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Nest-site Characteristics and Nest Abundance of *Coptodon zillii* (Pisces, Cichlidae) in Lake Buyo, Côte d'Ivoire

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Abstract: Nest sites and nest abundance of *Coptodon zillii* was investigated in Lake Buyo (Côte d'Ivoire), specifically in the Taï National Park' bordering side. Nest counts and determination of habitat characteristics such as water depth, bottom slope, and sediment analyses were performed from April 2019 through November 2019 in 11 sampling sites (9 sites around shoreline zone and 2 in deep water area). No nest was observed in deep water zone (sites located at distances > 600 m of shoreline and depth between 94 and 1253 cm). Nests were recorded only in part of littoral zone which start from shoreline to water depth varying between 27 and 927 cm. Nest density recorded varied between 1.47 to 3.67 nests/m². In this zone, *C. zillii* nests were absent in depths higher than 40 cm throughout the sampling period. Results of this study indicate that *C. zillii* build nests on a larger particle size (gravel and medium sand), preferentially choose a flat substratum (slope < 25°) and closed to a shoreline. Nest density was negatively correlated with slope and water depth while it was positively correlated with optimum nesting depth.
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1. Introduction

Tropical lakes and reservoirs are rich in ichthyofaunal diversity and support profitable fisheries (Negi and Negi 2010; Craig, 2015). Unfortunately, the last decades have witnessed in-creasing pressures on freshwater systems through introduced species, overexploitation, water pollution, hydropower and hydroelectric development, catchment deforestation, water di-versions, and overall land use change (Chapman and Chapman, 2003). Like in the other Lakes of Côte d'Ivoire (West Africa), Lake Buyo is vulnerable and undergo degradation under anthropogenic pressures, with numerous consequences on the riverine population (Ossey et al., 2008). Lake Buyo, with an area of 600 km², born from the construction of a hydroelectric dam on the Sassandra River, is one of the four largest coastal basins of Côte d'Ivoire. This lake, which is one of the most important sources of production of fish consumed in Côte d'Ivoire, has a part that integrates the Taï National Park, an environment that benefits from ecological protection and monitoring measures, especially for terrestrial animal and plant species.

The extent of threats requires us to establish priorities and to set goals and targets for the protection of aquatic systems and their biodiversity. On this point, much attention must be paid to the conservation of fish spawning for the production and management of fish stock. Many fish species inhabit shallow coastal areas, where anthropogenic disturbances tend to be most frequent and severe, representing the main threat to their survival. Because life history strategies of coastal fish are in association with high habitat specialization, these animals are particularly vulnerable both to habitat loss/degradation and to exploitation (Reynolds et al., 2005). Fish species have evolved various strategies to increase their reproductive success, including simple processes (e.g., reproduction of pelagic species in the water column) and complex mechanisms that involve parental care as demersal eggs laid within nests (Andersson, 1994). *Coptodon zillii*, as part of the reproductive tactic, is a nesting wrasse where territorial site selection is initiated by the male and the female joins later. The nest construction is carried out bi-parentally. The nests containing the eggs are guarded by both the male and female *C. zillii* (Gophen, 2016). *Coptodon zillii* is one of the fish regularly recorded in catches of Lake Buyo. Also, this species is important as a food fish as well as for aquaculture in Côte d'Ivoire.

Several studies regarding different nesting fishes highlighted difference in nests and nest sites, even if this difference led to variation in mating success (Wernerus et al., 1989; Alonzo and Heckman, 2010). For species in which egg predation is common, many authors have suggested that the quality of the nest depends on some characteristic of the nesting site, such as camouflage (Kraak et al., 2000; Candolin and Salesto, 2006; Raventos, 2006). According to Bruton and Gophen (1992), Mendonça and Gonçalves-de-Freitas (2008) and Rachel (2015), substratum, depth of water bodies, slope water, level fluctuation and the exposure to the wave action were identified as determinants of greater success on the nesting of cichlid species. Despite the evidence that *Coptodon zillii* chooses components to build the nest (Bruton and Gophen, 1992; Gophen, 2016), no study has identified any intrinsic physical characteristics of nests and nesting site of *C. zillii* that explain whether their building activities are in response to some particular characteristic or, instead, occur in a random pattern.

