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*Full Length Research Paper*

# Fish assemblage structure in the Tropical Coastal Lagoon of Grand Lahou (Côte D'Ivoire, West Africa)

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**Fish assemblages and their relationship with hydrological variables were investigated in the coastal lagoon of Grand-Lahou (Côte-d'Ivoire) from November 2013 to October 2014. Samplings were carried out by means of artisanal fisheries, once a month, in three sites. A total of 8571 fish belonging to 47 fish species from 25 families were recorded. The most represented families were Cichlidae and Mugilidae with six species. Each environmental variable, notably, dissolved oxygen (DO), temperature and salinity according to the canonical correspondence analysis (CCA) allowed the distinction of two main sectors in the lagoon, associated with three fish assemblages. Sector 1 including sampling sites 2 and 3, characterized by high salinity fluctuations, functioned as a typical estuary. Two fish assemblages identified in this sector were *Lutjanus dentatus*, *Mugil cephalus, Mugil bananensis, Tilapia guineensis* and *Tylochromis jentenki* in station 2 and *Sarotherodon melanotheron, Liza falcipinnis* and *Pomadasys jubelini* in station 3. Sector 2 comprising the sampling site 1, characterized by low salinity fluctuation is associated with 11 fish species, notably, *Ethmalosa fimbriata* and *Elops lacerta*. The fish assemblage in this sector depends on season, temperature and DO.**

**Key words:** Ichthyofauna distribution, environmental variables, Grand-Lahou lagoon, Côte d'Ivoire.

## INTRODUCTION

Costal lagoons are considered worldwide as sites of high biodiversity and productivity (Mitsch and Gosselink, 2000). Indeed, these ecosystems provide key habitats for migratory species and are important nursery areas (Basset and Abbiati, 2004). According to Garrido et al. (2011), the conservation of such habitats depends largely on the assessment of their natural characteristics, especially fish biodiversity, which is one of the main criteria used when elaborating environmental protection policies. Moreover, environmental parameters such as

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temperature, pH and dissolved oxygen (DO) or transparency, are known to affect fish distribution in these brackish lagoons (Marshall and Elliott, 1998). Thus, identification of significant associations between fish species and habitat conditions is the first step toward incorporating environmental information into fish abundance (Perry et al., 1994). The ichthyofauna in West African coastal lagoons have been well described by many authors stated that these ecosystems are currently subjected to several anthropogenic pressures. One of which is the increasing fishing pressure concentrated only on very few species (Villanueva, 2004). In Côte d'Ivoire, the lagoon system constitutes about 300 km along the coast and has a total surface area of about 1268 km². Three large lagoons can be identified from West to East: Grand Lahou (190 km²), Ebrié (566 km²) and Aby (424 km²) (Durand and Skubich, 1982). Among them, the Ebrié and Aby lagoons have been well investigated and several studies have addressed a wide variety of bio-ecological characteristic and fishing practices, on these water bodies (Albaret, 1994). In contrast, little is known considering the Grand-Lahou lagoon. However, recent investigations relating to environmental variables and zooplankton production were carried out on this lagoon, respectively, by Konan et al. (2008) and Etilé et al. (2009). Although, this step has a major importance to understand the biological functioning of this coastal lagoon, none study actually considered the fish diversity and its relationships with the environmental parameters. The aims of the present research were to (i) inventory the fish species composition in the Grand-Lahou lagoon through commercial catches and (ii) determine the main environmental variables (that is, salinity, temperature, dissolved oxygen, pH and transparency) that are associated with fish species distribution.

## MATERIALS AND METHODS

### Study area and fishery characteristic

Located between 5° 08'-5° 03'N and 4° 51'-5° 25'W, Grand-Lahou lagoon (Côte D'ivoire, West Africa) is an elongated open coastal water body which stretches to about 50 km, with a mean depth of 3 m (Laë, 1982). A channel connects the lagoon to the Atlantic Ocean in the eastern part, whereas in the north it receives freshwater discharged from three connecting rivers (Bandama, Boubo and Gô) (Laë, 1997). This aquatic system is essentially composed of four water bodies (Figure 1) which are from east to west, Tagba (57 km$^2$), Mackey (28 km$^2$), Tadio (90 km$^2$) and Niouzoumou (15 km$^2$) (Laë, 1982). The mean annual water temperature in the region fluctuates from 25 to 28°C (Konan et al., 2008). The climate is an equatorial transition, characterized by 4 seasons. A long dry season from December to March, a long rainy season from April to July, a short dry season in August and September and a short rainy season in October and November (Durand and Skubich, 1982). The lagoon region is a large area covered by swamps with vegetation dominated by mangrove raphia palm (*Raphia sudanica*), African oil palm (*Elaeis guineensis*), and coconut palm (*Cocos nucifera*) culture. Grand-Lahou lagoon is considered as an important fishing area with three main fishing sectors (Tadio, Agoudam and Passagri) (Laë, 1982; Diaby et al., 2012). The Tadio sector is an area located near the Tadio lagoon including the fisher's village of Tadio (Figure 1). The second sector comprising the village of Agoudam on the edge of the Tagba lagoon, receives marine waters from Atlantic Ocean and freshwater from two rivers (Bandama and Gô), and the third sector, located in the connection with the sea, Tagba lagoon and Bandama Rivers, includes a fishing ground called Passagri. Fishery is artisanal with several fishing gears such as various gill net mesh sizes, hooks, and cast nets. According to Laë (1982), commercial catches in Grand-Lahou lagoon were dominated by *Chrysichthys nigrodigitatus*, notably, in the Tadio sector.

### Data collection

Samplings were carried out in the described three main landing sites. Village Tadio, chosen as station 1, is the most inhabited site with 70 fishermen families. The stations 2 (Agoudam) and 3 (Passagri) are peopled by 45 and 18 fishermen, respectively (DAP, 2013).

Fish were collected monthly in 3 to 4 days per site from October 2013 to November 2014 from artisanal landings. Catches per fisherman were examined and weighted when boats arrived. For the purpose of the present study, the catches of 5 previously contacted fishers, per site, were analyzed with precision. Thus, the specific composition was determined by catch, all specimens were counted by specific group and each fish measured individually to the nearest millimeter for total body length (TL) and weighed to the nearest gram (g). All captured fish were identified to species level following Paugy et al. (2003a, b). When species identification was doubtful, specimens were kept in ice for a detailed study in laboratory.

Moreover, at each station and for each month, 5 environmental variables were measured: water salinity (‰), water temperature (°C), pH, dissolved oxygen content (mg/L) and water transparency (cm). These parameters were recorded every morning between 06:00 h (GMT) and 07:00 (GMT) during 2 days, using a scientific multiparameter (model HANNA Hi 9828) for the four first parameters and a Secchi disc for transparency.

