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Full Length Research Paper

Growth and feed utilization in *Clarias gariepinus* fingerlings fed on *Acacia auriculiformis* leaf supplemented diets

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Effect of 'Earleaf' plant (*Acacia auriculiformis*) as feed additive was examined on *Clarias gariepinus* fingerlings (4.2±0.5 g) over a period 56 days against farm-made feed which served as the control. *A. auriculiformis* leaves were collected, air-dried (under shade), powdered and added at varying inclusion levels (0, 0.5, 1.0, 1.5 and 2.0%) to basal diets containing 40% crude protein. Fish were randomly distributed into tanks at 10 fish tank^{-1} with each treatment in triplicate. *C. gariepinus* were fed at 5% body weight between 8:00 – 9:00 and 16:00 – 17:00 h for 56 days. At the expiration of the feeding trials, results showed significant differences (p<0.05) in growth performance and nutrient utilization indices measured. The highest weight gain (WG), feed intake (FI), specific growth rate (SGR), protein efficiency ratio (PER) and best feed conversion ratio (FCR) were recorded in *C. gariepinus* fed *A. auriculiformis* at 1.5% supplementation level. Fish fed *A. aurculiformis* supplemented diets had higher WG (3.60 and 5.73 g) than those fed the control diet. Incorporating *A. auriculiformis* into fish diets did not have any adverse effect on the physiochemical water parameters measured as they were within the recommended ranges for raising warm water fish species. Results showed that diet supplementation with *A. auriculiformis* at 1.5 and 2.0% gave best growth performance and higher protein conversion, hence, the recommendation for diet supplementation at 1.5 or 2.0% inclusion levels.

Key words: Catfish, growth, *Acacia auriculiformis*, utilization.

INTRODUCTION

There is the rising need to improve food security, among economically challenged developing countries. Aquaculture has become an increasingly important option for improving animal protein intake from 40 to about 60% so as to fulfil a core deliverable sustainable development goal. This can only be achieved using high-quality feeds rich in protein and other essential nutrients to improve growth while still maintaining the animal's health (Soltan and El-Laithy, 2008). The use of natural products as cheaper sources of growth promoters is making waves in the aquaculture industry as opposed to the expensive synthetic antibiotics and other growth promoters.

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The use of medicinal plants (ginger cloves, funnel seeds, fenugreek seeds, garlic bulbs, black seeds, peppermint leaves, etc) as natural growth promoters have been proven to significantly improve weight gain, survival and feed conversion rates in fish by about 50% (El-Dakar, 2004; Shalaby, 2004).

The African catfish *Clarias gariepinus* is a major cultivated fish of high commercial value in Nigeria with a production of 257, 368 tons in 2014 using intensive culture systems (FAO, 2016). This is because of its ability to consume supplementary feeds (agricultural by-products), good conversion of feed to flesh (can utilize 2 g of feed to gain 1 g of flesh), resistance to disease, ability to reproduce in captivity, fast growth rate and tolerance to a wide range of environmental conditions such as temperature and dissolved oxygen. The economic importance of this species has increased tremendously as a result of its extensive use in aquaculture (De Graff and Janssen, 1996). In Nigeria, revenue generation from *C. gariepinus* was 766, 024 USD in 2014 compared to 519, 060 USD in 2010 (FAO, 2016).

Acacia auriculiformis, commonly called “Earleaf Acacia or Australian wattle” belongs to the family Fabaceae. The tree grows tall and thrives in poor soils and is well adapted to areas with extended dry seasons (Norman, 2000). Various extracts (leaf, stem, bark and root) of this plant have shown antioxidant benefit on living organisms generally (Singh et al., 2007). It is reported to be significantly effective against helminthic diseases, filariasis and microbial diseases (Mandal et al., 2005; Ghosh et al*.,* 1993). The root extract is known to be useful in the treatment of various aches, pains and sore eyes in man. The Aborigines of Australia were known to have used the bark extract to treat rheumatism effectively (Girijashankar, 2011).

The major objective of this study was to evaluate the effect of the natural herb; *A. auriculiformis* as a growth promoter in *C. gariepinus* fingerlings, thus, deviating from the conventional use of synthetic additives. The conventional additives commonly used in this part of the globe are the antibiotic growth promoters which are not readily available to the local fish farmers.

MATERIALS AND METHODS

Preparation of test ingredient and experimental diets

Fresh leaves of *A. auriculiformis* were collected from the matured tree within the main campus and authenticated by the Department of Crop Soil and Pest Technology, The Federal University of Technology, Akure, Ondo State, South-Western Nigeria. Leaves (fresh) of about 1.5 g were air dried at room temperature or under shade (25 – 27°C) and milled to fine powder using Maulinex electric blender. All dietary ingredients; fish meal, soybean meal, groundnut cake, yellow maize, rice bran, vegetable oil, bone meal, etc were purchased in a local market (Oja-Oba). Ingredients were then weighed on a top load balance (METLER TOLEDO, PB 8001 LONDON) and milled to powder (less than 20 µm). *A. auriculiformis* leaf powder (AALP) was carefully added at varying inclusion (0.5, 1.0, 1.5 or 2.0) % levels to five iso-nitrogenous (40% crude protein) basal diets (Table 1). All ingredients were thoroughly mixed using a kitchen mixer to obtain a homogenous meal mixture. The mixture was then steam pelleted through a 0.6 mm diameter die opening using Hobart pelletizer (A-2007 MODEL, UK).

Pellets were oven-dried at 50°C for 48 h, cooled to room temperature before been bagged in airtight containers and refrigerated prior to use. Experimental diets were designated as AALP1 (control), AALP2 (0.5% *A. auriculiformis*), AALP3 (1.0% *A. auriculiformis)*, AALP4 (1.5% *A. auriculiformis)* and AALP5 (2.0% *A. auriculiformis)* based on the test ingredient inclusion levels. Proximate compositions of experimental diets were assayed according to Association of Official Analytical Chemists, AOAC (2010) methods.

Experimental design

The experimental site was Teaching and Research Farm of the Department of Fisheries and Aquaculture Technology, The Federal University of Technology, Akure, Ondo State, Nigeria. All analyses took place at the Central Research Laboratory of the University. The experimental design was completely randomized with a single source of variation; the quantity of test ingredient (*A. auriculiformis* leaf powder) in each diet.

C. gariepinus fingerlings (4.20 ± 0.15) g were procured from KEAFI Farms in Akure, Ondo State, Nigeria and transported in oxygenated bags to experimental site. Fish were acclimated to laboratory conditions for 14 days, during which they were fed with a commercial diet-Durante Feeds. *C. gariepinus* were randomly distributed at a density of 10 fish tank^{-1} into fifteen aerators-fitted rectangular glass tanks with each treatment in triplicate. Each experimental unit is a 60 L water capacity plastic tank filled to 40-L level.

Feeding trial

Experimental diets were fed to fish twice daily at 5% body weight in two equal portions between 8:00 - 9:00 h and 17:00 - 18:00 h for 56 days. Experimental tanks were cleaned weekly and culture water replaced with fresh water on alternate days.

Experimental analyses

Chemical compositions of dry *A. auriculiformis* leaf and pooled fish samples were analyzed using methods described by Association of Official Analytical Chemists, AOAC (2010). Some water quality parameters such as dissolved oxygen, ammonia, nitrate, pH and temperature were monitored daily using a multi parameter kit (digital YSI Meter; Model 57 and Knick Portamess; Model 912). Fish in each experimental unit were batch-weighed (10 fish/tank or batch) fortnightly using Citizen’s sensitive weighing balance with maximum capacity of 5 kg. The following growth and feed utilization parameters were evaluated following appropriate procedure:

Weight Gain (MWG) (g) = $WG = \frac{W_f - W_i}{n}$

Specific Growth Rate (SGR %day^{-1}) = $SGR = \frac{ln\frac{W_f}{n} - \frac{W_i}{n}}{t} \times 100$

Where: W1 and W2 are natural log of initial and final weight and T is number of experimental days.

Protein fed = % protein × Total diet consumed

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Total feed consumed}}{\text{Weight gained}}$$

$$\text{Feed intake (FI) (g)} = \frac{\text{5\% Body weight} \times \text{Experimental period}}{\text{Number of fish stocked}}$$

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Weight gain}}{\text{Protein intake}}$$

Statistical analysis

The effects of *A. auriculiformis* leaf powder as an additive on growth, nutrient utilization and body composition of *C. gariepinus* were statistically analyzed using one-way analysis (ANOVA). Data was first tested for homogeneity of variance and suitably transformed where significant differences were observed. Values generated were presented as mean (± Standard error). Significant differences (p<0.05) among means were compared and separated using Turkey's multiple range test (Zar, 1996) where applicable.

RESULTS

Chemical compositions of experimental diets

The result of proximate analysis of experimental diets is presented in Table 1. Table 2 shows chemical composition of *A. auriculiformis* leaf meal having a high concentration of nitrogen free extract. Crude protein, NFE and gross energy contents of experimental diets were not significantly different (p>0.05). Crude protein content in experimental diets were iso-nitrogenous and not significantly different (p>0.05) indicating that no prejudice was introduced in the process of compounding experimental diets (Table 1). Results showed that there was a linear increase of crude lipid in feed (from 5.45% in AALP1 - control to 7.55% in treatment AALP5) as the quantity of test ingredient (*A. auriculiformis*) increased. Also, a similar but opposite trend was observed in ash and crude fibre contents as the quantity of *A. auriculiformis* increased from 4.69 to 3.39%.

Water quality parameters

The values of water quality parameters measured are shown in Table 5. There were no significant differences (p>0.05) in all the parameters measured among treatments. Dissolved oxygen ranged from 5.76 to 6.35 mg l^{-l}, temperature from 26.40 to 27.80°C, while pH ranged from 8.20 to 8.34. Values of nitrate concentration were between 0.02 and 0.09 mgL^{-l} while ammonia concentration was between 0.001 and 0.002 mg L^{-l}.

Growth performance and nutrient utilization

At the expiration of the experiment, growth evaluation indices were used to assess response of *C. gariepinus* to *A. auriculiformis* leaf powder supplemented diets and the result is presented in Table 3. There were no significant differences (p>0.05) in the initial stocking weight of *C. gariepinus* in all treatments. Also, no mortality was recorded during the experimental period and fishes accepted diets administered as they were observed to be actively fed. Results showed that *C. gariepinus* fed diet AALP4 (1.5% *A. auriculiformis*) had the highest mean weight gain (13.63 g) while the least was recorded fish fed the control diet. The increase in weight did not follow a linear trend, that is, it was not dependent on the quantity of the test ingredient. Feed intake increased with inclusion levels of test ingredient with the highest value (50.32 g) recorded in fish fed diet AALP4 (1.5 g *A. auriculiformis*). Similarly, there were significant differences (p<0.05) and improvement in feed conversion ratio (FC), specific growth rate (SGR) and protein efficiency ratio (PER) of *C. gariepinus* fed *A. auriculiformis* supplemented diets in comparison with the control. The best FCR (3.70), SGR (1.09) and PER (0.34) were recorded in fish fed diet AALP4.

Chemical body composition of *C. gariepinus*

Chemical composition (dry matter) of *C. gariepinus* fed different inclusion levels of *A. auriculiformis* supplemented diets is presented in Table 4. Moisture and crude lipid contents in fish were not significantly different (p>0.05) in fish in all the treatments. Crude protein contents were significantly different (p<0.05) in *C. gariepinus* fed test diets when compared with the control, but not statistically different within the test diets treatment groups, although fish fed diet AALP5 had the highest body protein retention. A linear increase in body ash content of *C. gariepinus* was observed with the highest recorded in fish fed diet AALP5 while a downward (decrease) trend was observed in NFE content with the highest recorded in fish fed diet AALP1 (control).

DISCUSSION

In recent years, focus has shifted from the use of synthetic substances as additives in fish diets to use of plants and its by-products for health reasons. Several medicinal plants have been used in nutritional studies in the field of aquaculture such as marjoram (*Majorana syriaca*), licorice (*Glycyrrhiza glabra*) roots, black (*Nigella sativa*) seeds, peppermint (*Mentha piperita*), caraway (*Carum carvi*) seed, fennel (*Foeniculum vulgare*) seed, fenugreek (*Trigonella fornum-graceum*) seeds and ginger (*Zingiber officinale*) cloves (El-Dakar et al., 2008; Khalil et al., 2009; Al-Absawy, 2010; Abdelhamid, 2010). There

Table 1. Gross and proximate compositions (% DM basis) of experimental diets.

Ingredients	AALP1 (Control)	AALP2	AALP3	AALP4	AALP5
Fish meal	23.00	23.00	23.00	23.00	23.00
Soybean Meal	26.00	26.00	26.00	26.00	26.00
Groundnut Cake	28.00	28.00	28.00	28.00	28.00
Yellow Maize	11.00	11.00	11.00	11.00	11.00
Vegetable Oil	4.00	4.00	4.00	4.00	4.00
Rice Bran	2.00	2.00	2.00	2.00	2.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Vit. / Min. Premix*	2.00	2.00	2.00	2.00	2.00
Binder	2.00	1.50	1.00	0.50	0.00
Acacia auriculiformis leaf Powder (AALP)	0.00	0.50	1.00	1.50	2.00
Proximate composition (dry matter) of experimental diets (%)					
Crude protein	40.01±0.07[a]	40.03±0.06[a]	40.06±0.09[a]	40.08±0.03[a]	40.09±0.05[a]
Ether extract	5.45±0.42[a]	6.23±0.39[b]	6.42±0.45[b]	6.95±0.58[b]	7.55±0.67[c]
Ash	16.96±0.42[c]	15.94±0.26[b]	15.48±0.12[b]	14.56±0.45[a]	14.79±0.30[a]
Crude fibre	4.61±0.77[b]	4.23±0.04[b]	3.91±0.29[ab]	3.51±0.77[a]	3.39±0.04[a]
**NFE	26.46±0.02[a]	26.11±0.41[a]	25.33±0.30[a]	25.39±0.51[a]	25.43±0.89[a]
***Gross energy (kcal 100 g^{-1} DM)	400.55±5.04[a]	406.17±6.24[a]	403.69±6.12[a]	408.30±6.31[a]	413.93±6.75[a]

Vitamin premix*: An Animal Care® Optimix Aqua product for catfish, containing the following per 5 kg of premix: A = 20 000 000 IU, D3 =2 000 000 IU, E = 200 000 mg, K3 = 10 000 mg, B2 =12 000 mg, B12 = 9 mg, B1 = 6 000 mg, B6 = 11 000 mg, C = 50 000 mg, Folic acid = 2 000mg, Niacin =80 000 mg, Calpan = 25 000 mg, Biotin = 100 mg, x Zinc =30 000 mg, Copper = 5 000 mg, Iron = 30 000 mg, Manganese = 50 000 mg,Iodine = 1 000 mg, Selenium = 100 mg, Antioxidant = 125 000 mg, **NFE: Nitrogen free extract, ***Gross energy: 5.65, 9.45, 4.0 and 4.0 kcal/g of protein, ether extract, crude fibre and NFE (Jobling, 1983). DM = dry matter.