The aim of this study is to analyze the effect of some environmental factors (nature of the substrate, water depth and slope) on the nesting of *Coptodon zillii* in Lake Buyo.

2. Material and methods

Study area

Lake Buyo is an artificial lake located on the Sassandra River in South west of Côte d'Ivoire (1°14'-7°03'N, 6°54'- 7°31' W) and provides electric power (Ossey et al., 2008) (Figure 1). It covers an area of 920 km² with a catchment area of 75 000 km² (Traoré, 1989). By its size, this lake is the second largest hydroelectric power plant in Côte d'Ivoire after Kossou Lake (Traoré, 1989). The vegetation of the region is primarily tropical rainforest. Lake Buyo is located in a region under the influence of subequatorial climate characterized by two rainy seasons, a short (September-October) and a long season (March-June); and two dry seasons, a long (November-February) and a short season (July-August) (Collinet et al., 1984). The hydrological regime of the lake depends on that of the Sassandra River, tributaries of N'zo and rainfall of the region.

This study was conducted in the part of the Lake Buyo located in Taï National Park (Figure 1); specifically, in the part which included the old bed of flooded N'zo River (OIPR, 2006). A total of 11 sites were selected, of which 9 sites (S1, S2, S4, S5, S6, S7, S9, S10 and S11) were located in shoreline zone (depth varying between 27 and 927 cm) and 2 sites (S3 and S8) in deep water (sites located at distances > 600 m of shoreline; and depth between 94 and 1253 cm). Sites were selected based on their easy accessibility. Also, in all sampling stations, nests observed were those of *Coptodon zillii* (> 80 % of individuals caught in Lake Buyo were those of *C. zillii*) (Figure 2).

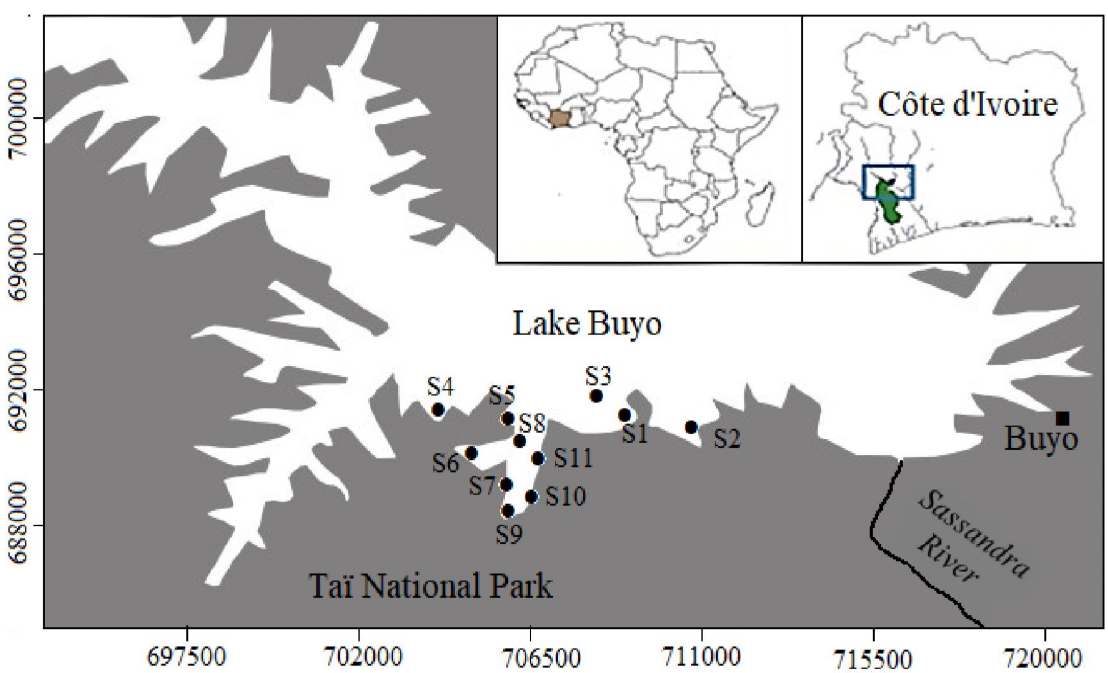

Figure 1. Map showing the localization of the sampling sites (•) in Lake Buyo (Côte d'Ivoire)