### Data analysis

Our approach was temporal and spatial and for this, data were grouped by months and by sampling sites. The number of individuals and the relative frequency of species were calculated. Species diversity was assessed using three different indices: species richness (SR), the Shannon-Wiener diversity (*H'*) and Pielou index (*E*). These indexes were computed using the numerical abundance of the captured species and estimated by site and season (Hossain et al., 2012). Moreover, species were categorized into bio-ecological groupings, depending on their temporal utilization of the lagoon, during all, or a part of their life history stage. Eight bio-ecological groupings were determined by Albaret (1994) for Ebrié Lagoon. There are, strictly estuarine species (Es), estuarine species of marine origin (Em), marine estuarine species (ME), marine species accessory in estuaries (Ma), marine species occurring occasionally in estuaries (Mo), estuarine species of freshwater origin (Ec), freshwater species with estuarine affinities (Ce) and freshwater species occurring occasionally in estuaries (Co). One–way analysis of variance (ANOVA) was used for hydrological parameters (temperature,

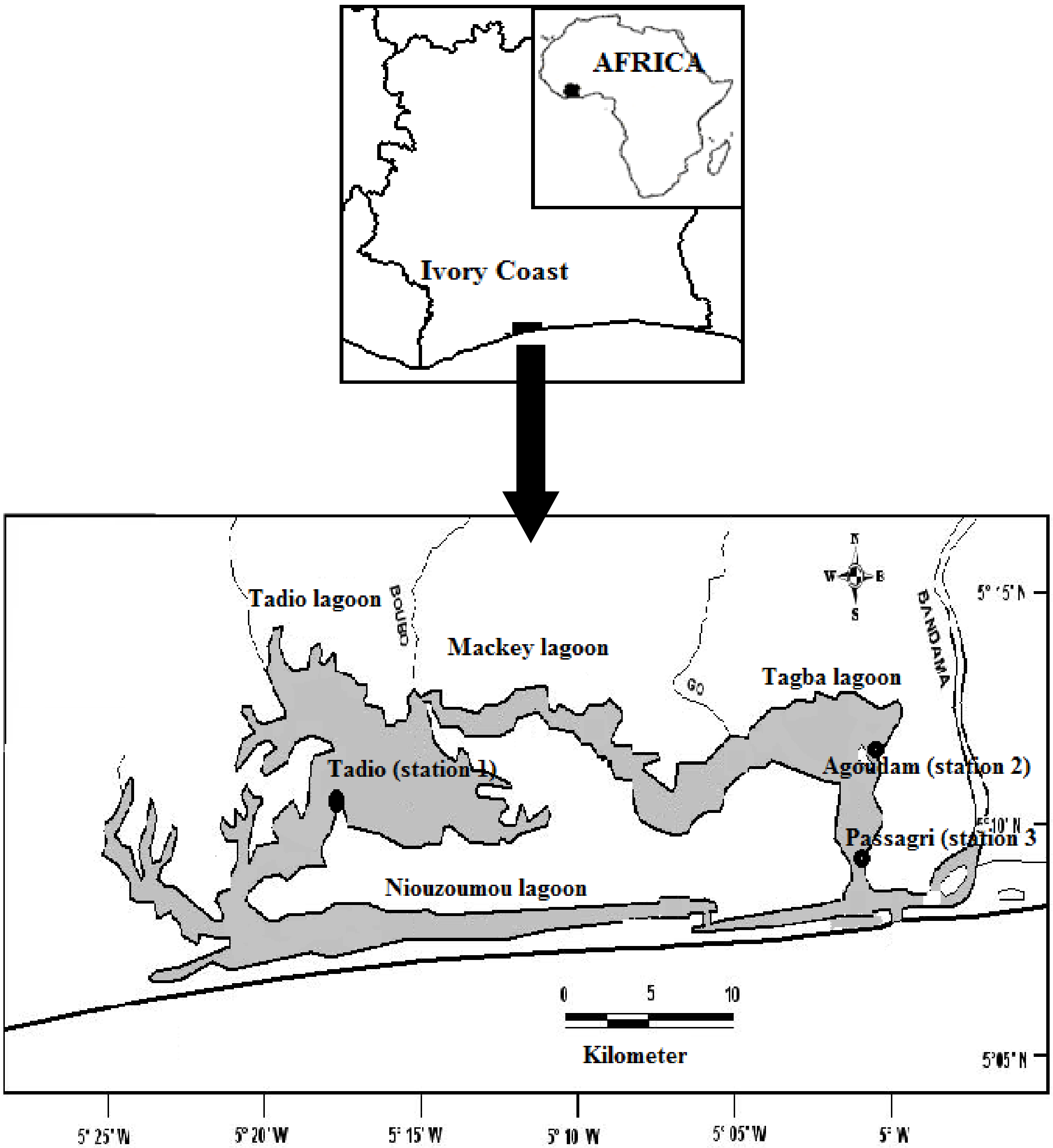


**Figure 1.** Map of Grand-Lahou lagoon showing sampling stations ( • ).

salinity, dissolved oxygen, transparency and pH) and species diversity (species richness, Shannon-Wiener diversity and Pielou index) to calculate any existence of difference among stations and months. All these analysis were carried out using the STATISTICA 7.1 software computer (version 7.1). A canonical correspondence analysis (CCA) was used to identify possible correlations between fish assemblages and the environmental variables (Ter Braak, 1988). A series of CCA with forward selection of environmental variables and unrestricted Monte Carlo permutation tests (permutations 199, $p < 0.05$) was used to select variables explaining variation in fish species data. Environmental and fish data were $\log_{10}(x + 1)$ transformed prior to analysis, using CANOCO (version 6.0). For the CCA analysis, species with low abundance values (less than 30 individuals over all of sampling area) were excluded from the analysis.

