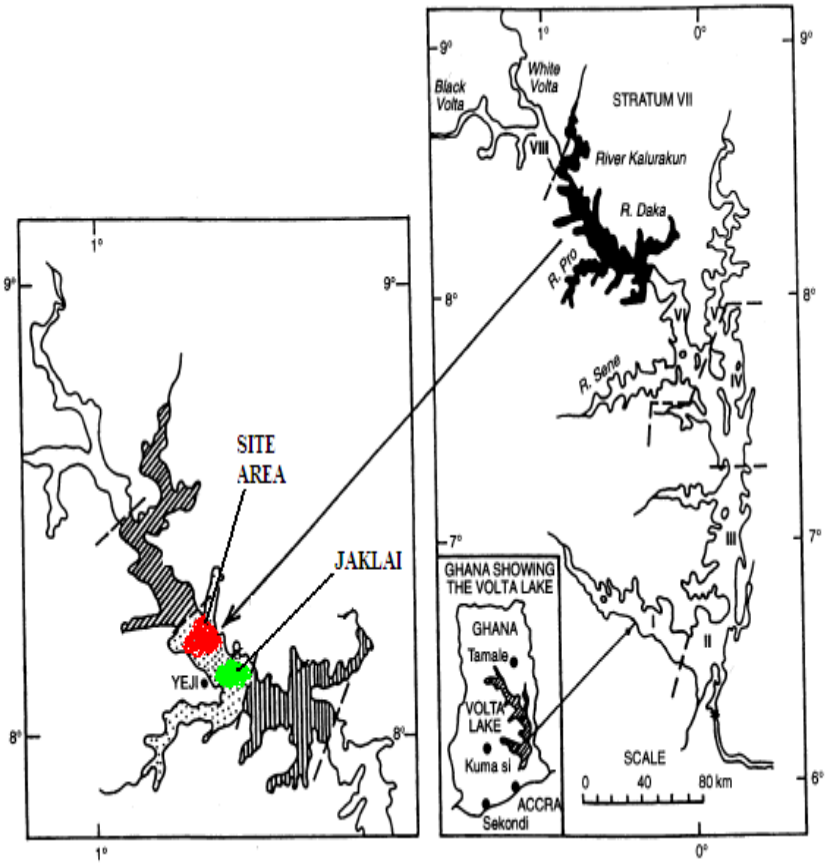

Figure 1. Map of Volta Lake showing Stratum VII and sampling sites (Source: Directorate of Fisheries, Yeji).

are located at the central part of Stratum VII. These landing sites were selected because they form the largest and most active among the five major landing sites of Stratum VII.

The data collected were in two folds namely primary data and secondary data. The primary data included gillnet catch, selectivity and physico-chemical data. The secondary data comprised monthly catches and mean rainfall values compiled from the records of Fisheries Directorate of the Ministry of Food and Agriculture, Yeji and Ghana Meteorological Agency, Accra respectively. Sampling for catch and determination of fishing effort were carried out at the selected sites once every week for 10 months (from June, 2009 to March, 2010). At each landing site, about 2.5 to 5.0 kg of fish was weighed using a balance scale and a bowl after sorting from each landed canoe and the following data collected: (i) fish species composition (ii) total body length (from snout to anal fin) and weight of fish in kg (iii) mesh size of gillnets in cm (iv) number of fishermen per canoe and (v) total number of operational and non-operational canoes.

Fish samples obtained from commercial gillnet catches were identified up to species using freshwater fish identification guide (Dankwa et al., 1999). Monthly fish catches (C) were estimated using C = Catch per unit effort (CPUE) × Number of fishing days (Fd).The CPUE was estimated as catch per canoe per day (kg/canoe/day). On selectivity parameters, two monofilament gillnets of stretched mesh sizes 3 and 5 cm representing small and large sizes respectively with equal surface area (100 m2) and hanging depth of between 1.5 and 3.0 m were set for a period of about 16 h before removal once every month (from June, 2009 to March, 2010). The catches then were sorted for species composition. The weight of the fish sample and then the overall catch was recorded. *In situ* measurements of temperature, pH, dissolved oxygen and transparency were taken from the surface to the bottom of the lake by the help of a Hyro-Bio water sampler of 1.7 L monthly.

In order to show the distribution of dominant species and total lengths of fish sampled, pie chart and bar graph of Microsoft Office Excel 2007 were used. Again, the distribution and trends of fish catch were established using percentage and graph (curves) of Microsoft Office Excel 2007. Data on gillnet selectivity was analysed using Fish Stock Assessment Tool II, Version 1.1.3 (FISAT II). The selectivity parameters, optimum selection length and selection factor were estimated using Holt (1963) model. The model assumes that when the catches (CA, CB) of two mesh sizes (ma, mb) overlap, their common standard deviation and estimate of optimum selection length for catch of the mesh sizes can be obtained by a linear regression of the form:

$$\ln (C_A/C_B) = a + b\,L$$

Where 'L' is length interval midpoints, 'a' the intercept and 'b' the slope of the regression line, C_A = catch of mesh size m_a and C_B = catch of mesh size m_b. The optimum lengths (L_{ma} and L_{mb}) for the 2 nets was then estimated from equations of Sparre and Venema (1992) and Pauly (1984).

$$L_{ma} = -2\,[(a \times m_a) / (b)\,(m_a + m_b)]$$

Table 1. Some physico-chemical parameters in Stratum VII of Lake Volta.

Parameter	Depth (m)				Average
	0	2	6	10	
Temperature (°C)	31.6	30.8	29.4	29.0	30.2 ± 0.0738
pH (units)	7.0	6.9	6.8	6.5	6.8 ± 0.0738
Dissolved oxygen (mg/L)	9.2	8.6	7.6	6.8	8.1 ± 0.0738
Transparency (cm)	60.5	-	-	-	60.5 ± 0.0738

$L_{mb} = -2[(a \times m_b) / (b) (m_a + m_b)]$

The common standard deviation is given by:

$SD = \sqrt{2a (m_a - m_b) / b^2 (m_a + m_b)}$

The selection factor (SF) of the 2 nets was estimated from

$SF = 2a / b (m_a + m_b)$

The probability of capture (P) at any given length for meshes m_a and m_b was estimated from:

$P_{ma} = \exp [- (L - L_{ma})^2 / 2 S.D^2]$
$P_{mb} = \exp [- (L - L_{mb})^2 / 2 S.D^2]$

A plot of the natural logarithms of the probability of capture against length interval midpoints provided estimates of L_{ma}, L_{mb} and the selection curves of the two mesh sizes. To be able to determine the physico-chemical parameters that influenced the CPUE (catch per unit effort) greatly, multi-linear regression of Statistical Package for Social Sciences (SPSS), Version 14.0 for windows was performed. Matrix Laboratory 2008a (MATLAB) was also used in depicting the relationship between precipitation and CPUE.