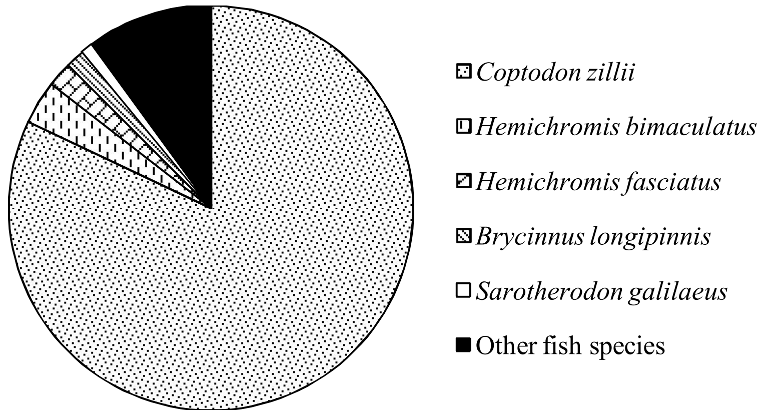

Figure 2. Relative abundance of fish species collected around shoreline zone in sampling sites of Lake Buyo (Côte d'Ivoire)

Sampling and statistical analysis

This study was carried out monthly from April 2019 through September 2019. Three quadrats of 10m × 3m size were established. These quadrats were not fixed, but were changed according to fluctuations in the water level. In each quadrat, nest density and one soil sample were collected. Only functional nests, as determined by the appearance i.e., those which are not covered with debris, were chosen. As it was difficult to observe nests occupied by male and female of *Coptodon zillii*, nests which were not covered with silt and those which were not invaded by aquatic plants were considered as freshly constructed.

Nests density (d) was estimated as follows:

$$\text{Density (d)} = \frac{\text{Number of nests (n)}}{\text{Area (s)}}$$

Sediment samples collected in different sites were dried and sieved in order to evaluate the grain size distribution (Bruton and Gophen, 1992; Bandara and Amarasinghe, 2017).

Grain sizes were divided in 8 categories following Blott and Pye (2001):

- boulder (D ≥ 64 mm),
- gravel (2≤ D <64 mm),
- very coarse sand (1≤ D <2 mm),
- coarse sand (0.5 ≤ D <1 mm),
- medium sand (0,25 ≤ D <0,5 mm)
- fine sand (0.125 ≤ D <0.25 mm),
- very fine sand (0.063 ≤ D <0.125 mm), and
- silt+clay (D <0.063 mm).

Fish-nests were counted in different sampling site by quadrat method. For each quadrat measurement, nest density was determined for different water depths (Depth 1: 0-15 cm; Depth 2: 15-25 cm; Depth 3: 30-40 cm; Depth 4 > 40 cm). Water depth (cm), maximal nesting depth (cm) (maximal nesting depth is the depth where the last nest has been found when going in deep water zone) and slope of nesting ground were recorded at each sampling site.

Nesting ground slope was determined by making two depth measurements: the first one was taken 2 m from shoreline and the second 2 m further from the shore relative to the respective nest rim locations. Slope was then calculated by using the formula:

$$\text{Slope} = \frac{\text{Depth1} - \text{Depth 2}}{4}$$

Slope was divided in 3 categories following Raventos (2006): flat, 0–25°; gentle, 26–60°; steep, > 60°.

Spatial and seasonal variation in nest density and environmental variables were evaluated using Kruskal-Wallis test and Mann-Whitney *U* test. The degree of association between the nest density and environmental characteristics was assessed by the determination correlation coefficient (r^2). Spearman correlation rank test was used for the analysis of the relationship between nest abundance and environmental variables.

3. Results

Nest density

The highest values of water depth were recorded in sites located relatively far from the shoreline (S3 and S8) (respectively 817 ± 293.33 cm and 539.33 ± 298.36 cm). Significant differences were obtained between site S3 and site S6, S7, S8, S9 and S10 (Kruskall-Wallis test, $p < 0.05$). Fish nests were found absent in sites located relatively far from shoreline (Figure 3). In sites located near shoreline, mean nest density varied between 1.47 ± 1.05 (S10) and 3.67 ± 2.10 nests/m² (S6). But, no significant difference (Kruskall-Wallis test, $p > 0.05$) was observed between sampling sites.

