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Diversity and abundance of Synodontis (Cuvier, 1816) species in the lower river Benue, Makurdi, Benue state, Nigeria

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Abstract
The diversity and abundance of the *Synodontis* species in River Benue at Makurdi were studied over a 24 month period, from January 2009 to December 2010. A total of 1104 specimens, comprising 16 species were identified. The 16 species were: *S.schall,* 635 (57.52%); *S.gambiensis,*109 (9.87%); *S.membranaceus,*106 (9.60%); *S.clarias,* 93 (8.42%); *S.omias*, 51 (4.62%); *S.melanopterus,* 28 (2.54%); *S.budgetti*, 19 (1.72%); *S.sorex*, 12 (1.09%); *S.nigrita*, 11(1.00%); *S.courteti*, 9(0.82%); *S.violaceus*, 9(0.82%); *S.resupinatus*, 8(0.72%); *S.filamentosus*, 6(0.54%); *S.batensoda*, 3(0.27%); *S.ocellifer*, 3(0.27%) and *S.vermiculatus*, 2(0.18%). Out of the 1104 specimens, 594 (54.80%) were males, while 510 (46.20%) were females, with the male to female sex ratio of 1.2:1. The diversity indices also showed that *S. schall* had the highest diversity (Shannon Weiner H 6.40; Simpson 1-D 1.00; Brillouin 6.20 and Margalef 71.30). The least was recorded from *S.vermiculatus* (Shannon Weiner H 0.69; Simpson 1-D 0.52; Brillouin 0.60 and Margalef 209.23).

Keywords: Diversity, Abundance, *Synodontis* species, River Benue.

1. Introduction
The genus *Synodontis*is commomly known as the up-side down catfish. It belongs to the family *Mochokidae,* which is made up of three genera, *Mochocus, Synodontis* and *Chinoglanis* (Reed *et al*., 1967 [36]; Holden and Reed, 1972 [20]; Araoye, 1999 [9]). It is the largest genus of the catfishes of the order *Siluriformes*, and most widely distributed (Bishai and Gideiri, 1968 [8]; Friel and Vigliotta, 2006 [16]).
The species of the genus occur throuthout most of the freshwaters of sub-saharan Africa and the Nile river system, but are restricted to water systems within the tropics (Bishai and Gideiri, 1968 [8]; Halim and Guma'a, 1989 [18]). They can be found in large rivers, smaller fast-flowing streams and massive African rift lakes (Bishai and Gideiri, 1968 [8]). Halim and Guma'a (1989) [18] reported that *Synodontis* was one of the most abundant genera in the Nile system.
Synodontis is the most common genus of the *Mochokidae* family and of great commercial importance in the inland waters of Nigeria and West Africa (Reed *et al.,* 1967 [36]; Araoye *et al.,* 2002 [6]; Lalèyè *et al*., 2006 [23]). In the Lower Benue River, it forms one of the most important commercial catches as its' species can be seen in the fish markets in Makurdi throughout the year.
There are no known published works on the diversity and distribution of the species of this genus in the Lower Benue River or elsewhere in Nigeria. The only works on the part of this river are those of Akombo *et al*., (2010 [1], 2011 [2], 2014 [3]) which were on one or a few species. This paper therefore is aimed at providing the different species that are found in the Lower Benue River and their abundance.

2. Materials and Methods
2.1 Study Area
The study was carried out in the Lower Benue River at Makurdi, Nigeria. The Lower Benue River is the portion of the Benue River that is contained within the Benue and Kogi States of Nigeria (Reid and Sydenhan, 1979 [37]). River Benue originates from the Adamawa Mountains of Cameroun and flows west across East-Central Nigeria (Nedeco, 1959 [29]). It is the largest tributary of the Niger which it joins at Lokoja in Kogi State, Nigeria.

The River has extensive alluvial plain stretching for many kilometers, which covers a distance of approximately 187 kilometers. The extensive flood plain forms breeding grounds for many fish species (Beadle, 1974 [9]). The highest water levels are in August to September and the Lowest are in March to April.

2.2 Sampling method:
The *Synodontis* specimens were purchased from the fishermen at Wadata Market landing site in Makurdi, which is one of the landing sites on the bank of River Benue. The fishes were caught with gill nets, cast nets, hooks and lines and other traps. They were procured fortnightly for 24 months and transported to the Biology Laboratory in Benue State University for identification and measurements. Identification was done using the keys of Reed *et al*., (1967) [36], Holden and Reed (1972) [20], Babatunde and Raji (1998) [8].