RESULTS

Physico-chemical condition of Stratum VII during the period of study

The vertical profile measurements of temperature, pH, dissolved oxygen and transparency showed decreasing values with increasing depth. The average values however for the parameters were 30.2 °C (temperature), 6.8 (pH), and 8.1 mg/l (dissolved oxygen) and 60.5 cm (transparency) with a standard deviation of ± 0.0738 as shown in Table 1.

Fish stock composition of commercial gillnet catches in Stratum VII of Lake Volta

Gillnet catches were dominated in terms of numbers by *Synodontis membranaceus* representing 24% of the total catch for the study period. Following closely was *Schilbe mystus* (21%). 'Others' (*Auchenoglanis occidentalis*, *Distichodus rostratus Hydrocynus brevis, Sarotherodon melantheron*, *Mormyrus macrophthalmus*, *Hippopotamyrus psittacus*, etc.) contributed the least in terms of numbers as these together represented 2% as shown in Figure 2. On the hand, *Labeo coubie* (28%) recorded the highest percent by weight followed by *Oreochromis niloticus* (16%) and thirdly *Bagrus bajad* (11%) as shown in Figure 3.

Length distribution of fish stock caught in gillnets during the period of study

Fish caught by gillnets ranged between 10 and 40 cm total length as shown in Figure 4. Fifty percent of fish caught measured around 20 cm total length, 37.5% of recorded 30 cm total length and 13.5% for 40 cm total length.

Mean monthly gillnet catches of fish recorded during the study period

In Figure 5, the greatest catch, 3.2427×10^{-3} metric tonnes (3242.7 kg) occurred around November, 2009. There was a continuous decline in catch after this peak. The lowest catch, 0.3961×10^{-3} metric tonnes (396.1 kg) however was recorded in March, 2010.

Fish catches for 2008 and 2009 in Stratum VII of Lake Volta recorded by the fisheries Directorate, Yeji

Figure 6 shows the fish catches by all gears for 2008 and 2009 based on secondary data obtained by courtesy of the Fisheries Directorate, Yeji. It can be observed that the total catch of fish for 2009 (1.066084×10^{-1} metric tonnes with a standard deviation, σ = 4804.6) was greater than that of 2008 (8.28521×10^{-1} metric tonnes, σ = 3259.5). Also, the peak catches were recorded around July and August for 2009 and 2008 respectively. There was a general decline in catches for both years after August.

The annual catches of dominant fish caught by diverse gears at Stratum VII of Lake Volta are shown in Table 2. Mochokidae (*S. membranaceus S. schall, S. ocellifer S. nigrita*) and Schilbeidae (*Auchenoglandis occidentalis Schilbe mystus, S. intermedius*) recorded13.6 and 5.05% by weight in 2008 respectively. In 2009, Mochokidae recorded 12.59% and Schilbeidae recorded 7.43% by

Table 2. Fresh fish catches for 2008 and 2009 in Stratum VII recorded by the department of fisheries, Yeji.

Family	Species	Catch (kg/year)		Percentage equivalent (%)	
		2008	2009	2008	2009
Characidae	*Hydrocynus brevis H. forskalii Alestes baremoze, A. dentex, A. nurse*	2783.9	1944.5	3.36	1.82
Bagridae	*Bagrus bajad, B. docmac, Chrysichthys auratus, C.nigrodigitatus Auchenoglandis occidentalis*	24094.1	29679.0	29.08	27.84
Citharinidae	*Citharinus citharus*	214	656	0.26	0.62
Claridae	*Clarias anguillaris*	2533.8	2479.1	2.65	2.33
Clupeidae	*Odaxothrissa mento, Pellonula leonensis, Sierrathrissa leonensis*	7356.4	10387.7	8.88	9.74
Distichodontidae	*Distichodus rostratus*	603.2	1086.9	0.73	1.02
Osteoglossidae	*Heterotis niloticus*	16.5	9.1	0.02	0.01
Cyprinidae	*Labeo coubie, L. senegalensis*	6225.6	7972.7	7.51	7.48
Malapteruridae	*Malapterurus electricus*	9	12	0.01	0.01
Mormyridae	*Mormyrus rume, M. macropthalmus*	2000.7	3131.5	2.41	2.94
Schilbedae	*Schilbe mystus, S. intermedius*	4178.8	7921.2	5.05	7.43
Mochokidae	*Synodontis membranaceus, S. schall, S. ocellifer, S. nigrita*	11276.2	13418.8	13.61	12.59
Cichlidae	*Tilapia dageti, T. zillii, T. guineansis, Oreochromis niloticus, Sarotherodon galilaeus, Hemichromis fasciatus, H. bimaculatus*	21560	27549.7	26.02	25.84
Total		82852.1	106608.4	100	100

weight in Stratum VII, Yeji. The family Bagridae recorded the highest percentage by weight for both 2008 (29.08%) and 2009 (27.84%). The families with the least percentage presentation were Osteoglossidae and Malapteruridae each of which had 0.01%.

