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# Fish Abundance and Diversity During the Pre- and Post-Impoundment Periods of the Black Volta at Bui, Ghana

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**ABSTRACT**

The fisheries of the Black Volta near the Bui dam in Ghana were studied during the pre- and post-impoundment periods between February 2011 and December 2012. The primary objective was to assess the ecological impact of the dam on the fisheries. During the survey, a sampling unit was considered as a fishers' catch per canoe per day. A three-level stratified random sampling approach was adopted. The first stratum which was defined by four designated hydrological seasons in the study area was as follows: dry season (January to March); pre-wet season (April to June); wet season (July to September); and post-wet season (October to December). The second stratum was defined by the three impoundment periods: pre-impoundment (March to May 2011); immediate post-impoundment (June to December 2011); and late post-impoundment (January to December 2012). The third stratum, on the other hand which was defined to improve sampling for accuracy was: above the dam site or reservoir area with sampling station at Bui (old town currently submerged); and below the dam site area with sampling station at Bamboi. Sixty-three fish species belonging to thirty-eight genera and twenty families were recorded in commercial gill net catches while thirteen species in nine genera and six fish families were recorded in experimental gill nets during the study. The change from riverine to lacustrine conditions during the formation of the reservoir, led to the immediate reduction in the numbers of a variety of fish families, including Latidae, Clarotidae and Distichodontidae which were very sensitive to oxygen depletion. The trend found in this study was towards the development of a community of herbivore fish species such as Sarotherodon galilaeus, Labeo coubie and Labeo senegalensis. The study revealed that the impoundment altered the fisheries characteristics of the downstream station. Hence, river management strategies should be implemented by fisheries managers and officials of the Bui Power Authority to lessen the impact of the dam on the downstream ecology.

*Keywords:* ecological impact, reservoir, lacustrine, riverine, river management

## INTRODUCTION

The change of a river to impoundment determines a series of modifications in its physical, chemical and biological characteristics observed from the filling stage until reaching a relative stability. This period is very variable and can last up to twenty years in some tropical reservoirs [2]. Dams also have significant consequences for fragmentation of habitats, blocking migration routes of organisms and causing loss of biodiversity [11]. The most obvious effects of placing dams on rivers result from the formation of new lentic environments upstream from the dam, and outflow environment downstream of the dam [12]. Cumulative effects of dams in catchment basins and tributary streams can significantly block nutrient flow, affecting plankton and fish production in river channels [15].

Despite these negative impacts, the number of damming projects worldwide keeps increasing purposely for the generation of hydroelectric power, irrigation and flood control. The Government of Ghana is contributing to the global increase in dams by creating another dam at the Bui gorge on the Black Volta for the generation of hydroelectric power. The Bui dam will create a reservoir covering an area of about 444km$^2$ at full supply level (FSL) of 183meters above sea level (masl) and holding about 12,600million m$^3$ of water which will be used for the generation of electricity. Most of the reservoir area

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will be contained within the nearby Bui National Park. The dam created by the Bui barrage is expected to impact through inundation, the assemblages of fishes, plankton and macro-benthic fauna.

A total number of 96 fish species were identified in the Ghana portion of the Black Volta [27]. Another fish survey conducted in the Black Volta within the Bui National Park identified 46 species of fish from 17 families [3]. Surveys in 2001 and 2002 at the Bui dam site, the possible reservoir inundation area, recorded a total of 49 species of fish belonging to 26 genera and 14 families [13].

Man-made lakes during their early stages of existence are studied because the new community undergoes series of ecological changes immediately after the construction before it gradually approaches a relatively stable state [29]. Thus it is predicted that after the completion of the Bui dam, there would be typical lacustrine, transitional and riverine zones, with their corresponding fish assemblages. This process will trigger a series of changes in the riverine community, which are similar to secondary community succession. Like the aftermath of creation of the Akosombo dam on the Volta River, a number of organisms would perish, few will migrate to more suitable environs and more hardy ones would adapt themselves to the changed habitats [12]. The present study has, therefore the specific objective of assessing the fish abundance and diversity in the Bui dam area of the Black Volta during the pre- and post-impoundment periods to generate information on the fisheries characteristics that would be altered as a result of river impoundment.