Table 2. Proximate composition (dry matter) of *Acacia auriculiformis*.

Parameter	Composition (%)
Crude protein	14.69±0.77
Ether extract	2.08±0.17
Crude Fibre	33.42±0.54
Ash	7.01±0.14
Nitrogen free extract	35.48±0.23

has not been any report on *A. auriculiformis* as a growth enhancing agent in *C. gariepinus* fingerlings, hence, its use in this study. *A. auriculiformis* is a leguminous plant in nature and previous work on the seeds had been reported to contain 31.8% crude protein, 7.5% crude fibre and 49.2% NFE (Sathya and Siddhuraju, 2013). Its high NFE content was further confirmed in this study when the leaf was examined. Crude protein of 40% in experimental diets was within recommended range used by other researchers in compounding diets for *C. gariepinus*. Similar studies using medicinal plants in fish diets have crude protein ranging from 35-45% (Harikrishnan et al., 2011).

Some medicinal plants have been reported to have growth stimulating effect when consumed by animals and this was also observed in this study as *C. gariepinus* fed *A. auriculiformis* supplemented diets had better weight gain than the control. Improved growth performance and better nutrient utilization was recorded in Nile tilapia fed fenugreek sprouts meal (Zaki et al., 2012). Goodarzi and Nanekarani (2014) reported an improvement in growth (50%) performance of broilers fed *Mentha pelegium* supplemented over the control. Similarly, Talpur (2014) who incorporated peppermint (*M. piperita*) as a feed additive in the diet of Asian seabass (*Lates calcarifer*) recorded improved growth. Furthermore, this result also agrees with that of Turan and Akyurt (2005) used red clover (*Trifolium pretense)* extract as a growth-enhancing agent in catfish, *C. gariepinus.* Mahdavi et al. (2013) also reported better growth indices when *Aloe vera* was

Table 3. Growth and nutrient utilization of *C. gariepinus* fed various levels of *Acacia auriculiformis* supplemented diets.

Parameter	AALP1 (Control)	AALP2	AALP3	AALP4	AALP5
Initial weight (g)	4.28±0.05^{a}	4.65±0.07^{a}	4.30±0.03^{a}	4.34±0.09^{a}	4.40±0.09^{a}
Final weight (g)	12.18±1.43^{b}	17.64±1.9^{a}	15.80±1.33^{ab}	17.97±1.82^{a}	16.50±1.27^{ab}
Weight gain (g)	7.90±1.50^{c}	12.99±1.92^{ab}	11.50±1.3^{b}	13.63±1.96^{a}	12.10±1.33^{b}
Feed intake (g)	34.10±4.72^{c}	49.40±7.22^{a}	44.24±4.74^{b}	50.32±5.73^{a}	46.20±6.33^{b}
FCR	4.31±0.35^{a}	3.80±0.70^{ab}	3.85±0.20^{ab}	3.70±0.56^{b}	3.82±0.45^{ab}
SGR (% day $^{-1}$)	0.82±0.04^{b}	1.04±0.01^{a}	1.02±0.06^{a}	1.09±0.04^{a}	1.04±0.06^{a}
PER	0.20±0.00^{b}	0.32±0.03^{ab}	0.29±0.01^{ab}	0.34±0.05^{a}	0.30±0.03^{ab}

Means in a given column with the same superscript letter were not significantly different at p<0.05. SGR=specific growth rate, PER = protein efficiency ratio, FCR = feed conversion ratio.

Table 4. Chemical composition of whole body of *C. gariepinus* fingerlings fed experimental diets (dry weight basis).

Parameter (%)	AALP1 (Control)	AALP2	AALP3	AALP4	AALP5
Moisture	6.48±0.13^{a}	6.24±0.35^{a}	6.41±0.015^{a}	6.49±0.00^{a}	6.27±0.03^{a}
Ash	16.90±0.3^{a}	16.93±0.17^{a}	16.94±0.415^{a}	17.82±0.10^{ab}	18.32±0.04^{b}
Lipid	9.18±0.53^{a}	9.22±0.57^{a}	9.47±0.40^{a}	9.63±0.450^{a}	9.86±0.28^{a}
Protein	62.94±0.02^{a}	63.40±0.90^{b}	63.46±1.21^{b}	63.65±0.48^{b}	63.74±0.15^{b}
NFE	4.50±0.04^{b}	4.21±0.09^{b}	3.72±0.10^{ab}	2.41±0.08^{a}	1.81±0.09^{a}

Means in a given column with the same superscript letter were not significantly different at p<0.05.

Table 5. Physio-chemical parameters of water in experimental units.

Parameter	AALP1 (Control)	AALP2	AALP3	AALP4	AALP5
Dissolved oxygen (mg L $^{-1}$)	6.35±0.21^{b}	6.18±0.17^{b}	6.02±0.38^{a}	5.83±0.09^{a}	5.76±0.11^{a}
Temperature (°C)	26.40±0.43^{a}	27.60±0.32^{a}	27.20±0.15^{a}	27.70±0.23^{a}	27.80±0.15^{a}
pH	8.34±0.23^{a}	8.31±0.00^{a}	8.27±0.01^{a}	8.24±0.08^{a}	8.20±0.02^{a}
Nitrate (mg L $^{-1}$)	0.02±0.01^{a}	0.07±0.01^{a}	0.09±0.01^{a}	0.03±0.01^{a}	0.05±0.01^{a}
Ammonia (mg L $^{-1}$)	0.001±0.00^{a}	0.002±0.00^{a}	0.001±0.00^{a}	0.001±0.00^{a}	0.002±0.00^{a}

Means with the same superscript in the same row are not significantly different (p>0.05).

included in the diets of common Carp (*Cyprinus carpio*). Soosean et al. (2010) also corroborated the fact that *C. gariepinus* fed on medicinal plant extract supplemented diets exhibited faster growth than those fed with the control diet.

In this study, dietary supplementation of *C. gariepinus* diets with *A. auriciliformis* improved SGR in all treatments when compared with the control. The highest SGR was observed in fish fed diet AALP4 (1.09% day^{-1}). Previous study using fresh or dried garlic (*Allium sativum*) as a natural feed supplement on growth performance and nutrients utilization of the Nile Tilapia (*Oreochromis niloticus*) showed that fish fed with garlic supplemented diets showed high SGR over the control (Omosowone, 2011; Kumar et al., 2013). Similarly, Dada and Sonibare (2015) recorded improved weight gain (40%) using Siam weed (*Chromolaena odorata*) in the diet of *C. gariepinus*. In this experiment, *C. gariepinus* fed diet AALP4 had better FCR and PER compared with the other treatments and control. This finding is contrary to that of Pakravan et al. (2012) who reported no significant difference in FCR of common carp, *C. carpio* fed dietary willow herb, *Epilobium hirsutum*. However, other researchers (Yu et al., 2008; Dada and Ikuerowo, 2009) have reported improved FCR in *C. gariepinus* using medicinal plants.

Moisture and lipid contents of whole body composition of *C. gariepinus* fed all diets were not significantly different (p>0.05) showing that inclusion of *A. auriculiformis* leaf powder had no negative effect. This result is in agreement with those reported by Talpur (2014) and Pakravan et al. (2012) that inclusion of medicinal plant; fenugreek seed did not affect lipid and moisture contents in Nile tilapia. Body protein composition of *C. gariepinus* fed *A. auriculiformis* supplemented was significantly different from control. It was observed that although protein retention in fish body was not different statistically, yet, *C. gariepinus* fed diet AALP5 had higher body protein content. Higher ash content was observed in the body of *C. gariepinus* fed diet AALP5 substantiating the assertion that *A. auriculiformis* is high in minerals (Girijashankar 2011). Generally, the result of proximate composition of *C. gariepinus* in this study agrees with reports of other researchers such as Pakravan et al. (2012), and Dada and Abiodun (2014) that used other medicinal plants.

The physiochemical parameters of water quality in experimental units measured during the experiment were not significantly different among all treatments except dissolved oxygen. There was a decrease in dissolved oxygen as the quantity of *A. auriculiformis* leaf powder increased in fish diets. Results of the dissolved oxygen though statistically different, were still the range values for culture of tropical fishes such as *C. gariepinus*. Similar results were reported by Tolan and Sherif (2007), Musa et al. (2013) and Samkelisiwe and Ngonidzashe (2014) using different medicinal plants and additives in the laboratory culture of tropical fishes. Water temperature is an important parameter in fish culture as it could affect protein intake either positively or negatively. Water temperature and other parameters; pH, nitrate and ammonia were within tolerance levels for aquaculture species. Furthermore, Lamai and Kolo (2013), Osuigwe et al. (2005), and Hussain (2004) also gave varying levels similar to those obtained in this project in which farm raised aquaculture species could thrive well.

Conclusion

This study has shown that incorporating *A. auriculiformis* leaf powder meal in the diet of *C. gariepinus* at varying inclusion levels led to higher growth and better nutrient utilization than the control. It can be concluded that under the experimental conditions used, inclusion of *A. auriculiformis* leaf powder in diet of African catfish fingerlings at 1.5 – 2.0% is suitable as a feed additive to produce visible changes in its growth and body composition.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Socio-economic characteristics of small-scale catfish farming enterprise in Obio/Akpor Local Government Area, Rivers State, Nigeria

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The study of the socio-economic characteristics of any group is a requirement to a successful implementation of effective government assisted programme. The study examined the socio-economic characteristics, production processes and production constraints of small-scale catfish fishing enterprises in Obio/Akpor Local Government Area in Rivers State, Nigeria. Simple randomized sampling technique was used to select 60 small-scale catfish farming enterprises. Structure questionnaires were used to collect primary data from the respondents. The collected information were analyzed using simple descriptive statistics. The results showed that majority of the farmers were females (58%), married (74%), within the age group (31-40 years), Christians (92%), Igbo tribe (22%), and had university degree (58%) with household size (6-10). Majority have fish farming as primary occupation (32%), 1-5 years of experience, non-members of association (83%) and chose fish farming for profit maximization (50%). Based on this study, different aquaculture production systems were identified at the study area such as concrete tanks (34%), plastics tanks (20%), concrete+plastic (20%), earthen ponds (12%), earthen+concrete (8%), and earthen+plastics (6%). Respondents purchased land (66%), kept record (52%), used imported feed (52%), flow-through techniques (88%), monoculture as culture system (66%), stocked *Clarias gariepinus* (88%), bore-hole as water source (96%), procured fingerlings from private farms (84%) and personal savings as source of funding (86%). Some of the constraints like lack of extension service (76%), disease outbreak (52%), lack of capital (44%), lack of electricity (38%), preservation and processing (18%), lack of skilled human labour (10%), and lack of government assisted programmes (0%) were faced. In conclusion, catfish farming promises to improve in the area if there is adequate government assistance.

Key words: Catfish, *Clarias gariepinus*, production constraints, production processes, small-scale.

INTRODUCTION

In Nigeria, aquaculture ventures are mainly at the small-scale fish farming levels (Fagbenro, 2005) contributing

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the greatest percentage (80.4%) of the Nigerian's annual fish production output (FDF, 2008). However, since the inception of aquaculture in Nigeria, several efforts have been made to promote aquaculture practices by Organizations (Satia, 1990; NEPAD, 2005; FAO, 2005; FMAWR, 2008). Some of these provided subsidy for inputs and exemption from tax; distribution of free fingerlings to small-scale fish farmers; up to 50% subsidy of the cost of fingerlings for the large-scale farmers (FMAWR, 2008) and establishment of over 3,000 homestead fish ponds as well as hatcheries in each of the then existing states of Nigeria by the Directorate of Food, Road and Rural Infrastructure (DFRRI) (Satia, 1990; NEPAD, 2005). Despite these efforts the results were not satisfactory (Dada, 2004; Oluwasola and Ajayi, 2013). Thereby, increasing concerns effort to enhance fish production through small-scale fish farming might not be fruitful.

According to FAO (2005), the careful study of the socio-economic characteristics of any group is a prerequisite for good design and successful implementation of effective government assisted programme. Thus, the first step towards addressing the concerns is to have a considerable amount of information on the demographic and socio-economic characteristics of the small-scale catfish farmers as well as understanding the constraints in the areas where the farms are located. Reports on small-scale fish farming show rapidly expanding profitable venture with constraints responsible for low productivity. These constraints included: high cost of inputs (Oladejo, 2010; Olaoye et al., 2013; Oluwasola and Ajayi, 2013), poor extension services (Oluwasola and Ajayi, 2013); lack of trained personnel (Raufu et al., 2009); lack of credit facilities (Olaoye et al., 2013; Oluwasola and Ajayi, 2013); water pollution and epileptic electricity supply (Baruwa et al., 2012); shortage of inputs (fingerlings and feed), lack of knowledge resulting in poor management practices, inadequate funding and theft (Anetekhai et al., 2004).