Except in site S6, mean nest density of *Coptodon zillii* was higher in dry season (2.18- 4.19 nests/m²) and lower in rainy season (0.94-3.13 nests/m²) in sampling sites located near shoreline (Figure 4).

Mann-Whitney U-test performed showed significant difference between seasons only for sites S7, S9 and S10 ($p < 0.05$).

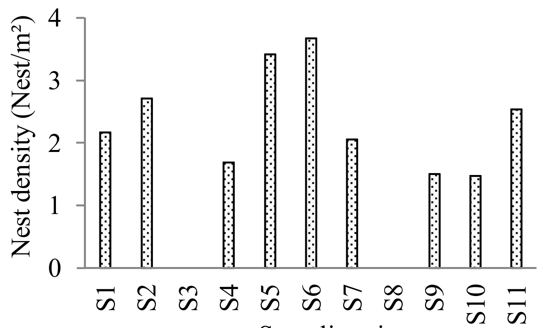

Figure 3. Spatial variation of *Coptodon zillii* nest density in sampling sites of Lake Buyo (Côte d'Ivoire)

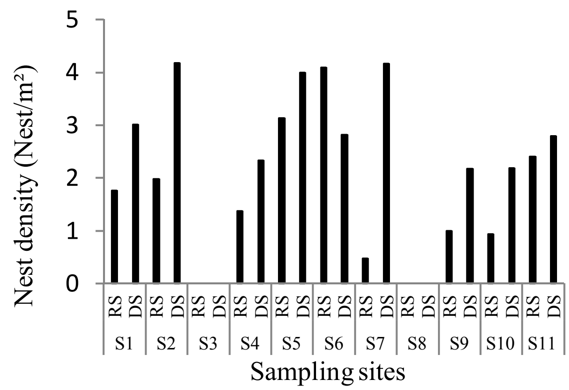

Figure 4. Seasonal variation of *Coptodon zillii* nest density in sampling sites of Lake Buyo (Côte d'Ivoire): DS=dry season; RS=rainy season

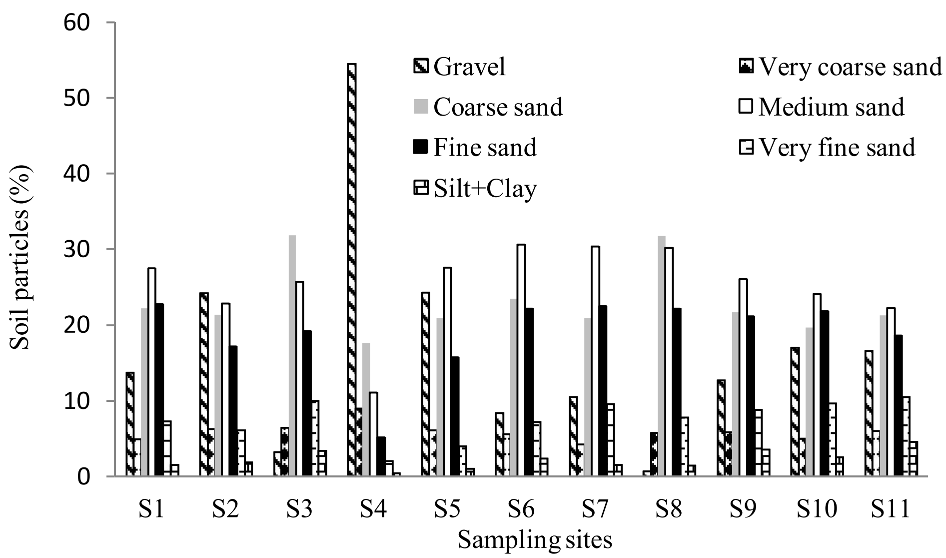

Figure 5. Mean percentages of different soil particles in the sediments of sampling sites (S1 to S11) of Lake Buyo (Côte d'Ivoire)

Table 1: The mean (±SE) of maximal nesting depth of *Coptodon zillii* and slope of nesting sites characteristics in the Lake Buyo (Côte d'Ivoire)

