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Full Length Research Paper

Length-weight relationships and condition factors of *Alestes baremoze*, *Brycinus nurse* and *Schilbe intermedius* from the lower reaches of White Volta River (Yapei), Ghana

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A study to assess the length-weight relationships and the condition factors of 3 abundant and commercial fish species namely *Alestes baremoze*, *Brycinus nurse* and *Schilbe intermedius* in the lower reaches of the White Volta River (Yapei) was conducted from October 2011 to March 2012. Using $W = aL^b$, the length-weight relationships of the species were calculated. Condition factors of the species were obtained using the formula: $W*100/L^b$. A total of 284 *A. baremoze* were measured with total mid length size range of 10.5 to 44.5 cm. A total of 197 *B. nurse* were measured and ranged from 6.5 to 27.5 cm total mid-length whereas 175 of *S. intermedius* were measured and had total mid length size range of 8.5 to 26.5 cm. The slope *b* of the length-weight relationships of the 3 species were within the acceptable range of 2.5 to 3.5 and can be used to approximate the weight for the 3 species in the lower reaches of the White Volta River. The condition factors variation of *A. baremoze* and *B. nurse* showed a pronounced change in December 2011, when the surface water temperature was lowest. *S. intermedius* had no significant changes in the condition factors over the study period.

Key words: White Volta River, total mid-length, size range, species, surface water temperature.

INTRODUCTION

The Lake Volta is the most important inland fishery area in Ghana. According to FAO statistics, inland capture fisheries contributed 27 of total Ghanaian fish production in 2009 (FAO FishStat Plus). It is estimated that the reservoir provides 90% of the national freshwater fish production (Abban, 1999). The Lake Volta in Ghana is an immense reservoir created after a completion of the Akosombo Dam on the Volta River in 1964. It is the largest man-made lake by surface area in the world. It has a length of 520 km and covers about 8,500 km^2, or 3.2% of Ghana's total land area. The reservoir stores about 149 km^3 of water (van Zwieten et al., 2011). The lake Volta extends from the Akosombo Dam in southeastern Ghana to the town of Yapei in the Northern region of Ghana. Yapei is thus the terminal point for the lake Volta and the lower reaches of the White Volta River (WVR) starts from there. According to Braimah (2003) some 300 000 fisherfolk depend on the Volta reservoir for their livelihood. The Volta reservoir is endowed with fisheries resources. Dankwa et al. (1999) identified 121 species in the Volta reservoir.

The Lake Volta and its tributary Volta Rivers in the last

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4 decades have undergone great changes in its ecology, limno-chemistry and socio-economy. Increased pressure on land along the banks has led to high rates of deforestation. This has resulted in increased soil erosion leading to the transportation of high loads of silt and nutrients through rivers into the lake, thereby contributing to its eutrophication. Furthermore, wetlands bordering the lake are being converted into agricultural land or land for grazing cattle, and therefore may not be able to act as natural filters for nutrients and silt, and now do not provide breeding grounds for many fish species (Ofori-Danson et al., 2001). As a result of these problems, the Lake Volta Research and Development Project (VLR and DP) was undertaken under the Food and Agricultural Organization and United Nations Development Programme during the first decade of the lake's existence (FAO and UNDP 1971, 1979). These studies came to an end in 1978. Since then, systematic data collection from the Lake Volta and Volta Rivers natural resources has been lacking. There have been calls for renewed studies to facilitate their management due to declining catches.

A. baremoze, B. nurse and *S. intermedius* are very abundant from October to March in the Yapei stretch of the White Volta River. During this period, these fishes constituent a significant part of the fish diet of the local inhabitants. In this way, they provide a source of animal protein.

The importance of the Yapei fishery cannot be underestimated. Yapei is 52 km from the Northern regional capital Tamale. Tamale is the third largest city in Ghana with a population of 537,986 (Wikipedia, 2012). Yapei is easily accessible as it is on the Accra-Kumasi-Tamale trunk road. Yapei is one of the 9 main sources of smoked fish to the Tamale Central Market (Obodai et al., 2009). The Tamale Central Market is the largest market center in the metropolis and majority of the inhabitants buy their food stuffs from this market. It thus makes Yapei an important supplier of fish especially smoked fish. Fishermen at the Yapei stretch of the White Volta River practice unregulated and unselective harvesting of fish with fishermen harvesting all sizes of fish without regard to the sustenance of the fishery. These practices targeted at more catches for more income. Fish can only be harvested at the maximum sustainable yield (MSY) when all the biological parameters are known.

Length-weight relationship and condition factor are of great importance to the fishery industry as they help to predict the best length and time suited to harvest a particular species of fish. The study therefore focused on providing information on the length-weight relationships and condition factors of *A. Baremoze*, *B. Nurse* and *S. Intermedius* from White Volta River, Ghana.

MATERIALS AND METHODS

Study area

The samples were conducted at the Yapei stretch of the White Volta River, which is a major landing site in the Northern Region of Ghana. 3 non-overlapping landing sites namely Pataplapei, Porturto and Aglassipei were selected (Figure 1) to provide a representative overview of the fisheries in the area.

Fish sampling and measurement

The samples of the selected fish species were taken at random from landings and their total length recorded to the nearest 0.1 cm using a fish measuring board while the body weight was recorded to the nearest 0.01 g using a balance after using tissue to mop off water from the surface of the specimens.

The measured lengths were later grouped into class intervals for analysis. The length-weight equation; $W= aL^b$ as described by Ricker (1975) was used to establish the length-weight relationship of the species measured, where W is the weight (g), L is the total length (cm), *a* is a constant determined empirically and *b* is the slope of the equation. The slope *b* has a numerical value which is mostly between 2.5 and 3.5 and is often close to 3 (Bagenal and Tesch, 1978; Carlander, 1969; Gayanilo and Pauly, 1997; Froese, 2006; Weatherley and Gill, 1987). Under isometric growth *b* equals to 3 but isometric growth in fish is rare (Bolger and Connolly, 1989; McGurk, 1985).

The equation relating weight-length gives some indication of the state of wellbeing of a fish in a population which is known as the condition factor. Fish in good condition have higher condition factor value than those in poor condition.

The condition factor (K) is defined as:

$$K=\frac{\text{weight (g)}}{\text{length (cm)^b}}\times 100$$

Modified from Fulton (1902) formula of K: W/L^3 (W: weight and L: Total length)

The total body weight (in grams) of the ungutted fish was used; the length was total length (TL) in centimeters. The exponential b value is the slope of the length-weight equation. Having weighed and measured over hundreds of the selected fish species from the lower reaches of the White Volta River, the condition factor (K) was multiplied by 100 in order to bring the K value close to unity.

Physicochemical parameters

Using Garmin GPS 60, the coordinates of the sampling points in the water were stored and at each time of sampling, the sampling points were traced back using the GPS tracking system. All the parameters were taken monthly at all the landing site. The readings and the water samples were taken between 10.00 am and 12.00 pm GMT.

The surface water temperature was measured using Hanna Checktemp1 (a digital pocket thermometer). 3 readings were made at each landing site (20 m from the mouth of the landing site, and then in the middle of water and 20 m from the mouth of the opposite end of the landing site) and the average was taken as the mean surface water temperature for the site.