## MATERIALS AND METHODS

*Study area:*

The study was conducted on the Bui dam section of the Black Volta (Figure 1). The study area stretched from the Bui reservoir (upstream) to Bamboi (downstream) within latitudes 8º 09´ - 8º 16´ N and longitudes 2º 01´ - 2º 15´ W and a distance of about 37.5 km. This formed part of the Black Volta basin primarily located in north-western Ghana approximately 150 km upstream of Lake Volta. The basin covers portions of the Upper, Northern and Brong Ahafo Regions of Ghana. The basin has a total catchment area of 142,056 $km^2$ including areas outside Ghana. The portion of the Black Volta in Ghana is estimated to be 650 km in length with a catchment area of 35,105 $km^2$ [27].

*Sampling design:*

In order to provide all-year round picture of the fish production of the study area, a three-level stratified random sampling approach was adopted. The first stratum which was defined by the four designated hydrological seasons in the study area was as follows: dry season (January to March); pre-wet season (April to June); wet season (July to September); and post-wet season (October to December) [1]. The second stratum which was defined by the three impoundment periods in the study area was as follows: pre-impoundment (March to May 2011); immediate post-impoundment (June to December 2011); and late post-impoundment (January to December 2012).

The third stratum, on the other hand which was defined to improve sampling for accuracy was as follows: above the dam site or reservoir area with sampling station at Bui (old town currently submerged); and below the dam site area with sampling station at Bamboi.

*Gill net catches:*

Monthly fish sampling surveys were undertaken during the four seasons from February, 2011 to December, 2012 at the Bui and Bamboi sampling stations (Figure 1). During the survey, a sampling unit was considered as catch of a fisher utilizing a canoe normally with gillnet. The gears used by the commercial fishermen consisted of a mixed battery of multi-filament gill nets of mesh sizes of a minimum of 20 mm and maximum of 80 mm. At each sampling station, the catch from a sampling unit were separated into species and weighed in grams and the number of fish counted for individual species caught. The fish caught were identified individually using identification keys by Dankwa *et al*. [9] and Paugy *et al*. [22].

Experimental fishing was also undertaken during the sampling period to ascertain whether experimental catches could be a good indicator of trends in commercial fish catches [28]. The gears used consisted of a mixed battery of multi-filament gillnets of mesh sizes 15 mm, 17.5 mm, 20 mm, 22.5 mm, 25 mm, 30 mm and 40 mm (lateral stretched). All nets were set in the evening (1700 – 1800 GMT) by a hired local fisher using a canoe. The nets were retrieved the following morning.

*Statistical analysis:*

*Fish species diversity indices:*

The data on diversity of fish species during each hydrological season were calculated with the data from fish abundance by number using the PRIMER software version 6.1.6 [7].

Species diversity was estimated using the Shannon-Wiener index (H´) [26] from the density data (bits $ind.^{-1}$) and was expressed as:

$H´ = - \Sigma pi \log Pi$, where Pi is the proportion of individuals in the $i^{th}$ species [8].

Between 0600 and 0800 GMT. The fish caught were identified individually using taxonomic identification keys by Dankwa *et al*. (1999) and Paugy *et al*. (2003).The fish was later weighed in grams and the number of fish counted for individual species caught.

*Results:*

*Commercial gill net catches:*

Table 1 shows a checklist of fish species identified during the pre- and post-impoundment periods. Sixty-three fish species, thirty-eight genera and twenty families were recorded in 2011 with a total number of 1445 fishes sampled. The following species were recorded as the most abundant in the catches in this order: *Synodontis sorex* > *Schilbe mystus* > *Heterobranchus bidorsalis* representing 12.46%, 7.47 % and 6.44%, respectively by + presence; - absence number. *Bagrus docmak* > *Synodontis sorex* > *Labeo coubie* dominated the fish catches representing 7.12%, 5.83 % and 4.47 %, respectively by weight. In 2012, thirteen fish families, twenty-four genera and forty-two species were identified with a total number of 1268 fish sampled. The following species dominated the catches by abundance: *Labeo senegalensis* > *S. galilaeus* > *Brycinus nurse* representing 18.14%, 11.2 % and 7.57 %, respectively while *Labeo senegalensis* > *L. coubie* > *S. galilaeus* represented 20.44%, 10.99 % and 5.27 %, respectively by weight.