Monofilament gillnet selectivity

Catch and length records of S. membranaceus and S. mystus

The total number of *S. membranaceus* and *S. mystus* caught by both 3 cm stretched mesh size and 5 cm stretched mesh size during the study period was 1222 with 35 kg total weight. The 3 cm stretched mesh size net contributed 527 individual fish while 695 individual fish was recorded for the 5 cm stretched mesh size net. *S. membranaceus* caught in mesh size 3 cm ranged between 5.4 to 24.3 cm. Those caught in mesh size 5 cm ranged between 7.5 and 25.5 cm total length. The mean modal lengths for the 3 cm mesh and 5 cm mesh size gillnets were 18.0 and 22.2 cm, respectively. On the other hand, a total body length range of 5.2 to 24.3 cm and 7.5 to 26.6 cm were recorded for the 3 cm mesh size gillnets and 5 cm mesh, respectively for *S. mystus.* Its mean modal lengths were 15.9 cm (3 cm mesh size) and 18.0 cm (5 cm mesh size) as shown in Figure 11.

Gillnet selectivity plot

The optimum length for capture of *S. membranaceus* increased from 11.8 to 19.7 cm (Total length) for the 3 and 5 cm mesh sizes (Figure 7). The plot of the regression of the natural logarithms of the catch ratios of

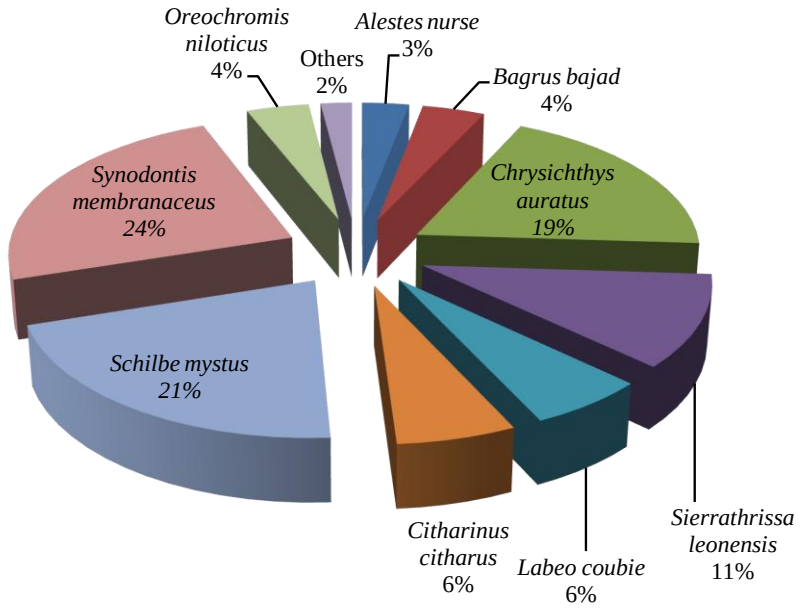

Figure 2. Percentage composition by number of main fish species caught by gillnets during the study period (June, 2009 - March, 2010).

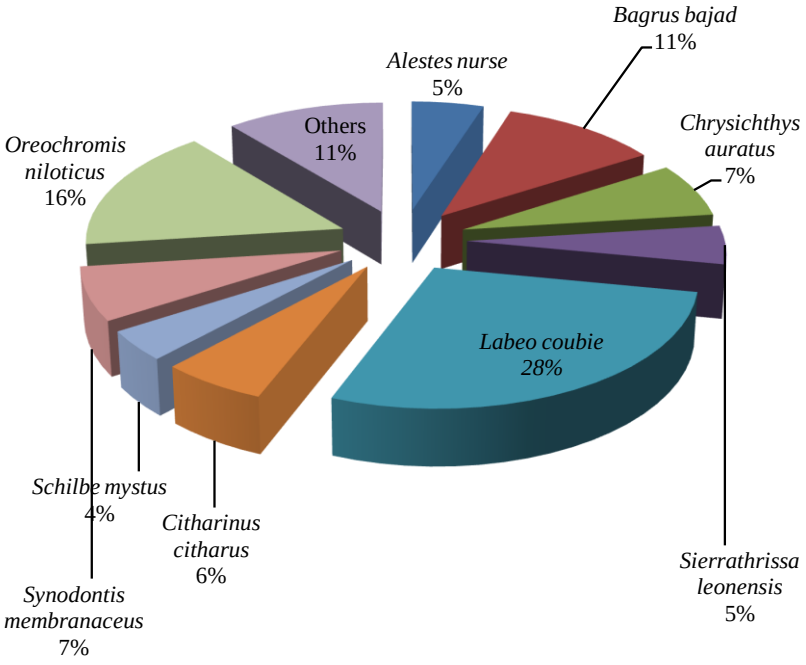

Figure 3. Percentage composition by weight of the main commercial fish species caught by gillnets in Stratum VII from June, 2009 to March, 2010.

mesh sizes 3 and 5 cm on the length interval midpoints for *S. membranaceus* (Figure 8). Figure 9 shows new optimum length for capture of *S. membranaceus* in a log-normal plot of the same variables. The selection ranges for *S. membranaceus* were 5.4 to 24.3 cm and 7.5 to 28.5 cm for mesh sizes 3 and 5 cm respectively. The log-normal plot of the regression of the natural logarithms of the catch ratios of mesh sizes 3 cm and 5 cm on the length interval midpoints for *S. membranaceus* (Figure 10) indicated that the optimum length for capture in the