Dissolved oxygen concentration was measured using the Azide modification of Winkler method. The bubble free water samples were taken from the center of the water at each landing site and treated on the field by removing the stopper from the 250 ml BOD bottle and adding 2 ml of Manganese (II) Suphate ($MnSO_4$) (Winkler 1) to the water samples, followed by 2 ml alkali-iodate-azide (Winkler 2). The stopper was restored at once and the contents were mixed by inverting the bottle for about 3 min. The precipitates were allowed to settle. The samples were stored in ice chest and

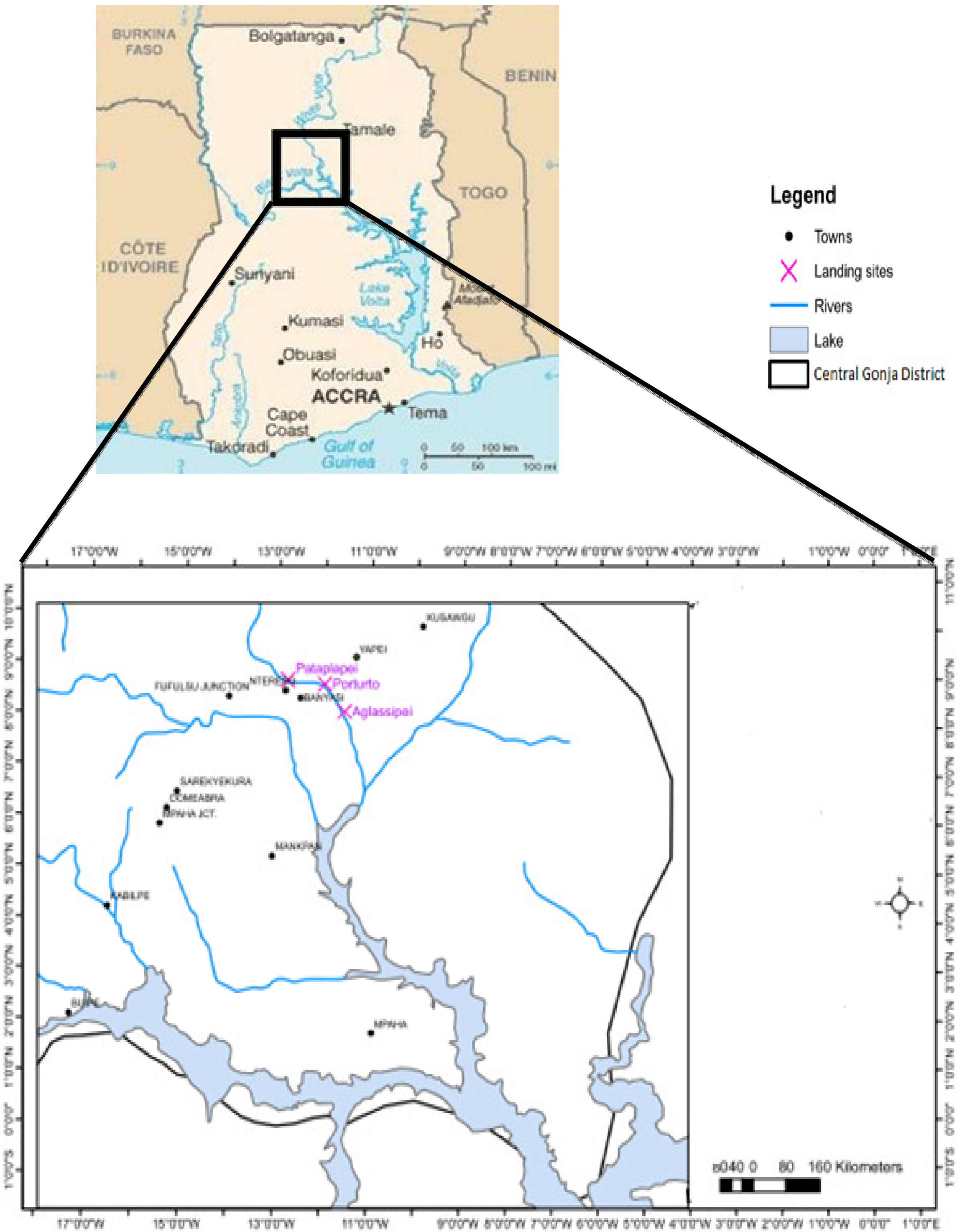

Figure 1. Map of Ghana with an insert of the detailed study area showing Yapei, and the 3 landing sites; Pataplapei, Porturto, and Aglassipei.

transported to the laboratory. In the Water Research Institute (WRI) laboratory Tamale, Ghana, 2 ml concentration of sulphuric acid was added along the neck and shaken till dissolution was complete. Hundred (100) ml of the solution was taken and titrated with M/80 sodium thiosulphate solution to a straw yellow colour. 1 to 2 ml of starch solution was added and the titration continued to the point where the blue colour changed to colourless. The calculation was as follows: mg/l O_2 = Vol. of thiosulphate used × 101.6 / Vol. of sample used. pH meter and combination of electrode (pH Meter-Jenway Model 3510) was used to measure the pH at middle of the

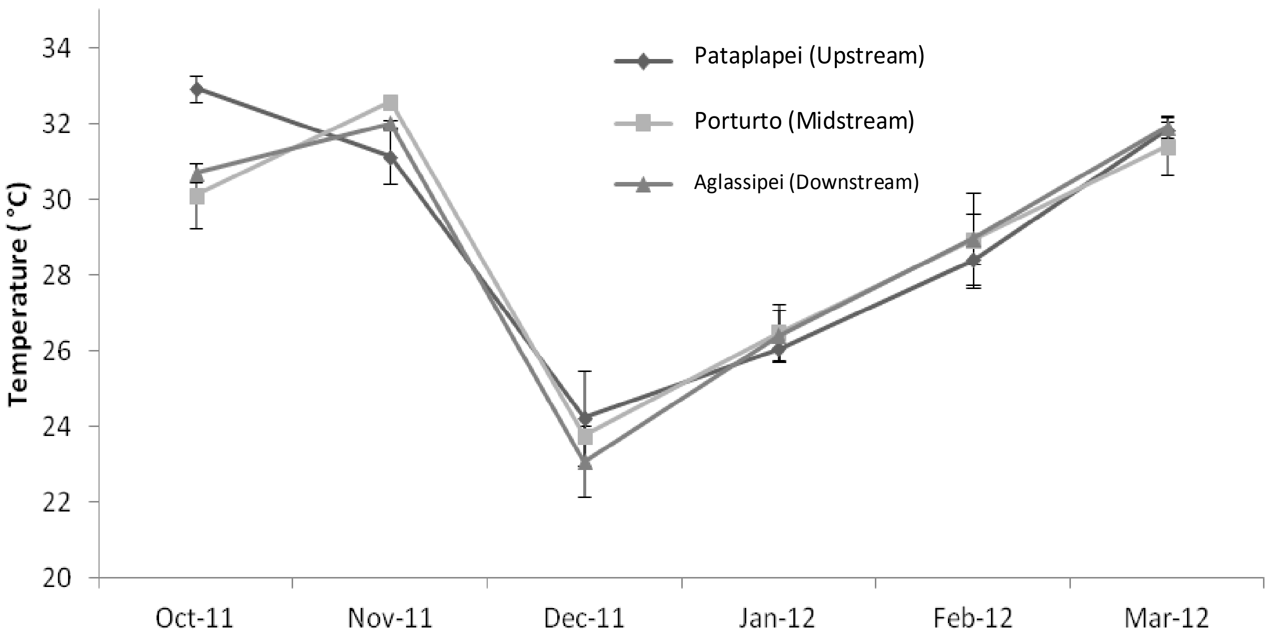

Figure 2. Mean and SD (±) of the surface water temperature of 3 landing sites in the lower reaches of the White Volta River from October 2011 to March, 2012.

water. The readings were also compared to the observations made with pH strips and colour charts.

The water depths of 3 points at the center (the coordinates stored on the GPS) of the water and perpendicular to the landing site were measured monthly with Speedtech Hand Eco sounder.

Data analysis

Descriptive statistics of the Software STATISICA 8.1 and Microsoft Excel 2010 were used to analyze catches data for means, frequencies, percentages, length-weight relationships and condition factors.

RESULTS

Physico-chemical condition of lower reaches of the white volta river during the period of study

Monthly mean temperature values recorded were between 23.1and 32.9°C. The mean temperature of the whole 8.84 km stretch (Pataplapei, Porturto and Aglassipei) during the 6 months period of study was 28.8°C. In the landing site Pataplapei, the highest temperature was recorded in October 2011 whereas the landing sites, Porturto and Aglassipei had the highest temperature readings in November 2011. All the 3 landing sites had their lowest and striking changes in temperature in December 2011 (Figure 2).