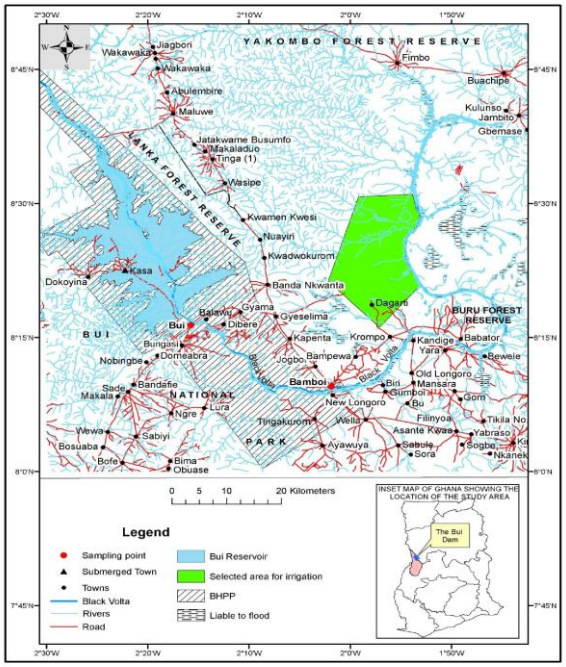


**Fig. 1:** Map of Study area showing sampling stations.

**Table 1:** Checklist of fish species identified during the pre- and post-impoundment periods using both sampling methods.

| FAMILY/SPECIES | Pre-impoundment (Mar - May 2011) | Immediate post-impoundment (Jun - Dec 2011) | Late post-impoundment (Jan - Dec 2012) |
|---|---|---|---|
| ALESTIDAE | | | |
| *Alestes baremoze* | + | + | + |
| *Alestes dentex* | - | + | + |
| *Brycinus leuciscus* | + | - | + |
| *Brycinus macrolepidotus* | + | + | + |
| *Brycinus nurse* | - | + | + |
| *Hydrocynus brevis* | + | + | - |
| *Hydrocynus forskalii* | + | + | + |
| ANABANTIDAE | | | |
| *Ctenopoma petherici* | - | + | - |
| BAGRIDAE | | | |
| *Bagrus bajad* | + | + | + |
| *Bagrus docmak* | + | + | + |
| CICHLIDAE | | | |
| *Chromidotilapia guntherii* | + | + | + |
| *Hemichromis fasciatus* | - | + | - |
| *Oreochromis niloticus* | - | + | - |
| *Sarotherodon galilaeus* | - | + | + |
| *Steatocranus irvinea* | + | - | + |
| *Tilapia dageti* | + | - | - |
| *Tilapia zillii* | + | + | - |
| CITHARINIDAE | | | |
| *Citharinus citharus* | + | + | - |