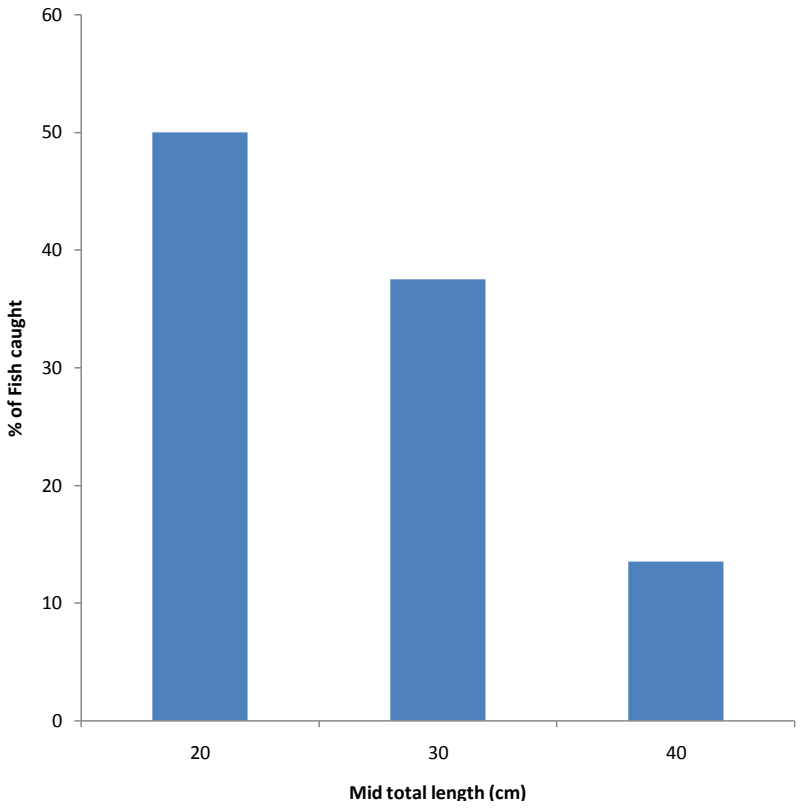

Figure 4. Length distribution of major fish stock caught by gillnets in Stratum VII of Lake Volta from June, 2009 to March, 2010.

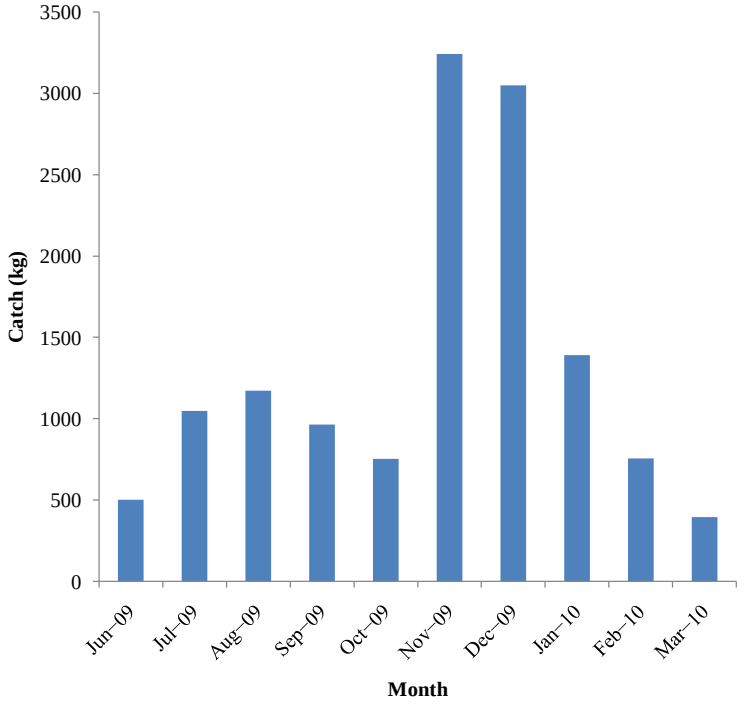

Figure 5. Mean monthly gillnet catches of fish recorded during the study in Stratum VII of Lake Volta.

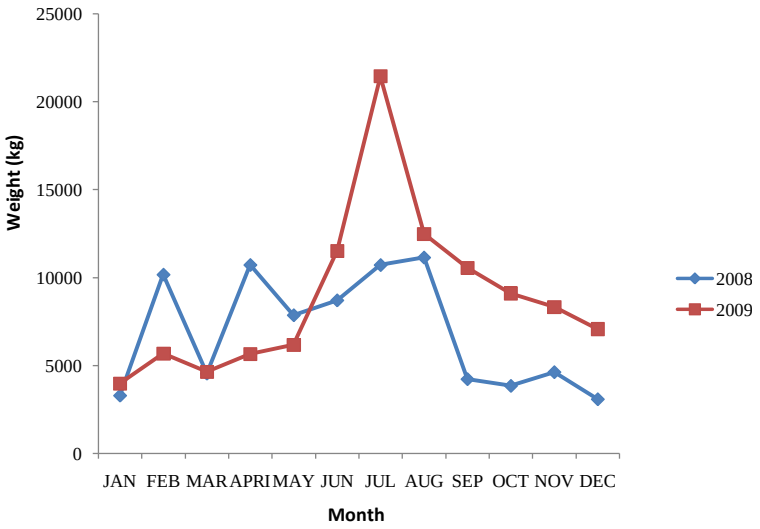

Figure 6. Monthly fish catches recorded by the Fisheries Directorate, Yeji for 2008 and 2009 by all gears in Stratum VII of Lake Volta.

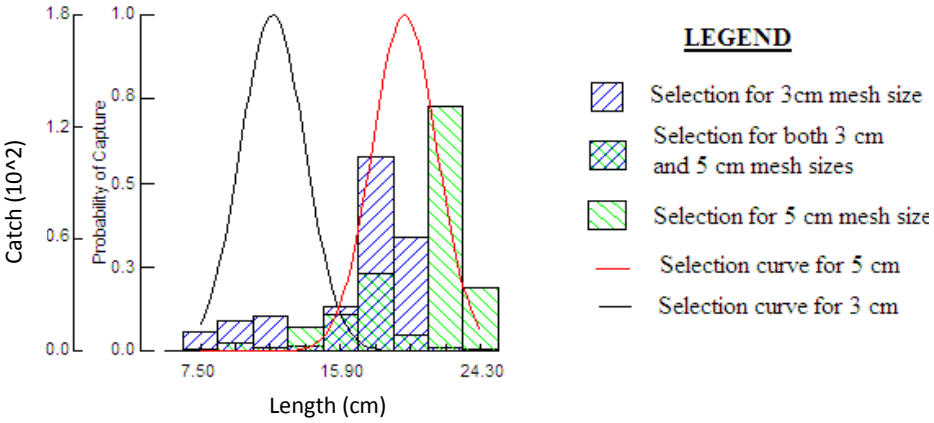

Figure 7. Gillnet (3 and 5 cm mesh sizes) selectivity curves obtained with FISAT for *S. membranaceus* in Stratum VII.

