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# Fish distribution in relation to environmental characteristics in the Aby-Tendo-Ehy lagoon system (Southeastern Côte d'Ivoire)

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**Although West African lagoons are known to provide significant fishery resources to populations, few studies have been done on processes responsible for their fish composition, abundance and spatial distribution. The aim of this study was to assess fish species distribution along the Aby-Tendo-Ehy lagoon system in Côte d'Ivoire. Sampling sites were distributed in the lagoon and grouped into three zones from a freshwater zone with high contributions of freshwater (zone 1) to a mixo-eurihaline water zone (zone 3), with a transition site (zone 2) located between the first two zones. Environmental characteristics showed gradual decrease of mean pH from zone 1 to 3, whereas mean conductivity, total dissolved solids and transparency measurements increased from zone 1 to 3. Salinity data were 0 all along the sampling period in zones 1 and 2 and increased up to 3 ppt in zone 3. A total of 67 species belonging to 29 families were caught. Overall fish diversity decreased from zone 1 (n=58) to 3 (n=40), with 45 species caught in zone 2. The number of species in different fish trophic categories (invertivorous, herbivorous, piscivorous and omnivorous species) decreased from the zone 1 to 3. Fish compositions in zones 1 and 2 were dominated by freshwater species, while in the zone 3 it was dominated by estuarine dependent species. The canonical correspondence analysis performed showed a clear-cut influence of some environmental variables on fish ecological categories distribution: the zone under continental freshwater discharges had higher pH and temperature measurements and housed more freshwater, estuarine resident, marine migrant and estuarine dependent freshwater species, while the site with marine influences had higher conductivity, salinity, transparency and dissolved oxygen data and was mainly associated with estuarine dependent marine species.**

**Key words:** Ichthyofauna, species distribution, environmental variables, Aby lagoon, Côte d'Ivoire.

## INTRODUCTION

Estuaries are transition zones between freshwater and marine environments with an extreme spatial and temporal variability of physical, chemical and biological characteristics. In these environments, the diversity of

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fish community is an outcome of ecosystem processes reflecting changes in productivity, energy pathways and material flow, disturbance regimes, abiotic stress and biological interaction (Lowe-McConnell, 1987). Research on fish assemblages in estuaries has shown that salinity plays a major role in shaping assemblage structure (Marshall and Elliott, 1998; Barletta et al., 2005; Selleslagh and Amara, 2008), although only a few studies encompass the full salinity gradient, that is, from ocean to tidal freshwater. Its influence on fish is often due to the tolerance and preference of species for this variable (Elliott et al., 1990).

Other environmental variables such as temperature, depth, transparency, dissolved oxygen, pH, conductivity and total dissolved solids can also play important roles in determining fish assemblages (Pombo and Rebelo, 2002; Aboua et al., 2010). Fish are known to play a fundamental role in the functioning of shallow waters through a series of physico-chemical (e.g. nutrient release, sediment turbation) and biological mechanisms (for example, competition, predation) (Gelós et al., 2010). Fish may affect the spatial distribution of their prey through the behavioural cascades processes (Schmitz et al., 2004; Súarez et al., 2004; Gelós et al., 2010).

Many human uses of estuaries (transportation, wastewater, pollution, overfishing, etc.) are potentially in conflict with the aquatic resources (Vinagre et al., 2004; Baeta et al., 2005). They not only have an impact on fish communities, but in the same way also rebound in human communities associated with the exploitation of these resources (Costa and Elliott, 1991). Thus, fish community diversity is a basic ecological indicator of health, knowledge of which is necessary for the correct exploitation, regulation and management of fishing resources since it can provide a first approach to the health level of the estuarine system and allows for the identification of response patterns to possible environment impacts.

Although, the importance of fish in these ecosystems is well recognized, few studies have attempted to characterize the fish communities and to elucidate the processes responsible for their composition and abundance in West Africa. The objectives of this paper were to establish fish species composition and abundance in different zones of the Aby-Tendo-Ehy lagoon system and to assess the impact of environmental factors on fish assemblages.

## MATERIALS AND METHODS

### Sample collection

The Aby-Tendo-Ehy lagoon system (5°05'-5°22'N; 2°51'-3°21'W), located in southeast of Côte d'Ivoire encompasses an area of 424 $km^2$ and is 24 km long north-south direction and extends 54 km wide east-west direction (Figure 1). The Aby lagoon is the most extended on the studied lagoon system and covers 305 $km^2$. It has a total shoreline of 24.5 km long, and is 15.5 km wide. The Tendo lagoon, which is the median part of the studied system, is more stretched, with a length of 22 km and a width varying between 1.5 and 3.5 km. Its surface is 74 $km^2$. The Ehy lagoon is located in the eastern side of the lagoon system and has a surface area of 45 $km^2$ (Chantraine, 1980). The overall Aby-Tendo-Ehy lagoon complex is lined with mangroves, and communicates with the sea by the Assini channel. It is supplied with freshwater inputs by the rivers Bia in the northwest and Tanoe in the east.