The dissolved oxygen ranged from 2.7 to 4.7 mg/l whereas pH values ranged between 6.8 and 7.86.

Water levels

The highest water depth was 6.5 m and it was recorded in October 2011 at the downstream Aglassipei. The lowest was 3.9 m and it was recorded in March 2012 at upstream Pataplapei. All the landing sites had the highest water level in October 2011 and the water level consistently decreased month by month in all the sites and subsequently the lowest water level at all the sites was recorded in March 2012 (Figure 3). Pataplapei which is upstream, is the shallowest. It is followed by Porturto (midstream). Aglassipei has the deepest water levels.

Length frequency distributions of the three fishes

The size frequency histograms for *A. baremoze*, *B. nurse* and *S. intermedius* is shown in Figures 4 to 6 respectively. Over the 6 months period of study, *A. baremoze* had the largest sample size with a total of 284 fish measured. The total length ranged from 10.5 to 44.5 cm. 2 cohorts of the species were observed throughout the period of the study. The first cohort had total lengths around 10.5 to 15.5 cm and the second cohort 27.5 to 33.5 cm. The first cohort remained within the same size range from month to month whereas the second cohort had a slight shift in size range. This shift was realized from January to March when the peaks of the total lengths moved to the left towards a smaller size range around 28.5 cm. Length distributions of *A. baremoze* as

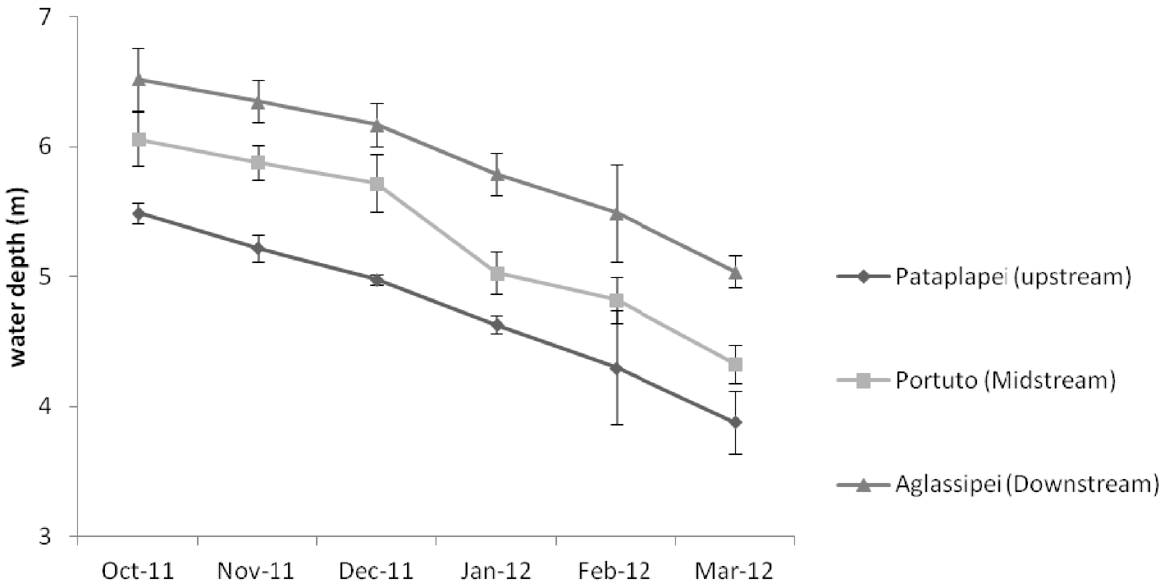

Figure 3. Mean and SD (±) of the water depth of 3 landing sites in the lower reaches of the White Volta River from October 2011 to March 2012.

shown in Figure 4 depicts that different sizes of the species prefer different areas of the lower reaches of the white volta river. Aglassipei which is downstream had more of smaller sizes of the species with total length around 12.5 cm. Porturto (midstream) had the species evenly distributed over the entire size range. Pataplapei (upstream) had more of the middle sizes of the species with most of their total lengths around mean of the entire size range of the *A. baremoze* in the lower reaches of the white volta river.

A total of 197 of *B. nurse* were measured over the 6 months period of the study. *B. nurse* total length ranged from 6.5 to 27.5 cm. One cohort was observed over the entire period of the study. The cohort had a mean total length around 15.5 cm. The following observations are apparent from the *B. nurse* distribution. Firstly, a higher percentage of the species is concentrated at the middle of the size range. Secondly, larger sizes with total lengths between 25.5 and 27.5 cm were only observed in October to November, 2011, suggesting that possibly a cohort was facing or dying out. The next observation is that, the smaller sizes with total lengths around 6.5 to 8.5cm were also observed only in the last 2 months (February to March, 2012) of the study, a possible indication of an emerging cohort.

One hundred and seventy five (175) of *S. intermedius* from the lower reaches of the white volta river were measured over the 6 months period. The *S. intermedius* total lengths ranged from 8.5 to 26.5 cm. One cohort with a wide size range (total length traverses 17.5 and 21.5 cm) was observed from October 2011 to March 2012. Though, there were little differences in size ranges among the sites, smaller sizes of the species were more concentrated at Porturto which had seemingly an emerging cohort appearing in the last 2 months (February and March, 2012) of the study.

Length-weight relationships

The length to weight relationships of *A. baremoze*, *B. nurse* and *S. intermedius* are presented in Figure 7. A total of 283 *A. baremoze* were measured. *B. nurse* and *S. intermedius* were 197 and 175 respectively. Exponential value of the length-weight relationship ‘b’ in *A. baremoze* was 2.9502. In *B. nurse*, the ’b’ value was 3.0737 whilst *S. intermedius* had a highest ’b’ value of 3.4592.

Condition factor

The condition factor is an indicator of the wellbeing of a fish. The monthly condition factors of *A. baremoze*, *B. nurse* and *S. intermedius* from the lower reaches of the white volta river over the 6 months study period are shown in Figures 8 to 10, respectively.

The highest condition factors of *A. baremoze* were in the month December 2011 in all the 3 landing sites. *A. baremoze* condition factors variation over the 6 months period were similar in the landing sites Pataplapei and Aglassipei which had relatively higher condition factors than the landing site Porturto. January to March 2012 mean condition factor of Pataplapei was higher than the