| | | | |
|---|---|---|---|
| CLARIIDAE | | | |
| *Clarias anguillaris* | - | + | + |
| *Clarias gariepinus* | - | + | + |
| *Heterobranchus bidorsalis* | - | + | - |
| *Heterobranchus isopterus* | - | + | - |
| CLAROTIDAE | | | |
| *Auchenoglanis occidentalis* | + | + | + |
| *Chrysichthys auratus* | + | + | + |
| *Chrysichthys nigrodigitatus* | + | + | + |
| CLUPEIDAE | | | |
| *Odaxothrissa mento* | + | + | - |
| CYPRINIDAE | | | |
| *Labeo coubie* | + | + | + |
| *Labeo parvus* | - | + | + |
| *Labeo senegalensis* | + | + | + |
| *Raiamas senegalensis* | + | - | - |
| DISTICHODONTIDAE | | | |
| *Distichodus brevipinnis* | + | + | - |
| *Distichodus engycephalus* | + | + | + |
| *Distichodus rostratus* | - | + | + |
| HEPSETIDAE | | | |
| *Hepsetus odoe* | + | + | + |
| LATIDAE | | | |
| *Lates niloticus* | + | + | + |
| MALAPTERURIDAE | | | |
| *Malapterurus electricus* | + | + | + |
| MASTACEMBELIDAE | | | |
| *Aethiomastacembelus nigromarginatus* | - | + | - |
| MOCHOKIDAE | | | |
| *Hemisynodontis membranaceus* | + | + | + |
| *Synodontis clarias* | - | + | + |
| *Synodontis eupterus* | + | - | - |
| *Synodontis filamentosus* | + | + | + |
| *Synodontis nigrita* | + | + | + |
| *Synodontis ocellifer* | + | + | + |
| *Synodontis schall* | + | + | + |
| *Synodontis sorex* | + | + | + |
| *Synodontis velifer* | - | + | + |
| MORMYRIDAE | | | |
| *Campylomormyrus tamandua* | + | - | - |
| *Hyppopotamyrus pictus* | - | + | + |
| *Hyperopesus bebe* | - | + | + |
| *Marcusenius abadii* | - | - | + |
| *Marcusenius senegalensis* | - | + | + |
| *Mormyrops anguilloides* | + | + | + |
| *Mormyrops breviceps* | - | + | + |
| *Mormyrus macrophthalmus* | - | + | + |
| *Mormyrus rume* | - | + | + |
| *Petrocephalus bovei* | - | + | - |
| OSTEOGLOSSIDAE | | | |
| *Heterotis niloticus* | + | + | - |
| POLYPTERIDAE | | | |
| *Polypterus birchir* | + | - | - |
| *Polypterus endlicheri* | + | - | - |
| *Polypterus senegalus* | + | - | - |
| SCHILBIDAE | | | |
| *Schilbe intermedius* | - | + | - |
| *Schilbe mystus* | - | + | + |
| *Siluranodon auritus* | - | + | + |
| TETRAODONTIDAE | | | |
| *Tetraodon lineatus* | + | + | - |

The fish families Mochokidae, Alestidae, Clariidae clearly dominated the catches representing 33.63%, 11.28 % and 11.07 %, respectively by number while Mormyridae, Clariidae and Mochokidae dominated the catches representing 14.18%, 12.7 % and 12.6 %, respectively by weight during 2011.The following fish families dominated the fish catches by number: Cyprinidae (25.71 %) > Alestidae (17.9 %) > Mochokidae (14.27 %) in 2012. The following fish families also dominated by weight: Cyprinidae (33.81%) > Alestidae (14.28 %) > Mochokidae (10.48%) in 2012. The results showed that there were more fish families, genera and species recorded in 2011 than 2012 (Figure 2).

Seasonal abundance and diversity of fishes were also observed during the study period (Figure 3). The highest fish catches were recorded in the post-wet season, while the lowest catches were recorded in the pre-wet season in 2011. By comparison, the dry season recorded the highest fish catches, while the post-wet season recorded the lowest in 2012. Diversity of fishes on the other hand, decreased from the post-wet season to the wet season in 2011. In 2012, the wet season recorded the highest diversity of fishes whilst the post-wet season recorded the lowest. Table 2 shows the distribution of fish families during the pre- and post-impoundment periods with emphasis on the impact of the dam on the abundance of the fish families.