A total of 6 sampling sites were selected, distributed along the lagoon in three areas (two sites per zone) according to different environmental characteristics related to horizontal salinity range (Figure 1). Seu-Anoï et al. (2011) describes the salinity gradients found in the lagoon. Sampling zone 1, in the most inland part of the system (Ehy lagoon) had no marine water influences, but was under a considerable contribution of freshwater from the Tanoe Ehy Swamp Forest and the Tanoe River. Zone 2 (Tendo lagoon) sampling sites were in transition positions within the study area, while zone 3 (in Aby lagoon) were greatly influenced by marine waters and corresponded to the closest zone to the ocean. Monthly fish samplings were carried out between March 2012 and February 2013 using two sets of 12 weighted monofilalement gill nets (bar mesh sizes 6, 8, 10, 12, 15, 20, 25, 30, 35, 40, 45 and 50 mm), each measuring 30 m long by 1.5 m deep. Nets were set overnight (17-7 h). Fish collected were identified to species level following Paugy et al. (2003a, b) and Decru et al. (2012), counted and measured to the nearest 1 mm body length. The depth (cm) was recorded at each sampling station. Water temperature (°C), dissolved oxygen (mg/l), pH, conductivity (µS/cm), and total dissolved solids (mg/l) were recorded between 7 and 9 h using a Sper Scientific multiparameter while salinity (ppt) and transparency (cm) were recorded with a Hydrobios refractometer and a Secchi disc, respectively. The study area is characterized by two rainy seasons (April-June and October-December) and two dry seasons (July-September and January-March) (Konan et al., 2014).

### Data analysis

To categorize the fish composition within the coastal lagoon, fish species were grouped into ecological categories following Albaret (1994, 1999) and Chabanne (2007), and classified as estuarine resident fish (ER) (those that inhabit estuarine waters throughout their life cycle), estuarine dependent marine fish (EDM) (marine species which are predominantly found in lagoons at some stages of their life cycle), estuarine dependant freshwater fish (EDF) (freshwater species which are predominantly found in lagoons at some stages of their life cycle), estuarine nondependent marine fish (EN) (species commonly found in both estuarine and coastal inshore areas and do not depend to estuarine environment to complete their life cycles), accessory marine visitor fish (AV) (marine species which are regularly caught in lagoon but not abundant in the catch), occasional marine visitor fish (OV), and freshwater fish (FW).

Fish classification into herbivorous, invertivorous, omnivorous, piscivorous, and planktivorous categories were made following Trewavas (1983), King (1994), Diomandé et al. (2009), Yao et al. (2010), Kouamélan et al. (2012), and FishBase (2013). Species richness (which is the number of species sampled at each sampling zone) was used to determine the structure and ecological dynamics of the community. Jaccard's coefficient (J) was used to measure similarity between the sampling zones. Mann-Whitney U tests, based on ecological categories occurrence, were used for univariate comparisons.

Environmental influences on the ecological categories of each sampling zone were assessed with a canonical correspondence analysis (CCA) performed on log-transformed [log10(x+1)] data (ter Braak, 1986).

The CCA was done using CANOCO software for windows (version 4.5). This analysis was based on fish ecological categories occurrence data and physico-chemical data as well.

