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(Research Article)

Seasonal variation of ichthyological diversity in catches of trawlers operating in the Exclusive Economic Zone of Côte d'Ivoire

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Abstract

A study on the seasonal evolution of the diversity of ichthyofauna from trawler catches was conducted in Ivorian marine waters. Monthly sampling carried out from August 2021 to July 2022 at the rate of four samples per month when the trawlers landed and the analyses carried out in the laboratory made it possible to count 1047 fish specimens during the long cold season and 1036 specimens during the long warm season. Individuals from the first season are divided into 9 orders, 32 families and 68 species; those from the warm season are divided into 10 orders, 23 families and 39 species. During the short warm season, 507 specimens (5 orders, 19 families and 34 species) were recorded. The smallest number of fish was recorded during the short cold season (381 specimens divided into 5 orders, 20 families and 30 species). The Carangidae family is the most diverse in all seasons. In terms of abundance, Haemulidae dominate the fish population during the short seasons, while Ophidiidae are more abundant in the long warm season, followed by Polynemidae in the long cold season. Analysis of diversity indices (Shannon and equitability) did not reveal any significant differences (ANOVA; $p > 0.05$), reflecting a good distribution of species. The Bray-Curtis similarity index highlights a similarity between the fish population of the short warm and cold seasons. These results provide essential information for the sustainable management of fishery resources in Côte d'Ivoire.

Keywords: Seasonal variation; Ichthyological diversity; Trawler capture; Exclusive Economic Zone; Côte d'Ivoire

1. Introduction

The ivorian "Exclusive Economic Zone (EEZ)" is a region rich in fish biodiversity. It is influenced by seasonal upwellings that promote high biological productivity [1]. However, anthropogenic pressure, including overfishing and habitat degradation, affects these resources, compromising their sustainability [2]. Intensive exploitation by trawling contributes to the capture of non-target species and the depletion of fish stocks [3, 4]. Similarly, this fishing has led to the reduction of catches per unit of effort of several species, in particular coastal demersal species such as: the white grouper (*Epinephelus aeneus*), the pageot (*Pagellus bellottii*), the porgy (*Sparus caeruleostictus*), the little captain (*Galeoides decadactylus*), red mullet (*Pseudupeneus prayensis*), octopus (*Octopus vulgaris*) and coastal shrimp (*Farfantepenaeus notialis*) [3], [5]. Today, the conservation of this biodiversity is a major challenge that requires, in particular, better management of fisheries and natural resources. However, this management is based on the assessment of the impacts of the activities of these fisheries on these resources. Faced with these challenges, it is crucial to update data on ichthyological diversity in order to optimize fisheries management. This study therefore aims to analyze the seasonal variation in catches by trawlers operating in the ivorian EEZ.

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2. Methodology

2.1. Study area

The Ivorian EEZ extends over approximately 600 km from Cap des Palmes (to the west, border with Liberia) to Cap des Trois Pointes (to the east, border with Ghana) [6]. It is located between 4° and 5°30' north latitude and 2°25' and 7°30' west longitude (Figure 1). This area is subject to marine environmental variations marked by the alternation of warm and cold seasons. The cold season includes the long cold season (LCS) which extends from July to October and the short cold season (SCS) from January to February. It is characterized by a rise to the surface of cold waters rich in mineral salts, also called "upwelling", with a temperature lower than 23°C and a salinity equal to 35 ‰. The intensity of this upwelling varies during the year, but the maximum is observed from July to September. The warm season includes the long warm season (LWS) which extends from March to June and the short warm season (SWS) from November to December. During this period, warm and desalinated ocean waters of Liberian-Guinean origin cover those of the upwelling, with a temperature between 27 °C and 28 °C and a salinity of 33.7 ‰ [7].