*Experimental gill net catches:*

A total number of six fish families, nine genera and thirteen species were recorded in experimental gill nets during the study period. In order of importance by number, the fish species followed the following trend: *Brycinus nurse* (16.3 %) > *Alestes dentex* (13.04 %) > *Synodontis nigrita* (11.95 %). By weight the species were dominated by *Clarias gariepinus* (14.02 %) followed by *Mormyrops anguiloides* (12.86 %) and *Alestes dentex* (12.54 %) (Figure 4). From the above, the fish species abundance by number and weight were lower in experimental catches compared to the commercial catches. Figure 5 shows the percentage composition of fish catches by mesh sizes in experimental gill nets. The fish catches decreased in number as the mesh size increased from 15 mm to 25 mm. Thus the mesh sizes that made the highest catches by number followed this order: 15 mm (33.69 %) > 17.5 mm (24.46 %) > 20 mm (15.76 %). By comparison, the mesh sizes that made the highest catches by weight followed this order, 25 mm (30.23 %) > 17.5 mm (28.06 %) > 15 mm (15.24 %).

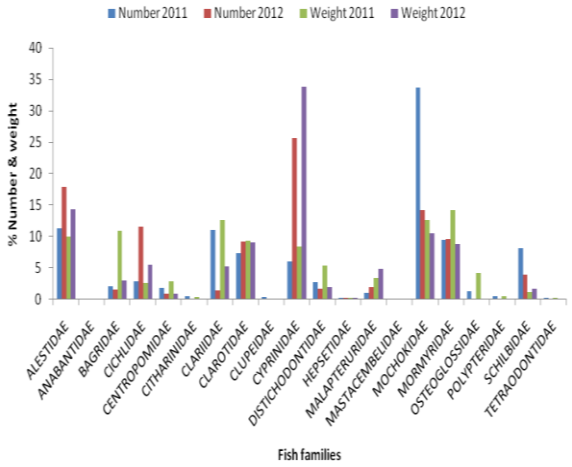


**Fig. 2:** Fish family abundance by number and weight (kg) in 2011 and 2012.

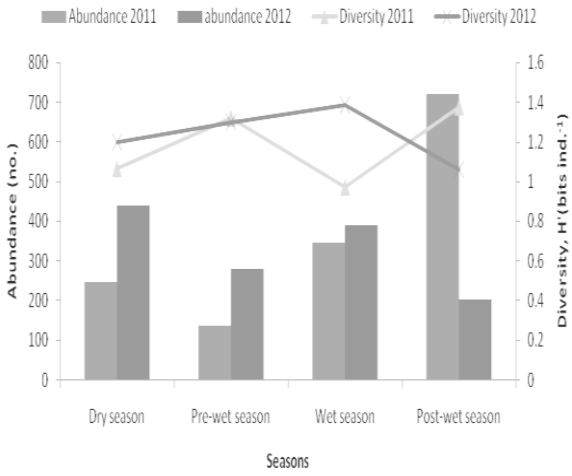


**Fig. 3:** Seasonal variations in abundance (bars) and diversity (lines/curves) of fish in 2011 and 2012.

*Discussion:*

A total of sixty-four fish species (out of ninety-six recorded for the Black Volta by [27] belonging to thirty-eight genera and twenty families were recorded during both the 2011 and 2012 sampling periods. This represented 66.7% of recorded fish

species for the Black Volta, suggesting high fish species diversity in the Bui dam area. The number of species recorded in the present study was higher than it was found in the same area by earlier studies [3,13]. This could probably be due to the length of stretch (37.5 km) of sampling along the Black Volta and relatively long duration of the sampling period of this study.

There were differences in fish family dominance by number and weight during the 2 years of study. The change from riverine to lacustrine conditions during the formation of the reservoir, led to the immediate reduction in the numbers of a variety of fish families, including Latidae, Clarotidae and Distichodontidae which are very sensitive to oxygen depletion. The trend that was indicated in this study was a change from carnivorous fish species towards the development of a community of fish species which were phytoplankton feeders such as *S. galilaeus*, *L. coubie* and *L. senegalensis*. A similar pattern was observed by Petr [23] following the initial 2 years of Lake Volta's formation. Petr however, recorded a reduction in the numbers of zooplanktivores such as *A. dentex* and *B. macrolepidotus* in Lake Volta. These differences in fish dominance in the two sampling years of the present study could also be attributed to the fact that the fish distribution was not yet stabilised, possibly because the impoundment was still in the interphase between the lacustrine and riverine conditions. This same phenomenon was also observed after the formation of Lake Kariba on the Zambezi River between Zambia and Zimbabwe. The abundance of *S. galilaeus* in the 2012 sampling year was probably due to the establishment of a large static water body during the post-impoundment period. The results also showed that three families: Clarotidae, Distichodontidae and Mochokidae differed significantly ($p< 0.05$) during the pre- and post-impoundment periods indicating that the construction of the Bui dam had impact on the abundance of only these three fish families during the study period. Hence, variations in the abundance of these fish families were altered by river impoundment.