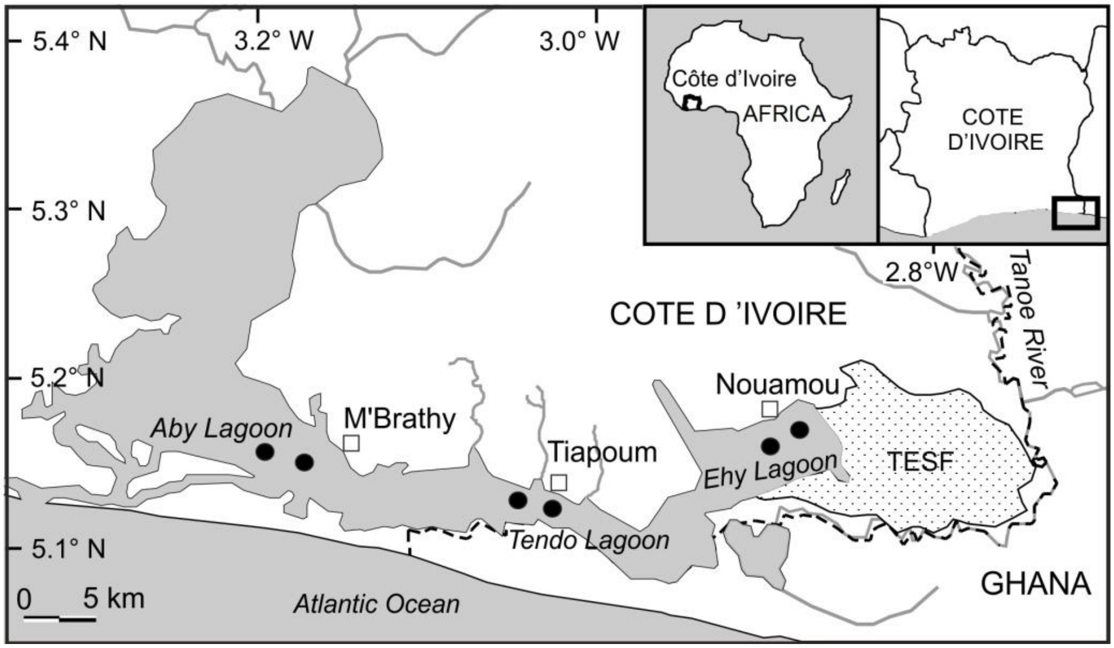


**Figure 1.** Sampling sites (●) in the Aby-Tendo-Ehy lagoon system (Côte d'Ivoire). TESF = Tanoe Ehy Swamp Forest.

**Table 1.** Environmental parameters [minimum (min), maximum (max), mean and standard deviation (SD)] in the different sampling zones of the Aby-Tendo-Ehy lagoon system (Côte d'Ivoire) between March 2012 and February 2013. T°C = temperature, DO = dissolved oxygen, Salt = salinity, Cond = conductivity, TDS = total dissolved solids, and Transp = transparency.

| Sampling zone | | Environmental characteristic | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | T°C | DO (mg/l) | pH | Salt (ppt) | Cond (µS/cm) | TDS (mg/l) | Transp (cm) | Depth (cm) |
| | Min | 25.5 | 1.18 | 5.3 | 0 | 48.2 | 25.1 | 20 | 64 |
| Zone 1 | Max | 35.8 | 7.35 | 9.15 | 0 | 123.1 | 65.5 | 120 | 298 |
| (Ehy Lagoon) | Mean | 30.13 | 5.17 | 7.27 | 0 | 65.47 | 34.98 | 43.86 | 147.87 |
| | SD | 3.41 | 1.51 | 0.84 | 0 | 16.05 | 8.88 | 16.37 | 64.15 |
| | Min | 25.3 | 2.03 | 5.31 | 0 | 60 | 30 | 24 | 68 |
| Zone 2 | Max | 31.8 | 6.91 | 8.55 | 0 | 497 | 249 | 82 | 510 |
| (Tendo lagoon) | Mean | 28.22 | 4.74 | 7.02 | 0 | 156.76 | 84.91 | 42.69 | 289.75 |
| | SD | 1.87 | 1.07 | 0.8 | 0 | 119.82 | 64.74 | 14.41 | 153.37 |
| | Min | 25.6 | 3.18 | 4.29 | 0.5 | 70.7 | 36.8 | 37 | 46 |
| Zone 3 | Max | 30.9 | 7.72 | 8.78 | 3 | 1546 | 804 | 101 | 264 |
| Aby Lagoon | Mean | 28.5 | 5.45 | 6.65 | 1.73 | 594.27 | 349.08 | 63.43 | 179.6 |
| | SD | 1.36 | 0.98 | 0.92 | 0.87 | 416.22 | 227.75 | 17.39 | 63.1 |

## RESULTS

### Environmental characteristics

Overall environmental parameters showed spatial trends in Aby-Tendo-Ehy lagoon system (Table 1). Mean pH decreased slightly from zone 1 (pH=7.27) to 3 (pH=6.65). Zones 1 and 2 had freshwater all along the sampling period (salinity=0 ppt) versus brackish water in zone 3 (with a salinity varying between 0 and 3 ppt). Furthermore, means of conductivity (65.47, 209.69 and 594.27, respectively for zones 1, 2 and 3) and total

**Table 2.** Ecological categories, trophic groups, occurrence percentage (%F), mean abundance (mean ab.±SD) of species collected in different sampling zones of the Aby-Tendo-Ehy lagoon system (Côte d'Ivoire) between March 2012 and February 2013.