The constraints also include the use of poor quality catfish seeds, inadequate information, poor storage facilities, traditional techniques and low capital investment (Ugwumba et al., 2006; Adeogun et al., 2007; Ugwumba and Nnabuife, 2008; Ugwumba and Chukwuji, 2010). According to Adeoye et al. (2012), poor production planning and inadequate technical know-how are the two major factors affecting the unprofitable operation of fish farms in Nigeria. A lot of research had been reported on the economics and socio-economic analysis of fish farming in some Africa countries. For example in Rwanda, fish farming was reported as the most profitable enterprise in agriculture (Nathanael et al., 1998). Although, Kenya has not fully harnessed the potentials of fish farming, it is considered high (Gachucha et al., 2014). Also, in Nigeria, examples include Anambra State (Ugwumba and Chukwuji, 2010), Kaduna State (Kudi et al., 2008), Oyo State (Oladejo, 2010; Olaoye et al., 2012), Lagos State (Raufu et al., 2009), and Osun State (Williams et al., 2012; Oluwasola and Ajayi, 2013). However, there is little or no report on the socio-economic characteristics of small-scale catfish farming in Obio/Akpor Local Government Area, Port Harcourt, Rivers State.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Obio/Akpor Local Government Area (LGA), Rivers State, Nigeria with focus on small-scale catfish farmers. Obio/Akpor LGA is one of the two LGAs in Port Harcourt metropolis, Rivers State. Obio-Akpor is bounded by Port Harcourt (local government area) to the south, Oyigbo to the east, Ikwerre to the north, and Emohua to the west. It is located between latitudes 4°45'N and 4°60'N and longitudes 6°50'E and 8°00'E (Figure 1). Port Harcourt is the administrative capital of Rivers State, in the Niger Delta area of Nigeria. Port Harcourt lies between 4.75°N and 7°E with network of rivers and tributaries (e.g., New Calabar, Orashi, Bonny, Sombrero and Bartholomew Rivers) which provide great opportunity for fish farming (Ibemere and Ezeano, 2014). Obio/Akpor L.G.A is one of the Agricultural Zones of Agricultural Development Programs of Rivers State (Ibemere and Ezeano, 2014). Crop farming (e.g yam, cassava and vegetables) is the principal source of livelihood. There are also rivers, streams, and creeks which make fishing one of the occupations. These water bodies link the various communities to each other. More recently is the population increase triggered by urban sprawl and the infrastructural development (the tertiary institutions - University of Port Harcourt, Choba and Ignatius Ajuru University of Education, Rumuolumeni and two important jetties at Rumuolumeni and Choba, respectively) in the area.

Sampling techniques, frame and sample size

Simple random sampling method was used for the study. The sampling frame was obtained from the Catfish Farmers Association Nigeria, Rivers State Chapter. A total of 60 small-scale fish farms were randomly selected from Obio/Akpor LGA.

Methods of data collection

The selected small-scale catfish farmers were interviewed with the aid of structured questionnaires. The total number of questionnaires used for the analysis represented 83.8% (50) of the total number of sampled small-scale catfish farmers as 10 were discarded due to incomplete information (Adeoye et al., 2012). The structured questionnaires used for this study contained 46 questions under 4 sections, viz: (A) socio-economic characteristics of fish farmers; (B) production processes; and (C) production constraints of the small-scale fish farmers in the study area.

Criteria for selection of small-scale fish farm

The criterion for selection of small-scale fish farms used in this study was based on the categorization of the National Council of Industry, NCI. The NCI defined a small-scale industry as an industry with capital investment of over ₦1.5 million ($4166.67), but not more than ₦50 million ($138,888.87), including working capital but

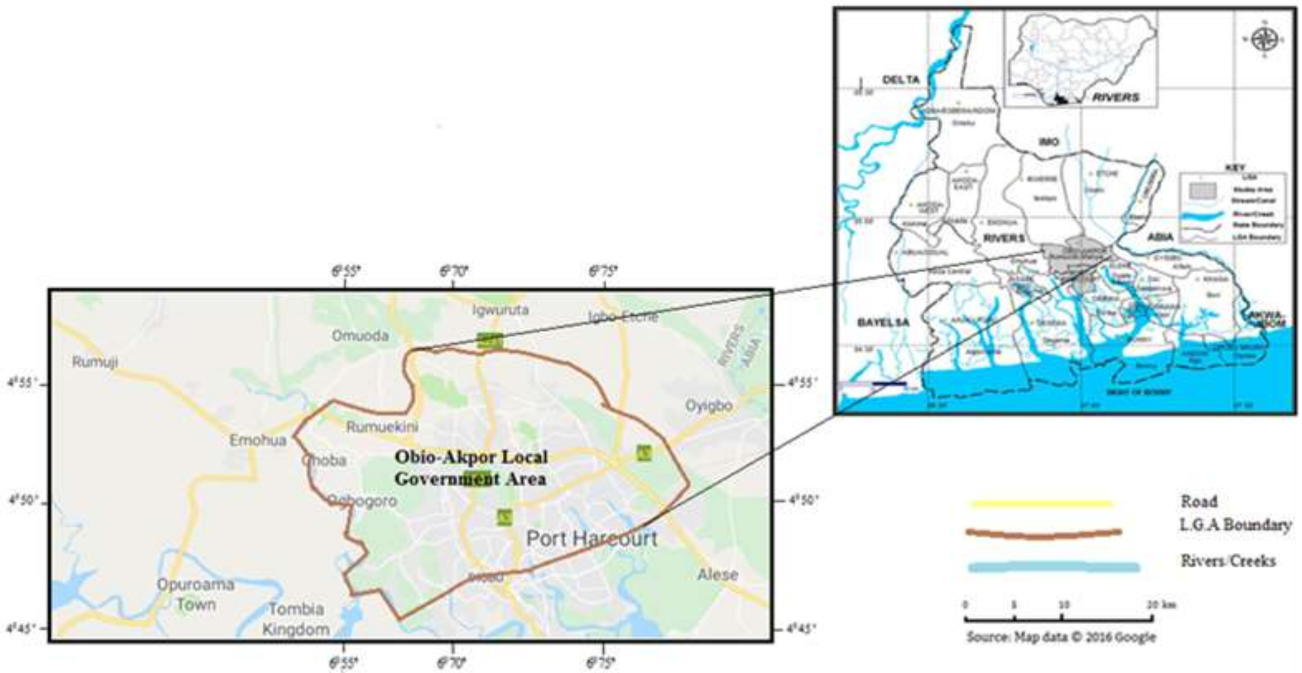

Figure 1. Map of Nigeria, Rivers State and Obio/Akpor Local Government Area.

excluding cost of land and/or a labor size of 11 to 100 workers (Aiyeloja et al., 2014).

Method of data analysis

The collected data was analysed using descriptive statistics (e.g. percentages, means, graphs and frequency tables) (Oladejo, 2010).

RESULTS AND DISCUSSION

Socio-economics characteristics distribution of small-scale catfish farming enterprise in Obio/Akpor L.G.A, Rivers State, Nigeria

Age distribution

Age is an important factor that affects overall stamina and level of productivity. The result on Table 1 showed the age distribution of the respondents. Majority of the respondents for the different production systems fall within the age group (31 - 40 years), apart from the earthen + plastic which fall within (41 - 50 years) (33.3%). Mean percentage distributions of the age group (31-40 years) were 33.3, 35.3, 50, 50 and 50 for earthen pond, concrete tank, plastic tank, earthen + concrete and concrete + plastic, respectively. Overall, 40% of the total number of respondents (n=50) operating in all production systems (Table 1) were within the age group (31-40 years), while the below 30 years (14%) were the least age group. These age groups were considered economically active, productive and signify better future for catfish production in the study area (NBS, 2016). The result of the present study was in line with those reported in other areas of Nigeria (Olowosegun et al., 2004; Adeoye et al., 2012; Olaoye et al., 2013). They reported the age group (31-50 years) and suggested that fish farming required youth that were strong and active because fish farming required adequate attention and a lot of responsibility.

Sex distribution

Sex played an important role in fish farming and agriculture, in terms of property acquisition (Olaoye et al., 2013). It also determined the ability to perform some physical work as it was generally believed that men were more efficient in activities than women. The result in Table 1 showed the sex distribution of the respondents. The mean percentage distributions of males in the different production systems were 66.7, 29.4, 60, 75, 33.3 and 50, while the females were 33.3, 70.6, 40, 25, 66.7 and 50 for earthen pond, concrete tanks, plastic tanks, earthen + concrete, earthen + plastic and concrete + plastic, respectively. The overall result showed more female (52%) than male (48%) in all the production system. The result is contrary to most reports where the males were dominated (Brummett et al., 2010; Adeoye et al., 2012; Olaoye et al., 2013). However, it is in line with Lahai et al. (2000) who suggested that women participated more than men in most farming activities.

Table 1. Socio-economic characteristics distribution of respondents (*n*=50) of small-scale catfish farmers in Obio/Akpor LGA, Rivers State.

Socio-economic	Earthen pond		Concrete tank		Plastic tank		Earthen + Concrete		Earthen + Plastic		Concrete + Plastic		Total respondents in all PS	
Characteristics	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Age group														
Below 30	1	16.7	2	11.8	3	30.0	-	-	-	-	1	10	7	14
31-40	2	33.3	6	35.3	5	50.0	2	50	-	-	5	50	20	40
41-50	2	33.3	4	23.5	2	20	-	-	1	33.3	3	30	12	24
51-60	1	16.7	5	29.4	-	-	2	50	2	66.7	1	10	11	22
Total	6	100	17	100	10	100	4	100	3	100	10	100	50	100
Gender														
Male	4	66.7	5	29.4	6	60	3	75	1	33.3	5	50	24	48
Female	2	33.3	12	70.6	4	40	1	25	2	66.7	5	50	26	52
Total	6	100	17	100	10	10	4	100	3	100	10	100	50	100
Marital status														
Single	1	16.7	3	17.6	4	40	1	25	-	-	2	20	11	22
Married	4	66.7	13	76.5	6	60	3	75	3	100	8	80	37	74
Divorced	1	16.7	-	-	-	-	-	-	-	-	-	-	1	2
Widowed	-	-	1	5.9	-	-	-	-	-	-	-	-	1	2
Total	6	100	17	100	10	100	4	100	3	100	10	100	50	100
Household size														
1-5	2	33.3	2	11.8	3	30	2	50	2	66.7	3	30	14	28
6-10	4	66.7	14	82.4	6	60	1	25	1	33.3	3	30	29	58
11-15	-	-	1	5.9	1	10	-	-	-	-	4	40	6	12
16 - 20	-	-	-	-	-	-	1	25	-	-	-	-	1	2
Above 20	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Total	6	100	17	100	10	100	4	100	3	100	10	100	50	100

Marital status distribution

In Nigeria, marriage is sacred and confers some levels of responsibility on the individuals involved (Fakoya, 2000; Ekong, 2003). The result in Table 1 showed the marital status distribution of the respondents. Majority of people operating in the different production system were married, few are single, divorced and windowed (Table 1). For instance, mean percentage distributions of the married respondents were 66.7, 76.5, 60, 75, 100 and 80 for the earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. The highest mean percentage of the married respondents was observed at the concrete tanks (76.5%) while divorced and widowed showed the least frequency (1 in each case). The overall percentage of marital status distribution in all production system combined in descending order was 74, 22, 2, and 2 for married, single, divorced and widowed respectively. This finding indicated that responsibility/commitment was in line with Adeoye et al. (2012) who reported 93.7% for married in Ogun State large-scale aquaculture farmers.

Religion distribution

Religion is an important aspect in the life of most Nigerians. The result of the religion distribution of the respondents showed that majority of people operating in the different production systems were Christians, few Muslims and traditional (data not shown). For example, percentage distribution for Christians were 100, 88.2, 90, 100, 100 and 90% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic respectively. Overall, the percentage religion distributions in all production system were 92, 6 and 2% for Christians, Muslims and Traditional respectively. This might suggest the area as being dominated by Christians and was in line with Olaoye et al. (2013).

Household size distribution

Most of the respondents for the different production systems fell within the household size 6-10, very few within the 16-20 and none above 20 (Table 1). Overall, majority (58%) of the total number of respondents (n = 50) operating in all production systems were within the 6-10 household size. This implied a moderate household. There was the likelihood that the size of household may influence the number of hired labor thereby reducing cost (William et al., 2012).

Tribe distribution

The result showed the tribe distribution of the respondents. Majority of the catfish farmers in the study area for all the production systems were Igbos followed by Ikwerre, Ebonyi and Kalabari were the least (data not shown). The percentage distributions of the Igbos were 33.3, 23.5, 20, 50 and 10% for earthen pond, concrete tank, plastic tank, earthen + concrete and concrete + plastic respectively. There were no respondent recorded for earthen + concrete (0%). Overall, the percentage distribution for the tribes in all production systems were 22, 18, 4, 14, 8, 6, 2, 6, 6, 8, 2 and 4% for Igbo, Ikwerre, Andoni, Ahoada, Akwa-Ibom, Yoruba, Kalabari, Benin, Ogoni, Delta, Ebonyi and Bayelsa, respectively. The majority of the farmers were from the Igbo Tribe (33.2%), corresponding with the notion that the tribe is industrious, like business and anything that will generate income.

Educational qualification distribution

Majority of respondents in the different production systems had some form of education. For example, percentage distribution for university degree holder was earthen pond (33.3%), concrete tanks (52.9%), plastic tank (60%), while earthen + concrete (25%), earthen + plastic (66.7%) and concrete + plastic (80%). Overall percentage distribution showed the highest for university degree holders (58%) > secondary school (28%) > NCE/OND (12%) > primary and unable to complete primary school (2% each) and none was recorded for no formal education and unable to complete secondary school (0% each, data not shown). This meant that fish farming is dominated by the educated class and mostly by those armed with high level of education. This is so because fish farming required a lot of technical and scientific knowledge to be successful. The result is in line with those previously reported by Olaoye et al. (2013).

Primary occupation distribution

Majority of people operating in the different production systems are fish farming as the primary occupation, none was recorded for company workers. Percentage distribution for primary occupation as fish farming was 16.7, 23.5, 30, 50, 33.3 and 50% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. Overall, the percentage distribution for primary occupation in all production systems was 32, 24, 20, and 24% for fish farming, business, civil servant and self-employed, respectively. None was recorded for company workers (0%). The result suggests there might be other sources of income for the respondents.

Years of experience distribution

Majority of the respondent for the different production systems were within 1-5 years of experience. Percentage distributions for the years of experience were 83.3, 41.2, 90, 75, 100 and 50% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. Overall, majority (64%) of the total number of respondents (n=50) operating in all production systems were within 1-5 years, followed by 6-10 (34%) then 11-5 years (2%). None was recorded for 16-20 and above 20 years of experience. The result suggests that respondents were still new in the business and face risk. “As commonly said, experience is a good teacher” and experience enhances efficiency, respondents with the experience above 5 years of experience will have good skill and better approaches to fish farming business, they will be able to forecast market situation in which they sell their products at higher prices. Those with less years of experience, especially with less than 5 years faced many risks in the early days of their fish farming business (Olaoye et al., 2013). The idea is also in line with Schumpeterian theory of economic development which suggested that technical efficiency was influenced by technical knowledge and understanding in addition to other socio-economic environment with which the farmers must take decision (Kalirajan, 1990).

Members of farmer association distribution

Membership of association involved a social participation that helped farmers to pool their resources, have access to inputs, government funding, etc. In the present study, the percentage distribution of respondents with no association was 83.3, 64.7, 80, 25, 0 and 60%, while members of the Catfish Farmers Association Nigeria (CAFAN) Rivers Chapter were 16.7, 35.3, 20, 75, 100 and 40% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. Overall, 62% of the respondents were not registered member of any association while CAFAN members are 38% which might be the reason for them not benefiting from any sort of government assistance. This idea is in line with those reported in Akinbile (1998).