**Table 2:** Fish family abundance by number during the pre- and post-impoundment periods (means ± standard error).

| Families | Pre-impoundment (Mar - May 2011) | Immediate post-impoundment (June - Dec 2011) | Late post-impoundment (Jan - Dec 2012) | *P* value |
|---|---|---|---|---|
| ALESTIDAE | 25.0 ± 1.6 | 56.5 ± 8.5 | 54.3 ± 4.9 | 0.54 |
| ANABANTIDAE | - | 0.5 ± 0.5 | - | 0.25 |
| BAGRIDAE | 10.5 ± 0..5 | 4.0 ± 0.0 | 5.0 ± 0.8 | 0.34 |
| CENTROPOMIDAE | 9.5 ± 0.5 | 3.5 ± 0.5 | 3.0 ± 0.4 | 0.54 |
| CICHLIDAE | 4.5 ± 0.5 | 16.0 ± 0.7 | 28.5 ± 1.5 | 0.25 |
| CITHARINIDAE | - | 0.5 ± 0.5 | - | 0.18 |
| CLARIIDAE | - | 80.0 ± 7.2 | 4.5 ± 1.9 | 0.21 |
| CLAROTIDAE | $55.0^{a}$ ± 0.0 | $13.0^{b}$ ± 0.9 | $29.0^{b}$ ± 4.7 | $0.02^{*}$ |
| CLUPEIDAE | 0.5 ± 0.5 | 1.5 ± 0.5 | - | 0.31 |
| CYPRINIDAE | 22.5 ± 2.5 | 20.5 ± 2.5 | 81.5 ± 17.7 | 0.09 |
| DISTICHODONTIDAE | $17.0^{a}$ ± 3.0 | $2.5^{b}$ ± 0.1 | $5.5^{b}$ ± 0.9 | $0.00^{*}$ |
| HEPSETIDAE | 0.5 ± 0.0 | 1.0 ± 0.1 | 1 ± 0.7 | 0.89 |
| MALAPTERURIDAE | 5.0 ± 1.0 | 2.0 ± 0.2 | 6.3 ± 0.4 | 0.68 |
| MASTACEMBELIDAE | - | 0.5 ± 0.5 | - | 0.25 |
| MOCHOKIDAE | $47.0^{a}$ ± 3.0 | $195.5^{b}$ ± 32.5 | $45.3^{a}$ ± 3.3 | $0.01^{*}$ |
| MORMYRIDAE | 2.0 ± 0.0 | 66.5 ± 8.5 | 30.3 ± 2.7 | 0.29 |
| OSTEOGLOSSIDAE | 0.5 ± 0.0 | 8.5 ± 1.5 | - | 0.26 |
| POLYPTERIDAE | 3.0 ±0. 2 | - | - | 0.08 |
| SCHILBIDAE | - | 58.5 ± 9.5 | 12.5 ± 1.7 | 0.15 |
| TETRAODONTIDAE | 1.5 ± 0.5 | - | - | 0.25 |

* indicates significant differences ($p < 0.05$); figures on the same row with different superscript letters are also significantly different ($p < 0.05$) from one another.