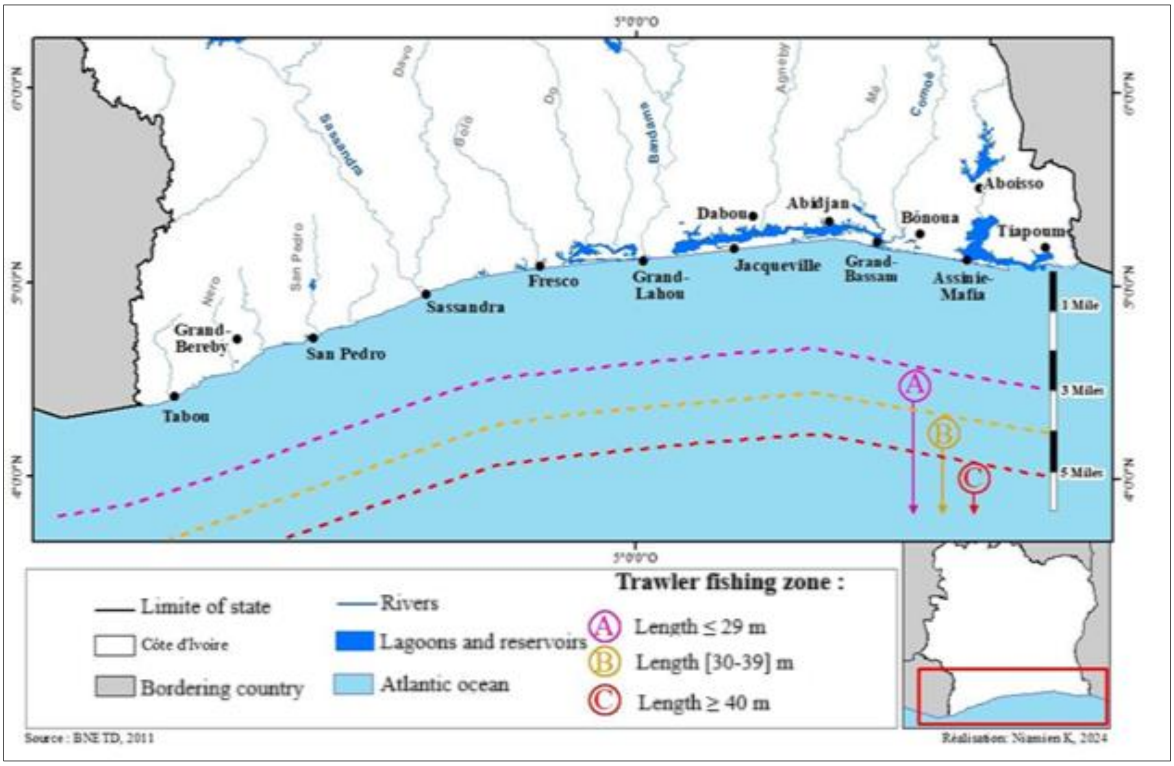

Figure 1 Fishing zone of trawlers in the Ivorian Exclusive Economic Zone

2.2. Sampling and species identification

The samples were carried out at the auction of the fishing port of Abidjan, during the landing of the trawlers during the period from August 2021 to July 2022. The choice of this site is based on the fact that it is the only place where the trawlers land their catch. The fishing gear used to catch the fish is the bottom otter trawl. The data was collected once a week at a rate of four times a month. The process of landing the trawlers consists of separating large fish from small fish on board the boat, then on the quay, sorting them by species and distributing them in boxes for sale at the auction. Before the second sorting, a box of fish per trip was taken before commercial sorting, the fish are kept in a cooler then sent to the laboratory of the Department of Living Aquatic Resources (DLAR) of the Oceanological Research Center (ORC) for identification and measurement. Large fish are measured in the field (size and weight). The species were identified using the identification keys of [8], [9] and [10]. The specific codes are those of the FAO. The physicochemical parameters, temperature and salinity recorded were made by daily download on the map of the Ivorian Exclusive Economic Zone on the Copernicus Marine site at a depth of 100 m. The seasonal evolution of these parameters was made according to the seasons determined by [7] in Ivorian waters. Thus, four marine seasons were defined by this author. These are: the long cold season (LCS) from July to October, the long warm season (LWS) from March to June, the short cold season (SCS) from January to February and the short warm season (SWS) from November to December.