| Taxa | Zone 1: Ehy lagoon | | | Zone 2: Tendo lagoon | | | Zone 3: Aby lagoon | | |
|---|---|---|---|---|---|---|---|---|---|
| | F (%) | Mean ab. | SD | F (%) | Mean ab. | SD | F (%) | Mean ab. | SD |
| **Estuarine resident (ER)** | | | | | | | | | |
| *Monodactylus sebae* (I) | 18.18 | 0.25 | 0.71 | 40.00 | 2.08 | 5.85 | 72.73 | 5.75 | 0.55 |
| *Sarotherodon melanotheron* (Pt) | 100.00 | 15.42 | 5.29 | 100.00 | 9.58 | 8.13 | 100.00 | 5.92 | 5.18 |
| *Tilapia guineensis* (I) | 72.73 | 9.25 | 2.76 | 90.00 | 4.17 | 5.32 | 72.73 | 5.67 | 8.65 |
| *Tylochromis jentinki* (I) | 100.00 | 14.67 | 11.63 | 80.00 | 2.08 | 2.90 | 100.00 | 5.33 | 5.60 |
| *Awaous lateristriga* (U) | 18.18 | 0.25 | 0.71 | 0.00 | 0.00 | 0.00 | 63.64 | 0.92 | 0.98 |
| *Porogobius schlegelii* (I) | 45.45 | 1.58 | 0.96 | 80.00 | 4.83 | 1.81 | 63.64 | 1.58 | 2.36 |
| *Eleotris vittata* (U) | 36.36 | 0.33 | 0.49 | 50.00 | 0.58 | 0.89 | 81.82 | 3.25 | 3.61 |
| *Eleotris senegalensis* (U) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.09 | - | - |
| **Estuarine dependent freshwater fish (EDF)** | | | | | | | | | |
| *Pellonula leonensis* (I) | 81.82 | 3.17 | 4.84 | 90.00 | 20.75 | 1.33 | 100.00 | 30.17 | 11.71 |
| *Chrysichthys maurus* (I) | 72.73 | 1.42 | 2.10 | 60.00 | 4.25 | 7.20 | 36.36 | 1.08 | 1.71 |
| *Chrysichthys nigrodigitatus* (I) | 100.00 | 32.17 | 3.70 | 100.00 | 6.67 | 5.64 | 90.91 | 8.58 | 8.14 |
| *Chrysichthys teugelsi* (I) | 9.09 | - | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Hemichromis fasciatus* (P) | 100.00 | 6.50 | 6.12 | 100.00 | 3.08 | 1.88 | 100.00 | 5.33 | 1.67 |
| *Tilapia mariae* (Pt) | 72.73 | 1.42 | 1.81 | 80.00 | 2.00 | 2.20 | 9.09 | - | - |
| **Estuarine dependent marine fish (EDM)** | | | | | | | | | |
| *Ethmalosa fimbriata* (Pt) | 9.09 | - | - | 0.00 | - | - | 63.64 | 1.33 | 2.36 |
| *Hemiramphus balao* (Pt) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.09 | - | - |
| *Trachinotus teraia* (I) | 27.27 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 18.18 | 0.25 | 0.71 |
| *Plectorhincus macrolepis* (U) | 9.09 | - | - | 0.00 | 0.00 | 0.00 | 9.09 | - | - |
| *Pomadasys jubelini* (I) | 18.18 | 0.17 | 0.00 | 70.00 | 1.50 | 0.41 | 45.45 | 1.08 | 1.34 |
| *Liza falcipinnis* (Pt) | 90.91 | 12.25 | 1.62 | 60.00 | 1.67 | 2.25 | 72.73 | 3.25 | 3.36 |
| *Citharichthys stampflii* (I) | 18.18 | 0.33 | 1.41 | 10.00 | - | - | 100.00 | 11.50 | 9.26 |
| **Estuarine nondependent marine fish (EN)** | | | | | | | | | |
| *Elops lacerta* (P) | 63.64 | 0.75 | 0.76 | 50.00 | 2.00 | 5.22 | 54.55 | 1.75 | 2.43 |
| *Caranx hippos* (I) | 63.64 | 0.67 | 0.38 | 20.00 | 1.25 | 7.78 | 54.55 | 3.00 | 4.47 |
| *Eucinostomus melanopterus* (I) | 27.27 | 0.50 | 1.73 | 30.00 | 0.33 | 0.58 | 90.91 | 5.25 | 6.04 |
| *Mugil cephalus* (Pt) | 9.09 | - | - | 0.00 | 0.00 | 0.00 | 9.09 | - | - |
| **Occasional marine visitor fish (OV)** | | | | | | | | | |
| *Hemicaranx bicolor* (U) | 9.09 | - | - | 0.00 | 0.00 | 0.00 | 9.09 | - | - |
| **Accessory marine visitor fish (AV)** | | | | | | | | | |
| *Hyporamphus picarti* (Pt) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.09 | - | - |
| *Lutjanus goreensis* (I) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.09 | - | - |
| *Synaptura lusitanica* (U) | 0.00 | 0.00 | 0.00 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |

* = introduced species, ** = hybrids, H = herbivorous, I = invertivorous, O = omnivorous, P = piscivorous, Pt = planktivorous, U = unknown.

dissolved solids (34.98, 150.92 and 349.08, respectively for zones 1, 2 and 3) increased importantly from zone 1 to 3. Mean transparency varied relatively slightly from zones 1 and 2 (43.86 and 42.69 cm, respectively) to zone 3 (63.43 cm).