Why choose fish farming as an occupation distribution

The result showed that the fish farming was chosen for different reasons. The majority choose fish farming for profit maximization and as hobby. The percentage distribution for profit maximization was 50, 29.4, 40, 50, 33.3 and 60% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. The percentage distribution for choosing fish farming as an occupation in all production systems was 42, 20, 20, and 18% for profit maximization, provision of family needs, hobby and employment, respectively. The result is in line with Olaoye et al. (2013), who reported 89.2% respondent got involved with farming for profit maximization.

Production processes of small-scale fish farming enterprise in Obio/Akpor L.G.A, Rivers State, Nigeria

Method of land acquisition distribution

The result showed that majority of land for fish farming were purchased, some inherited. For example, the percentage distribution of purchased land was 8 for 3.3, 58.8, 40, 75, 66.7, and 90% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. Overall, the percentage distribution for method of land acquisition was 24, 8, 2, and 66% for inherited, leased, gift and purchased, respectively.

Record keeping distribution

The percentage distribution of respondents that keep records was 33.3, 52.9, 50, 66.7, and 60%, while respondents that do not keep records were 66.7, 47.1, 50, 50, 33.3 and 40% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. In all, 52% of the respondents keep records while 48% do not.

Feed types distribution

The respondents used locally compounded feed, imported feed or both in the farms. Majority of the feed used were imported with percentage distribution of 66.7, 41.2, 40, 25, 66.7 and 80% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. In all, 52% of the respondents used imported feed, 30% used both (locally compounded and imported feed) while the remaining 18% used locally compounded feed.

Source of labor distribution

The respondents used family, hired or both in the farms. For example, the percentage distribution of the respondents that used family were 66.7, 47.1, 70, 25, 33.3, and 10% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic respectively. Overall, the percentage distribution for sources of labor was 44, 46 and 10% for family, hired and both, respectively.

Production systems distribution

The result for the distributions of the various production systems used by the respondents, showed that majority of the respondents used concrete tanks. Overall, the percentage distributions for production systems were earthen pond (12%), concrete tank (34%), plastic tank (20%), earthen + concrete (8%), earthen + plastic (6%) and concrete + plastic (20%).

Production techniques distribution

The result showed the distributions of the various production techniques used by the respondents (Figure 2) indicating farmer's preference. Majority of the respondents used flow-through production technique with

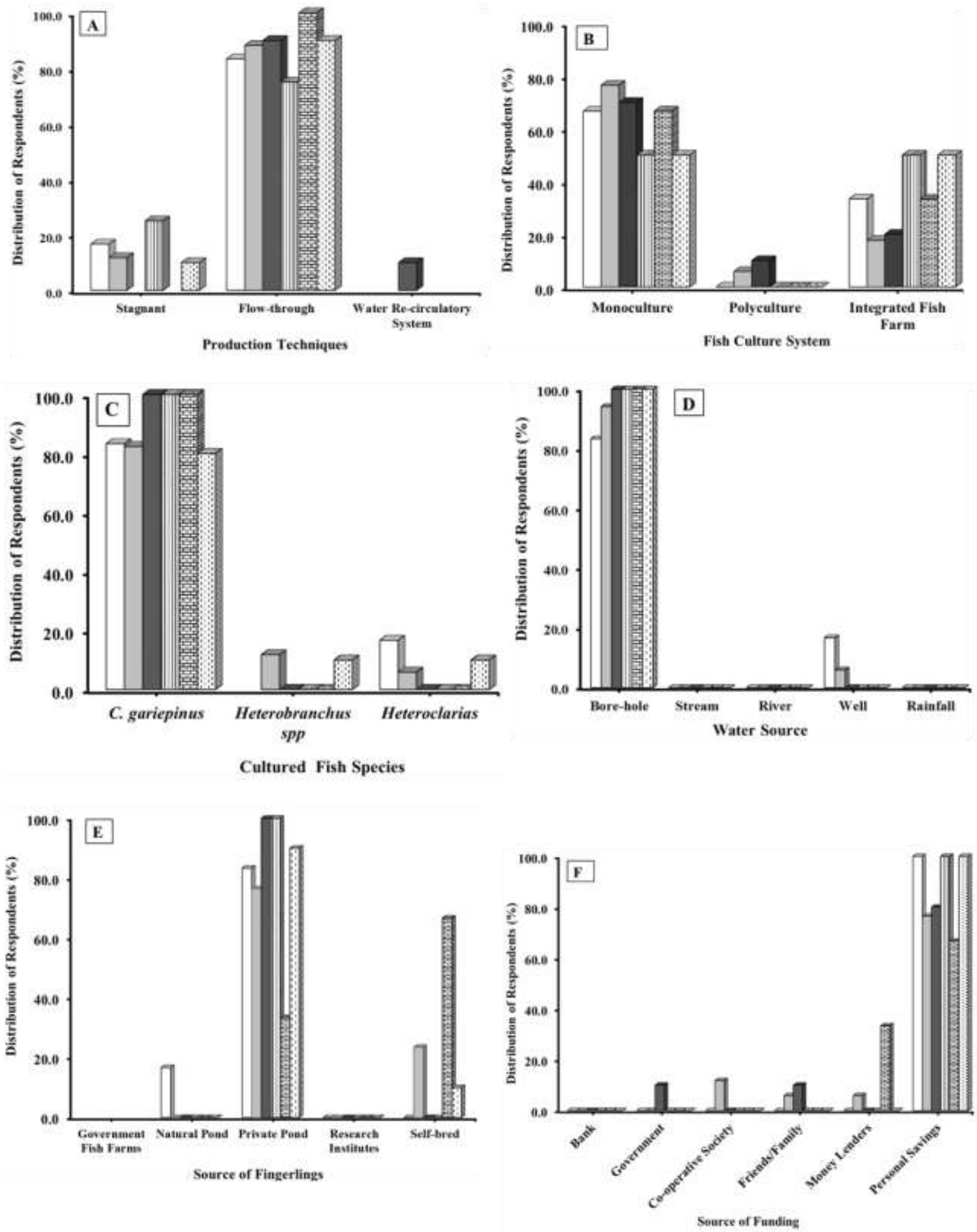

Figure 2. Percentage distribution of respondents on production processes (*n*=50) in Obio/Akpor LGA, Rivers State. (A) Production techniques; (B) Fish culture system; (C) Cultured fish species; (D) Water source; (E) source of fingerlings; and (F) sources of funding. The bars represent earthen ponds (white bar), concrete tanks (grey bar), plastic tanks (black bar), earthen + concrete (vertical lines), earthen + plastic (horizontal bricks) and concrete + plastic (dashed line), respectively.

percentage distribution for earthen pond (83.3%), concrete tank (88.2%), plastic (90%), earth + concrete (75%), earthen + plastic (100%) and concrete + plastic (90%). In all, the percentage distributions for production techniques were 10, 88 and 2% for stagnant, flow-through and water recycling system, respectively.

Fish culture system distribution

The result showed the distributions of the fish culture systems practiced by the respondents (Figure 2). Majority of the respondent practiced monoculture with percentage distribution for earthen pond (66.7%), concrete tank (76.5%), plastic (70%), earth + concrete (50%), earthen + plastic (66.7%) and concrete + plastic (50%). Overall, the percentage distributions for culture systems were 66, 4 and 30% for monoculture, polyculture and integrated fish farming, respectively. The result was in line with those reported previously (Rundquist 1984; Olaoye et al., 2013), who observed that fishes grew better when cultured individually under monoculture system and also helped the species to grew to its biggest size.

Fish cultured distribution

The result showed the distributions of the fish culture systems practiced by the respondents (Figure 2). Majority of the respondent cultured *Clarias gariepinus* while only few cultured *Herobranchus* species or Heteroclarias. Percentage distribution of respondents that cultured *C. gariepinus* in earthen pond (83.3%), concrete tank (82.4%), plastic tank (100%), earthen + concrete (100%), earthen + plastic (100%) and concrete + plastic (80%). Overall, the percentage distributions for fish cultured were 88, 6 and 6% for *C. gariepinus, Heterobranchus* spp. and Heteroclarias, respectively. This might be due to the fact that catfish appeared to be hardy and generally accepted by people, greater demand preferences, hardiness of the stock, fast growth, high feed conversion ratio, high survival rate under captivity (Olaoye et al., 2013; Jamabo, 2017).

Water source distribution

Source and quantity of water available are one of the most important factors to be considered when selecting a site for aquaculture practice. The quantity of water needed for commercial aquaculture varies with the production method employed, type of aquaculture chosen, scale of operation, and species cultured. The result showed the distributions of the water source used the respondents (Figure 2). The majority of the respondent used bore-hole, only few used well water. Stream, river and rain water were not used in the study area. Overall, the percentage distributions for water source were 96 and 4% for bore-hole and well water, respectively. No respondent was recorded for the use of water from river, stream and rainfall. It might be because bore-hole was more dependable and free of diseases and parasites (Williams et al., 2012).

Source of fingerlings distribution

Fingerlings were sourced from private farms, self-bred and natural pond. The majority was from private pond with percentage distribution of 83.3, 76.5, 100, 100, 33.3 and 90% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively (Figure 2). Overall, the percentage distributions for source of fingerlings were 84, 14 and 2% for private farms, self-bred and natural pond, respectively. There were no respondent recorded against government farms, and research institutes. The result suggests that respondents were not trained and lacked needed information. The fact was that the fingerlings sourced from fish farms were more likely to be healthier and well-bred (Olaoye et al., 2013).

Source of funding distribution

The result showed the distributions of the source of funding (Figure 2). Funding was mainly sourced from personal savings, few from government, co-operative society, friends/family, money lenders but none from bank. The majority of the funding was sources from personal savings with percentage distribution of 100, 76.5, 80, 100, 66.7 and 100% for earthen pond, concrete tank, plastic tank, earthen + concrete, earthen + plastic and concrete + plastic, respectively. Overall, the percentage distributions for source of funding were 0, 2, 4, 4, 4 and 86% for banks, government, co-operative banks, friends/ family, money lenders and personal savings, respectively.

Production constrains of small-scale fish farming enterprise in Obio/Akpor L.G.A, Rivers State, Nigeria

Constraints (Figure 3) in the study were presented under three categories (a) types of losses/disaster, (b) common problems, and (c) access to extension services. The respondent claimed they experienced several losses/disasters ranging from disease outbreak (52%), lack of government assistance (50%), lack of capital (44%), power failure (38%), predator (34%), pollution (14%), lack of skilled labor (10%) to flood disaster (4%). Also, respondents claimed to have experienced common problems ranging from financial problems (62%), post-harvest losses (38%), marketing problems (36%),

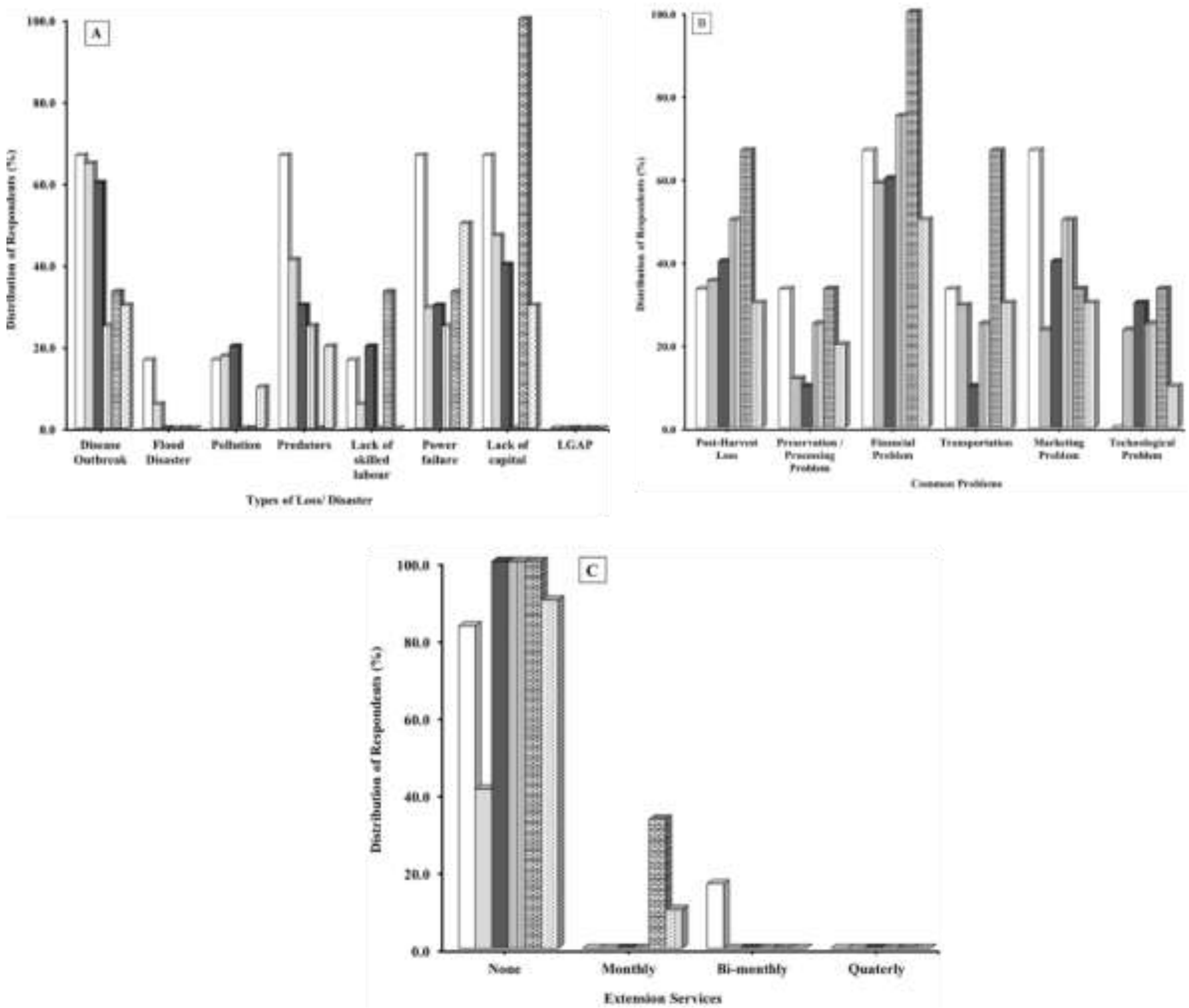

Figure 3. Percentage distribution of respondents on production constraints (*n*=50) in Obio/Akpor LGA, Rivers State. (A) Types of losses/disaster; (B) Common Problems; (C) Extension Services. The bars represent earthen ponds (white bar), concrete tanks (grey bar), plastic tanks (black bar), earthen + concrete (vertical lines), earthen + plastic (horizontal bricks) and concrete + plastic (dashed line) respectively. Note: LGAP represent lack of government assisted programmes.

transportation (28%), technological problems (20%) to preservation/processing problems (18%). For availability of extension services, 76% of the total respondents claimed they did not have any access to extension services, 4% get monthly while 2% gets bi-monthly extension services. Some of the constraints were in line with those previously reported (Ugwumba and Chukwuji, 2010; Adeoye et al., 2013). They reported in descending order of severity as lack of capital, disease outbreak, lack of modern technology, high cost of transportation and the least were post-harvest losses and poor storage facilities.