2.3. Species Diversity
Shannon Weiner H: this was calculated from the Genstat Discovery Edition 12 using the formular:

$$H' = -\sum pi \ln pi$$

Where pi is the proportion of individuals found in species i. For a well-sampled community, we can estimate this proportion as pi= ni/N, where ni is the number of individuals in species i and N is the total number of individuals in the community.

Simpson 1/D: Simpson' sindex is based on the probability of any two individuals drawn at random from an infinitely large community belonging to the same species:

$$D = \sum pi^2$$

Where again pi is the proportion of individuals found in species i. For a finite community, this is

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

Brillouin Index: this was calculated from the Genstat Discovery Edition 12 using the formular

$$H_B = \frac{\ln N! - \sum \ln n_i!}{N}$$

Where N is the total number of individuals and Ni is the number of individuals in the *i*th species.

Margalef Index: this was calculated from the Genstat Discovery Edition 12 using the formular

$$Mg(p) = (s - 1) / \ln N$$

Where N is the total number of individuals and is the richness index obtained from the species Richness index.

2.4. Sex Determination
The different sexes of *Synodontis* species can only be identified after dissection. Thus the fishes were dissected and the gonads were inspected using the keys of Nikolsky (1963) [31]. In the young males, testes were thin, thread like with very small projections, whitish in color and extend to about 1/3 of the abdominal cavity. In adult males, the testes were creamy in color with very conspicuous granules. The young females had thin, pink to white tubular structures occupying about 1/5 of the abdominal cavity. In adult females, that were about to spawn eggs were readily discernable in the ovaries which increased in size and filled most of the abdominal cavity (Bagenal and Tesch, 1978[8]; Halim and Guma'a, 1989 [18]).

3. Results
3.1 Species Diversity

Table 1: Diversity Indices of *Synodontis* Species in Lower River Benue at Makurdi

Species	Diversity Indices			
	Shannon-Weiner H	Simpson1-D	Brillouin	Margalef
S. batensoda	1.10	0.69	0.97	194.10
S. budgetti	2.88	0.94	2.73	112.32
S. courtetti	2.12	0.88	1.92	136.91
S. filamentosus	1.78	0.84	1.69	146.41
S. gambiensis	4.68	0.99	4.53	84.59
S. melanopterus	3.31	0.97	3.12	110.68
S. membranaceus	4.61	0.99	4.49	81.77
S. nigrita	2.07	0.88	1.90	145.74
S. occellifera	1.10	0.68	1.08	176.31
S. omias	3.91	0.98	3.77	93.20
S. resupinatus	2.07	0.88	1.96	139.43
S. schall	6.40	1.00	6.20	71.30
S. sorex	2.47	0.92	2.31	119.47
S. vermiculatus	0.69	0.52	0.60	209.23
S. violaceus	2.19	0.89	2.06	129.82
S. clarias	4.51	0.99	4.34	90.72

The diversity in the species of *synodontis* from lower River Benue is presented in table 1. Four diversity indices were used to analyze the species diversity of *synodontis* caught during the study.

Shannon Weiner H Index of measuring diversity evaluated *S. schall* to have the highest value of 6.40 and followed by *S. gambiensis* (6.48) and *S. membranaceaus* (4.61). The least value recorded was from *S. vermiculatus* (0.69). Simpson 1-D and Brillouin Index recorded the same trend in the diversity of species as *S. schall* (1.00) and *S. gambiensis, S. membranaceus* and *S. clarias* as 0.99. *S. vermiculatus* had the least diversity of 0.52.Margalef Index which presents diversity index in inverse form of actual abundance recorded 71.30 for *S. schall; S. gambiensis, S. membranaceus* 84.59 and 81.77 respectively. *S. vermiculatus* had a Margalef Index value of 209.23.

3.2 Distribution and abundance
On the whole sixteen species were identified. The most abundant species was *S.schall* with the number of 635 (57.52%), followed by *S.gambiensis* (N=109), and a percentage of 9.87%. The next species was *S.membranaceus* (N=106) with the percentage of 9.60%. Then *S.clarias* (N=93) with the percentage of 8.42%. Others were *S.omias* (N=51), 4.62%, *S.melanopterus* (N=28), 2.54%, *S.budgetti* (N=19), 1.72%, *S.sorex* (N=12), 1.09%, *S.nigrita* (N=11), 1.00%, *S.courteti* (N=9) 0.82%, *S.violaceus* (N=9), 0.82%, *S.resupinatus*(N=8), 0.72%, *S.filamentosus* (N=6) 0.54%, *S.batensoda* (N=3), 0.27%, *S.ocellifer* (N=3), 0.27% and finally *S.vermiculatus* (N=2), 0.18%.