## Fish composition and ecological categories

Overall 5175 individuals belonging to 67 species and 29 families were collected during the study period. Regarding the ecological categories, 8 permanent residents, 6 estuarine dependents freshwater, 7 estuarine dependents marine, 4 estuarine non-dependents marine, 1 occasional, 3 accessory visitors and 38 freshwater species occurred in the studied lagoon (Table 2). Among these, two introduced species in Côte d'Ivoire (*Heterotis niloticus* and *Oreochromis niloticus*) and one hybrid (*Tilapia zillii* × *Tilapia guineensis*) were recorded. The

**Table 2.** Contd.

| Species | Zone 1: Ehy lagoon | | | Zone 2: Tendo lagoon | | | Zone 3: Aby lagoon | | |
|---|---|---|---|---|---|---|---|---|---|
| | F (%) | Mean ab. | SD | F (%) | Mean ab. | SD | F (%) | Mean ab. | SD |
| **Freshwater fish (FW)** | | | | | | | | | |
| *Heterotis niloticus** (I) | 81.82 | 0.92 | 0.44 | 10.00 | - | - | 9.09 | - | - |
| *Papyrocranus afer* (I) | 90.91 | 2.00 | 2.88 | 20.00 | 0.25 | 0.71 | 0.00 | 0.00 | 0.00 |
| *Mormyrus rume* (I) | 27.27 | 0.33 | 0.58 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Marcusenius furcidens* (I) | 9.09 | - | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Marcusenius senegalensis* (I) | 63.64 | 3.33 | 0.00 | 30.00 | 0.58 | 2.31 | 0.00 | 0.00 | 0.00 |
| *Marcusenius ussheri* (I) | 27.27 | 0.50 | 1.73 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Mormyrops anguilloides* (P) | 18.18 | 0.33 | 1.41 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Petrocephalus bovei* (I) | 0.00 | 0.00 | 0.00 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Hepsetus akawo* (P) | 90.91 | 2.67 | 3.08 | 60.00 | 2.33 | 3.44 | 27.27 | 0.83 | 2.31 |
| *Brycinus longipinnis* (I) | 63.64 | 1.42 | 2.30 | 30.00 | 0.42 | 1.15 | 9.09 | - | - |
| *Brycinus nurse* (I) | 36.36 | 0.17 | 0.00 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Brycinus imberi* (I) | 18.18 | 0.75 | 1.50 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Brycinus macrolepidotus* (H) | 18.18 | 0.33 | 1.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Distichodus rostratus* (H) | 0.00 | 0.00 | 0.00 | 40.00 | 0.50 | 0.58 | 0.00 | 0.00 | 0.00 |
| *Barbus wurtzi* (U) | 0.00 | 0.00 | 0.00 | 10.00 | - | - | 9.09 | - | - |
| *Barbus snoeksi* (U) | 9.09 | - | - | 30.00 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Labeo coubie* (Pt) | 90.91 | 4.25 | 1.64 | 70.00 | 6.75 | 4.27 | 18.18 | 0.25 | 0.71 |
| *Labeo parvus* (Pt) | 9.09 | - | - | 40.00 | 0.33 | 0.00 | 9.09 | - | - |
| *Parailia pellucida* (I) | 9.09 | - | - | 60.00 | 26.92 | 2.36 | 27.27 | 5.50 | 6.36 |
| *Schilbe intermedius* (P) | 9.09 | - | - | 30.00 | 0.92 | 3.06 | 0.00 | 0.00 | 0.00 |
| *Schilbe mandibularis* (I) | 100.00 | 10.50 | 10.76 | 100.00 | 14.33 | 14.69 | 81.82 | 5.08 | 4.60 |
| *Heterobranchus isopterus* (O) | 45.45 | 0.42 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Heterobranchus longifilis* (O) | 18.18 | - | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Clarias anguillaris* (O) | 81.82 | 0.83 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Clarias buettikoferi* (O) | 63.64 | 1.75 | 0.84 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Malapterurus electricus* (P) | 18.18 | 0.25 | 0.71 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Synodontis bastiani* (O) | 0.50 | - | - | 30.00 | 0.42 | 0.58 | 0.00 | 0.00 | 0.00 |
| *Synodontis koensis* (H) | 9.09 | - | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Synodontis punctifer* (H) | 0.00 | 0.00 | 0.00 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Synodontys schall* (O) | 0.00 | - | - | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Parachanna obscura* (P) | 0.70 | 1.50 | 1.23 | 20.00 | 0.25 | 0.71 | 9.09 | - | - |
| *Thysochromis ansorgii* (U) | 9.09 | - | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Chromidotilapia guntheri* (I) | 2.92 | 7.50 | 0.45 | 70.00 | 2.17 | 2.93 | 36.36 | 5.83 | 17.99 |
| *Oreochromis niloticus** (Pt) | 27.27 | 0.42 | 0.58 | 0.00 | 0.00 | 0.00 | 18.18 | 0.33 | 1.41 |
| *Tilapia zillii* (H) | 90.91 | 6.42 | 2.14 | 100.00 | 12.17 | 4.22 | 100.00 | 13.58 | 13.46 |
| *Tilapia hybride*** (U) | 9.09 | - | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ctenopoma petherici* (I) | 72.73 | 1.00 | 0.93 | 10.00 | - | - | 0.00 | 0.00 | 0.00 |
| *Mastacembelus nigromarginatus* (U) | 36.36 | 0.42 | 0.50 | 0.00 | 0.00 | 0.00 | 9.09 | - | - |

highest monthly average of total fish abundance was obtained in zone 1 with 172.54 ± 137.35 individuals while the lowest was recorded in zone 3 with 147.54 ± 86.54 individuals.