2.3. Data analysis

The diversity analysis was based on:

2.3.1. Specific richness

Species richness (S) represents the total or average number of species recorded per unit area [11]. It also corresponds to the total number of species present in a given ecosystem [12]. Here, species richness can be defined as the total number of species encountered in the catches. It allows us to measure the diversity of species present in the catches.

$$S = \sum_{i=1}^{n} N_i$$

N_i : Number of species i encountered in the catches

2.3.2. Relative abundance

Relative abundance (RA) is defined as the ratio of the number of individuals of a taxonomic group (order, family or species) to the total number of fish sampled [13]. It is used to measure the dominance of taxa (order, family or species).

$$RA = \frac{n_i}{N} \times 100$$

- N: Total number of fish sampled
- n_i : Number of individuals in a taxonomic group

2.3.3. Frequency of occurrence

The frequency or percentage of occurrence (F) corresponds to the percentage of surveys for which species i is encountered. It provides information on the frequency of a given species in a habitat [14]. The frequency of occurrence can be defined as the ratio of the number of monthly samples in which a given species is found to the total number of samples. It is used to measure the frequency of appearance of a species in the captures.

$$F = \frac{F_i}{F_t} \times 100$$

- F_i: Number of monthly samples in which a given species is found
- F_t: Total number of samples

Thus according to [15] depending on the value of F obtained, the species can be classified into

- Constant species if F ≥ 50%;
- Accessory species if 25% ≤ F < 50%;
- Accidental species if F < 25%.

2.3.4. Shannon-weaver diversity index

The Shannon or Shannon-Weaver index (H') is used to express diversity by taking into account the specific richness and abundance of individuals within a species. It is used to express the degree of organization of the population [16]. Thus, a community dominated by a single species will have a lower coefficient than a community in which all the species are codominant. It is obtained by the following formula:

$$H' = -\sum_{i=1}^{S} \left(\frac{n_i}{N}\right) \times log_2 \left(\frac{n_i}{N}\right)$$

- S: Specific richness;
- n_i : Number of individuals of a species in the sample;
- N: Total number of individuals of all species in the sample.

Thus according to [17]:

- When H' tends towards 0, the population consists of only one species;
- When H' tends towards 5, the population is more diverse.

2.3.5. Pielou equitability index

The Pielou equitability index (E) or equi-distribution index allows us to assess the regularity of the distribution of individuals within the species of a given environment [18]. This index is derived from the Shannon-Weaver diversity index (H') and varies from 0 to 1 [11]. It is obtained by the following formula:

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

- H': Shannon index;
- S: Specific richness.

So:

- E tends towards 0, when only one species is abundant in the environment;
- E tends towards 1, when all the species present in the environment have the same abundance. We speak of equitability.

2.3.6. Bray-Curtis similarity index

The Bray-Curtis (BC) similarity index describes pairwise differences between seasons using species abundance data. It is expressed by a Principal Coordinate Analysis matrix. This index measures similarity between seasons. It is defined as the ratio of the difference in numerical abundance values to the sum of numerical abundance values for each species in a given sample. The Bray-Curtis index ranges from 0 to 1. Thus,

- BC is 0, when the seasons are completely different;
- BC is equal to 1, when the species composition of the two seasons is identical [19].

$$BC = 1 - \frac{\sum_{i=1}^{n} |X_{P_i} - X_{Q_i}|}{\sum_{i=1}^{n} (X_{P_i} + X_{Q_i})}$$

$X_{pi:}$ abundance of species i in short seasons

$X_{Qi:}$ abundance of species i in the main seasons

2.4. Statistical analysis

Analysis of variance (ANOVA) was used to compare the variability of physicochemical parameters, as well as diversity indices (Shannon and equitability) between different seasons. The analysis was performed using Past4.11 software.

3. Results

3.1. Physicochemical parameters

The recorded seasonal temperatures ranged from 26.24 ± 1.73 °C to 28.55 ± 0.34 °C. The highest temperature value was observed in the short warm season with a value of 28.55 ± 0.34°C while the lowest was obtained in the long cold season with a value of 26.24 ± 1.73 °C. The short cold season and the long warm season recorded respective values of 28.53 ± 0.12 °C and 28.49 ± 1.05 °C (Table 1). Tukey's test applied to the temperature values showed a significant difference between the long cold season and the other seasons (ANOVA, $p < 0.005$).

The recorded salinity values ranged from 33.73 ± 0.72 ‰ to 34.94 ± 0.36 ‰. The highest salinity was observed in the long hot season with a value of 34.94 ± 36 ‰ while the lowest was noted during the long cold season. The short cold and hot season recorded respective salinities of 34.52 ± 0.29 ‰ and 34.12 ± 0.16 ‰ (Table 1). Tukey 's test applied to the salinity values showed a significant difference between the long cold season and the other seasons (ANOVA, $p < 0.005$).