## RESULTS

### Fish abundance and composition

During the study, a total of 8571 individuals with a total biomass of 961.62 kg were collected from 345 trips throughout the lagoon. Captured fishes belong to 47 species representing 25 families and 36 genera (Table 1). Maximum number was counted for *Ethmalosa*

**Table 1.** List of fish species and relative abundance of the major species collected at the three sites. (Only species with more than 30 individuals all over the sampling area are considered in the percentage value).

| Family/Species | Code | Bio-ecological form | St 1 | St 2 | St 3 | Total individual | % |
|---|---|---|---|---|---|---|---|
| **Dasyatidae** | | | | | | | |
| *Dasyatis margarita (Günther, 1870)* | Dma | Em | + | + | + | | |
| **Elopidae** | | | | | | | |
| *Elops lacerta* Valencienne, 1846 | Ela | Em | + | + | + | 1543 | 18.00 |
| **Clupeidae** | | | | | | | |
| *Ethmalosa fimbriata* (Bowdich, 1825) | Efi | Em | + | + | + | 2036 | 23.75 |
| *Pellonula leonensis* (Boulenger, 1916) | Ple | Ec | + | + | | | |
| **Oteoglossidae** | | | | | | | |
| *Heterotis niloticus* (Cuvier, 1829) | Hni | Ec | + | + | + | | |
| **Hepsetidae** | | | | | | | |
| *Hepsetus odoe* (Bloch, 1794) | Hod | Ce | | + | + | | |
| **Claroteidae** | | | | | | | |
| *Chrisichthys maurus* (Valencienne, 1839) | Cma | Ec | + | + | + | 117 | 1.36 |
| *Chrisichthys nigrodigitatus* (Lacépède, 1803) | Cni | *Ec* | + | + | + | 923 | 10.83 |
| **Schilbeidae** | | | | | | | |
| *Schilbe mandibularis* (Günther, 1871) | Sma | Ce | + | + | + | 228 | 2.66 |
| **Clariidae** | | | | | | | |
| *Clarias anguillaris* (Limnaeus, 1758) | Can | Ce | + | + | + | | |
| *Heterobranchus longifilis* (Valencienne, 1840) | Hlo | Ce | + | + | + | | |
| **Mochokidae** | | | | | | | |
| *Synodontis schall* (Bloch & Schneider, 1801) | Sch | Ce | + | + | + | 159 | 1.85 |
| **Ariidae** | | | | | | | |
| *Arius latiscutatus* (Boulenger, 1911) | Ala | ME | + | | | 82 | 0.95 |
| **Hemiramphidae** | | | | | | | |
| *Hemiramphus balao* (Lesueur, 1825) | Hba | Em | + | | | | |
| *Hyporamphus picarti* (Valencienne, 1846) | Hpi | Ma | + | | | | |
| **Channidae** | | | | | | | |
| *Parachanna obscura* (Günther, 1861) | Pob | Ce | | + | + | | |
| **Serranidae** | | | | | | | |
| *Epinephelus aenus* (Geoffroy Saint Hilaire, 1817) | Eae | ME | | + | + | | |
| **Carangidae** | | | | | | | |
| *Caranx hippos* (Limnaeus, 1766) | Chi | ME | + | + | + | 192 | 2.24 |
| *Decapturus rhonchus* (Geoffroy S. Hilaire,1817) | Dro | Ma | + | + | + | | |
| *Senele dorsalis* (Gill, 1863) | Sdo | ME | | + | + | | |

**Table 1.** Contd.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Trachinotus teraia* (Cuvier, 1832) | Tte | Em | + | + | + | 199 | 2.32 |
| *Trachinotus ovatus* (Lumnaeus, 1758) | Tov | Ma | + | + | | | |
| **Lutjanidae** | | | | | | | |
| *Lutjanus dentatus* (Deméril, 1858) | Lde | Mo | + | + | + | 40 | 0.46 |
| *Lutjanus goreensis* (Valencienne, 1830) | Lgo | Mo | + | + | + | | |
| **Gerreidae** | | | | | | | |
| *Eucinostomus melanopterus* (Bleeker, 1863) | Eme | ME | + | + | + | 828 | 9.66 |
| **Haemulidae** | | | | | | | |
| *Pomadasys jubelini* (Cuvier, 1830) | Pju | Em | + | + | + | 157 | 1.83 |
| *Pomadasys peroteti* (Cuvier, 1830) | Ppe | Em | + | + | + | | |
| **Sciannidae** | | | | | | | |
| *Pseudotholithus elongatus* (Bowdich, 1825) | Pel | Em | | + | + | | |
| **Monodactylidae** | | | | | | | |
| *Monodactylus sebae* (Cuvier, 1831) | Mse | Es | + | + | + | | |
| **Cichlidae** | | | | | | | |
| *Hemichromis bimaculatus* Gill, 1862 | Hbi | Co | | + | + | | |
| *Hemichromis fasciatus* Peters, 1852 | Hfa | Ec | | | + | | |
| *Sarotherodon melanotheron* Ruppel, 1852 | Sme | Es | | + | + | 115 | 1.34 |
| *Tilapia guineensis* (Bleeker in Günther, 1862) | Tgu | Es | + | + | + | 489 | 5.70 |
| *Tilapia mariae* Boulenger, 1899 | Tma | Es | + | + | + | 33 | 0.38 |
| *Tylochromis jentenki* (Boulenger, 1915) | Tje | Es | | + | + | 212 | 2.47 |
| **Mugilidae** | | | | | | | |
| *Liza demeruli* (Steindachner, 1870) | Lid | Em | | + | + | | |
| *Liza falcipinnis* (Valencienne, 1835) | Lfa | Em | + | + | + | 739 | 8.62 |
| *Liza grandisquamis* (Valencienne, 1836) | Lgr | Em | | + | + | | |
| *Mugil bananensis* (Pellegrin, 1927) | Mba | ME | + | + | + | 181 | 2.11 |
| *Mugil cephalus* Limnaeus, 1758 | Mce | ME | + | + | + | 92 | 1.07 |
| *Mugil curema* (Valencienne, 1836) | Mcu | ME | | + | + | | |
| **Sphyraenidae** | | | | | | | |
| *Sphyraena afra* Peters, 1844 | Saf | ME | + | + | + | | |
| *Sphyraena guachancho* Cuvier, 1829 | Sgu | ME | + | + | + | | |
| **Polynemidae** | | | | | | | |
| *Galeodes decadactylus* (Bloch, 1795) | Gde | ME | + | | | | |
| *Polydactylus quadrifilis* (Cuvier, 1829) | Pqu | ME | + | + | + | | |
| **Gobiidae** | | | | | | | |
| *Gobioides africanus* (Giltay, 1935) | Gaf | Ma | + | | | | |
| **Cynoglossidae** | | | | | | | |
| *cynoglossus senegalensis* kaup, 1858 | Cse | Em | + | + | + | | |
| Species richness | | | 35 | 41 | 39 | | |

St1: Tadio; St2: Agoudam; St3: Passagri.