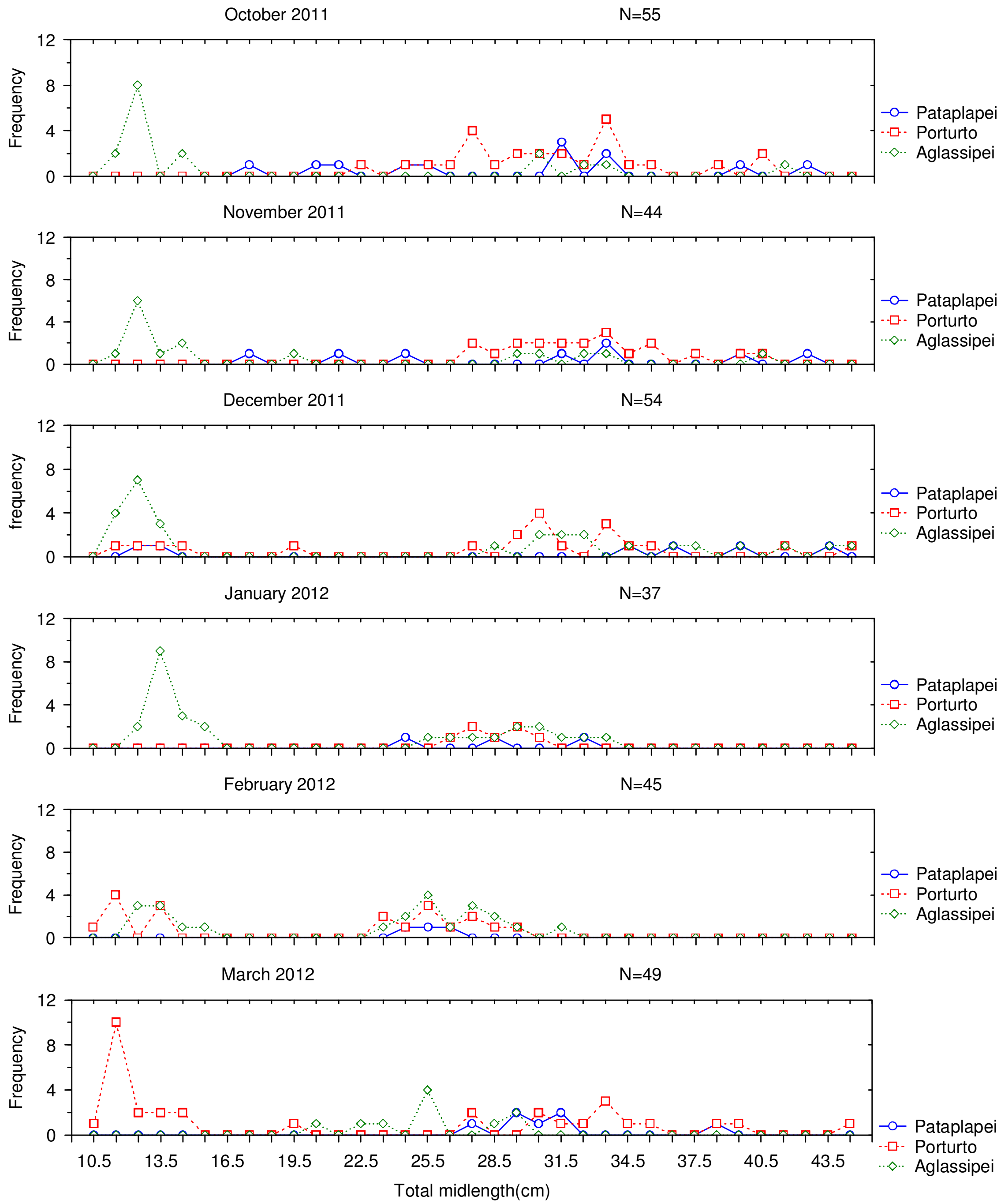

Figure 4. Length frequency distribution for *A. baremoze* from 3 landing sites in the lower reaches of White Volta River during the period of the study (October 2011 to March, 2012).

mean condition factor in October to November, 2011. Aglassipei also had slightly higher mean condition factor in January to March, 2012 than the mean condition factor of October to November, 2011. Porturto on the other hand was distinct in its monthly variation when compared to the other 2 sites. It had relatively little variability over the 6 months period and mean condition factor in October to November, 2011 was rather higher than that of January to March, 2012.

In B. *nurse*, condition factors of Pataplapei did not vary in October and November, 2011. In December 2011 the condition factor declined and then in the month January 2012, the condition factor rose to its highest in that site during the study period. The site had very little variation

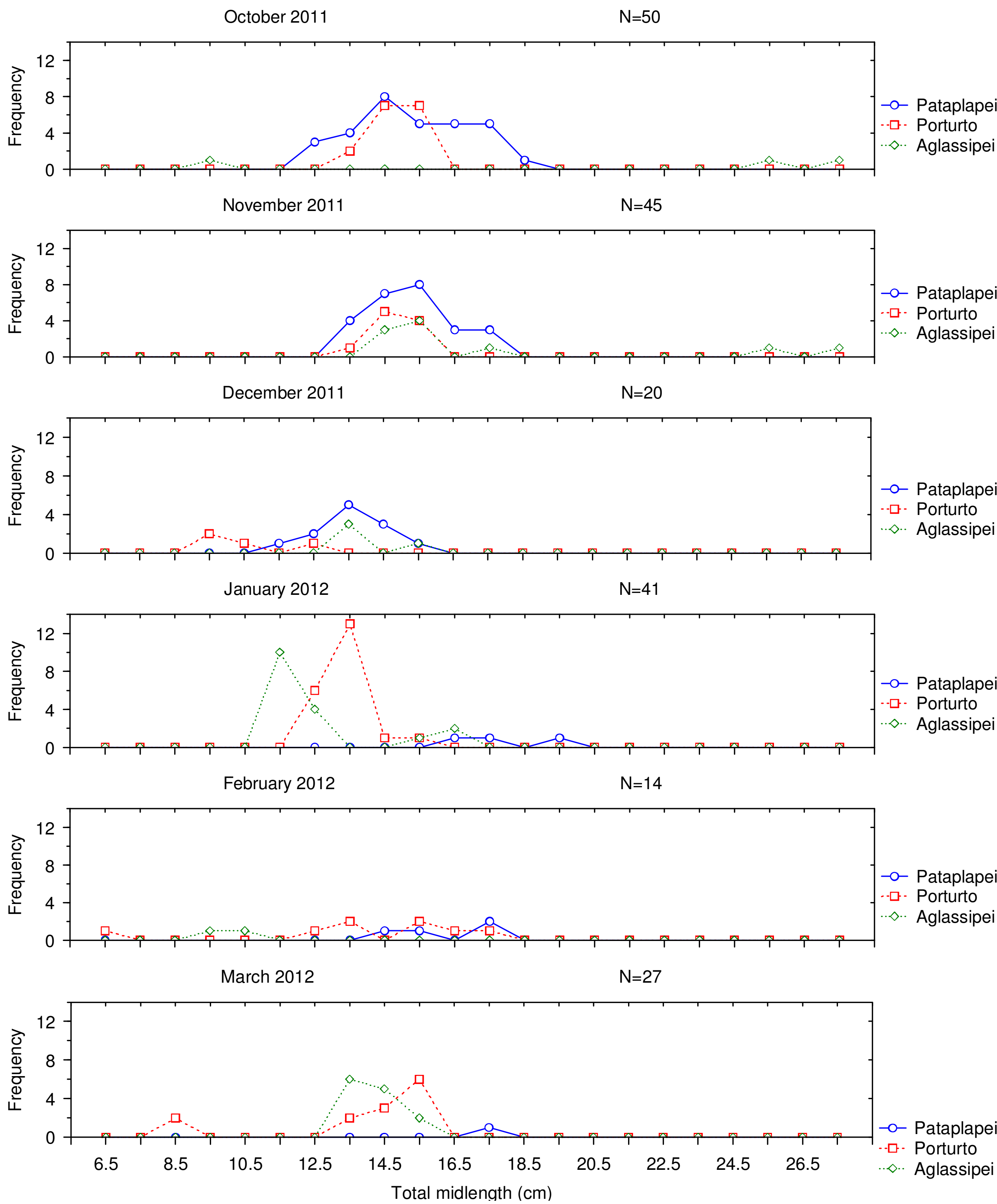

Figure 5. Length frequency distribution for *B. nurse* from 3 landing sites in the lower reaches of White Volta River during the period of the study (October 2011 to March 2012).

of the condition factors over February and March, 2012. Also, in the landing site Porturto the condition factors remained fairly the same in the October to November, 2011. There was a sharp decline in the condition factor in December 2011 and then in January 2012 increased and then decreased in February 2012 and sharply elevated at