Government assisted programs for small-scale fish farming enterprise in Obio/Akpor LGA, Rivers State, Nigeria

The study of socio-economic conditions of any business is aimed at providing good design and successful implementation of effective assistance programmes. In the present study, government assisted programs were not available to the respondents in the study area.

Conclusion

Small-scale catfish farming enterprises were present in Obio/Akpor LGA and various production systems (concrete tanks, plastics tanks, earthen ponds, concrete + plastic, earthen + concrete and earthen + plastics) were adopted. Catfish farming promises to improve in the area if there would be adequate assistance from government. Catfish farmers faced different constraints ranging from disease out-break, lack of extension services to lack of government assisted programmes.

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Full Length Research Paper

The spatio-temporal dynamics of the fish assemblage of the man-made Lake Buyo (Cote d'Ivoire, West Africa)

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This study aims to characterize the spatio-temporal variation of the fish assemblages in relation to the environmental variables of Buyo Dam Lake. Sampling was performed from July 2017 to June 2018 using experimental fishing and commercial fishing. Spatio-temporal analysis indicated a significant variation (p <0.05) in pH, electrical conductivity, total dissolved solids, and water transparency. A total of 45 species from 27 genus and 15 families were collected in the samples sites. Two species (*Chrysichthys johnelsis and Malapterurus barbatus*) are reported for the first time in the lake of Buyo. Among the fishes sampled, of Cichlidae (35.04%) and Claroteidae (16.43%) were the most abundants. The abundant species are *Oreochromis niloticus* (15.55%) and *Chrysichthys nigrodigitatus* (15.15%). The analysis of the structure of fish assemblages (H' from 2.28 to 2.75, E from 0.68 to 0.84) revealed a fairly diverse lake environment. The canonical correspondence analysis revealed the significant influence of water pH, electrical conductivity, dissolved solids content, water transparency and nitrite in the distribution of fish species in the lake of Buyo. This work constitute a baseline study for future investigations and will contribute to the implementation of a sustainable management plan for fisheries resources in the continental water.

Key words: Environmental parameters, fishes, settlement, Lake of Buyo, Côte d'Ivoire.

INTRODUCTION

Knowledge of the ichtyological fauna in African rivers and lakes is of concern to both scientists and development officials (Lalèyè et al., 2004). Indeed, the increasing intensification of the consumption of fish resources in continental environment in Africa associated with the processes of degradation of the natural environment pose real risks of regression and disappearance of species (Lalèyè et al., 2004). These anthropogenic pressures have led to conservation and rational management measures of fish stocks (Monchowui et al.,

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2008). For these authors, these measures concern the ecology, composition and level of exploitation of the ichtyological fauna of the water bodies. Therefore, any measure of conservation of ichtyological fauna requires a good knowledge of the fish species and the characterization of the factors that influence their distribution (Wu et al., 2011; Kamelan et al., 2013). In the preservation of natural resources for a sustainable and rational use, the systematic inventory and enumeration of living species must be performed before hand (N'Zi et al., 2003). Several works have been carried out on the lake of Buyo including those of Vanga et al. (2002), Vanga (2004), Ossey et al. (2008), and Kouamé et al. (2008). Their work focused on the impact of fishing on fish availability in the area surrounding the lake, the socio-economic consequences of the expulsion of the non-indigenouse fishermen, the analytical study of chemical characteristics and biological diversity and fish assemblage characterization of the lower Sassandra River. Apart from the work of Kouamé et al. (2008) which characterizes the fish assemblage of the lower Sassandra River, there are no available data concerning the fish assemblage of the lake of Buyo, nor on the environmental parameters that influence the distribution of these species. This lake plays a vital role in fish production in Côte d'Ivoire. Moreover, its ichtyological fauna is being exploited by the Ivorian and foreign population (Vanga et al., 2002). Therefore, preventive measures deserve to be taken for better management of fishery resource. It is within this framework that this study aims to characterize the ichthyological settlement in the lake of Buyo by a spatio-temporal approach while highlighting the environmental variables that influence the distribution of fish species of this lake.

MATERIALS AND METHODS

Study area

This study was conducted in the man-made lake Buyo (Figure 1). This lake is located between 06°14' and 07°03' North latitude and 07°31' West longitude and covers an area of 920 km^2 (Kouamé, 2010). It was built in 1981 on the edge of the Tai National Park, 4 km downstream from the confluence of the N'Zo River and the Sassandra River, drowning approximately 8400 ha of forest in the park (OIPR, 2006). This Lake of Buyo occupies a catchment area of 46 250 km^2 (Ossey et al., 2008). The hydrological regime of this lake depends on the Sassandra River, the N'Zo primary tributary and rainfall in the region (Traoré and Konan, 1989). It presents a hydrograph characterized by a period of high water from early October to mid-November with a maximum submerged area of 900 km^2 and a period of low water level from December to May with a minimum area of 230 km^2 (Traoré, 1996). Every year, the Lake of Buyo fills up completely by December and progressively empties until June of the following year. The depth of the lake varies on average from 9.2 to 20 m. Three study stations (Guessabo, Buyo city and PK15) have been outlined in this study area. The selection of these stations was made taking into consideration their closeness to the lake, the existence of commercial fishing, and their easy accessibility by road in all season.

Fish sampling

The fish were collected between July 2017 and June 2018 using a battery of 11 monofilaments gill nets (bar mesh size 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60 mm), each gill net measuring 30 m long by 1.5 m deep. Nets were set overnight (17-7 H) and during the following day (7-12 H). Experimental fishing data are added to the data from local fishermen captures. For the captures, the samples were collected from the fishermen as soon as they returned from fishing. All fishes were identified following Paugy et al. (2003a, b). The standard lengths (LS) of the fish were measured using a graduated ichtyometer and the total weight determined using precision scale (with ± 1 g).

Measurement of environmental variables

At each station, before each experimental fishing, the pH, dissolved oxygen level (in mg/l), conductivity (in µS/cm), total dissolved solids or TDS (in mg/L) and temperature of the water were measured using a multi-parameter Lovibond Senso Direct 150. The water transparency was measured in cm using a Secchi disk. Nitrite, total phosphorus and total chlorine levels were quantified using Hanna mini-photometers. The rates (%) of canopy closure, water cover by aquatic plants and substrate (sand, sand-gravel mixture, gravel, mud, rock, clay-mud mixture, deadwood-root-leaf mixture) were visually estimated (Arab et al., 2004; Rios and Bailey, 2006).

Data analysis

The data was analyzed for spatial and temporal variation using the Statistica 7.1 software. The descriptive analysis was applied to the physico-chemical data to highlight the central tendency (median, minimum and maximum). Before performing the comparison test, the normality of the data was verified by the Shapiro-Wilk test ($p > 0.05$ at all stations). The Kruskal-Wallis H test with Dunn's posterior multiple comparison test was used to verify the significant difference in spatio-temporal variations of physicochemical parameters (Zar, 1999). A level of significance of $p < 0.05$ was considered.
The descriptive analysis of the ichthyological settlement was carried out using the index below: Numeric percentage (N) or Abundance

$$N = \frac{n}{Nt} \times 100$$

Where n: Number of individuals in a taxonomic group (species, family or order) and Nt: Total number of individuals.

Also, Percentage weight (P) or Biomass.

$$P = \frac{p}{Pt} \times 100$$

Where p: Weight of individuals in a taxonomic group (species, family or order) and Pt: Total weight of individuals in a sample.

The numerical and weight percentages of the different species were determined according to N'Zi et al. (2008).

Diversity

Index of Shannon and Weaver (1963) (H ')

$$H' = \Sigma(\frac{Ni}{N}) \times \log_2(\frac{Ni}{N})$$

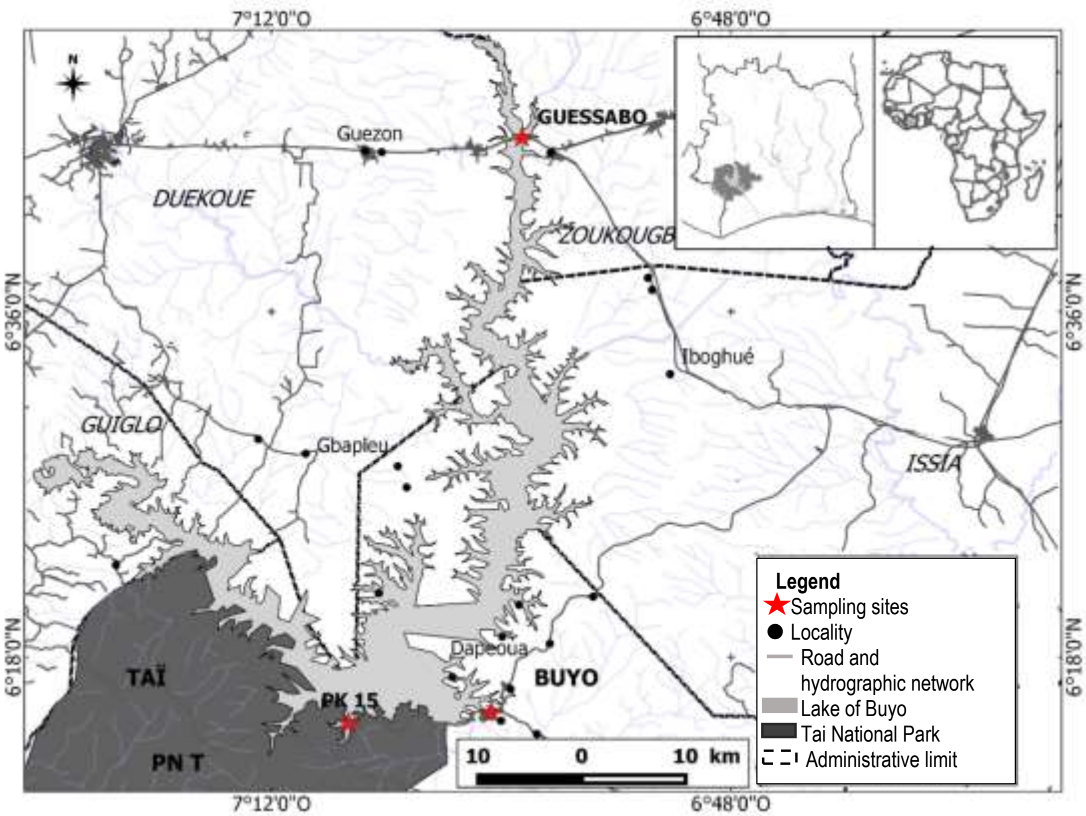

Figure 1. Location of the Lake of Buyo and location of the sampling stations (★) .

Where Ni: number of individuals of a given species, i ranging from 1 to S (total number of species) and N: total number of individuals. H' measures the degree of organization of the settlement (Amanieu and Lasserre, 1982).

H' is expressed in units of information per individual or bits / individual. It is nil if the sample is composed of a single species and maximal (in the order of 5) if all the species in the community are also represented in the sample (Ludwig and Renolds, 1988). Equality (E) of Piélou (1984).

$$E = \frac{H'}{\log_2 S}$$

Where H ': Shannon index and S: specific wealth.

E makes it possible to assess the quality of the settlement organization (Dajoz, 2000; Barbault, 2000). It varies between 0 and 1. It is maximal when the species have identical abundances in the settlement and minimal when a single species dominates the entire settlement. These indexs were made according to the program PAST.

Percentage of occurrence or frequency of species (%F)

Frequency of occurrence is the percentage of samples in which each taxon occurred (Gbenyedji et al., 2011):

$$F = \frac{Si}{St} \times 100$$

Where Si: number of stations where species i was captured and St: total number of stations examined. The classification of Djakou and Thanon (1988) was used for this study. It is established as follows: 80% ≤ F <100%: very frequent species; 60% ≤ F <79%: Frequent species; 40% ≤ F <59%: fairly frequent species; 20% ≤ F <39%: Ancillary species; F <20%: Accidental species.

Multivariate analysis

A canonical correspondence analysis (CCA) was used to identify possible correlations between fish assemblages and the environment variable (Ter Braak, 1988). The CCA was conducted using the Canoco Version 4.5 Software. This analysis has highlighted the main environmental variables that determine the distribution of fish (Ter Braak and Šmilauer, 2002). The CCA coupled with Monte Carlo permutation tests (499 permutations) was used to select the environmental variables that best explain the distribution pattern of fish species.

RESULTS

Environmental characteristics of the Lake of Buyo

The water variables in the Buyo Lake has been shown in Table 1. These results do not indicate any temporal variation within the same station. However, a significant spatio-temporal variation (p <0.05) in water pH, electrical conductivity, total dissolved solids (TDS), and water

Table 1. Spatiotemporal variation of physico-chemical parameters measured at the Lake of Buyo from July 2017 to June 2018.