Table 1 Seasonal variation in temperature and salinity of the waters of the Ivorian Exclusive Economic Zone. LCS = long cold season, SCS = short cold season, LWS = long warm season, SWS = short warm season

	LCS	SWS	SCS	LWS
Temperature	26.23 ^{a} ± 1.73	28.55 ^{b} ± 0.34	28.53 ^{b} ± 0.12	28.49 ^{b} ± 1.05
Salinity	33.73 ^{a} ± 0.35	34.12 ^{b} ± 0.10	34.53 ^{b} ± 0.26	34.94 ^{b} ± 0.27

Temperature or salinity values sharing the same letter (a or b) do not differ significantly (Tukey's test, $p > 0.005$).

3.2. Specific richness and distribution

A total of 1047 fish specimens were collected during the long cold season divided into 9 orders, 32 families and 68 species. This was followed by the long warm season with 1036 specimens divided into 10 orders, 23 families and 39 species and the short warm season with 507 specimens divided into 5 orders, 19 families and 34 species. The short cold season had 381 specimens divided into 5 orders, 20 families and 30 species (Table 2).

Taking into account the number of species per family, in the long cold season, Carangidae dominate with a proportion of 13.23 %, followed by Soleidae 8.82 %, Cynoglossidae 7.35 %, Haemulidae 5.88 % and Scianidae 4.41 %. The other families represent 29.41% of the total species richness. During the long warm season, Carangidae are in the majority with 23.08 %, then Cynoglossidae 7.69 %, Scianidae 5.13 %. The rest of the families are monospecific and represent 41.02 %. In the short hot season, Carangidae have more species, either a frequency of 21.21 %. It is seconded by Sparidae 9.09 %, Soleidae 6.06 %.

The other 36.36 % are composed of families with a single species (Figure 2). As for the short cold season, the Carangidae family still dominates with a percentage of 14.28 %, followed by the Soleidae 10.71 %, the Sparidae 7.14 % (Figure 2). However, the long cold season is the one that records the greatest specific richness and the Carangidae family is the most diverse in each season (Figure 3).

The fish caught by trawlers have a varied distribution depending on the season. The species *Brachydeuterus auritus*, *Brotula barbata, Caranx senegallus, Chloroscombrus chrysurus*, *Cynoglossus canariensi*, *Dentex angolensis*, *Drepane africana*, *Galeoides decadactylus*, *Pomadasys incisus*, *Pomadasys rogerii*, *Pseudotolithus senegalensis*, *Pseudupeneus prayensis*, *Selene dorsalis*, *Sphyraena guagancho*, *Stromateus Fiatola* and *Trichiurus lepturus* are present in all four seasons (Table 2). Some species were collected only in one season. Among these, *Acanthurus monroviae, Synapturichthys kleinii, Seriola carpenteri, Scomber japonicus, Sciana umbra, Sarda sarda, Rachycentron canadum, Apsilus fuscus, Bothus podas africanus, Decapterus Rhonchus* were collected in the cold season. The species that were captured only in the warm season are: *Zeus faber*, *Caranx crysos*. In the short cold season, we note the presence of the species *Chelidonichthys capensis*, *Ecinostomus melanopterus*. The species recorded only in the short warm season is *Alectis ciliaris* (Table 2).

Table 2 Seasonal variation of the ichthyofauna of the Exclusive Economic Zone of Côte d'Ivoire in the catches of trawlers and it occurrence of fish species (F). LCS = long cold season, SCS = short cold season, LWS= long warm season, SWS = short warm season

Families	**Species**	**Species FAO codes**	**LCS**	**SCS**	**LWS**	**SWS**
Acanthuridae	*Acanthurus monroviae*	MDO	***	-	-	-
Balistidae	*Baliste capriscus*	TRG	**	-	**	-
	Baliste punctatus	BVP	***	-	-	-
Belonidae	*Tylosurus crocodilys*	BTS	-	-	**	-
Bothidae	*Bothus podas africanus*	BOA	**	-	-	-
Carangidae	*Alectis alexandrinus*	ALA	***	-	**	***
	Alectis ciliaris	LIJ				***
	Caranx crysos	RUB	**	-	**	-
	Caranx hippos	CVJ	***	***	***	***