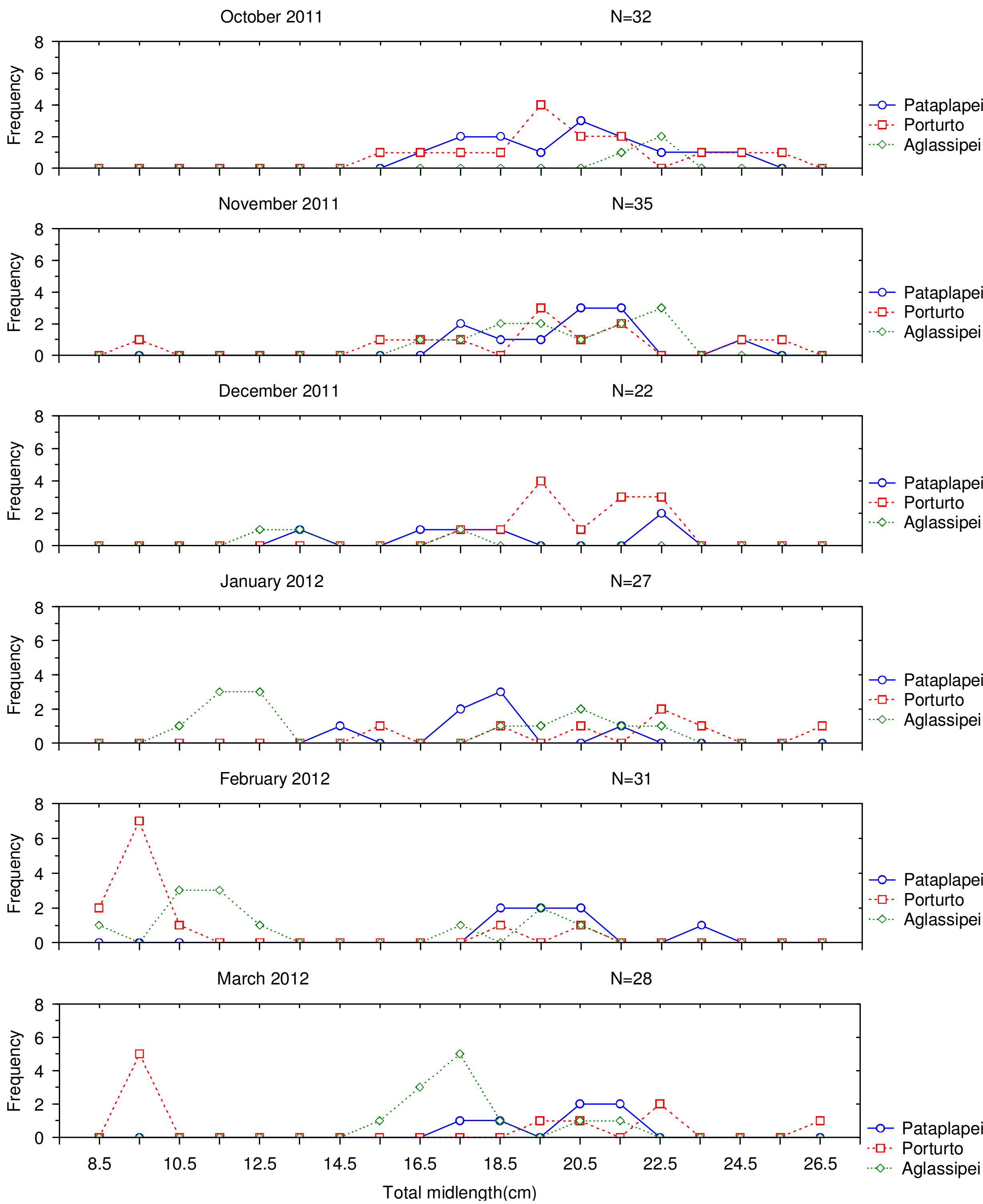

Figure 6. Length frequency distribution for *S. intermedius* from 3 landing sites in the lower reaches of White Volta River during the period of study (October 2011 to March 2012).

end of the study in March 2012. In Aglassipei, the condition factors were lower than those of Pataplapei and Porturto throughout the period of study. The monthly pattern was that of a normal variability or increase-decrease, starting with a mean condition factor of 0.81 in October 2011 and then increased in November 2011,

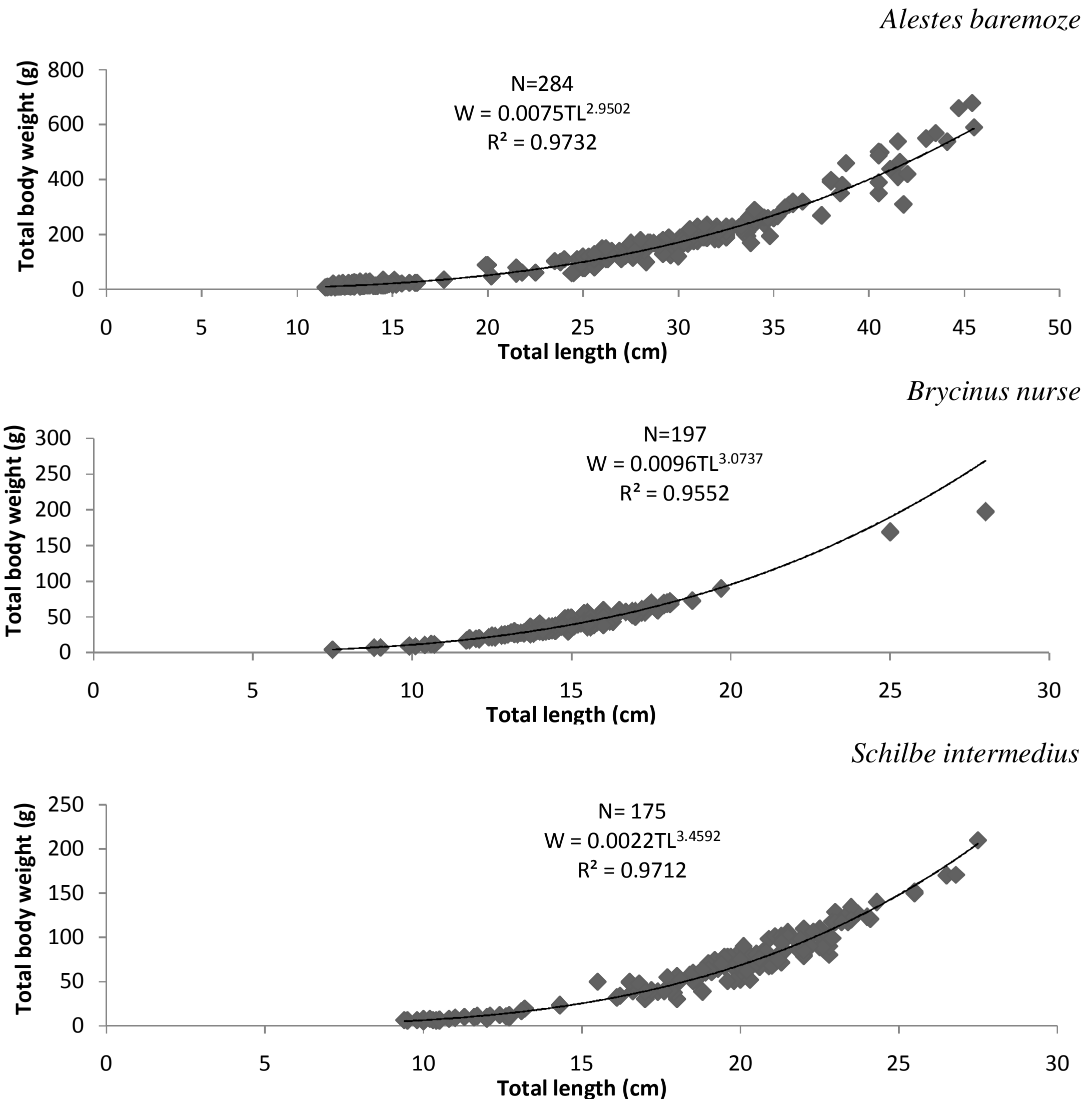

Figure 7. Length-weight relationship of 3 species in the lower reaches of the White Volta River during the study period (October 2011 to March 2012). N, Number of fish; W, Weight (grams) and TL, Total Length (cm).

declined in December 2011. This pattern of increase-decrease continued at similar rate till the end of the study, March 2012.