*fimbriata* with 2026 individuals and only one specimen for *Gobioides africanus*. Best represented families by number of captured species were Mugilidae and Cichlidae with 6 species. Only one species per family was recorded for Dasyatidae, Elopidae, Osteoglossidae, Hepsetidae, Schilbeidae, Mochikidae, Ariidae, Channidae, Serranidae, Gerreidae, Monodactylidae, Gobiidae, and Cynoglossidae. Considering numerical abundance, catches were dominated by a few species which represented about 60% of total catches. There are *E. fimbriata* (23%), *Elops lacerta* (18%), *C. nigrodigitatus* (10%) and *Eucinostomus melanopterus* (9%) (Table 1). Species distribution per ecological category (Table 1) indicated that all 8 the bio-ecological categories defined by Albaret (1994) were represented. Regarding the composition of the fish assemblages, the marine component including, marine estuarine species (ME), estuarine species of marine origin (Em), marine species accessory in estuaries (Ma) and marine species occasionally in estuary (Mo), was largely dominant in the Grand-Lahou lagoon with 30 out of 47 species. Among these ecological categories, (ME) and (Em) forms were the best represented with 12 species (25.53%) each, followed by (Ma) and (Mo) with 4 and 2 species, respectively. The freshwater component was represented by 12 species comprising 6 freshwater species with estuarine affinities (Ce), 5 estuarine species of freshwater origin (Ec) and 1 freshwater species occurring occasionally in estuaries (Co). Strictly estuarine categories (Es) were represented by 5 species (Table 1)

## Species richness and diversity index

The monthly fluctuations of species richness (RS), Shannon-Wiener index (*H'*) and Pielou index (*E*) in the three studied sites are summarized in Figure 2.

In the three sampling sites, the species richness (RS) distribution had a similar pattern (Figure 2a). The highest species richness (20 in station 1; 23 in station 2, and 22 in station 3) observed in July, during the last part of the long rainy season; whereas, the minimum values (5 in station 1 and station 3; 7 in station 2) occurred in April, in the beginning of long rainy season. The analysis of variance between months for the monthly average species richness revealed a significant difference ($F = 5.22$; $p < 0.01$). The annual average species richness ranged from 14 in station 2 to 11 (station 1 and 3) did not differ significantly (ANOVA: $F = 1.96$; $p = 0.155$) (Table 2).

The monthly variations of Shannon diversity index (*H'*) shows slightly the same trend in the three stations (Figure 2b). The lowest values of Shannon diversity index were recorded in April in the three sampling site (1.63 and 1.19 bit/ind) and the highest values in October (2.78 and 2.31 bit/ind). Regarding the Pielou index (Figure 2c), this variable fluctuates from 0.74 to 0.96 throughout the year in the three sampling stations, except in April where this index decreased to reach the lowest value of 0.33 in Tadio (station 3). The mean annual Shannon diversity (*H'*) and Pielou index (E) between stations revealed a significant difference (ANOVA: $p = 0.020$ for *H'*; $p = 0.004$ for E) during the study (Table 2).

## Environmental parameters

The monthly variations of temperature showed the same trend in the three sampling sites, throughout the year (Figure 3a). From November to April, during the long dry season, the highest temperature values approximately 29°C were recorded in the three sampling sites. From May to July corresponding to the last part of the long rainy season, temperature decreased close to 24.0°C in the three sampling sites. The mean monthly water temperature from the three sampling sites in the lagoon differed significantly between months (ANOVA: $F = 9.47$; $p = 0.00$) (Table 3). For this parameter, mean annual value varied from 27.27°C ± 1.8 in station 3 to 28.40°C ± 1.01 in station 1 and no significant difference was observed among the sampling sites (ANOVA: $F = 1.521$; $p = 0.233$) (Table 3).

Figure 3b indicates that from November to March (during the long dry season), water salinity increases in the three stations from 5.4, 7.18, and 13.42% in stations 1, 2 and 3, respectively, to 9.4 (Station 1), 24.77, and 26.67% (stations 2 and 3). Then, the salinity decreases and the lowest values in the order of 0% are recorded in June and July during the long rainy season, in station 2, 3 and around 1 in station 1. From July, this parameter increased and the highest value in the lagoon (26.67‰) occurred in August in station 3. The fluctuation of the monthly mean values of salinity from the three sampling sites did not differ significantly (ANOVA: $F = 1.952$; $p = 0.082$). Spatial variation of mean annual salinity among the sampling sites (Table 3) showed that the highest value occurred in station 3 (16.2 ± 9.18%) and the lowest in station 1 (5.81± 3.02%) with a significant difference between stations (ANOVA: $F = 6.485$; $p = 0.004$).

Monthly dissolved oxygen (DO) variations (Figure 3c) showed similar trend in the three stations. The highest values occurred in October (9.24 mg/L) (in station 1) and lowest values 2.69 mg/L (station 2) and 2.70 mg/L (station 3) were recorded in March. The monthly mean value of DO recorded in the three sites were significantly different between months (ANOVA: $F= 5.705$ $p = 0.00$) but spatial mean annual DO between stations did not differ significantly (Table 3).

The monthly variation of this parameter shows the same trend in three sampling sites. Highest values occurred from January to May (9.66, 9.63 and 9.80) at stations 1 and 3, respectively. Lowest pH was recorded in