Fifty-eight of the 67 species collected occurred in zone 1 (Table 1). *Chrysichthys nigrodigitatus*, *Hemichromis fasciatus*, *Sarotherodon melanotheron*, *Schilbe mandibularis* and *Tylochromis jentinki* were the most frequent (100%), followed by *Clarias anguillaris*, *Heterotis niloticus, Pellonula leonensis*, (81.81%), *Chromidotilapia guntheri*, *Chrysichthys maurus*, *Ctenopoma petherici, Tilapia guineensis* and *Tilapia mariae* (72.72%). Species with the highest monthly mean abundance data were *C. nigrodigitatus* (32.17±3.70), *S. melanotheron* (15.42±5.29), *T. jentinki* (14.67±11.63), *Liza falcipinnis* (12.25±1.62), *S. mandibularis* (10.50±10.76), and *T. guineensis*(9.25±2.76).

Forty-five of the 67 species collected occurred in zone 2. *C. nigrodigitatus*, *H. fasciatus*, *S. melanotheron,* and *S. mandibularis* were recorded in all the samples (100%). They were followed by *Tilapia zillii* (83.33%), *P. leonensis, T. guineensis* (75%), *Porogobius schlegelii*, *T. mariae* and *T. jentinki* (66.67%). The most abundant species were *Parailia pellucida* (26.92±2.36), *P. leonensis* (20.75±1.33), *S. mandibularis* (14.33±14.69), *T. zillii* (12.17±4.22), and *S. melanotheron* (9.58±8.13).

The lowest number of species was recorded in zone 3 (40 out of 67). The most frequent species in this area were *Citharichthys stampflii, C. nigrodigitatus*, *Hemichromis fasciatus*, *Pellonula leonensis, Sarotherodon melanotheron*, *Schilbe mandibularis, T. zillii,* and *T. jentinki* (100%). The species that were most abundant were *P. leonensis* (30.17±11.71), *T. zillii* (13.58±13.46), *C. stampflii* (11.50±9.26) and *C. nigrodigitatus* (8.58±8.14).

The Jaccard's coefficient of similarity (J) indicated that zones 1 and 2 were more similar in their species composition [$J_1(z_1,z_2) = 0.63$] than the comparisons between zones 1 and 3 [$J_2(z_1,z_3) = 0.53$], and between zones 2 and 3 [$J_3(z_2,z_3) = 0.51$].

Based on feeding habit data recorded in the literature the numbers of species in different trophic categories were higher (except for planktivorous species) in zone 1 than zone 2 and zone 3 with 26 invertivorous (versus 23 and 18 respectively), 7 piscivorous (versus 6 and 4), 5 omnivorous (versus 3 and 0), and 3 herbivorous (versus 3 and 1) (Table 2).

In terms of ecological categories, fish composition was dominated by freshwater species in zones 1 and 2 (respectively 34 and 26 out of 67 species) and by estuarine dependent fishes (including ER, EDF, and EDM) (20 out of 67) in zone 3. These estuarine dependent species were almost equally present in the three zones with 19 and 15 species, respectively in zones 1 and 2. The non-dependent marine fish species diversities were almost comparable, with 4 species in both zones 1, 3 and 3 species in zone 2 out of 4 species collected. For occasional marine visitor fishes, out of 4 species collected, 1 was recorded in zones 1 and 2, against 3 in zone 3.

Furthermore, univariate Mann-Whitney U tests on the occurrences of the ecological categories was performed to compare dry and wet season's samples between sampling zones. The results showed significant difference ($p<0.05$) only for estuarine nondependent fishes (EN) between zones 1 and 3 in dry season ($p=0.006$) and estuarine dependent marine fish (EDM) between zones 2 and 3 in wet season ($p=0.02$). Indeed, EN was represented in zone 1 by 66 specimens, versus 10 in zone 3. In this group, *Caranx hyppos* and *Eucinostomus melanopterus* exhibited a higher occurrence data differences with, respectively, 25 specimens in zone 1, against 5 in zone 3, and 35 specimens in zone 1, versus 1 in zone 3. The EDM was represented in zone 2 by 10 specimens, against 128 in zone 3. Specifically for this group, there were: 0 *C. stampflii* in zone 2, versus 87 in zone 3; 5 *L. falcipinnis* in zone 2, versus 16 in zone 3; and 0 *Ethmalosa fimbriata* in zone 2, versus 9 in zone 3.