Physico-chemical parameter		Guessabo		Buyo ville		PK15	
		Rainy (a)	**Dry (b)**	**Rainy (c)**	**Dry (d)**	**Rainy (e)**	**Dry (f)**
pH	Median	5.47	5.64[ec]	5.38[b]	5.51	5.34[b]	5.57
	Max	5.75	5.72	5.5	5.62	5.61	5.63
	Min	5.10	5.62	4.91	5.41	5.24	5.55
Conductivity (µS/cm)	Median	74.55[e]	76[ef]	62.2	57.15	55.65[ab]	55.6[b]
	Max	88.7	91.95	65.8	59.95	63.7	63.85
	Min	63	73.45	54.15	54.6	45.55	50.05
Oxygen (mg/L)	Median	5.7	6.6	4.05	5.15	5.7	5.05
	Max	7.5	7.95	6.8	5.8	7	6.25
	Min	1	4.95	1.2	3.3	4	4.8
TDS (mg/L)	Median	49.2[ef]	50.05[ef]	40.5	38.75	37.8[ab]	35.85[ab]
	Max	57.55	61.7	44.55	40.15	40.7	38.15
	Min	44.7	49.25	37.35	37.55	30.35	33.25
Temperature (°C)	Median	30.75	31.2	29.9	30.85	29.2	30.9
	Max	31.85	31.85	31.95	31.75	31.85	31.2
	Min	27.9	29.1	28.05	30.8	27.4	30.2
Transparency (cm)	Median	84[f]	99.5	118	108	130.5	176[a]
	Max	154.5	140	132.5	130.5	180.5	188
	Min	58	70.5	70.5	57.5	77	115
Nitrite (mg/L)	Median	0.001	0.004	0.001	0.003	0.002	0.003
	Max	0.003	0.005	0.004	0.02	0.004	0.004
	Min	0	0.001	0	0.001	0	0.001
Total Phosphorus (mg/L)	Median	0.198	0.198	0.194	0.198	0.162	0.196
	Max	0.198	0.198	0.198	0.198	0.198	0.198
	Min	0.072	0.198	0.081	0.169	0.062	0.168
Total Chlorine (mg/L)	Median	0.04	0.06	0.07	0.02	0.06	0.06
	Max	0.21	0.07	0.12	0.02	0.41	0.11
	Min	0	0.03	0.01	0.01	0	0.01

GSB : Guessabo ; **BV** : Buyo ville ; **(a)** : Significant statistical difference compared to Guessabo in the rainy season; (**b**): significant statistical difference compared to Guessabo in the dry season; (**c**): significant statistical difference compared to Buyo Ville in rainy season; (**d**): significant statistical difference compared to Buyo Ville in the dry season; (**e**) significant statistical difference compared to PK15 in the rainy season; (**f**): significant statistical difference compared to PK15 in the dry season; (**ce**): significant statistical difference compared to Buyo Ville and PK15 in the rainy season; (**ef**): statistically significant difference compared to PK15 in rainy season and dry season; (**ab**): statistically significant difference compared to Guessabo in the rainy season and in the dry season.

transparency was observed for the three stations examined. Higher level of electrical conductivity and dissolved solids content were recorded at Guessabo (CND = 74.50 - 76 µS/cm, TDS = 49.20 - 50.05 mg/L) compared to those measured at PK15 (CND = 55.50 - 55.65 µS/cm, TDS = 35.85 - 37.80 mg/L). This trend was also observed in the dry season for the water pH for the three stations examined. However, during this same period transparency has the highest values at PK15 (130.5 - 176 cm) compared to the values obtained at Guessabo (95 cm).

Qualitative analysis of the fish settlement

A total of 45 species of fish composed of 27 genus, 15 families and 6 orders (Table 2) have been identified throughout the Lake of Buyo. These fish fauna contain four marine and/or brackish water species (*Pellonula leonensis, Sarotherodon galilaeus, Tilapia guineensis and Sarotherodon melanotheron*) and two introduced species (*Oreochromis niloticus* and *Heterotis niloticus*). The species richest orders are Siluriformes (14 species), Perciformes (10 species), Osteoglossiformes and Characiformes with 8 species each respectively. The richest family is Cichlidae with 8 species, followed by Mormyridae (7 species) and Alestidae (6 species).

The most represented families at the station Guessabo are Mormyridae (7 species), Cichlidae (6 species) and Alestidae (5 species). In Buyo town and PK15, Cichlidae dominate with 8 species, followed by Mormyridae (7 species) and Alestidae (5 species). The station at Guessabo is the richest station with 41 species, followed by PK15 with 32 species and Buyo city with 31 species. In general, the species richness is higher at upstream of the lake (Guessabo, n = 41 species) than downstream of the lake (Buyo zone, n = 31 species).

The spatio-temporal analysis of the settlement of the lake of Buyo showed that Cichlidae dominate the fish population of the lake followed by Mormyridae, Mochokidae and Cyprinidae in both dry and wet seasons. The predominance of these families is clearly observed at the stations with the particular case of Mormyridae which come first in terms of predominance at Guessabo. The species richness on the whole lake (Figure 2) is higher in the rainy season with 44 species and lower in the dry season with 34 species.

Quantitative analysis of the fish population

A total of 5265 individuals (or 0.483 tonnes) were captured in the Lake of Buyo during the study period. The best represented families in number of individuals (Figure 3) are Cichlidae (35.04%) followed by Claroteidae (16.43%) and Mochokidae (10.92%).

O. niloticus is preponderant in terms of numerical abundance with 15.55% (Figure 4). Next are *Chrysichthys nigrodigitatus* (15.15%), *Synodontis koensis* (9%), *Distichodus rostratus* (6.49%) and *Malapterurus electricus* (5.96%). These species alone accounted for 52.15% of the captures.

The spatio-temporal analysis shows a predominance of *C. nigrodigitatus* in the Guessabo captures during the rainy season and in the dry season, while in the same periods in Buyo City and at PK15, the *Cichlidae O. niloticus* and *Tilapia zillii* dominate the settlement.

In terms of biomass, Cichlidae and Claroteidae alone accounted for 58.62% of the total biomass captured at Lake of Buyo (Figure 5). The species *C. nigrodigitatus* and *O. niloticus* are the most represented with 48.63% of the total biomass of this lake (Figure 6). This trend remains unchanged in our three stations during the rainy season and in the dry season.

The Kruskal-Wallis H test shows no significant difference ($p > 0.05$) in abundance and biomass in space and time.

Structure of the fish settlement

The diversity index (H') and equitability (E) calculated in the study area on the basis of numerical abundance of species vary from one station to another and from one period to another. Diversity and fairness index values are higher in Buyo city (H'= 2.754 and E= 0.8454) and lower in PK15 (H'= 2.283 and E= 0.6853) in the rainy season. In the dry season, these values are higher at PK15 (H'= 2.447 and E= 0.7699) and lower at Buyo city (H'= 2.283 and E= 0.7752).

The Kruskal-Wallis H test shows that there is no significant variation ($p > 0.05$) in the Shannon and Weaver (H') diversity index and the Pielou (E) equitability in time as well as in space (Table 3).

Distribution of species in the Lake Buyo

The analysis of percentages of occurrence revealed twenty-three very frequent species. These are *P. leonensis*, *H. niloticus, Marcusenius ussheri, Mormyrus rume, Brycinus longipinnis, Brycinus macrolepidotus, D. rostratus, Labeo coubie, Labeo parvus, Chrysichthys maurus, C. nigrodigitatus, Schilbe mandibualris, Clarias anguillaris, M. electricus, S. koensis, Synodontis punctifer, Lates niloticus, T. zillii, Hemichromis bimaculatus, Hemichromis fasciatus, O. niloticus, S. melanotheron* and *Tilapia hybrid (Tilapia guineensis x T. zillii)*. All these species are present at all times with the exception of *B. longipinnis* which occurs only in the rainy season. The rare species (*Mormyrops anguilloïdes, Hepsetus odoe, Alestes baremoze, Chrysichthys johnelsis, Heterobranchus isopterus, Heterobranchus longifilis, Malapterurus barbatus, Synodontis schall* and *Parachanna obscura*) have, in most cases, been captured in the rainy season except for *H. odoe* and *P. obscura* that were captured in both seasons.

Determination of the ichthyological settlement

The influence of environmental variables on fish distribution has been demonstrated by the Canonical Correspondence Analysis (CCA) (Figure 7). Only the axes I (eigenvalue $\lambda 1 = 0.180$) and II (eigenvalue $\lambda 1 = 0.062$) that express 74.4% of the cumulative variance values for the species data were considered in the interpretation of the results. The Monte Carlo test made it possible to select, among the nine initial variables, five variables that express at 54.51% the observed species-

Table 2. List, occurrence and distribution of fish species sampled in the Lake of Buyo between July 2017 and June 2018.

Orders, families and genus	species	GSB	BV	PK15	PO	Character
Clupeiformes						
Clupeidae: *Pellonula*	*Pellonula leonensis**	+	+	+	100	**ETF**
Osteoglossiformes						
Arapaimidae: *Heterotis*	*Heterotis niloticus***	+	+	+	100	**ETF**
Mormyridae: *Marcusenius*	*Marcusenius furcidens*	+	+		66.66	**EF**
	Marcusenius senegalensis	+	+		66.66	**EF**
	Marcusenius ussheri	+	+	+	100	**ETF**
Mormyrops	*Mormyrops anguilloïdes*	+			33.33	**EAc**
	Mormyrus rume	+	+	+	100	**ETF**
Petrocephalus	*Petrocephalus bovei*	+	+		66.66	**EF**
Pollimyrus	*Pollimyrus isidori*	+		+	66.66	**EF**
Characiformes						
Hepsidae: *Hepsetus*	*Hepsetus odoe*	+			33.33	**EAc**
Alestidae: *Alestes*	*Alestes baremoze*		+		33.33	**EAc**
Brycinus	*Brycinus imberi*	+	+		66.66	**EF**
	Brycinus longipinnis	+	+	+	100	**ETF**
	Brycinus macrolepidotus	+	+	+	100	**ETF**
	Brycinus nurse	+		+	66.66	**EF**
Hydrocynus	*Hydrocynus forskalii*	+	+		66.66	**EF**
Distichodontidae: *Distichodus*	*Distichodus rostratus*	+	+	+	100	**ETF**
Cypriniformes						
Cyprinidae	*Barbus ablabes*	+		+	66.66	**EF**
Barbus	*Barbus macrops*	+		+	66.66	**EF**
Labeo	*Labeo coubie*	+	+	+	100	**ETF**
	Labeo parvus	+	+	+	100	**ETF**
Siluriformes						
Claroteidae : *Chrysichthys*	*Chrysichthys johnelsis*	+			33.33	**EAc**
	Chrysichthys maurus	+	+	+	100	**ETF**
	Chrysichthys nigrodigitatus	+	+	+	100	**ETF**
Schilbeidae: *Schilbe*	*Schilbe mandibularis*	+	+	+	100	**ETF**
	Schilbe intermedius	+		+	66.66	**EF**
Clariidae: *Clarias*	*Clarias anguillaris*	+	+	+	100	**ETF**
Heterobranchus	*Heterobranchus isopterus*	+			33.33	**EAc**
	Heterobranchus longifilis	+			33.33	**EAc**
Malapteruridae : *Malapterurus*	*Malapterurus barbatus*			+	33.33	**EAc**
	Malapterurus electricus	+	+	+	100	**ETF**
Mochokidae:*Synodontis*	*Synodontis bastiani*	+		+	66.66	**EF**
	Synodontis koensis	+	+	+	100	**ETF**
	Synodontis punctifer	+	+	+	100	**ETF**
	Synodontis schall	+			33.33	**EAc**
Perciformes						
Channidae: *Parachanna*	*Parachanna obscura*	+			33.33	**EAc**
Centropomidae : *Lates*	*Lates niloticus*	+	+	+	100	**ETF**
Cichlidae						
Hemichromis	*Hemichromis bimaculatus*	+	+	+	100	**ETF**
	Hemichromis fasciatus	+	+	+	100	**ETF**
Oreochromis	*Oreochromis niloticus***	+	+	+	100	**ETF**
Sarotherodon	*Sarotherodon galilaeus**		+	+	66.66	**EF**
	*Sarotherodon melanotheron**	+	+	+	100	**ETF**
Tilapia	*Tilapia guineensis**		+	+	66.66	**EF**
	Tilapia zillii	+	+	+	100	**ETF**

Table 2. Contd.

	Tilapia hybride (T. guineensis X T. zillii)	+	+	+	100	**ETF**
6 orders - 15 families - 27 genus		**41 species**	**31 species**	**32 species**		

ETF: Very Common Species; **EF**: Frequent Species; **EAc**: Species Accessory; +: Presence; *: species with marine and / or estuarine affinity; **: introduced species.

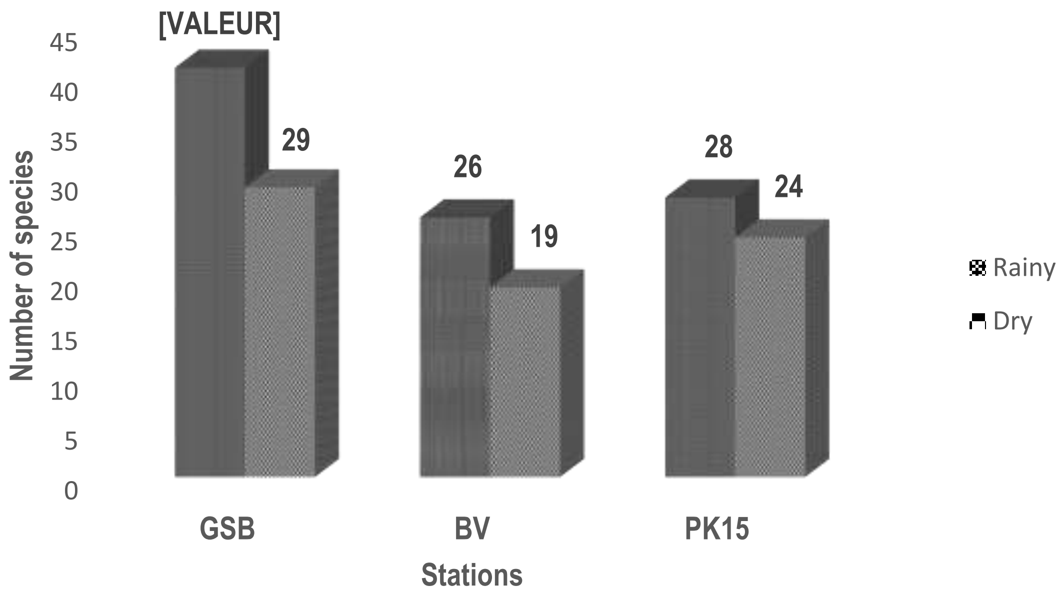

Figure 2. Spatio-temporal variation of species richness of the Lake of Buyo.
GSB: Guessabo; BV: Buyo Ville.