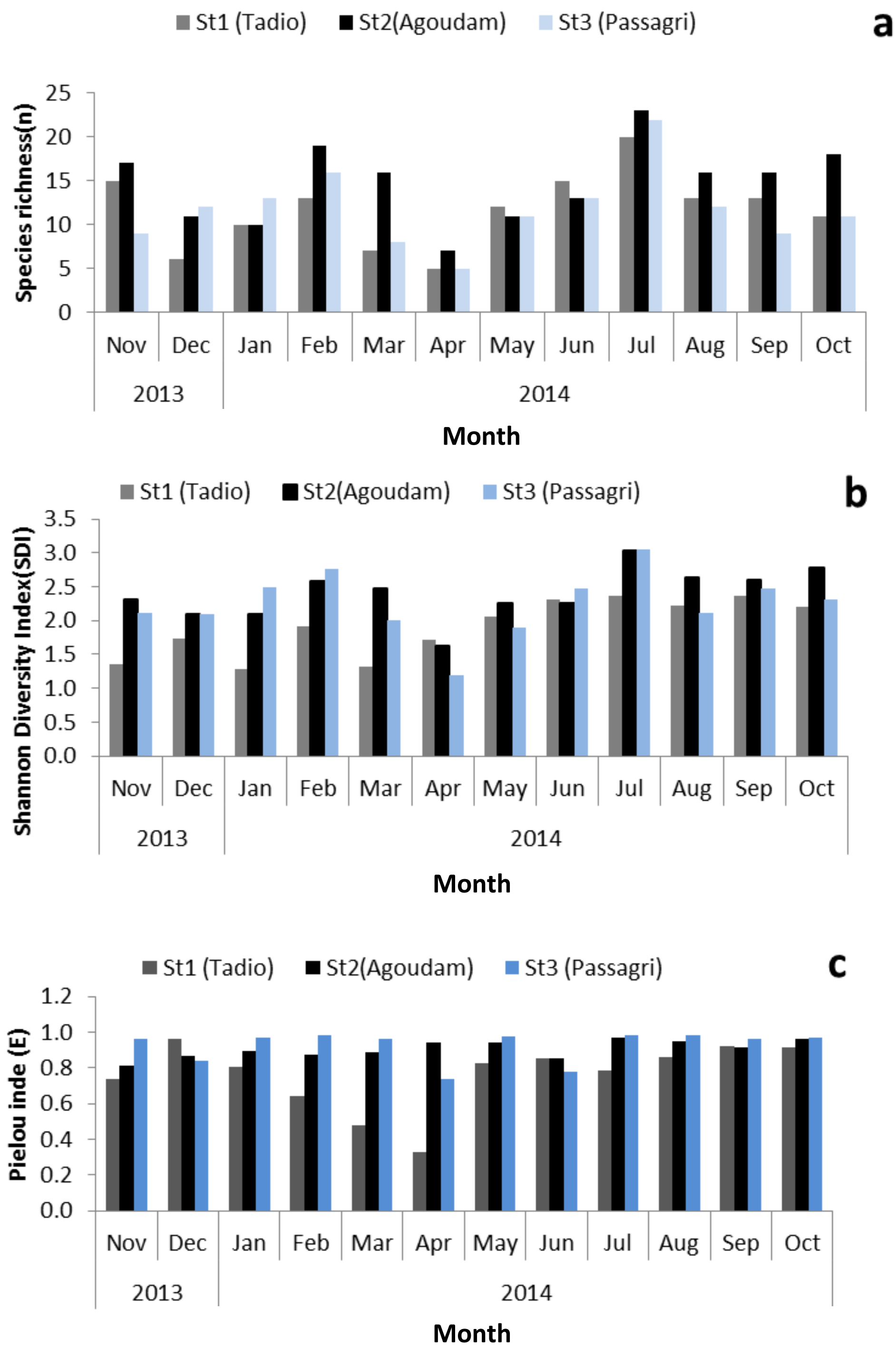


**Figure 2.** (a) Monthly variation of species richness (SR); (b) Shannon diversity index (*H'*); (c) Pielou index (E) at the three sampling stations.

September (7.5 at station 3 and 7.4 in station 1) and in June at station 2 (7.29). The mean monthly value of pH recorded in the three sites were significantly different between months (ANOVA: F = 10.345 p = 0.00), whereas no significant difference appeared between stations for mean annual pH value (Table 3).

The highest values of transparency were recorded in March in Tadio (196 cm); in December in Agoudam and

**Table 2.** Spatial variation of species richness and diversity index in the three sampling sites.

| Station | Species richness | | Shannon diversity index (*H'*) | | Equitability (*E*) | |
|---|---|---|---|---|---|---|
| | mean ±SE | Min-max | mean ±SE | Min-max | mean ±SE | Min-max |
| 1 | 11.6 ±2.2 | 5-20 | 1.90±0.4 | 1.28-2.36 | 0.76±0.18 | 0.33-0.96 |
| 2 | 14.7±4.4 | 7-23 | 2.39±0.37 | 1.63-3.03 | 0.90±0.04 | 0.81-0.96 |
| 3 | 11.7±4.3 | 5-22 | 2.24±0.47 | 1.18-3.04 | 0.92±0.08 | 0.73-0.98 |
| ANOVA: F | 1.967 | - | 4.353 | - | 6.456 | - |
| ANOVA: *p* | 0.1559 | - | 0.020* | - | 0.004 ** | - |

*Significant at $p < 0.05$; **Significant at $p < 0.01$.

Passagri (147 and 144 cm), respectively. The mean annual value of this parameter throughout the year was 110.44 cm. The mean monthly values of transparency recorded in the three sites were significantly different between months (ANOVA: F = 5.080 p = 0.0004), whereas no significant difference appeared between stations for mean annual transparency value (Table 3).

**Fish species distribution in relation to seasons and environmental variables**

Three groups of fish assemblages can be distinguished according to the seasons (long rainy season or LRS and long dry season or LDS) and fish abundance (Table 4). The first group comprising species constituted more than 14% of the total catches whatever the season. These were *E. fimbriata* with 27.79 and 17.57% of total catches during rainy and dry seasons, respectively and *E. lacerta* with 14.92 (rainy season) and 22.41% (dry season) of total catches. The second group constituted by fish which abundance varied from 1.15 to 7.32% according to the season, such as *C. nigrodigitatus, Tylochromis jentenki, Caranx hippos, Sarotherodon melanotheron, Pomadasys jubelini* and *Mugil cephalus*. The last group was composed of single species caught only in the rainy season (*Lutjanus dentatus*).

In the canonical correspondence analysis (CCA), axis 1 (Eigenvalue = 0.49) and axis 2 (Eigenvalue = 0.15) expressed 88.2% of the cumulative variance of the relationship species-environment (Figure 4). Monte Carlo permutation attested that both axes were significant ($p \leq 0.05$). Three variables DO (31.03%), temperature (22.98%) and salinity (21.98%) accounted for 75.99% of the variance explained by all the original variables. These three variables were significant ($p < 0.05$). The vector length of a given variable indicates the importance of that variable in the CCA analysis. In Figure 4, the longest vectors of DO and temperature showed a significant relation with station 1 (Tadio), whereas salinity shows significant relation with station 2 (Agoudam).

High value of DO is associated with species such as *E. fimbriata*, *E. melanopterus* and *Synodontis schall* during the LRS. High value of temperature was associated with the occurrence of *C. nigrodigitatus, Chrysichthys maurus, C. hippos, E. lacerta, Arius latiscutatus, Trachinotus teraia, Polydactylus quadrifilis* and *Schilbe mandibularis* during the LDS. High values of salinity are associated with the occurrence of *L. dentatus*, *M. cephalus, Mugil bananensis, T. jentenki* and *Tilapia guineensis* during long rainy and dry seasons. Three species, *S. melanotheron, P. jubelini,* and *Liza falcipinnis* appeared to be not in relation with any studied environmental parameter, but are associated with station 3 during the long dry season (LDS) (Figure 4).