The condition factors of *S. intermedius* among the 3 landing sites were not very distinct. Pataplapei had the highest condition factors of the species. It started with 0.21 in October 2011 and then continuously went up over the months to 0.27 in January 2012 and slightly declined to 0.26 in February 2012 and also to 0.24 in March 2012. There was very little monthly variability of the condition factors between the landing sites Porturto and Aglassipei with the condition factor values varying between 0.20 and 0.23. Porturto for instance had the same condition factor of 0.22 in November 2011, December 2011 and January 2012. Pataplapei had fairly higher condition factors during the dry season (January 2012 to March 2012) than the other post flood season and also, than the other landing sites.

DISCUSSION

A. baremoze

The numerical value of *b* of the length-weight relationship of *A. baremoze* obtained from this study is within the acceptable range of 2.5 and 3.5 which is typical for tropical fish stocks (Carlander, 1969; Froese, 2006) and was very close to 3. It also conforms to what www.fishbase.org has published on the species. The value

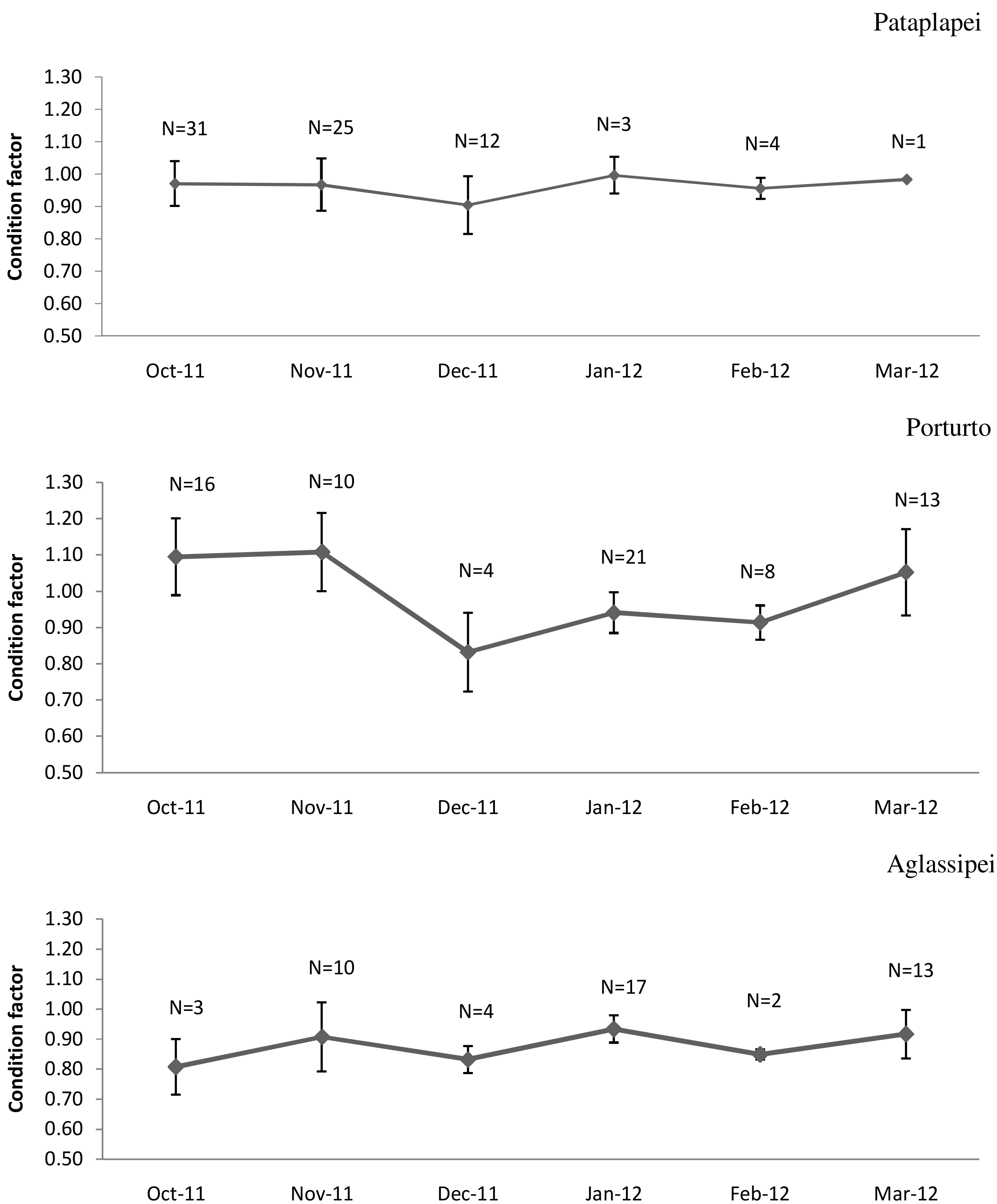

Figure 8. Condition factors ($K=W*100/L^b$) of *A. baremoze* from 3 landing sites in the lower reaches of White Volta River over the 6 months study period (with their standard deviations as bars in the graph).

can thus be used for approximation of length-weight relationship of *A. baremoze* populations in the lower reaches of the White Volta River. Condition factor defined as the state of wellbeing of the fish reflects through variations, some information on the physiology of the fish. It is assumed that the higher the value, the better the state of wellbeing. Nutritionally, it is assumed that increases or higher condition factor reflects improvement in nutritional status of the fish whereas a decline or lower condition factor could mean malnutrition (Koskela et al., 1997). In using the *b* for the condition factor (W/L^b) calculation, there were some differences among the