		Maximal Nesting depth		Slope of nesting sites	
Seasons		RS	DS	RS	DS
Sites	S1	21.2± 7.59	23.5±6.52	10.03±5.93	6.6±1.51
	S2	23.1±4.43	25.17±7.33	10.06±2.76	6.75±2.84
	S4	19.45±6.36	21.8±7.56	14.26±9.94	11.37±4.93
	S5	24.86±6.62	21.17±7.63	9.46±5.51	9.11±5.40
	S6	22.82±7.04	22.25±6.31	6.13±2.30	7.18±4.03
	S7	22.5±4.95	27.33±4,41	7.70±2.35	6.40±2.50
	S9	19±9.99	21.5±7.12	12.27±5.12	8.59±4.30
	S10	18.4±7.92	20.42±5.63	8.99±4.33	7.40±2.00
	S11	19.95±8.55	20.08±6.90	9.99±5.31	8.92±3.53

Factors related to nesting of *Coptodon zillii*

The results (Figure 5) clearly indicate that *Coptodon zillii* selected substrate with larger particle size for nest construction within sheltered area. In sites S2 and S4, substrate that was used by *C. zillii* for nest construction is dominated by gravel (respectively 24.24 and 54.55%). In contrast, in sites S1, S5, S6, S7, S9, S10 and S11, substrate was predominately covered by medium sand (22.24-30.65%). In sites located far from shoreline zone (S3 and S8), nesting ground is dominated by coarse sand (31.79-31.88%).

Hierarchical classification analysis, based on the values of sediment particles help isolated site S4 which was dominated by gravel (Figure 6).

The mean of maximal nesting depth varied between 19.5 ± 6.48 cm (S10) and 26.13 ± 4.73 cm (S7). But, no significant difference (Kruskall-Wallis test, $p > 0.05$) was observed between sampling sites. Except in sites S5, mean of maximal nesting depth was higher in dry season (18.17- 27.33 cm) and lower in rainy season (5.63-20.92 cm) in sampling sites closed to shoreline (Table 1). Mann-Whitney U-test performed showed significant difference between seasons only for site S7 ($p < 0.05$).

The mean of substratum slope varied from 6.49 ± 2.91° (S6) and 13.30 ± 8.54° (S4). But, significant difference (Kruskall-Wallis test, $p < 0.05$) was observed between site S4 and sites S6 and S7. Except in site S6, mean slope was higher in rainy season (7.70-14.26°) and lower in dry season (6.40-11.37°) in sampling site closed to shoreline (Table 1). Mann-Whitney U-test performed showed significant difference between seasons only for site 2 ($p < 0.05$).

Correlation between nest density and environmental factors

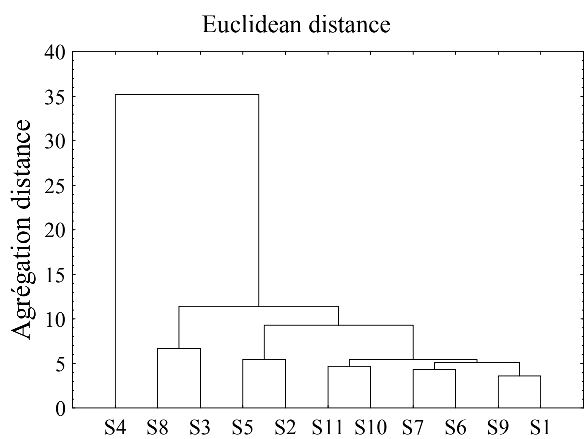

Figure 6. Hierarchical classification of sampling sites (S1 to S11) in Lake Buyo (Côte d'Ivoire) based on the values of different soil particles in the sediments