**Influence of environmental variables**

Results of CCA showed that first and second axes accounted respectively for 86.1 and 13.9% of the total variance for the environmental-species ecological categories relationship. Based on first axis which expressed maximum percentage variance, there is a clear-cut separation of species ecological categories and environmental characteristics between Ehy (zone 1) and Aby (zone 3) lagoons (Figure 2): The first zone, with higher pH and water temperature measurements is associated with freshwater, estuarine resident (ER), marine migrant (MM) and estuarine dependent freshwater (EDF) species. Aby lagoon had higher values of conductivity, salinity, transparency, and dissolved oxygen and was associated with EDM species. The Tendo lagoon, which had an intermediate position, could be distinguished from other sampling sites mainly by its higher water depth based on axis 2 of the CCA.

## DISCUSSION

Physical and chemical data showed spatial trends in Aby-Tendo-Ehy lagoon system, based on sampling sites chosen in this study. The fact that there was no variation in the salinity of zones 1 and 2 further showed that these parts of the lagoon are freshwater environments, as compared to the zone 3 where the salinity varied between 0 and 3 ppt. The spatial variation in the salinity level corresponded to results of N'Goran (1998) and Seu-Anoï et al. (2011) for the Aby-Tendo-Ehy lagoon system. According to Chantraine (1980) salinity level in coastal
Coastal lagoon depends on freshwater supply: lagoon salinity is relatively lower when freshwater inputs are higher. Hauhouot (2004) indicated that the Tanoe River, which is connected to Ehy lagoon (zone 1), contributes to 63% of the Aby-Tendo-Ehy lagoon system. This data could explain why the overall salinity measurements along the Aby-Tendo-Ehy complex increased from sampling zone 1 to 3.

Species richness recorded for the Aby-Tendo-Ehy lagoon system is 67 in this study. It was lower than 83 species reported by Charles-Dominique (1993), but higher than 60 species noted by Daget and Iltis (1965), and 33 species mentioned by N'Goran (1998). Species recorded by Daget and Iltis (1965) and Charles-Dominique (1993) but not caught in the present study in the Aby-Tendo-Ehy lagoon included *Arius latiscutatus, Epinephelus aeneus, Sphyrena afra, Polydactylus*

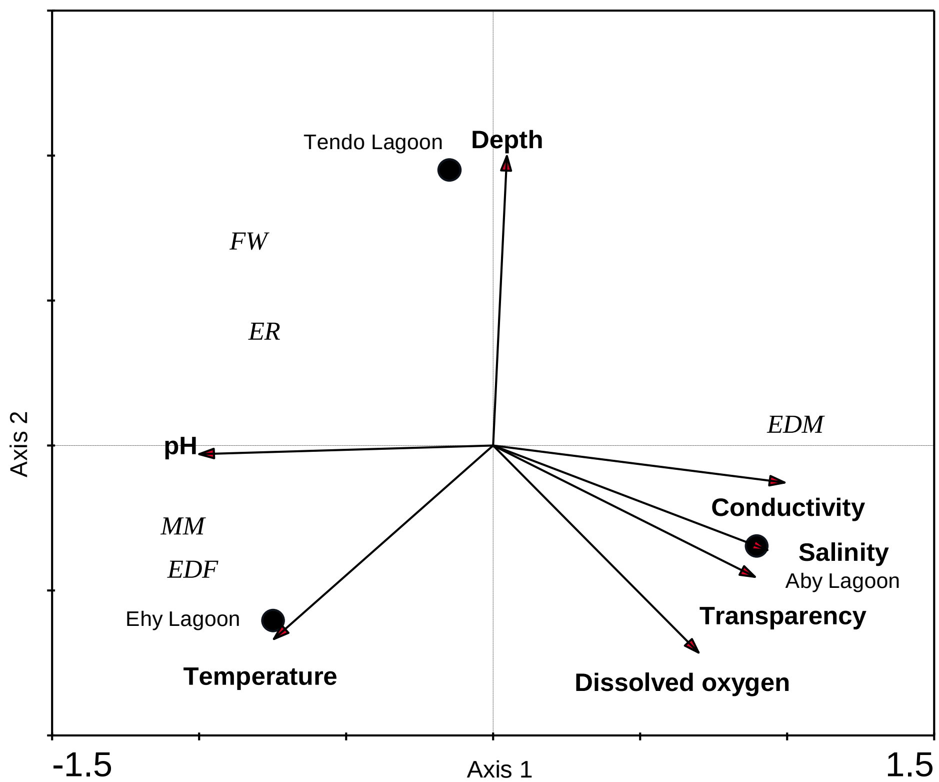


**Figure 2.** Canonical correspondence analysis applied to the environmental variables and to the fish ecological categories in the Aby-Tendo-Ehy lagoon system (Côte d'Ivoire). EDM = estuarine dependent marine fish, EDF= estuarine dependent freshwater fish, MM = marine migrant, ER = estuarine resident and FW = freshwater fish species.