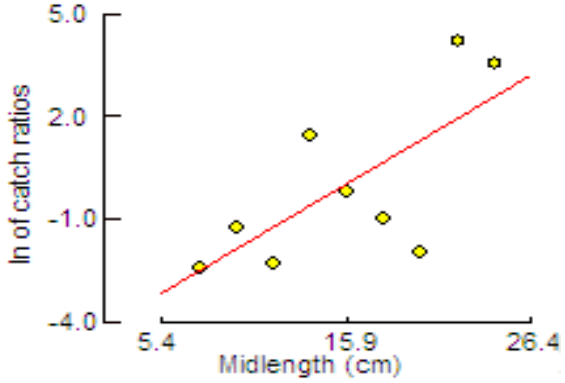

Figure 8. FISAT output of ln of catch ratios versus mid-length for *S. membranaceus* caught with gillnets of mesh sizes 3 and 5 cm.

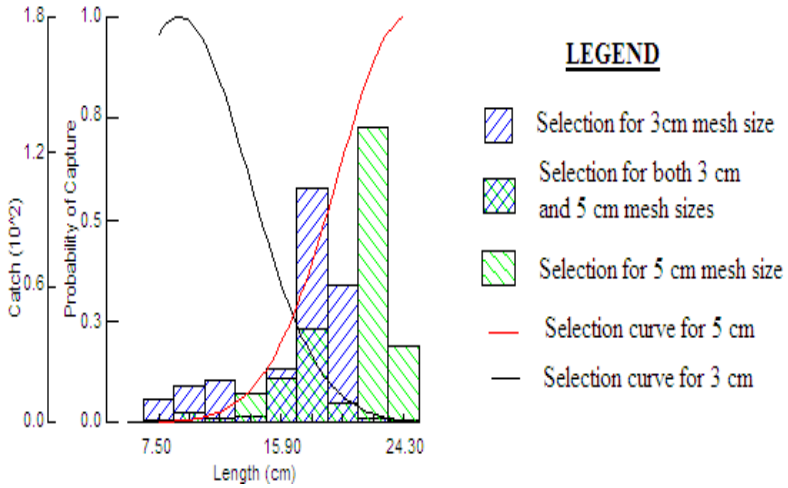

Figure 9. FISAT Log-normal plot of catch and probability of capture versus total length for *S. membranaceus* caught by gillnets of 3 cm and 5 cm mesh sizes in Stratum VII.

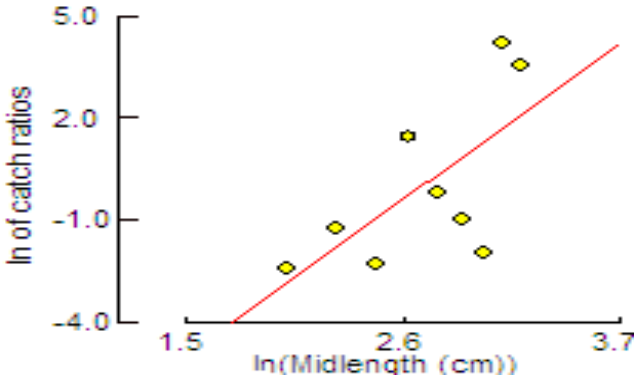

Figure 10. FISAT Log-normal plot of catch ratio versus mid-length for *S. membranaceus* caught by gillnets of 3 and 5 cm mesh sizes in Stratum VII.

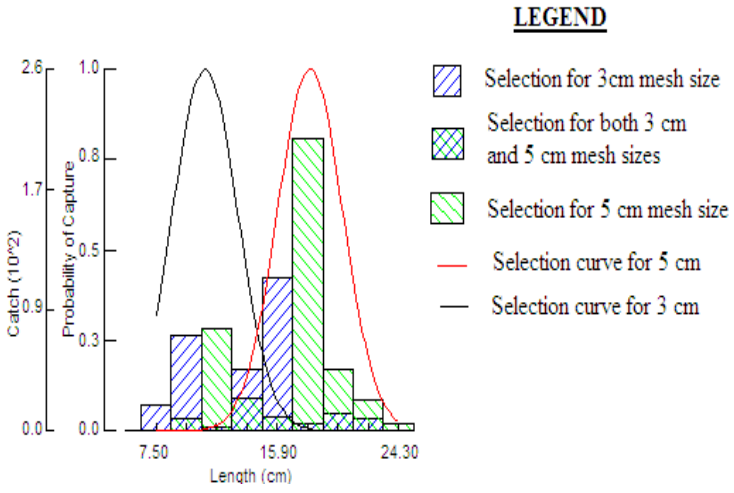

Figure 11. Gillnet (3 and 5 cm mesh sizes) selectivity curves obtained with FISAT for *S. mystus* in Stratum VII.

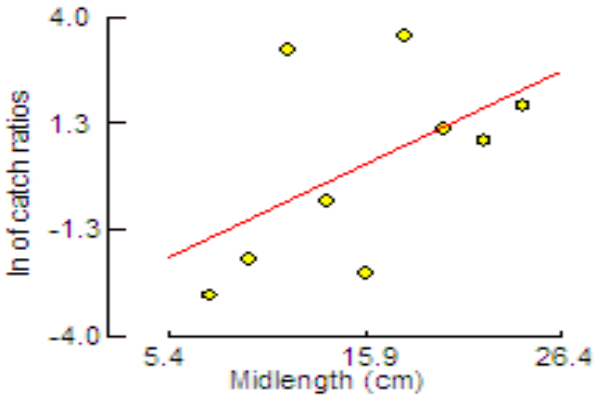

Figure 12. FISAT output of ln of catch ratios versus mid-length for *S. mystus* caught by gillnets of 3 and 5 cm mesh sizes in Stratum VII.

Table 3. Common selection factor (SF), common standard deviation (SD) and estimated optimum lengths (in cm), L_3 and L_5, of *S. membranaceus* and *S. mystus* for gillnet of 3 and 5 cm mesh sizes, respectively.