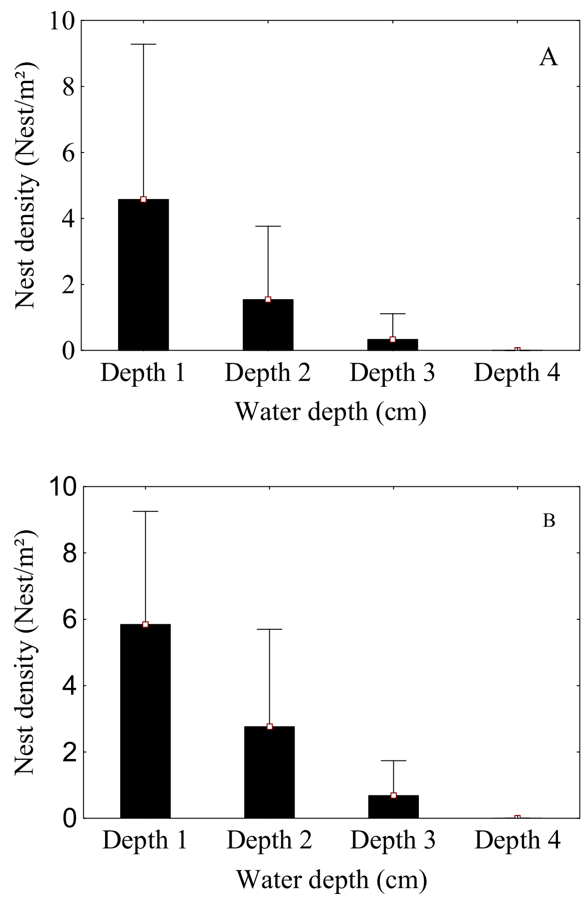

Figure 7. Depth-wise nest densities (mean ± SD) of *Copton zillii* in Lake Buyo during rainy (A) and dry (B) seasons. Depth1= 0-15 cm; Depth2= 15-25 cm; Depth3=25-40 cm, Depth > 40 cm

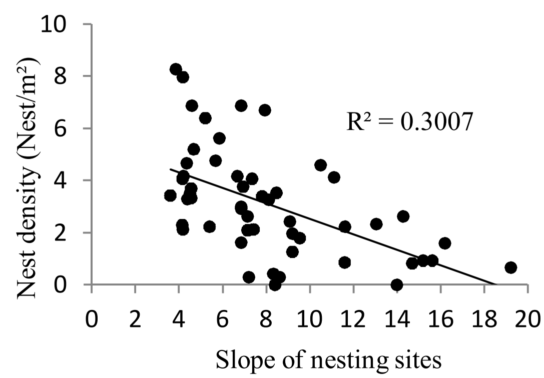

Figure 8. Relationships between *Coptodon zillii* nests density and slope of nesting sites during dry A season in Lake Buyo (Côte d'Ivoire)

Nests densities decreased with water depth during dry and rainy seasons (Figure 7). Nests were found absent in depths higher than 40 cm throughout the sampling period. But, significant difference (Kruskall-Wallis test, $p < 0.05$) was observed between depth 1 and other depths (depth 2 to depth 4) and between depth 2 and other depths (depth 3 and 4) for all seasons.

Nest density was found to have a negative relationship with substratum slope and water depth both for dry and rainy seasons (Figure 8-11).

The Spearman correlation rank analysis performed on nest density revealed that water depth, slope and optimum nesting depth strongly influenced the abundance of nest (Table 2). The abundance of nests was negatively correlated with slope and water depth while it was positively correlated with optimum nesting depth. Also, optimum nesting depth was negatively correlated with slope.

4. Discussion

Fish reproduction is a cyclic phenomenon which is synchronized with seasonal fluctuation of environmental characteristics. This synchronization between reproduction cycle and forecastable environmental characteristics is an adaptative process: during their evolution species have adjusted their sexual cycle so as to reproduce during the period most favourable to eggs survival (Paugy et al., 2006). To increase reproduction success, many fish species exhibit parental care strategies which include 1) guarding eggs and larvae, 2) nest construction and eggs incubation (Paugy et al., 2006). An interesting way of protecting fish eggs and larvae is to lay them in nests which can be guarded or not. Parental care is also a way to reduce predation of fish eggs and fish larvae. In present study, fish capture made in different sampling sites (80% of species caught) showed that the nests encountered belong to *Coptodon zillii*. Nest construction has been found in many other cichlid species such as *Lethrinops aurita*, *Copadichromis eucinostomus*, *Protomelas kirkii*, and *Oreochromis squamipinnis* (Fermon and Bigorne, 2006).