## DISCUSSION

During the present study, 47 species were recorded in the Grand-Lahou lagoon. No previous study inventoried the ichtyofauna of this lagoon and the results seem to be the first data about fish biodiversity in this Lagoon. In Côte d'Ivoire, a total of 153 species have been recorded in the Ebrié lagoon (Albaret, 1994) and about 82 species for the Aby lagoon (Baran, 2000). When comparing our result with these data, the species richness in Grand-Lahou lagoon appears to be very low. Three reasons can explain this fact: (i) the area of Grand-Lahou lagoon (190 $km^2$) less larger than those of Ebrié (566 $km^2$ and Aby (424 $km^2$), (ii) the weak number of sampling sites (only 3 sites) and fishers involved by the study (5 fishers during 2 days per sites) and (iii) commercial fishing catches instead of experimental fishing gear catches. Moreover, the forbidden use of purse seine within the lagoon could explain the low species richness observed in commercial catches. Compared with other coastal lagoons in West Africa, the species richness of Grand Lahou in this study (47) is close to those of the Benin lagoons (52 species in Lake Ahémé, 50 species in Lake Nokoué) (Lalèyè, 1995; Lalèyè and Philippart, 1997; Lalèyè et al., 2003) but lower than the 79 species identified in the Lagos Lagoon in Nigeria (Fagade and Olaniyan, 1974). Generally, species richness comparisons among lagoons are not easy, due

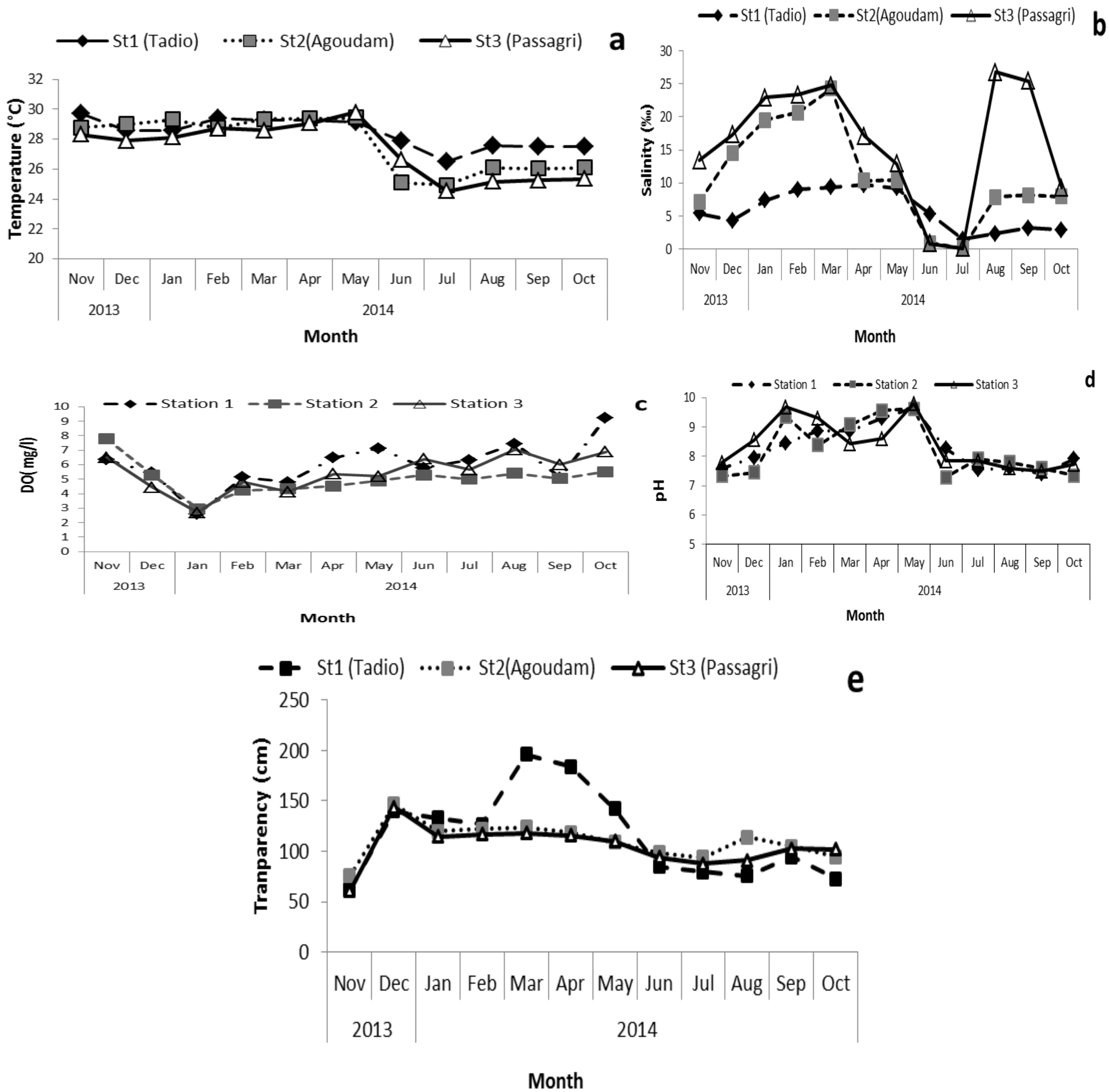


**Figure 3.** Monthly variation of water parameters: Temperature (a); Salinity (b); Dissolved Oxygen (c), pH (d) and water transparency (e) at the three sampling stations.

to differences in sampling methods (e.g. fishing gears, sampling effort), temporality geographical variations (Kneib, 1997) and size of lagoons (Pérez-Hernăndez and Torrez-Orozco, 2000). Three major dominant species was observed in the Grand-Lahou lagoon, *E. fimbriata* (23%), *E. lacerta* (18%), and *C. nigrodigitatus* (10%), which is similar to the Ebrié and Aby lagoons in Côte d'Ivoire with *E. fimbriata* (33%) *C. nigrodigitatus* (11%) and *E. lacerta* (10%) (Durand and Guiral, 1994). Several species identified in our study are common in most of the West African lagoons, all of them being intensively exploited by fisheries. The most abundant are: *S.*

**Table 3.** Spatial variation of annual mean water parameters at the three sampling sites.

| Station | Temperature (°C) | | Salinity (‰) | | DO (mg/L) | | pH | | Transparency (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Temp. range | mean±SE | Sal. range | mean±SE | DO range | mean±SE | PH range | mean±SE | Temp. range | mean±SE |
| 1 | 26.47-29.72 | 28.40±1.01 | 1.49-9.70 | 5.81±3.02 | 4.79 .-9.24 | 6.21± 1.63 | 7.55-9.66 | 8.44±0.71 | 62-196 | 116.08 |
| 2 | 24.92-29.45 | 27.68±1.84 | 0.17-24.30 | 11.01±7.49 | 4.33-7.79 | 5.18±1.11 | 7.29-9.63 | 8.33±0.99 | 76-147 | 110.33 |
| 3 | 24.53-29.77 | 27.27±1.80 | 0.14-26.77 | 16.20±9.18 | 4.12-7.05 | 5.49±1.2 | 7.73-9.8 | 8.55±0.79 | 61-144 | 104.91 |
| ANOVA: F | - | 1.521 | - | 6.485 | - | 1.558 | - | 0.171 | - | 0.666 |
| ANOVA: *p* | - | 0.233 | - | 0.0042 ** | - | 0.225 | - | 0.843 | - | 0.410 |