3.3 Sex ratio
Only *S.filamentosus* and *S.vermiculatus* had sex ratios of 1:1. *S.melanopterus* had slightly more females than males (1:1.3).

S.resupinatus and *S.ocellifer* had no females at all, while *S.batensoda* had only females. The following species had slightly more males than females, *S.schall*, *S.gambiensis*, *S.membranaceus*, *S.clarias*, *S.omias, S.budgetti*, *S.sorex*, *S.nigrita*, *S.courteti* and *S.violaceus.*

Table 2 below shows the distribution and sex ratios of *Synodontis* obtained from the River Benue at Makurdi during the period of study from January, 2009 to December, 2010.

Table 2: Percentage Abundance and Sex Ratio of the Species of *Synodontis* in the Lower River Benue at Makurdi

Species	Male (M)	Female (F)	Total	% Abundance	Sex Ratio (M:F)
S.schall	329	306	635	57.52	1.1:1
S.gambiensis	56	53	109	9.87	1.1:1
S.membranaceus	59	47	106	9.60	1.3:1
S.clarias	53	40	93	8.42	1.3:1
S.omias	33	18	51	4.62	1.9:1
S.melanopterus	12	16	28	2.54	1:1.3
S.budgetti	12	7	19	1.72	1.7:1
S.sorex	7	5	12	1.09	1.4:1
S.nigrita	6	5	11	1.00	1.2:1
S.courteti	6	3	9	0.82	2:1
S.violaceus	6	3	9	0.82	2:1
S.resupinatus	8	0	8	0.72	1:0
S.filamentosus	3	3	6	0.54	1:1
S.batensoda	0	3	3	0.27	0:1
S.occellifer	3	0	3	0.27	1:0
S.vermiculatus	1	1	2	0.18	1:1
Total	594	510	1104	100	

4. Discussion

Throughout the 24 months of study (January, 2009–December, 2010) only 16 species of *Synodontis* were encountered. The most abundant species was *S.schall* with a total number of 635 specimens (329 males and 306 females) giving a percentage of 57.52% followed by *S.gambiensis* with a total of 109 specimens (56 males and 53 females) and a percentage of 9.87%, then *S.membranaceus* with the total number of 106 specimens (59 males and 47 females) and a percentage of 9.60%. *S.clarias* had a total number of 93 specimens with 53 males and 40 females, giving a percentage of 8.42%. *S.omias* had a total of 51 (33 males and 18 females) with the percentage of 4.62%. *S.melanopterus* had 28 specimens (12 males and 16 females) with a percentage of 2.54%, *S.budgetti* had 19 specimens (12 males and 7 female) with a percentage of 1.72%, *S.sorex* had 12 specimens (7 males and 5 females) with a percentage of 1.09%, *S.nigrita* had 11 specimens (6 males and 5 females) with a percentage of 1.0%, *S.courteti*, and *S.violaceus* had 6 males and 3 females each, (a total of 9 each) with a percentage of 0.82% each. *S.resupinatus* had 8 males and 0 females with a percentage of 0.72%, *S.filamentosus* had 3 males and 3 females (a total of 6) with a percentage of 0.54%. *S.batensoda* had 0 males and 3 females and *S.ocellifer* had 3 males and 0 females with a percentage of 0.27% each and finally *S.vermiculatus* with 1 male and 1 female and a percentage of 0.18%.