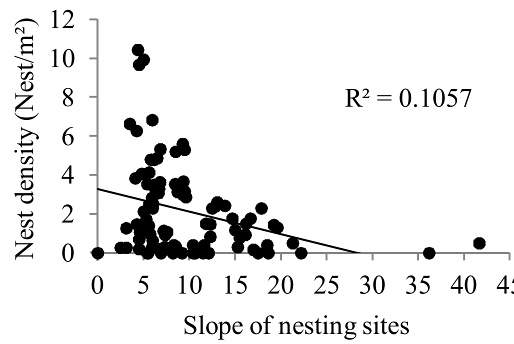

Figure 9. Relationships between *Coptodon zillii* nests density and slope of nesting sites during rainy season in Lake Buyo (Côte d'Ivoire)

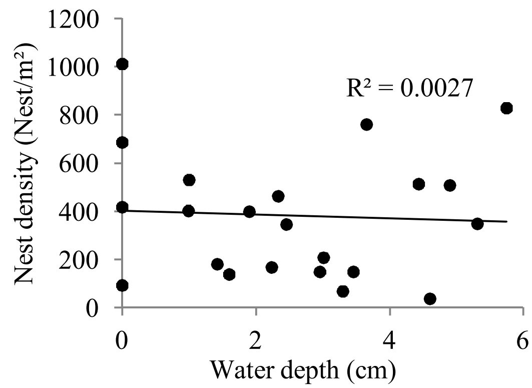

Figure 10. Relationships between *Coptodon zillii* nests density and water depth during dry season in Lake Buyo (Côte d'Ivoire)

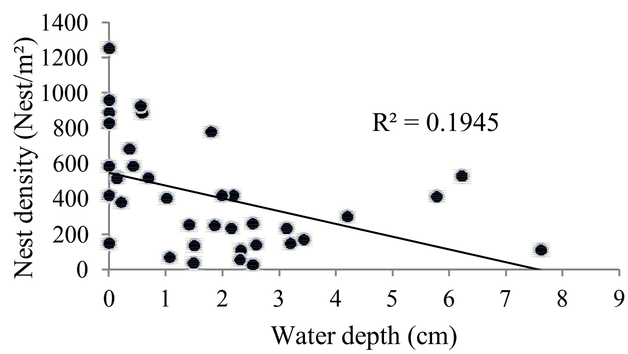

Figure 11. Relationships between *Coptodon zillii* nests density and water depth during rainy season in Lake Buyo (Côte d'Ivoire)

Table 2. Results of the Spearman rank correlation analysis (*p*-values) between *Coptodon zillii'* nest density and environmental factors in Lake Buyo (Côte d'Ivoire)

	Environmental variables									
Nest	WD	Slope	OND	Gravel	VCS	CS	MS	FS	VFS	Silt+clay
density	**-0.63**	**-0.42**	**0.72**	0.09	-0.01	0.09	**0.20**	0.13	-0.05	-0.04

Significant correlations are in bold; WD: water depth; OND: Optimum nesting depth; VCS: very coarse sand; CS: coarse sand; MS: medium sand; FS: fine sand; VFS: very fine sand

Many fish species aggregate to spawn. Whereas some species may aggregate behaviourally and so may have extensive spawning grounds that may aggregate over a more restricted spatial extent. There are numerous modes of reproduction in fishes (Balon, 1984; Ellis et al., 2012). Nest counts in Lake Buyo revealed that nest density varied between 1.47 m² and 3.67 m² within sampling sites for water depth varying from shoreline to 927 cm depth. These density data tend to show that *Coptodon zillii* may aggregate to spawn.

Many studies showed that fish nesting ground characteristics vary with species (Kraak et al., 2000; Candolin and Salesto, 2006; Ellis et al., 2012). Results of study performed in Lake Buyo indicate that *Coptodon zillii* preferentially built nests on substratum with larger particle size (gravel and medium sand). Nest density in Lake Buyo was found to be influenced by substratum slope, and water depth as well. Flat substratum, with slope lower to 25° were preferred while nests were much more abundant in sites located near shoreline, where the water depth is reduced. *C. zillii* nests were found absent in sites with water depths higher than 40 cm. De Silva and Chandrasoma (1980) found similar results in a Sri Lankan reservoir where cichlid fish *Oroechromis mossambicus* nests were scarce in water depths beyond 70 cm deep.