**Significant at p < 0.01.

*melanotheron*, *T. guineensis*, *E. fimbriata, E. lacerta*, *M. cephalus*, *L. falcipinnis*, *C. nigrodigitatus Chrysichthys maurus*, *P. jubelini, Hemichromis fasciatus, C. hippos, Arius lantiscutatus, Dasyatis margarita* and *Sphyraena afra*. Variations in species richness, Shannon diversity index (*H'*) and Pielou index (*E*) are seasonal throughout Grand-Lahou lagoon. The highest values are recorded in July, during rainy season, corresponding to the spawning period of many tropical fish species occurring in tropical ecosystems (Pullin and Lowe McConnell, 1982). In contrast, the low values of species richness of *H'* and (*E*) observed in April-May, derived from the long dry season from December to March. Albaret (1994), stressed that during the dry season, the communities seems to reach a certain degree of structural stability, which is however, never very high. Moreover, the abundance of only few species in the catches (that is, *E. fimbriata, E. lacerta, C. nigrodigitatus,* and *L. falcipinnis*) in Grand Lahou lagoon could explained the relatively low Shannon diversity index (*H'*) recorded within the lagoon. Low fish diversity values, but high fish abundances (mainly juveniles) are the main characteristics of estuaries and coastal lagoons (Whitfield, 1999). Many interacting physical and biological factors influence the occurrence, distribution, abundance, and diversity of estuarine tropical fishes (Hossain et al., 2012). Among the six environmental variables recorded in the present study, only water temperature, water salinity and dissolved oxygen content, showed the most impact on fish distribution.

In Grand-Lahou lagoon, the highest temperature values (approximately 29°C) and the lowest values (in the order of 24°C) were recorded during dry season and rainy season, respectively. This indicates a seasonal fluctuation of this parameter depending on sunlight and the effect of winds and water current (Hossain et al., 2012). Moreover, it has been demonstrated that the range of mean water temperature (27 to 28°C) recorded within the sampling sites, was the optimum one for local species, notably Tilapias (Pullin and Lowe McConnell, 1982). As quoted by Albaret and Diouf, (1994), salinity is highly variable within estuaries, controlled by hydrological pattern which is related to the season, location of the water and the importance and duration of the connection with the sea. This was observed during our study in the Grand-Lahou lagoon, where salinity varied from the lowest values (0%) in the rainy season to the highest values (25 to 26%) in the dry season. Effects of rainfall and Bandama rivers inflow on the lagoon promote freshwater conditions in stations 2 and 3 during the rainy season. Conversely, the increasing trend in salinity around the mouth of Bandama rivers is induced by saline water intrusion from the Atlantic Ocean, during the dry season. Similar result was mentioned by Lalèyè et al. *(*2003) for Nokoué lagoon in Benin. High values of dissolved oxygen were recorded in October while the lowest values were recorded in March. The temporal differences of monthly mean value of dissolved oxygen were significant ($p < 0.05$). The high values of this parameter during floods periods (October, 2014) caused by incoming water from adjacents rivers, which bring in oxygen statured water as observed by Durand and Skubich (1982) in Ebrié lagoon. The spatial differences of mean annual dissolved oxygen values were not significant. However, in station 1, the oxygen content observed was higher than those of stations 2 and 3. This station 1 is located in Tadio lagoon the largest one, with 90 $km^2$. According to Tardiff et al. (2005), the area of a given lagoon has an effect on dissolved oxygen production.

The environmental variables best describing the fish assemblages in Grand-Lahou lagoon are DO, temperature and salinity according to the CCA analysis (Figure 4).

In the present study, three distinguished fish

**Table 4.** Number of individuals caught during the long rainy season (LRS) and the long dry season (LDS).

| Species | Number collected in LRS | % of total number in LRS | Number collected in LDS | % of total number in LDS |
|---|---|---|---|---|
| *Ethmalosa fimbriata* | 937 | 27.79 | 432 | 17.57 |
| *Elops lacerta* | 503 | 14.92 | 551 | 22.41 |
| *Chrysichthys nigrodigitatus* | 230 | 6.82 | 353 | 14.36 |
| *Eucinostomus melanopterus* | 489 | 14.50 | 148 | 6.02 |
| *Liza falcipinnis* | 215 | 6.37 | 180 | 7.32 |
| *Tilapia guineensis* | 219 | 6.49 | 142 | 5.77 |
| *Schilbe mandibularis* | 186 | 5.51 | 40 | 1.62 |
| *Tylochromis jentenki* | 39 | 1.15 | 143 | 5.81 |
| *Trachinotus teraia* | 116 | 3.44 | 49 | 1.99 |
| *Caranx hippos* | 62 | 1.83 | 82 | 3.33 |
| *Mugil bananensis* | 13 | 0.38 | 75 | 3.05 |
| *Synodontis schall* | 119 | 3.53 | 15 | 0.61 |
| *Pomadasys jubelini* | 62 | 1.83 | 17 | 0.69 |
| *Chrysichthys maurus* | 25 | 0.74 | 92 | 3.74 |
| *Sarotherodon melanotheron* | 39 | 1.15 | 75 | 3.05 |
| *Mugil cephalus* | 28 | 0.83 | 23 | 0.93 |
| *Arius latiscutatus* | 31 | 0.91 | 20 | 0.81 |
| *Polydactylus quadrifilis* | 26 | 0.77 | 21 | 0.85 |
| *Lutjanus dentatus* | 32 | 0.94 | 0 | 0.00 |

assemblages were revealed by the CCA analysis. These groupings appear to represent the spatial and seasonal use of the lagoon by fish. The first fish assemblage including *M. cephalus*, *M. bananensis, L. dentatus, T. jentenki* and *T. guineensis* were abundant in station 2, whatever the season. Station 2 located in the area of Tagba lagoon is characterized by high fluctuations of salinity with high values during the dry season (24.30%) in August and very low values during the rainy season (0.17% in July). Fish assemblage found in this station are adapted to waters salinity fluctuation's and species, such as *M. cephalus* are goods osmoregulators and maintain a stable internal osmolarity in a wide range of external salinity levels (Kulikova et al., 1989). The second fish assemblage comprising *C. nigrodigitatus, C. maurus, C. hippos, E. lacerta, Arius latiscutatus, Trachinotus teraia, Polydactylus quadrifilis* and *Schilbe mandibularis* associated with temperature in station 1 during the dry season. In this same station 1, during rainy season, with the incoming water from Boubo river, resulting in an oxygen-saturated water, three other species, *E. fimbriata, E. melanopterus,* and *Synodontis schall* were in addition to the seven previous species. Stability in environment conditions, particularly, salinity ranged from 1 to 9% throughout the year can explain the great abundance of species in station 1 located in Tadio lagoon. Abundance of juveniles (size <12 cm) demonstrates that sampling site 1 was used as refuge and feeding ground for juveniles of several species. However, species such as *E. fimbriata* and *E. lacerta* are known for their adaptation to brackish environment and their juveniles stages are able to live in water of reduced salinity (Fagade and Olaniyan, 1974). Concerning *C. nigrodigitatus*, this species has a tolerance to low salinity that enables this species to enter brackish environment (Lalèyè et al., 2003).