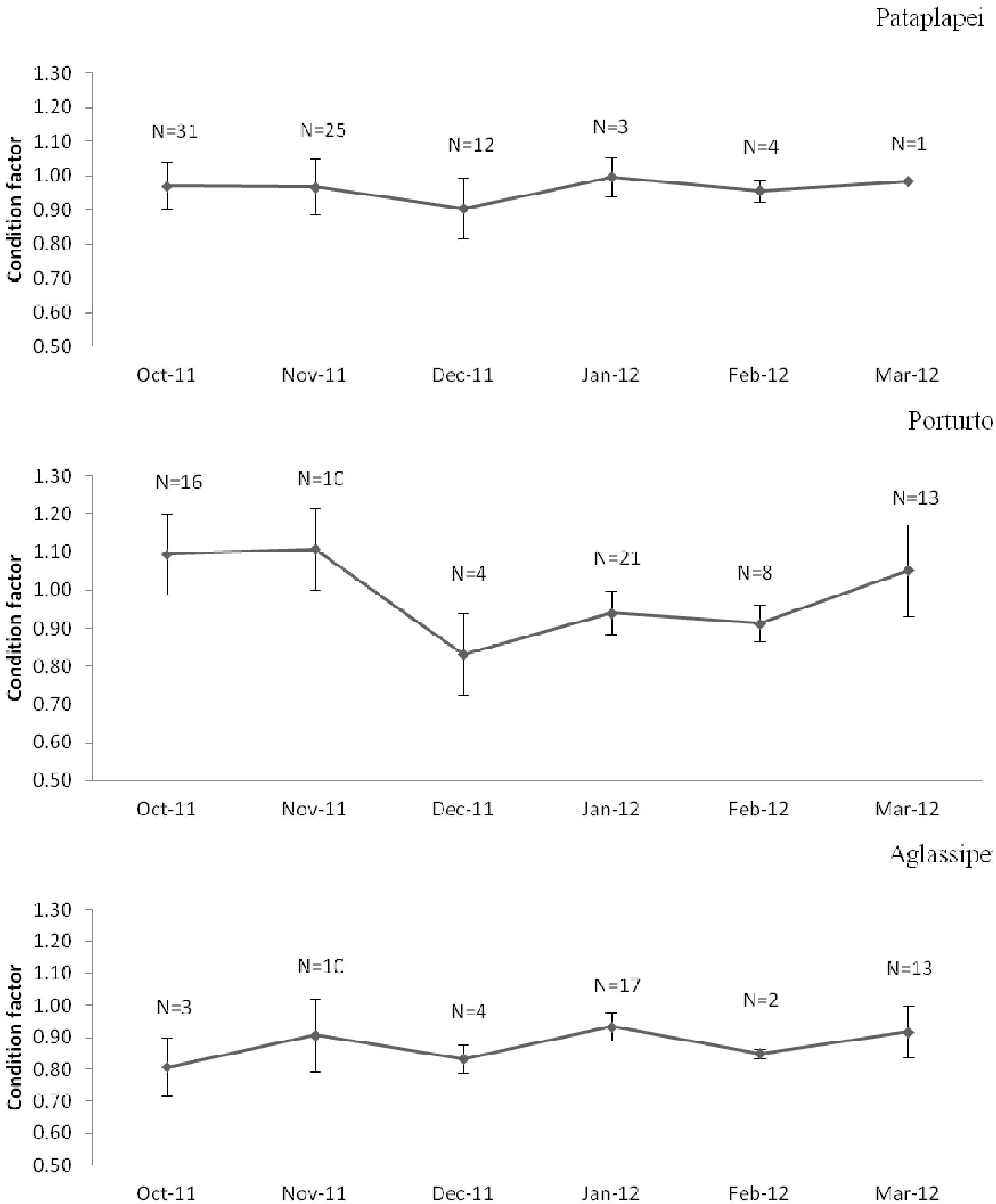

Figure 9. Condition factors (K=W*100/L^b) of *B. nurse* from 3 landing sites in the lower reaches of White Volta River over the 6 months study period (with their standard deviations as bars in the graph).

landing sites. On average, the sites Pataplapei which is upstream and Porturto which is midstream had higher condition factors than the downstream site Aglassipei. The highest condition factors which were recorded in December 2011 could be related to the low temperature observed in the month as it was this same month December 2011 that the lowest temperatures of the study were recorded. Moreover, it is reported by Chinci World Atlas (2012) that December is the coolest month in Yapei due to the influence of the North - easterly winds otherwise known as harmattan. The low temperatures possibly influence and enhance some food items and their sources for *A. baremoze* and such a providing more food for a better wellbeing of the species populations in the lower reaches of the white volta river at Yapei during the month December. It is also possible that the species

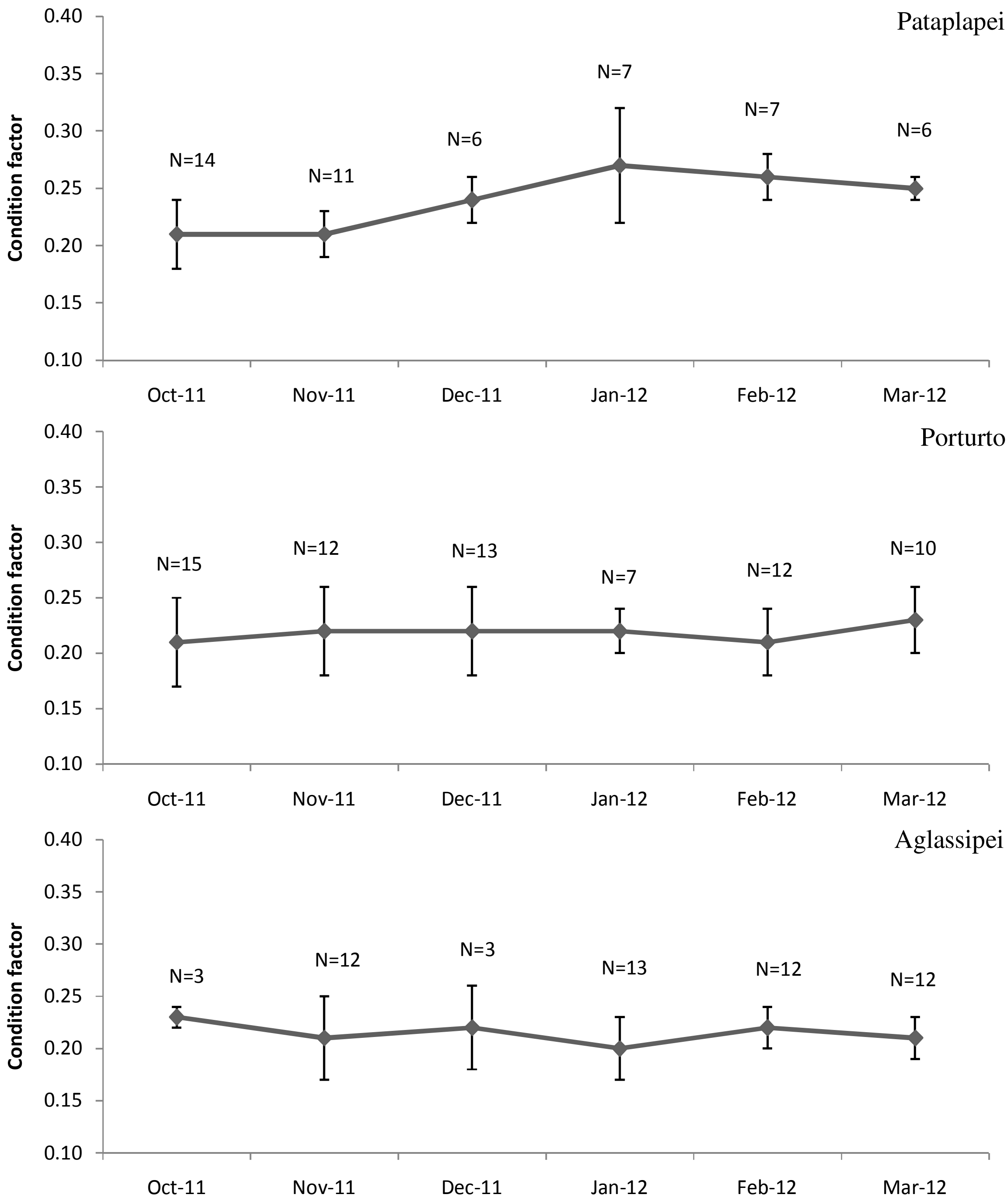

Figure 10. Condition factors (K = W*100/L^b) of *S. intermedius* from 3 landing sites in the lower reaches of White Volta River over the 6 months study period (with their standard deviations as bars in the graph).

due to low sample size and as the highest standard deviations of the species condition factors in all the 3 landing sites were obtained in the same month December, 2011.

It was evident in at least 2 landing sites namely Pataplapei (upstream) and Aglassipei (downstream) that the months January to March 2012 (dry season) on average had higher condition factors than the months October to November, 2011, suggesting *A. baremoze* in those 2 sites had a better state of wellbeing in dry season than major part of the post flood (October to December). The post flood season is the time that water level draws down and sediments and materials transported by runoff to the water would be settling. It is thus presumable that starting from December when much suspended materials would have settled; a better state of wellbeing of the species should be anticipated.

B. nurse

From the length-weight relationship of *B. nurse*, the slope *b* of 3.0737 is within the acceptable range of 2.5 to 3.5 and thus offers an approximate account of the length-weight relationship and as such the results of the length-weight relationship of *B. nurse* in the lower reaches of the White Volta River can be useful for assessing the species growth conditions. It was similar to *b* value of *A. baremoze* observed in this study. In comparing the state of wellbeing using condition factors over the 6 months period of study and also among the landing sites, it was realised that unlike the condition factors in the previous species *A. baremoze*, which was highest in December 2011, the lowest condition factors of *B. nurse* in upstream Pataplapei and midstream Porturto landing sites were rather in the month December, 2011. This shows that the 2 species although belong to the same family Alestidae, may have quite a distinct pattern of variation in the condition factors when they occur in the same habitat. The relatively lower condition factors of the species in the downstream Aglassipei as compared those of Pataplapei and Porturto may not as result of any peculiar differences in physicochemical characteristic as no significant differences in temperature, dissolved oxygen concentration or pH were observed among the landing sites during the period of the study. It is thus possible to have the same species occurring within similar locations and within common physicochemical characteristic and yet may have some differences in the state of wellbeing otherwise the condition factor. It may be necessary to study different stages of the species among the sites; since Aglassipei had relatively small sizes and large sizes of the species occurring at different times whereas the upstream Pataplapei and the midstream Porturto had all the species sampled at the middle of the size range.