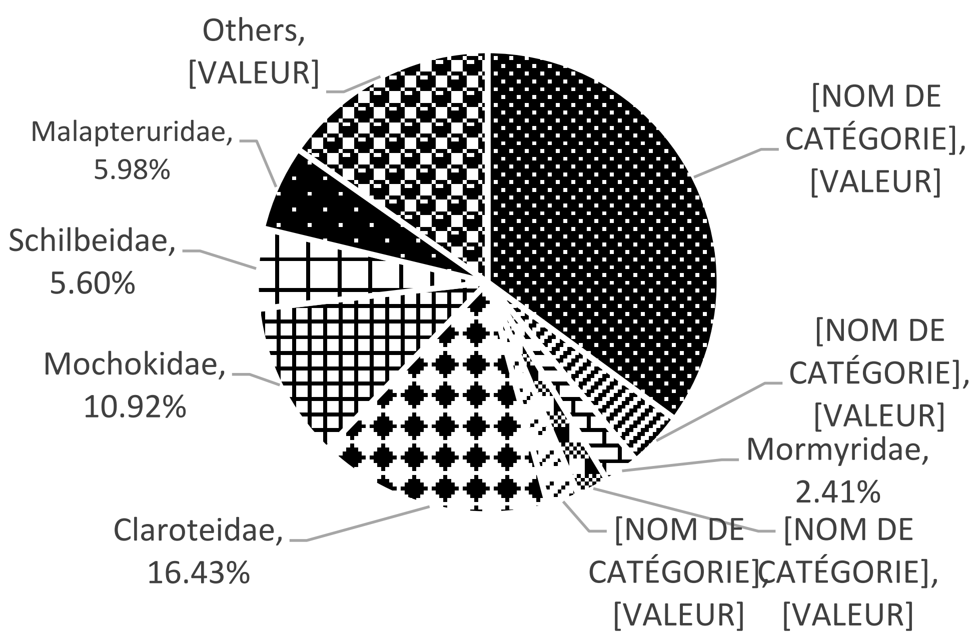

Figure 3. Numeric percentage of fish families captured in Lake of Buyo.

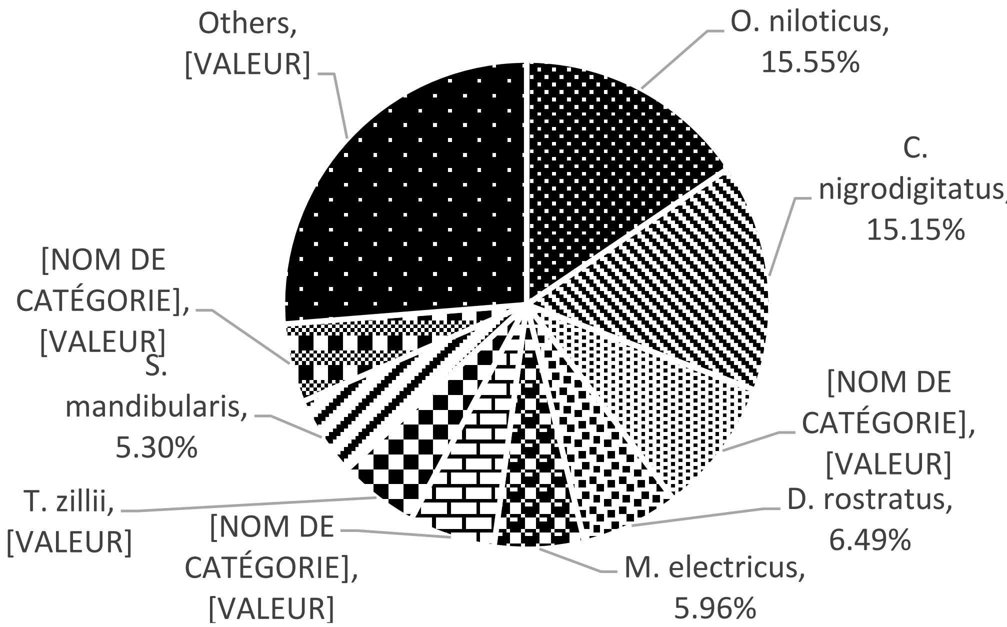

Figure 4. Percentage of fish species caught in Lake Buyo.

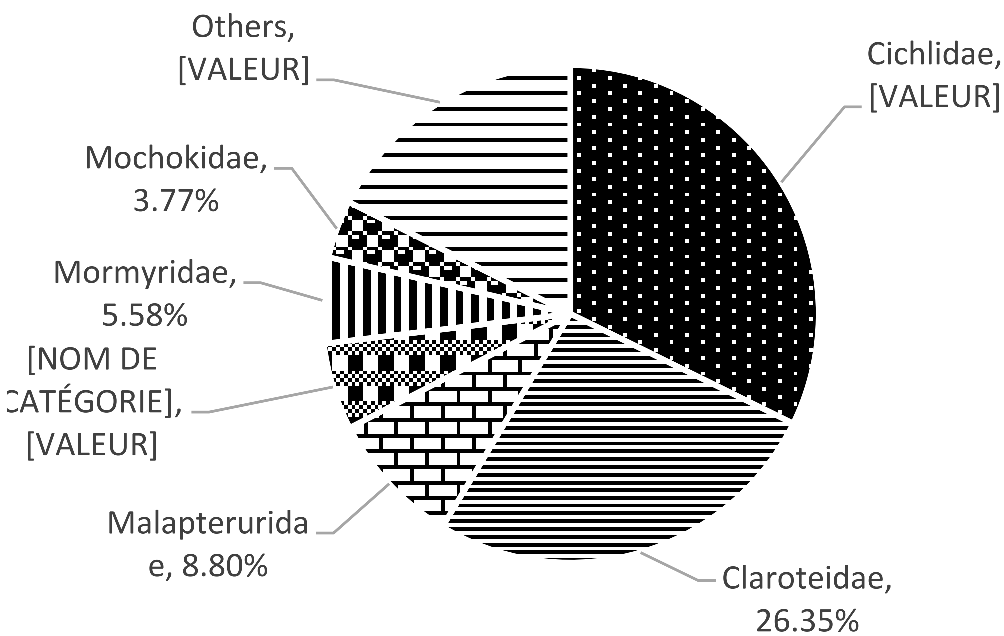

Figure 5. Percentage weight (biomass) of fish families captured in Lake of Buyo.

variable correlations. These variables are: Conductivity (12.65%), total dissolved solids (12.44%), pH (11.58%), nitrite (9.03%) and transparency (8.81%). Axis I makes it possible to separate the species into two groups A and B. The first group (A) of species consisting of *Marcusenius furcidens*, *Marcusenius senegalensis*, *Labeo coubie*, *Petrocephalus bovei*, *Hydrocynus forskalii*, *Brycinus imberi*, *P. leonensis*, *C. maurus*, *H. isopterus*, *H. longifilis*, *S. schall*, *C. johnelsis*, *M. anguilloïdes*, *B. macrolepidotus*, *L. parvus*, *D. rostratus*, *Brycinus nurse*, *H. odoe*, *P. obscura*, *Schilbe intermedius*, *M. rume*, *Barbus ablabes*, *Synodontis bastiani*, *Barbus macrops* and *Pollimyrus isidori* are associated to the station Guessabo and positively correlated with the variables like

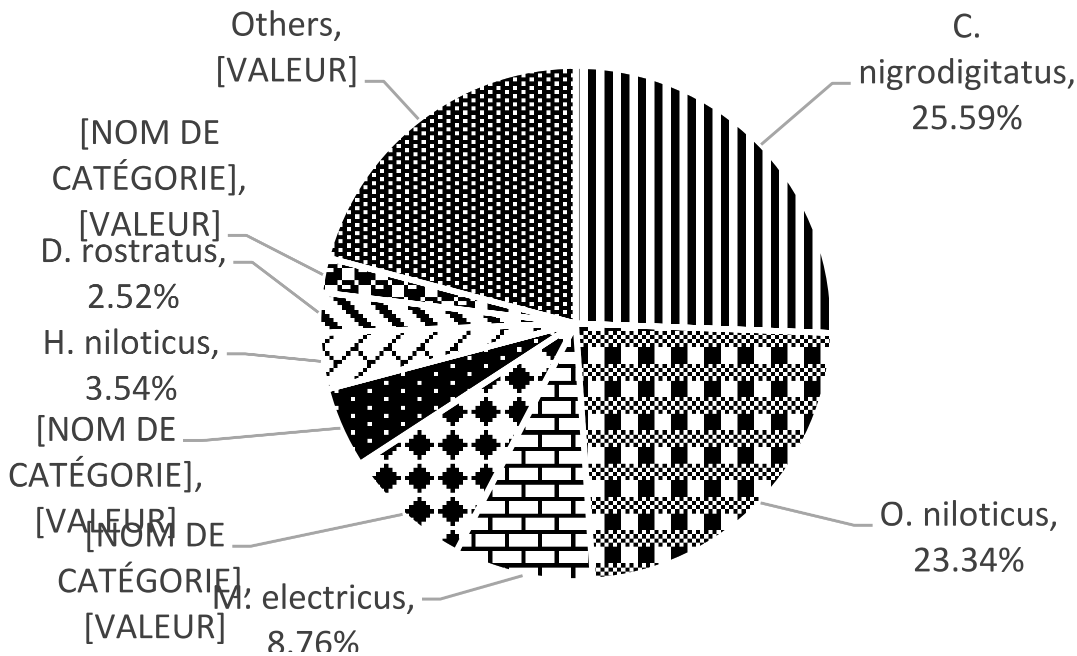

Figure 6. Percentage weight (biomass) of fish species caught in Lake of Buyo.

Table 3. Spatio-temporal variation of diversity (H') and equitability (E) index based on numerical abundance of species sampled in Lake of Buyo from July 2017 to June 2018.

Season	GUESSABO		BUYO VILLE		PK15		
	Shannon (H')	Equitability (E)	Shannon (H')	Equitability (E)	Shannon (H')	Equitability (E)	Variation
Rainy season	2.667	0.7182	2.754	0.8454	2.283	0.6853	NO
Dry season	2.403	0.7136	2.283	0.7752	2.447	0.7699	NO

conductivity, dissolved solids level and pH on the axis I. The second group (B) is composed of the species *A. baremoze, M. ussheri, S. mandibularis, B. longipinnis, H. bimaculatus, H. fasciatus, Lates niloticus, T. guineensis, Tilapia hybrid (T. guineensis x T. zillii), S. melanotheron, S. punctifer, T. zillii, O. niloticus, H. niloticus, C. nigrodigitatus, S. koensis, C. anguillaris, M. electricus, Sarotherodon galilaeus and M. barbatus* associated to Buyo City and PK15 stations. These species are negatively correlated to the nitrite and transparency variables on axis I. Axis II separates the second group (B) into two subgroups (B1 and B2). The first sub-group (B1) of species composed of *Baremoze alestes, M. ussheri, S. mandibularis, S. koensis, B. longipinnis, H. bimaculatus, H. fasciatus, L. niloticus, S. melanotheron, S. punctifer, T. guineensis, O. niloticus* and *Tilapia hybrid (T. guineensis X T. zillii*) is associated with the Buyo city station and is positively correlated to the nitrite variable along axis II. The second subgroup (B2) composed of the species *T. zillii, C. anguillaris, C. nigrodigitatus, M. electricus, S. galilaeus, H. niloticus* and *M. barbatus*, associated to the PK15 station is negatively correlated to the variable transparency.

DISCUSSION

Analysis of the environmental characteristics of the Lake of Buyo indicated a significant spatio-temporal variation in pH, electrical conductivity, total dissolved solids and water transparency of the various stations examined. This variation highlights the existence of different microhabitats on the lake whose ecological quality is closely related to surrounding human activities. Indeed, extreme values of water pH, conductivity and TDS were observed at the station of Guessabo located in urban area contrary to the values measured at the PK15 station located in forest zone closer to the Taï National Park and Buyo city near this park. Barakat et al. (2016) asserted that the deterioration of water quality in Guessabo would result mainly from anthropogenic activities such as the industrial and domestic wastewater discharge as well as

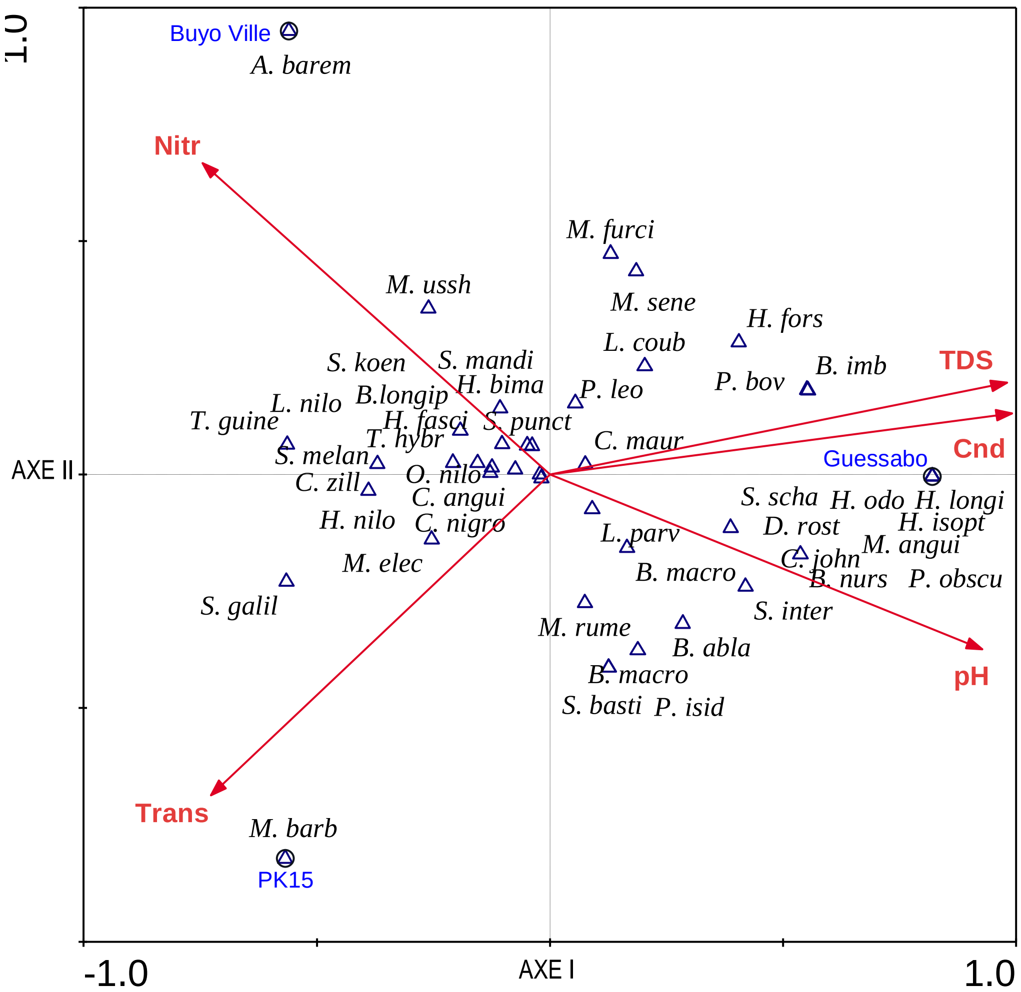

Figure 7. Canonical Correspondence Analysis (CCA) applied to environmental variables and fish species captured in Lake Buyo. The codes and the corresponding species are recorded in Table II. Cnd = conductivity; TDS = total dissolved solids; trans = transparency; pH = hydrogen potential; Nitr = nitrite.

agricultural drainage. This observation is confirmed by the work of Biggs et al. (2004) in the Amazon Basin, Martinelli et al. (2008) in the watersheds of the state of São Paulo, Salomão et al. (2008) in ten subtropical watersheds located in the State of São Paulo in Brazil, Germer et al. (2009) in the south-west of the Brazilian Amazon, and Andrade et al. (2011) in the small watersheds of the Atlantic coastal forest in south-eastern Brazil, which highlighted the impact of urbanization and agricultural practices on water quality. In addition, Silva et al. (2008) and Germer et al. (2009) reported in Amazonian rivers an increase in conductivity in relation to nutrient inputs (NO_3^-, PO_4^{3+}, K^+ and Mg^{2+}) in grazing watersheds relative to forest catchments. The results of this study indicated a spatio-temporal variation in transparency. This water parameter is affected by the amount of suspended sediment, the concentration of dissolved organic matter and the abundance of plankton present in the water column (Cherbi et al., 2008). The high value of transparency at PK15 in the dry season is related to the cumulative effect of the presence of forest that limits watershed erosion and the reduction of rainfall that allows the water body to settle fairly well. The external input of materials by runoff is also reduced (Cherbi et al., 2008).