*quadrifilis, Pseudotholitus elongatus, Eleotris senegalensis, Scomberomorus tritor, Liza grandisquamis, Drepane africana, Strongylura senegalensis, Galeoides decadactylus, Cynoglossus senegalensis, Lutjanus dentatus, Caranx rhonchus, Dasyatis margarita, Trachinotus ovatus, Sardinella maderensis, Bathygobius soporator, Caranx senegallus, Ilisha africana, Lichia amia, Mugil curma, Pegusa triophtalma, Sardinella aurita, Megalops atlantica, Gymnothorax afer, Dalophis cepholopeltis, Myrophis plumbeus, Neolebias unifasciatus, Aplocheilicthys splilauchen, Epiplatys chaperi, Nimbapanchax petersii, Enneacampus kaupi, Gerres nigri, Pomadasys perotaei, Oblada melanura, Scarus hoefleri, Gobionelus occidentalis, Periophtalmus barbarus, Acanthurus monroviae* and *Sphoeroides spengleri*. Many reasons such as the differences in sampling gear [experimental gillnets for the present study, against commercial fishing captures considered by Charles-Dominique (1993) and N'Goran (1998)] (Koné et al., 2003), the variation in fishing pressure due to human population increase (Albaret and Laë, 2003), and the environmental characteristic modifications (Charles-Dominique, 1993) could explain these species diversity differences.

In zone 3 which was much more investigated by previous studies, N'Goran (1998) and Charles-Dominique (1993), based on artisanal fisheries, indicated that the most abundant species was clupeid *E. fimbriata* (60 to 80% of total catch), versus *P. leonensis* for the present study. N'Goran (1998) and Charles-Dominique (1993) noticed a gradual decline in the capture of *E. fimbriata* in the Aby lagoon and attributed this to the increasing fishing intensity. In addition to these reasons, fishing gears characteristics in the present study could also have caused some differences: *P. leonensis* is a small sized species that was caught only by gillnet with small mesh size (06 and 08 mm), which is prohibited for commercial fisheries in the Aby-Tendo-Ehy lagoon. This result raised the question of some small-sized species that can be abundant but not exploited due to regulations on fishing gear.

Several studies suggested that tropical fish communities do not exhibit a clear organizational pattern (Goulding et al., 1988; Saint-Paul et al., 2000; Súarez et al., 2004). However, this study does not support the concept of unpredictability in the richness of fish community along Ehy-Tendo-Aby lagoon system: the number of species was found to decrease from zone 1 under freshwater influence to zone 3 with marine water influence. Furthermore canonical correlation analysis showed that sampling zone characteristics explain the variation in species richness: lowest values of salinity, transparency, dissolved oxygen and conductivity were associated with zones 1, whereas the highest values occurred in zones 3. This study also showed a variation in the number of different trophic categories. Piscivorous, herbivorous and omnivorous species number was higher in zone 1 with a reduced conductivity, salinity and transparency and a higher pH and temperature data. Planktivorous species were almost equally (species number) found in zones 1 and 3. Fish may affect diversity and water transparency by indirect trophic cascading effects: by consuming zooplankton and plant-attached macroinvertebrate grazers, fish may indirectly enhance phytoplankton and periphyton biomass (Jones and Sayer, 2003; Gelós et al., 2010), thus increasing water turbidity. But in the case of Ehy lagoon (zone 1) low transparency could also be the consequence of the turbulence phenomenon that occurred in this part of the lagoon due to high nutrient loads from both continental drainage and flooding tides (Neves et al., 2011; Konan et al., 2014).

Indeed, it is recognized that during the rainy season, runoff brings to aquatic environments a significant amount of organic material (which may include plant materials and/or insects) and nutrients from land that enrich these environments (Castillo-Rivera, 2013). The Tanoe River which is directly connected to zone 1 and the surrounding swampy forest of this zone act as important nutrient input sources. Insects and other terrestrial organisms, fruit and plant debris would also likely fall in the water under the effect of wind and rain (Konan et al., 2014). This possible importance and heterogeneity of food resources in this area could explain, partly, the high diversity both in species and trophic category diversities observed in zone 1.

In conclusion, this study recorded 67 species in the Aby-Tendo-Ehy lagoon system. Overall, fish diversity was higher in the most continental part of the studied lagoon than in the zone that was closer to the ocean. Species distribution along the Aby-Tendo-Ehy lagoon system was influenced by some environmental characteristics: the zone under the influence of freshwater discharges had higher pH and water temperature data and was mainly associated with freshwater, estuarine resident, marine migrant, and estuarine dependent freshwater species; the zone under marine water influences presented higher conductivity, salinity, transparency and dissolved oxygen data and had higher proportion of estuarine dependent marine species.

## Conflict of Interests

The author(s) have not declared any conflict of interests.


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