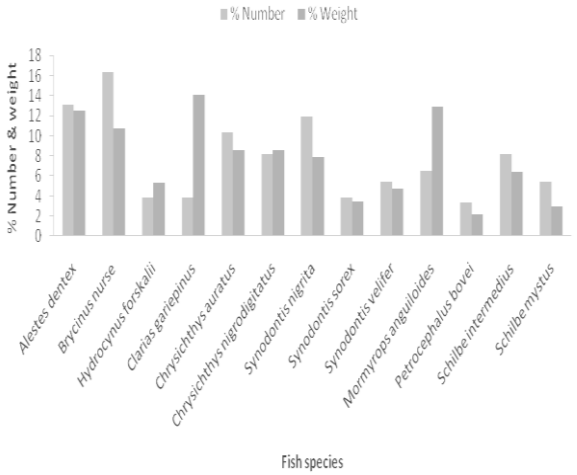

**Fig. 4:** Fish species abundance by number and weight (kg) in experimental gill net catches.

Differences in seasonal abundance were also observed during the study period. The highest numerical abundance of fishes was recorded in the post-wet season during 2011. Fish populations in reservoirs usually increase rapidly in numbers after filling and thereafter occur seasonally or from year to year [25]. According to Bhukaswan [5], the alteration of existing ecological and bio-physical processes after impoundment such as the slowing of the flow of the river both upstream and downstream and the invasion of aquatic weeds have underpinned the changes in the relative abundance of fish species. The marked differences in seasonal abundance could also possibly be due to habitat preferences associated with water levels in the river [13]. Freshwater fishes are among the most diverse groups of vertebrates in the world, exhibiting extraordinary taxonomic breadth and geographic scope in their distribution [19]. The diversity of freshwater fishes stem largely from the fact that streams, rivers, lakes and wetlands are embedded in terrestrial landscapes which limit the dispersal of freshwater organisms by promoting habitat isolation [4].

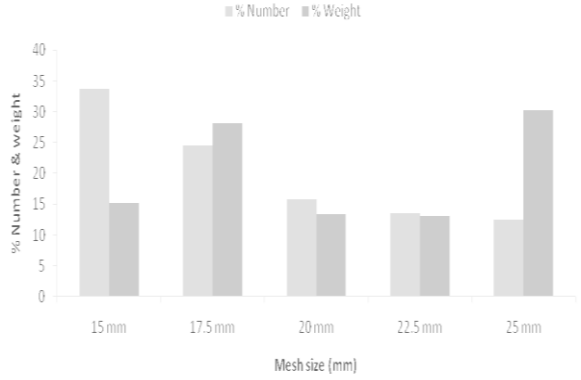


**Fig. 5:** Composition by number and weight (kg) of fish catches by mesh sizes in experimental gill nets.

The diversity of fish species in the Black Volta near the Bui dam is presently high. Patterns of diversity were investigated in relation to four hydrological seasons. Diversity of fishes in the Bui dam area of the Black Volta decreased from the post-wet season to the wet season in 2011. In 2012, the wet season recorded the highest diversity of fishes whilst the post-wet season recorded the lowest. Spatio-temporal variations in the environmental characteristics as well as resource availability are among the main determinants of the species distribution [14], species interaction [31,10] and habitat adaptations [24,20].

A total of thirteen fish species of experimental gill net catches (out of the sixty-four recorded in the commercial gill net catches) belonged to nine genera and six families. This represented only 20.3 % of the commercial catches. Vanderpuye found high correlation between experimental and commercial gill net catches, and experimental catches proved to be a good indicator of trends in commercial catches. This scenario was not confirmed in the Black Volta because comparison of the species composition of the commercial and experimental gill net catches revealed large differences perhaps due to different mesh sizes of gill nets used by the commercial fishermen. Similar observation was found on Kainji and Oyan lakes, Nigeria [17,16] and same authors confirmed that experimental gill net catches were not good indicators of trends in commercial gill net catches.

The study showed that the change from lotic to lentic conditions during the formation of the reservoir, led to the immediate reduction in the numbers of a variety of fish families. Hence, variations in the abundance of these fish families were altered by river impoundment. It is therefore recommended that, environmental flow requirements (including management of flood releases) should be used by the Bui Power Authority to reduce the impacts of changed river flow regimes on the abundance of fishes downstream.

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