S. intermedius

Length-weight relationship of the species showed that the *b* of 3.4592 though was within the acceptable range of 2.5 and 3.5, it depicted a strong allometric type of growth among the *S. intermedius* populations in the lower reaches of the White Volta River. It is also comparable to the *b* value of 3.1398 Ofori-Danson (2005) reported on the species at Yeji, Lake Volta of Ghana. The significance of this higher *b* value of the *S. intermedius* populations in the lower reaches of the white volta river is that it gives an indication that the species may be growing more allometrically than *A. baremoze* and *B. nurse*. This is agreeable as *A. baremoze* and *B. nurse* belong to the same family and have very similar features and as such similar growth types but *S. intermedius*, a catfish belonging to the family S. dae expectedly grew quite differently. Regarding monthly variations in mean condition factors of *S. intermedius* among the landing sites; very little variability was observed, meaning the species during the period of the study were not impacted by factors that could results in substantial changes of wellbeing. The month of December which was a notable period of changes in the condition factors of *A. baremoze* and *B. nurse* was not period of any significant change in *S. intermedius* condition factors. Pataplapei which is upstream and the shallowest part of the whole stretch had higher condition factors during the dry season (January 2012 to March 2012) than other the post flood season and also than the other landing sites. This can be as a result of its greatly reduced water levels during dry seasons, which might have exposed some food items for the species to feed on, and thus species in this site being in a better state of wellbeing than those from the other 2 sites.

Although, all the 3 species are semi-pelagic omnivorous, the differences in growth among the species can be related to the species physiology, some physicochemical parameters, as well as nutrition. There may be more linkages or complexities among these factors

Conclusion

The length frequencies had shown that *B. nurse* of the family Alestidae and *S. intermedius* of the family S.dae have similar size ranges with their maximum total length around 27 cm. Their occurrence was also identical as 1 cohort was realized in both species during the period of study. *A. baremoze* of the family Alestidae, on the other hand, was quite distinct in size range and occurrence. It had maximum total length of 45 cm and 2 cohorts were observed during the period of the study. The length-weight relationship is a useful tool in fishery assessment that helps in predicting weight from length required in yield assessments (Garcia et al., 1998), and in the calculation of the standing crop biomass (Martin-Smith, 1996). According to Carlander (1969); Gayanilo and Pauly (1997) and Froese (2006), the slope *b* values may range between 2.5 to 3.5. The *b* of length-weight relationships of all the 3 species were within the 2.5 to 3.5 range which is typical for tropical fish stocks. Therefore, for the 3 species, the *b* values can be used in length-weight relationships to approximate the weight of the species. Weight gain of the species will be at the same rate as growth in length. In terms of rate of growth, all the 3 had high growth rates and thus the findings on the selected species in this study support the widely-held assumption that tropical fishes are generally fast growing. The monthly variation in condition factors was very pronounced in December 2011 when the surface water temperatures were lowest. *A. baremoze* had sharp increase in condition factors in December and these increases were the highest in all the landing sites. Therefore, in December, *A. baremoze* species of a given length in the lower reaches of the white volta river are heavier than the other remaining 5 months of the study. *B. nurse* on the contrary had its lowest condition factors in 2 of the 3 landing sites in December 2011. It is probable that the low temperatures might not have directly influenced condition factors or the state of wellbeing of the fishes but rather it may have triggered other unknown factors that brought the dissimilar changes in the condition factors between the 2 species. *S. intermedius* had little variability in condition factors and even in December 2011 there was no change in its variation. Ultimately, significant drop in temperature has corresponding effects on the state of wellbeing of the species in the lower reaches of the white volta river, but it should be noted that, the temperature effects on the condition factors of the different species are not direct and are also not comparable/identical.

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REFERENCES

Abban EK (1999). Integrated development of artisanal fishes. Integrated Development of Artisanal Fisheries Project. GHA/93/008. P. 43.

Bolger T, Connolly PL (1989). The selection of suitable indices for the measurement and analysis of fish condition. J. Fish Biol. 34:171-182.

Braimah LI (2003). Fisheries Management Plan for the Volta Lake, Accra, Ghana. Ministry of Food and Agriculture, Directorate of Fisheries. P. 77.

Carlander KD (1969). Handbook of freshwater fishery biology. The Iowa State University Press, Ames, IA. 1:752.

Chinci World Atlas (2012). www.chinci.com/travel/pax/q/2293844/Yapei/GH/Ghana/0/#(Last accessed: 30.07.2012).

Dankwa HR, Abban EK, Teugels GG (1999). Freshwater fishes of Ghana: identification, distribution, ecological and economic importance. Annls.Sci. zool. P. 283.

FAO: UNDP (1971). Physico-chemical conditions of Lake Volta, Ghana. Report prepared for the Government of Ghana by FAO of the UN acting as executing agency for the UNDP. Based on the work of C.W. Czernin-Chudenitz. FI: SF:GHA:10:Technical Report. Rome: FAO. P. 77.

FAO: UNDP (1979). Volta Lake research and development project, Ghana. Project findings and recommendations. Terminal Report. Report prepared for the Government of Ghana by FAO of the UN Acting as Executing Agency for UNDP. FAO:FI:DP:GHA:67:510:71:535. Rome: FAO. P. 75.

Froese R (2006). Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. J. Appl. Ichthyol. 22:241-253.

Fulton T (1902). Rate of growth of seas fishes. Sci. Invest. Fish. Div. Scot. Rept. P. 20.

Gayanilo FC, Pauly D (1997). The FAO-ICLARM Stock Assessment Tools (FISAT). Reference manual. Rome, FAO. P. 262.

Koskela J, Pirhonen J, Jobling M (1997). Growth and feeding responses of a hatchery population of brown trout (Sulrno trutta L.) at low temperatures. Ecol. Freshw. Fish. 6:116-121.

Martin-Smith KH (1996). Length/weight relationship of fishes in a diverse tropical freshwater community, Sabah, Malaysia. J. Fish Biol. 49:731-734.

McGurk MD (1985). Effects of net capture on the post preservation morphometry, dry weight, and condition factor of Pacific herring larvae. Transactions of the Am. Fish. Soc. 114:348-355.

Obodai EA, Muhammad BA, Obodai GA, Opoku E (2009). Effect of Fuel wood on the Quality of Smoked Freshwater Fish Species Sold in Tamale Central Market, Northern Region, Ghana. Ethiopian J. Environ. Stud. Manage. 2(2):27-35.

Ofori-Danson PK (2005). An assessment of the purse-seine (winch-net) fishery in Lake Volta, Ghana. Lakes & Reservoirs: Res. Manage. 10:191-197.

Ofori-Danson PK, Vanderpuye CJ, de Graaf GJ (2001). Growth and mortality of the catfish, *Hemisynodontis membranaceus* (GeoffroySt.Hilaire), in the northern arm of Lake Volta, Ghana in: Fisheries Management and Ecology, Blackwell Sci. Ltd. 8:37-45.

Ricker WE (1975). Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada .191:382.

van Zwieten PAM, Béné C, Kolding J, Brummett R, Valbo-Jørgensen J (2011). Review of tropical reservoirs and their fisheries – The cases of Lake Nasser, Lake Volta and Indo-Gangetic Basin reservoirs. FAO Fisheries and Aquaculture Technical Paper. Rome, FAO. 557:148.

Weatherley AH, Gill HS (1987). The biology of fish growth. Academic Press, London (UK). P. 443.

Wikipedia (2012). http://en.wikipedia.org/wiki/Tamale,_Ghana (last accessed: 16.07.2012).

www.fishbase.org (Last accessed: 11.08.2012).