S.schall was the most abundant species out of all the 16 species found in this study. It contained 635 (57.52%) specimens out of the 1104, comprising more than half of all the specimens obtained for the period. The abundance of *S.schall* has been observed in other places as well. Lalèyè *et al.,* (2006) [23] observed that *S.schall* was more abundant in Ouémé River than *S.nigrita*. Midhat *et al.,* (2012) [27] reported that *S.schall* was one of the most common species in the Nile River, at Gizza. Halim and Guma'a (1989) [18] reported that *S.schall* was among the commonest species of *Synodontis* in the Nile at Sudanese waters. Ofori-Danson (1992) [33] showed that *S.schall* contributed about 50% of the biomass of the five *Synodontis* species found in Kpong Head pond, Ghana. Araoye (1999) [5] indicated that *S.schall* was caught abundantly in Asa Lake. Akombo *et al*., (2011) [2] also reported that *S.schall* was more abundant in River Benue at Makurdi than the other species of *Synodontis*. Araoye (1997) [4] explained that the abundance and fairly distribution of *S.schall* throughout the sampling period could be attributed to its successful adaptation within its environment due to its diverse feeding habits and low predation. He also reported that the distribution of *S.schall* could be due to its ability to tolerate to some extent hard environmental conditions. Willoughby (1979) [38] reported that the presence of physostomous swim bladder, bony shield of the head and high fat deposition had availed *S.schall* the opportunity to occur universally in freshwater bodies.

Sex ratio which is the percentage of males to females is generally dealt with in the study of reproduction to understand the sexual behaviour of the fish under study during different months of the year (Shenouda *et al*., (1994) [35]. The ideal value of sex ratio as reported by Hashem (1981) [19] is 1:1. However, it may vary according to the year of capture (Latif and Shenouda, 1973) [24], the season (Nikolsky, 1963 [31]; Downs and White, 1997 [14]), the type of gears, and the month (Lalèyè *et al*., 2006) [23] and length group (Dulcic *et al*., 2003) [15]. Geographical location and ecological habitat can also influence sex ratio (Willoughby, 1979) [38]. In some cases, males may prevail in some populations (Downs and White, 1997 [14]; Midhat *et al*., 2012 [27]) or females in other ones (Bishai and Abu-Gideiri, 1968 [12]; Olele and Etim, 2011 [35]).

In this study, *S.batensoda* with only 3 samples was found to be all females with the male to female sex ratio of 0:1. *S. resupinatus* had 8 samples and all were males with the male to female ratio of 1:0, *S.ocellifer* had only 3 samples which were all males, also with the male to female sex ratio of 1:0. *S.filamentosus* and *S.vermiculatus* had the male to female sex ratios of 1:1. All the other species had slightly more males than females (Table 3). This is in agreement with the works of Midhat *et al.,* (2012) [12] on *S.shall* in Egypt, where they found that the number of males exceeded that of the females with the sex ratio of 1:0.83 (males 361, females 298). Offem *et al.,* (2009) [32] observed a similar situation in the Cross River inland wetlands. Akombo *et al*., (2011) [2] observed in River Benue at Makurdi that *S.clarias* and *S.resupinatus* had more males than females with the sex ratios of 1.2:1 and 8:1 respectively. The presence of more males according to Offem *et al*., (2009) [32] could be favourable to the fishery as it could serve as a regulatory mechanism for the sex ratio. This may be attributed to majority of the gears being set close to breeding grounds or the females avoiding the gears. Fryer and Iles (1972) [17] pointed out that in the African water bodies it was common that the populations of male fish dominated because they generally presented more growth than females without this representing a risk situation for the fishery.

Luff and Bailey (2000) [25] reported that, in *S.schall* samples taken from River Nile at El-Minya, Egypt, female fish outnumbered males by a ratio of 1.5:1. In the Kpong Headpond in Ghana, it was reported that *S.schall* females outnumbered males (Ofiri-Danson, 1992) [33]. Akombo *et al*., (2011) [2] also observed that *S.membranaceus* had more females than males with the male to female sex ratio of 1:1.6

while *S.schall* had the sex ratio of 1.1:1.1. The pattern of variations between *S.schall* populations reflects time and locality factors.

Mekkawy and Hassan (2011) [26] suggested that when choosing a species of freshwater fishes for culture and reproduction, sex ratio should be a consideration. According to Khallaf and Authman (2010) [22], sex ratio in fishes varied from one species to another. Nieto-Navarro *et al.,* (2010) [30] explained that the differences in observations could be due to seasonal variability of the environment, food availability, gear selectivity, sampling size and length interval within different areas or habitat suitability.

The abundance of *S. schall* reported in the work is further confirmed in the values recorded from the diversity indices obtained. For all the indices used, the species recorded the most notable value to explain its abundance.

5. Conclusions

Out of the sixteen species identified, *S.schall* was the most abundant with more than half the number of all the species (57.52%). It is the only species that occurred in all the 24 months of the study period while the other species occurred only in certain months of the year and absent in others.

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