Species	SF	SD	L_3 (cm)	L_5 (cm)
S. membranaceus	3.9	5.8	11.8	19.7
S. mystus	3.6	5.8	10.9	18.2

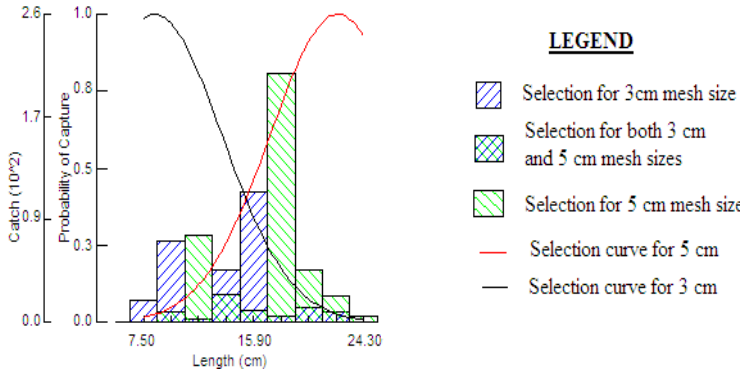

Figure 13. Log-normal gillnet selection curves obtained with FISAT of 3 cm and 5 cm mesh sizes for *S. mystus* in Stratum VII.

log-normal plot of *S. membranaceus* increased from 8.9 to 24.6 cm. The optimum length for capture of *S. mystus* also increased from 10.9 cm to 18.2 for the 3 and 5 cm mesh sizes (Figure 12). The selection ranges of *S. mystus* for the 3 and 5 cm mesh sizes were 5.4 to 24.3 cm and 7.5 to 26.4 cm. The plot of the regression of the natural logarithms of the catch ratios of mesh sizes 3 cm and 5 cm on the length interval midpoints for *S. mystus* is shown in Figure 13. Figure 14 shows new optimum length for capture of *S. mystus* in a log-normal plot of the same variables. The optimum length for capture of *S. mystus* in a log-normal plot increased from 8.3 to 22.3 cm for 3 and 5 cm mesh sizes. The selection factor (SF), standard deviation (SD) and optimum lengths (L_3 and L_5) of the two fish species are summarized in Table 3.

Relation between the catch per unit effort (CPUE) and precipitation during the period of study in Stratum VII of Lake Volta

The CPUE and precipitation showed a monthly inverse relation as depicted by Figure 15. In other words, where CPUE was increasing, precipitation (rainfall) was

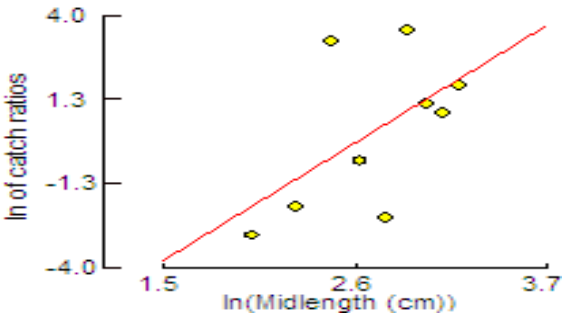

Figure 14. FISAT output of log-normal catch ratio versus midlength for *S. mystus* caught by gillnets of 3 and 5 cm mesh sizes in Stratum VII.

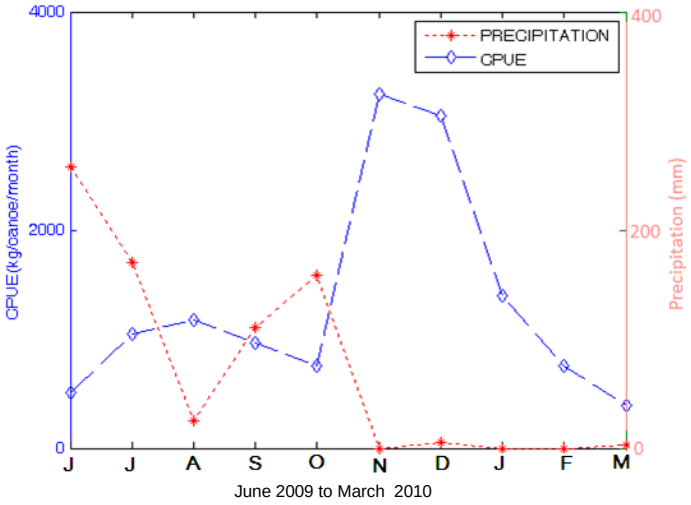

Figure 15. Relationship between CPUE and precipitation in Stratum VII of Lake Volta from June, 2009 to March, 2010.

decreasing and vice versa. While the peak of CPUE (3242.7 kg/canoe/month) occurred in November, 2009 that of precipitation (258.4 mm) was realized in June, 2009. The multi-linear regression analysis revealed a relationship (R^2 = 0.827) among the variables. Also, the test was significant (0.011) at 95% confidence level (α = 0.05) as shown in Table 4.

DISCUSSION

Physico-chemical condition of Stratum VII

The mean surface water temperature recorded for Stratum VII was 31.6°C. This dropped gradually to 29.0°C at the bottom representing a temperature difference of 2.6°C between the surface and the bottom waters. This observation indicates a weak thermal stratification. This phenomenon could be due to the riverine nature of Stratum VII of the lake. Clearly, the lake at the Yeji area is influenced principally by the Black Volta. Ofori-Danson and Antwi (1994) made a similar observation at the Akosombo gorge area. In general the temperature was optimal and characteristic of tropical lakes and did not exceed the critical value (40°C), lethal temperature to fish (Jeppe and Zwieten, 2005). The water of the Lake generally, had low pH value with slight variation in values with depth, with higher pH value on the surface. With a mean pH of 6.8 the Volta lake at Yeji exhibited a pH value within the World Health Organisation (WHO) range of 6.5 to 8.5 (WHO, 1993) a condition which may be described as near neutrality. This pH range is also suitable for fish growth and reproduction.

The vertical distribution of oxygen showed a decrease

Table 4. Multi-linear regression of pH, Temp (temperature) and DO (dissolved oxygen) on CPUE (catch per unit effort).