Three species, *S. melanotheron, L. falcipinnis* and *P. jubelini* were found associated with station 3 characterized by high fluctuations of salinity ranged from 0.14 to 26.77%. Among them, *S. melanotheron* known as a strictly estuarine form, has a certain tolerance to high salinity. This was demonstrated during hypersaline condition in Casamance (Albaret, 1987). Regarding the salinity fluctuations, the eastern part of Grand-Lahou lagoon including stations 2 (Agoudam) and 3 (Passagri) can be considered as a typical estuary, as mentioned by Ecoutin et al. (2005) for the sector II of Ebrié lagoon. Conversely, area of station 1 (Tadio) with a low salinity fluctuation is a brackish water body characterized by a stable environmental condition. However, the different fish assemblages found in this study can be related to the fishing activity level deployed within the lagoon. Indeed, fishing pressure decreases from station 1 with 70 fishermen involved in fishery to stations 2 and 3 with 45 and 18 fishermen, respectively.

In conclusion, our findings which reported 47 fish

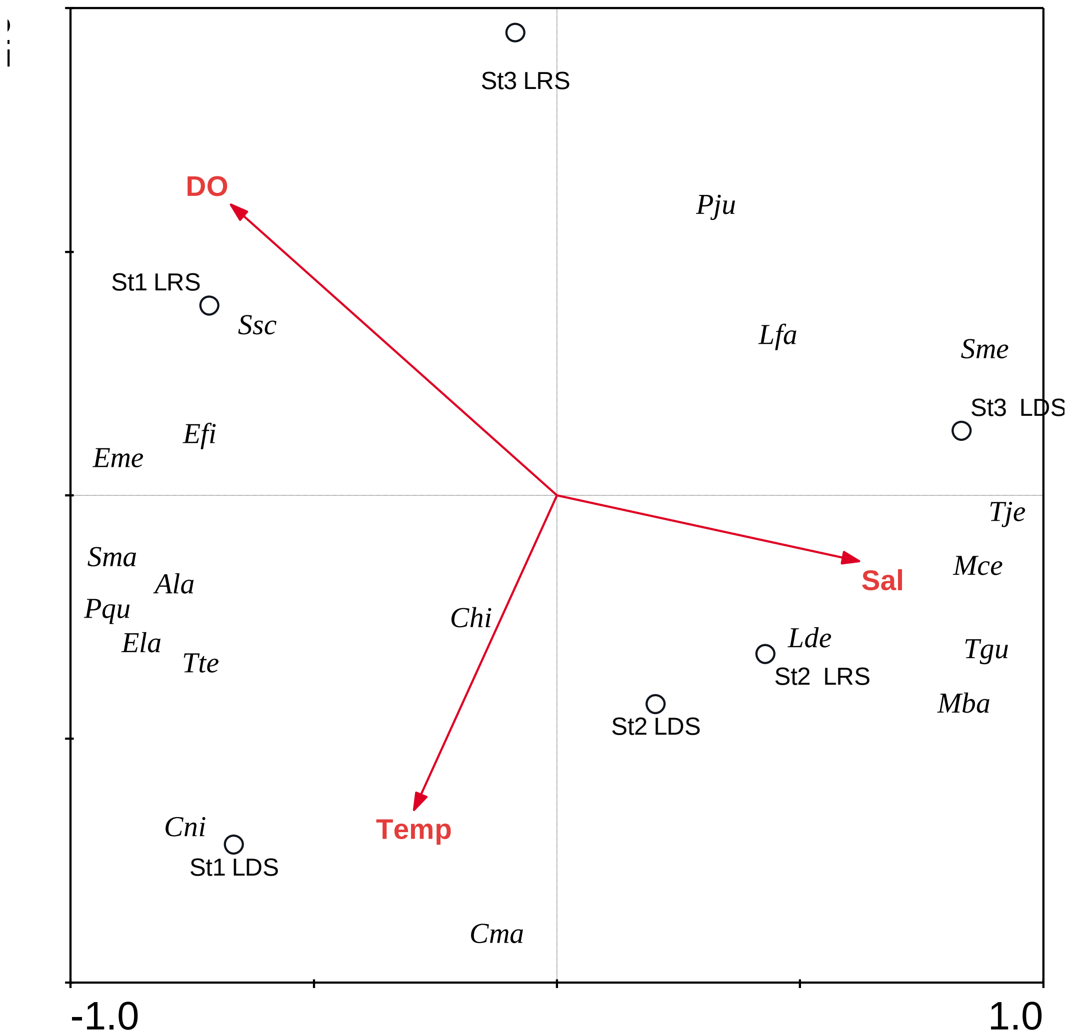


**Figure 4.** Plot of species scores with three environmental variables in the first two Canonical Correspondence Analysis (CCA) axes. (St1-sampling site 1; St2-sampling site 2; St3-sampling site 3; LRS-Long rainy season; LDS-Long dry season. Species are abbreviated considering the first letter of the genus followed by the two first letters of the species name. Temp-temperature; DO- Dissolved oxygen; Sal- salinity.

species constitute a first database on fish biodiversity of Grand–Lahou lagoon in Côte d'Ivoire. However, this list seems to be partial, because of the middle zone of the lagoon (Mackey lagoon) was not sampled. Considering the environmental parameters recorded in the lagoon, two main sectors have been distinguished on the basis of salinity fluctuations. Sampling sites 2 and 3 work as a typical estuary and sampling site 1 with a low fluctuation of salinity. Three main fish assemblages were associated to these three sampling sites. However, the analysed data coming from commercial fishery and the fishing pressure can be reflected on the distinguished fish assemblage determined in the present study. So, future studies should especially include the sampling sites located in the middle section that may complete the list of fish in one hand and experimental fishing using purse seine can improve the present results in the second hand.

## Conflict of Interests

The authors have not declared any conflict of interests.

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