Mean of nest density of *Coptodon zillii* was higher in the months of low water level (dry season) justifying the importance of investigating the effect of lake water level fluctuation on fish nesting sites availability. Water level fluctuations in reservoirs has been reported to influence benthic and eulittoral fish communities in various ways including loss of suitable spawning grounds (Gafny et al., 1992; Sutela and Vehanen, 2008). Further, nests of the Cichlid *Oreochromis niloticus* in Lake Mutirikwi in southeastern Zimbabwe were found to be affected by water level fluctuations (Rachel, 2015). This show that water level fluctuations related to electricity production process by the Buyo electricity power dam is a possible factor that could impede nesting availibity in Lake Buyo. Similar observations have been made in irrigation reservoirs of Sri Lanka by Bandara and Amarasinghe (2017) where water level fluctuations were mainly governed by irrigation authorities and, as such, the irrigation authorities responsible for reservoir water level fluctuations have a potential role in enhancement of recruitment to the fisheries of *O. niloticus* in reservoirs.

According to Reynolds (1974) spawning season for a given species could change with variation of environmental characteristics as part of attempt of the species to adjust their reproduction strategy to better cope with most suitable environmental characteristics. But the low maximum nesting depth recorded during the rainy season and the negative relationship between water depth and nest abundance seemed to show that underwater visibility is an important factor in the choice of nest construction site by *C. zillii*.

In *Coptodon zillii*, sexual selection by females is dependent on visual cues of strong males. In polygynic animals, females are reported to invest in selecting strong males based on their successful characteristics favoring reproduction (Alcock, 2001; Mendonça and Gonçalves-de-Freitas, 2008; Davies et al., 2012). Visual cues during reproductive process are crucial in cichlids (Douglas and Hawryshyn, 1990; Horppila et al., 2004; Venesky et al., 2005). Turbidity is known to be linked with reduced fish vision (Berg and Northcote, 1985) and predator avoidance behavior (Miner and Stein, 1993; Meager et al., 2005). The present study gives further evidence that deep water environments have negative impact on nests construction in *C. zillii*. According to Lejeune (1985), the least cryptic nests are the most visited. Results presented here are consistent with these observations and show that nesting males actively select sites near marginal zone, where nests are more visible to females. Further, other studies (Ostlund-Nilsson and Holmlund, 2003) previously demonstrated that female *C. zillii* choice related to some nest attribute can be reflected in nesting success, but the work performed here did not allow this to be statistically tested.

Mean nest density of *Coptodon zillii* observed in this study varied from 1.47 to 3.67 nests/m². Nest density of *C: zillii* in this lake is higher than that of *Oreochromis niloticus* recorded by Bandara and Amarasinghe (2017) in 10 irrigation reservoirs in Sri Lanka (0.18-0.56 nests/m²). This high nest density of *C. zillii* in present study showed that sampling sites in the Taï National Park offer suitable environmental characteristics for *C. zillii* reproduction.

Since the modes of construction and shape attributes of nests in cichlid species vary from species to species (Fryer and Iles, 1972), the present analysis on the nest locations of *C. zillii* in relation to water level fluctuations provides supports to the consideration of hydrological management for reservoir fisheries enhancement in Lake Buyo.

The littoral zone is the area near shore where the light penetrates to the water body's floor. It is also the area most often affected by human activity. The littoral zone is the most productive area in a lake or river. Light serves as an energy source for the growth of algae and aquatic plants. According to Gophen (2016) food resources of adults and young fingerlings of *C. zillii* are found at the bottom of the shallow waters. The littoral zone also serves as a spawning and nursery area for many fish species (Land Owner Resource Centre, 2000). As a consequence, sampling sites of this study seem to be important habitats which need to be protected. This is consistent with the idea that shoreline modification is as a top threat to aquatic ecosystems and the protection of unmodified habitat, such as aquatic habitats in Taï National Park appears as primary focus for ecosystem research.

Conclusion

Lake Buyo, specifically sites located in the Taï National offer favourable environmental characteristics for reproduction of *Coptodon zillii*. The present study has shown that *C. zillii* used larger particle size substrate for nest construction. This species preferentially chooses flat substratum closed to shoreline. Nest density of *C. zillii* in the Lake Buyo was influenced by slope of the site, water depth.

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