Model summary				
Model	**R**	**R square**	**Adjusted R square**	**Std. error of the estimate**
1	0.909	0.827	0.740	2.76883

ANOVA					
Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	2219.930	3	73.243		
Residual	45.999	6	7.666	9.554	0.011
Total	265.727	9			

Coefficients					
Model	**Unstandardised Coefficients**		**Standardised Coefficients**	**t**	**Sig.**
	B	Std. Error	Beta		
Constant	1648.368	498.047		3.310	0.016
Temp	-54.964	13.884	-0.746	-3.970	0.007
DO	-31.770	15.062	-0.431	-2.109	0.079
pH	40.786	13.884	0.554	2.946	0.026

with depth and was uniform. The surface waters of the lake were well oxygenated (9.2 mg/l) representing about 107.7% oxygen saturation while the bottom recorded 6.8 mg/L which could be translated into 79.6% oxygen saturation. Generally, the oxygen concentrations were satisfactory, being present in sufficient quantities (over 70% of saturation) to support fish life.

Mean Secchi disc transparency was 60.5 cm. The depth of light penetration was drastically reduced during the flood period (July to September) as also observed by Braimah (1995). The multi-linear regression analysis factors (pH, DO and Temp) on the CPUE indicated that all three partial coefficients are statistically significant ($P < 0.05$), thereby proving a strong relation of pH, temperature and dissolved oxygen on CPUE. Although, a decline in CPUE could be attributed to significant changes of any of the above variables as confirmed by the regression analysis (Table 4), the case in Stratum VII could be as a result of an increased number of canoes and a reduced water level. This is because pH, dissolved oxygen and temperature values have not reached lethal levels as long as the result of this study is concerned. DeGraaf and Ofori-Danson (1997) observed a similar trend of increased number of canoes coupled with a reduced water level affecting CPUE negatively.

Fish stock composition of commercial gillnet catches

Commercial gillnet catches comprised mainly *Oreochromis niloticus*, *Synodontis membranaceus*, *Alestes nurse*, *Bagrus bajad, Chrysichthys auratus*, *Labeo coubie*, *Citharinus citharus*, *Sierrathrissa leonensis* and *Schilbe mystus* during the study period, with no respect to the order in which they are listed. These fish were mostly caught by gillnet probably of their morphology, behaviour and trophic characteristics which rendered them prone to be caught by gillnet. Numerically, *S. membranaceus* was the highest (24.1%) as shown in Figure 3. Olaosebikan and Raji (1998) reported that *S. membranaceus* occur in both shallow and deep waters close to the shore where they feed on plankton, detritus and insects. *S. membranaceus* has replaced *Labeo coubie* and *Chrysichthys auratus* which were reported to be dominant (Ofori-Danson, 1999). *S. mystus* recorded 21% by number following *S. membranaceus* closely. Teugels et al. (1988) indicated that *S. mystus* are mostly caught by gillnet and are generally more active at night or in subdued light and feed from mid-water and surface waters on a wide variety of foods including fish, insects, shrimps, snails, plant seeds, and fruit. This may account partly for the high number of *S. mystus* in Stratum VII of Lake Volta. This is because gillnets were often set over night hence making the species vulnerable to capture. In terms of percentage composition by weight, *S. membranaceus* (7%) and *S. mystus* (4%) values were very low. Even though *S. membranaceus* and *S. mystus* contributed greatly in terms of numbers, this did not reflect in their unit weight. The reason may be that these species were dominated by small fish specimens.

The instability of the hydrological regime and increasing fishing efforts in the lake pose adverse consequences on composition of fish stock. Willis (1971) revealed that changes in the composition of fish stock continued to occur after the formation of the lake in 1964. The study

also noted the disappearance of some species that were originally present (Goudswaards and Avoke, 1993b). They included *Gymnarchus niloticus, Lates niloticus, Steatocranus irvinei* and *Hepsetus odoe*. *Gymnarchus niloticus, Lates niloticus* and *Steatocranus irvinei* were not encountered throughout the study period.

Additionally, *L. niloticus* and *Hydrocynus* spp. were earlier observed to occur in small numbers in the lake (Vanderpuye, 1982). *L. niloticus and Hydrocynus* spp. are piscivores and therefore can change in their dominance and abundance should their prey such as those in the family Clupeidae (*Odaxothrissa mento, Pellonula leonensis* and *Sierrathrissa leonensis*) get over-exploited.

Gillnet catches in Stratum VII during the study period

The use of gillnets generally is affected by several factors including colour of net, mesh size, twine size and strength, and morphology and behaviour of fish among others. Fishermen in Stratum VII were much aware of these factors based on a preliminary interaction. However, they were more attached to twine strength, mesh size and net colour. It was observed that gillnet of mesh sizes 3.0 to 6.0 cm were mostly used; since small and big fish alike can be caught by the range of these nets. White colour was preferred by fishermen to other colours because it blended relatively well with the colour of the water to ensure maximum gilling, entangling, wedging and nagging of fish.

The highest monthly catch was recorded in November, 2009 (Figure 6). The possible reason could be the rise in water level of the lake during the rainy season. This agrees with the observation of Vanderpuye (1982). During rainy season, turbidity increases resulting in poor visibility of fish which probably make them vulnerable to capture. By March, 2010 the water level had retreated to about 1 to 1.5 m and this might have accounted for the significant reduction in monthly catch.

Assuming all other factors are constant, the current estimated mean CPUE of 8.0 kg/canoe/day can produce a total monthly catch of 396.1 to 3,242.7 kg (σ = 1003.9) in Stratum VII. However due to increasing number of fishing efforts, the quantity of catch may decrease in subsequent years if even uncontrollable factors such as climate, water dynamics and food remain unchanged.

Length distribution of fish stock in gillnet catches

The minimum and maximum total lengths of fish species caught with gillnets were 20 and 40 cm, respectively(Figure 5). Fish that recorded 20 cm total length contributed 50%, the highest percentage of fish caught with gillnets. Olaosebikan and Raji (1998) reported that *S. membranaceus* can reach a maximum total length of 50 cm. Additionally, the standard length of *S. membranaceus* was estimated to be 33 cm in the northern arm of Lake Volta (Ofori-Danson et al., 2001). *S. mystus* according to Teugels et al. (1988) grows to a maximum total length of 40 cm. Considering these reported values of lengths of *S. membranaceus* and *S. schilbe,* this study revealed rather low values of length. Therefore 50% of the fish caught with gillnets during the study period were probably juveniles. Although, fish remain smaller, grow slower and mature earlier as a fishery-induced evolution (Mollet, 2010), the small size of fish caught with gillnets in Stratum VII during the study was perhaps as a result of the deployment of undersize mesh gillnets.