The present study identified 45 species in Buyo. This specific richness is lower than that of Traoré's work (1996) but higher than that of Kouamé et al. (2008) who reported 56 species and 33 species respectively in the Lake of Buyo. The difference between our results and those of previous work is due to sampling methods and sampled habitats. The results of this study are obtained from sampling based mainly on gill net while the work of Kouamé et al. (2008), in addition utilized a battery of nets associated with electric fishing. This active fishing is more practical in shallow depths. This is not the case in the

Lake of Buyo. These differences could also be explained by (1) the sampling technique used by these authors, (2) the large number of sampling stations and (3) the extent of the study area. Indeed, Traore sampled on the Lake of Buyo in several stations: the zones of Buyo, 1er carrefour, PK28, Mossibougou, Liahinou, Badjan, Guessabo, Guiglo, Gbapleu, Beablo and Kéitadougou. As for Kouamé, his sampling took place only in two stations: the right bank and the left bank of the Lake of Buyo. However, the sampling of the present study considered three stations going from the upstream (Guessabo zone) to the downstream (Buyo city) and including a station located in the reserve part of the primary forest of the Tai National Park (PK15). According to N'Douba et al. (2003), the high number of sampling stations would be necessary because of the habitat diversity. This diversity of habitat positively influences the specific richness of the watercourse (Changeux, 1995). The presence of marine or estuarine species (*P. leonensis, S. galilaeus, S. melanotheron* and *T. guineensis*) shows that they migrate from the Atlantic Ocean to the Sassandra River, and then from the Sassandra River to Lake of Buyo in order to feed or for reproduction. Similar results were noted by Paugy et al. (2003a, b) in African freshwaters.

In the Lake of Buyo, the Cichlidae family dominates in the captures made. These results are similar to those reported by Traoré (1996), Tah et al. (2009), Adou et al. (2017), Montchowui et al. (2008), Ouedraogo et al. (2015) and Kouamé (2010) respectively in the Lakes of Buyo (Côte d'Ivoire), Ayamé 1 and Ayamé 2 (Côte d'Ivoire), Hlan (Benin), Sahelian of Higa (Burkina Faso) and on the lower Sassandra River (Côte d'Ivoire). According to Koné et al. (2003a), the creation of lakes caused by the installation of dam in general is followed by their colonization by Cichlidae species and certain fluvial species. Also, the high number of this family of fish in the captures could be explained by the dam built on the main river bed. Indeed, the Lake of Buyo, due to its stagnant water character, offers adequate ecological conditions that favor the proliferation of phytoplankton and zooplankton (Lévêque, 1997). The lake would be a preferred medium for these microphages who found a vacant trophic niche formed by the proliferation of plankton (Traoré, 1996). The spatio-temporal variation in species richness observed in the lake of Buyo is not a new phenomenon in open-type lacustrine environments (Lévêque, 1999). According to Bouchereau (1997), this variation is related either to the behavioral changes of individual fish, who becomes more or less vulnerable to fishing technique, or to migrations of populations. In the Lake of Buyo, spatio-temporal variations in species richness would be much more related to species migrations between the lake and its associated rivers during periods of low and high water. Indeed, the highest species richness on the lake is observed during the months of August-September which correspond to the rainy season. Fish migrate downstream from the N'zo and Lobo Rivers and the Sassandra River to Lake of Buyo at Guessabo and its flooding in search of suitable sites for spawning. In contrast, low specific richness is observed in December and March. It is the dry season and species that have come to reproduce in the shallow marginal areas of the lake migrate in the opposite direction. This situation was reported by Montchowui et al. (2008) in Lake Hlan in Benin where species richness would be higher during the rainy season because fish migrate from downstream of the Sô and Ouémé Rivers to Hlan Lake. The species *H. odoe, C. johnelsis, H. isopterus, H. longifilis, S. schall and P. obscura* were captured only at Guessabo station. The majority of these captures were made during the rainy season, the reproduction period for the majority of fish where the larvae and juveniles of the year's breeding are the most numerous with favorable feeding conditions for piscivorous species such as *H. odoe* and *P. obscura*. In addition, in this station, unlike the other two, is characterized by a muddy substrate, a preferred medium for species of the genus *Heterobranchus* and *Synodontis*. These fish search the mud in the bottom to extract plant debris, insect larvae, seeds and animal detritus. According to Yao et al. (2010), the muddy substrate plays an important role in feeding some *Synodontis* species that feed on benthic prey. Also, during the capture of these species in the rainy season, the station was largely covered with aquatic plants creating different types of habitats that could offer an availability of food resources due to the presence of floating vegetation, herbaceous and emergence and submergence of adjacent terrestrial vegetation. These habitats would also be suitable spawning grounds for these species and would encourage significant colonization by fish. *C. johnelsis* hitherto known from the Bia River is reported for the first time in the Lake of Buyo. Alestes baremoze, surface fish near the shoreline and essentially insectivorous according to Traoré (1996), was captured only at the Buyo Ville station, not far from the hydroelectric dam. This part of the station is characterized by a sandy and stony substrate constituting the preferential biotope of Chironomidae (Kouamélan, 1999). According to this author, these insects, which breed throughout the year, are an important source of food to these fishes. In addition, stony substrates are suitable for the development of insect larvae and other small organisms that are important food for fish (Morin, 2003). The species *M. barbatus* was captured only at PK15 station, the only station located in the Taï National Park. Kamelan (2014) for the first time reported this species in the Sassandra Basin, specifically in the Zakoué River, the only tributary of the river that irrigates the Taï National Park. For this author, anthropogenic actions would influence this species that would come to find refuge in the Park. Indeed, Lalèyè (2010a, b) indicated that *M. barbatus* and *M. punctatus* are threatened by agricultural activities, mining, urbanization and deforestation in Liberia, Sierra Leone and Guinea. This threat has also been observed in Nigeria where individuals of *Malapterurus beninensis* are threatened by oil exploration (Lalèyè et al., 2010). The species *H. isopterus* and *H. longifilis* were caught only in Guessabo during the rainy season. In fact, during the rainy season, this station is mostly covered with aquatic plants leading to a reduction in dissolved oxygen levels. However, species of the genus *Heterobranchus* also have an accessory respiratory organ that allows them to breathe oxygen from the air and thus to withstand the hypoxic conditions of the environment. During the dry season, the high dissolved oxygen level (6.56 ± 1.19 mg/l) causes Mormyridae *Marcusenius senegalensis* and *P. bovei*, to proliferate. According to Kamdem Toham and Teugels (1997), Mormyridae are very demanding fish in dissolved oxygen.

In terms of numerical abundance, Cichlidae (34.04%) are the most represented in the Buyo Dam. This trend resembles that observed by Traoré (1996), and Kouamé et al. (2008) in Lake of Buyo and Montchowui et al. (2008) in Lake Hlan in Benin. According to Balogun (2005), Cichlidae are important components of fish fauna in open-type African lakes such as Lakes Ihema (Rwanda), Kainji (Nigeria), Kangimi (Nigeria), Tiga (Nigeria), Georges (Uganda) and Toho-Todougba. The species *O. niloticu*s (15.55%) dominates the captures of Lake Buyo. This is due to the fact that *O. niloticus* is an all year-round reproducing species in the lake (Traoré, 1996) in addition to the appropriate ecological conditions that would favor the proliferation of phytoplankton and zooplankton that the lake would offer. The phytoplankton fraction constituting the diet of this species will favor its adaptation and its proliferation (Lévêque, 1997). This result is similar to those reported by Balogun (2005) in Kainji, Tiga and Bakolori lakes in Nigeria where *O. niloticus* is dominant in captures. The preponderance of *C. nigrodigitatus* in the captures in Guessabo, PK15 and Buyo Ville in the rainy season as well as in the dry season is due to the fact that this species would be benthic invertivore, which could explain its strong geographical distribution in the waterways of Côte d'Ivoire and Africa (Aboua et al., 2010).

In terms of abundance, Siluriformes (Claroteidae, Malapteruridae, Clariidae and Mochokidae) alone accounted for 44.58% of total biomass. This large proportion of Siluriformes fish could be explained by the fact that they are species that resist degrading ecological conditions (Tejerina-Garro et al., 2005). In the Lake of Buyo, for the species that dominate the settlement, their maximum numerical and maximum relative abundances were recorded during the rainy season. Indeed, when the water level rises, it invades the banks and is enriched with nutrients from the decomposition of organic matter and vegetation. This results in a rapid development of phytoplankton, zooplankton ... implying a rapid growth of fish correlated with a large biomass. In addition, the biomass is higher at the PK15 station compared to the Guessabo station, where the numerical abundance is high. This result would mean that the PK15 station in the Taï National Park, which is a reserved area, would offer adequate nutritional resources for the good development of the species found there, moreover, since these do not suffer from anthropic pressures (intense fishing activities, domestic and industrial pollution ...) as is the case in the Guessabo and Buyo Ville stations. Hugueny (1990) reported that the change in the vegetation cover due to agricultural and logging activities causes a reduction in the nutritional resources for species living in these environments. According to Kamelan (2014), the Taï National Park would be a good area for species development. The values of the diversity index (H' varying from 2.283 to 2.74) and of the equitability (E ranging from 0.685 to 0.845) in the three stations of the Lake of Buyo indicate a good settlement organization of studied stations. The results of this study indicate that the value of equitability in the different stations of the Lake of Buyo is above average. These results reflect a more or less balanced distribution of species.

The canonical correspondence analysis (CCA) indicates that the distribution of *M. furcidens* species, *M. senegalensis, L. coubie, P. bovei, H. forskalii, B. imberi, P. leonensis, C. maurus, H. isopterus, H. longifilis, S. schall, C. johnelsis, M. anguilloïdes, B. macrolepidotus, L. parvus, D. rostratus, B. nurse, H. odoe, P. obscura, S. intermedius, M. rume, B. ablabes, S. bastiani, B. macrops* and *P. isidori* at Guessabo station are significantly related to physico-chemical parameters such as pH, conductivity and total dissolved solids (TDS). In Côte d'Ivoire, several studies (Kouamé et al., 2008; Aboua et al., 2010 ; Kamelan et al., 2013, 2014) carried out on different rivers established relationships between species and environmental variables. Kouamé et al. (2008) showed the influence of dissolved solids levels on the species *H. forskalii, L. coubie* and *D. rostratus* in the main stream of the Sassandra River. Aboua et al. (2010) reported that dissolved solids, pH, and electrical conductivity significantly influence *B. ablabes, C. maurus, P. bovei,* and *B. imberi* species in the Bandama River. The importance of pH in the distribution of *M. senegalensis, B. macrolepidotus and M. anguilloides* species was also noted by Kamelan et al. (2013). The significant influence of these physicochemical parameters is related to the closeness of this station to human activities (cultivation, laundry, dishes, washing of vehicles). Indeed, the Guessabo station has the highest values of conductivity, pH and TDS in the zone Lake Buyo. These anthropogenic activities favor the variation of the parameters related to the mineralization of the waters (pH and conductivity). In addition, TDS is one of the discriminating factors influencing the distribution of fish communities in this study. Indeed, a high level of TDS is correlated to a strong accumulation of dissolved elements which influences the presence of fish species in

Guessabo. Similar results have been found in some rivers in Côte d'Ivoire. They are the Agnébi and Bia Rivers (Da Costa et al., 2000) and the Comoé River (Yao et al., 2005).

Nitrite is the only parameter influencing the distribution of *A. baremoze, M. ussheri, S. mandibularis, S. koensis, B. longipinnis, H. bimaculatus, H. fasciatus, L. niloticus, S. melanotheron, S. punctifer, T. guineensis, O. niloticus,* and *Tilapia hybrids (T. guineensis x T. zillii)* at Buyo Ville Station. In the Taï space hydrosystems in Ivory Coast, Kamelan (2014) found that the species *M. ussheri*, *S. mandibularis, B. longipinnis*, *H. fasciatus* and *S. melanotheron* had a preference for nitrite. The significant influence of nitrite in the distribution of species is linked to the strong agricultural activities in the vicinity of Buyo Ville Station. The nitrite level is higher (0.006 mg/l) in this station but does not exceed the threshold value (0.06 mg/l) above which nitrites becomes a threat to the development of aquatic fauna.

Transparency influences the distribution of *T. zillii, C. anguillaris, C. nigrodigitatus, M. electricus, S. galilaeus, H. niloticus and M. barbatus* at PK15. Aboua (2010) has highlighted the importance of transparency in the distribution of *C. nigrodigitatus* in the Bandama River. Kamelan (2014) argues that the transparency of water is affected by the amount of suspended elements, the dissolved organic matter concentration and the abundance of plankton (algae and microorganisms) in the water column. High transparency implies a small amount of these elements food source to these bhophophagous insectivorous species.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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