Annual fish catches of 2008 and 2009 in Stratum VII

Catch data as a matter of policy are being taken in Stratum VII from five landing sites by the Yeji Fisheries Department. Data collected ranged from fish caught by all the 11 methods of fishing namely *atidza*, bamboo pipe, beach seine, cast net, gillnet, hook-and-line, *nifa nifa*, spear, trap, winch net, and *wangara* net (Braimah, 1998). All these methods yielded a total catch of 82.8521×10^{-3} metric tonnes (standard deviation, σ = 3259.5) and 106.6084×10^{-3} metric tonnes (σ = 4804.6) in 2008 and 2009, respectively.

The peak catches occurred in the rainy season (July and August), this could be related to availability of food since nutrients are flushed from inland and the catchment drainage, due to gravitational depression of the adjacent wet lands as reported by Nwankwo (2004) and Emmanuel et al. (2008). The low catches recorded in the past could be as a result of poor hydrological regime especially water level. Vanderpuye (1982) reported that annual catches of Lake Volta continued to decline year after year from 1969. On the contrary, in 1996, an estimated total annual catch of 22.422 metric tonnes was reported (DeGraaf and Ofori-Danson, 1997) for the Yeji sector and this increased to 74.5 metric tonnes in 2008 (FAO, 2008). Therefore it suggests that water level and fish food greatly affect annual catches in the lake.

Fish stock composition of 2008 and 2009 annual catches

The results revealed the following families from which the main commercial fish were caught with all gears operating in Stratum VII (Yeji Sector) of Lake Volta for 2008 and 2009. They included Mochokidae, Schilbeidae,

Cichlidae, Characidae, Bagridae, Cyprinidae, Citharinidae and Clupeidae (Table 2). The family Mochokidae which *S. membranaceus* belong contributed 13.61 and 12.59% by weight of fish catches recorded by the Fisheries Directorate, Yeji for 2008 and 2009, respectively (Table 2). Schilbeidae on the other hand, recorded as low as 5.05 and 7.43% by weight in 2008 and 2009 respectively. The reason for the low contribution by weight of fish in the families Mochokidae and Schilbeidae was not clear. However, Bagridae recorded the highest of 29.08 and 27.84% for 2008 and 2009, respectively. This could be attributed to the adoption of specialized gears like *nifa nifa* that target species belonging to this family (Goudswaard and Avoke, 1993a).

Gillnet selectivity of *S. membranaceus* and *S.mystus*

S. membranaceus and *S. mystus* were the most dominant species caught in commercial gillnet fishery in Stratum VII of lake Volta and target species for this study. This study provided initial selectivity estimates of gillnets used in Stratum VII of lake Volta to catch *S. membranaceus* and *S. mystus*. The optimum catch lengths increased with increasing mesh size which agreed with similar study conducted by Ahmed and Inpinjolu (2008) on *S. membranaceus, Citharinus citharus*, *Hydrocynus forskalii*, and *Distichodus rostratus* in lake Kainji, Nigeria.

The optimum catch lengths of 11.8 cm for *S. membranaceus* and 10.9 cm for *S. mystus* of mesh size 3 cm were less than the reported length of 26.7 cm (Ofori-Danson, 2002) and 13.3 cm (Teugels et al., 1988) at first sexual maturity for the species. Considering the recommendations of FAO (1995a) Code of Conduct for Responsible Fisheries and the Precautionary Approach to fisheries (FAO, 1995b), and the multi-species nature of the lake fishery the 3 cm mesh size gillnet was considered too low; it would be of immense help to discourage completely the use of 3 cm mesh size gillnets for reasons of sustainability and conservation of fisheries resources of the lake.

The optimum catch lengths of 19.7 cm for *S. membranaceus* with deployment of mesh size 5 cm gillnets must also be discouraged since it was less than the reported length of 26.7 cm at first sexual maturity. Although the optimum catch length of 18.2 cm for *S. schilbe* of mesh size 5 cm appeared greater than the reported length of 13.3 cm at first sexual maturity, due to the multi-species nature of the lake, gillnets of 5 cm mesh size may not be encouraged in order to ensure optimum protection and conservation of such species.

In the interest of conservation and judicious exploitation of the fishery, the use of 8 cm mesh size could be prescribed as the precautionary minimum mesh size so as to allow most fish species to reach sexual maturity and grow big enough before they are caught to prevent growth and recruitment overfishing. The adoption and enforcement of 8 cm mesh size gillnet as the minimum legal mesh size would not only be precautionary enough to enhance recruitment and increase fish production and conserve the lake fisheries through prevention of the catch of fish before they are sexually mature, but would also prevent loss of stock to the ecosystem with age.

Conclusions

The dominant commercial gillnet fish species observed in Stratum VII of Lake Volta during the study period were *S. membranaceus, S. mystus, Chrysichthys auratus, Sierrathrissa leonensis, Labeo coubie, Citharinus citharus, Bagrus bajad, Oreochromis niloticus* and *Alestes nurse.* The two most dominant species in numbers (*S. mystus* and *S. membranaceus)* was as a result of suitable physico-chemical conditions for their spawning in Stratum VII. The mean monthly gillnet catch during the study period was estimated to be in the range $0.3961 \times 10^{-3} – 3.2427 \times 10^{-3}$ metric tonnes (σ = 1003. 9), which was far lower than 2083.3×10^{-3} metric tonnes from earlier studies.

The optimum catch lengths for *S. membranaceus* and *S. mystus* were 11.8 and 10.9 cm respectively for the 3 cm mesh size gillnet. For the 5 cm mesh size gillnet the optimum catch lengths were 19.7 and 18.2 cm for *S. membranaceus* and *S. mystus* respectively. In view of the recommendations of code of conduct for responsible fisheries and the precautionary approach to fisheries, and the multi-species nature of the lake fishery the 3 cm mesh size gillnet was found too small. Also, for the sake of conservation and optimum protection of the fishery, the 5 cm mesh size gillnet for *S. mystus* may not be encouraged though the reported length of 13.3 cm appeared greater than the optimum length of catch.

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