	Caranx melanpygus	NXM	-	-	**	-
	Caranx senegallus	NXS	***	***	**	***
	Chloroscombrus chrysurus	BUA	***	***	***	***
	Decapterus rhonchus	HMY	**	-	-	-
	Selene dorsalis	LUK	***	***	***	***
	Seriola carpenteri	RLR	**	-	-	-
	Trachinotus ovatus	POP	***	-	***	***
	Trachurus trecae	HMZ	***	***	***	***
Chanidae	*Chanos chanos*	MIL	**	-	**	-
Clupeidae	*Sardinella aurita*	SAA	***	***	***	***
	Sardinella maderensis	SAE	***	***	***	***
Cynoglossidae	*Cynoglossus browni*	YOW	**	-	-	***
	Cynoglossus cadenati	YQF	**	-	**	-
	Cynoglossus canariensis	YOI	***	***	***	***
	Cynoglossus monodi	YQG	***	-	**	-
	Cynoglossus senegalensis	YOE	**	-	-	-
Drepanidae	*Drepane africana*	SIC	***	***	***	***
Elopidae	*Elops lacerta*	CEC	**	-	***	***
Ephippidae	*Chaetodipterus goreensis*	CGO	***	-	-	-
Gerreidae	*Ecinostomus melanopterus*	MFF	***	***	-	-
Haemulidae	*Brachydeuterus auritus*	GRB	***	***	***	***
	Pomadasys incisus	BGR	***	***	***	***
	Pomadasys jubelini	BUR	**	-	-	-
	Pomadasys rogerii	BGZ	***	***	***	***
Holocentridae	*Sargocentron hastatum*	AXH	***	-	**	-
Lethrinidae	*Lethrinus atlanticus*	LTN	***	-	-	***
Lutjanidae	*Apsilus fuscus*	AFK	**	-	-	-
	Lutjanus bohar	LJB	***	-	-	-
	Lutjanus fulgens	LVN	***	-	-	-
	Lutjanus gorensis	LJO	**	-	-	-
Malacanthidae	*Branchiostegus semifasciatus*	UAE	***	***	***	-
Moronidae	*Dicentrarchus* sp	BSE	***	-	-	-
Mulidae	*Pseudupeneus prayensis*	GOA	***	***	***	***
Ophidiidae	*Brotula barbata*	BRD	***	***	***	***
Paralichthyidae	*Syacium micrurum*	YAM	***	-	-	***
Polynemidae	*Galeoides decadactylus*	GAL	***	***	***	***
	Pentanemus quinquarius	PET	**	-	**	-
Pristigasteridae	*Ilisha africana*	ILI	**	***	-	***

Psettodidae	*Psettodes betcheri*	SOT	***	-	***	-
Rachycentridae	*Rachycentron canadum*	CBA	***	-	-	-
Scianidae	*Pseudotolithus senegalensis*	PSS	***	***	***	***
	Sciana umbra	CBM	**	-	-	-
	Umbrina canariensis	UCA	***	***	***	***
Scombridae	*Euthynnus alletteratus*	LTA	***	-	-	-
	Sarda sarda	BON	**	-	-	-
	Scomber japonicus	MAS	**	-	-	-
	Scomberomorus tritor	MAW	***	-	***	***
Scorpaenidae	*Scorpaena angolensis*	SSW	**	***	**	-
	Scorpaena scrofa	RSE	**	-	**	-
Serranidae	*Epinephelus aenus*	GPW	***	***	***	-
Soleidae	*Dicologoglosas cuneata*	CET	***	***	-	***
	Microchirus frechkopi	MIF	**	***	-	-
	Solea senegalensis	OAL	**	-	-	-
	Synaptura cadenati	YNY	***	-	-	***
	Synaptura lusitanica	SYC	**	***	-	-
	Synapturichthys kleinii	KSY	**	-	-	-
Sparidae	*Boops boops*	BOG	**	-	-	-
	Dentex angolensis	DEA	***	***	***	***
	Dentex congoensis	DEN	***	-	-	-
	Dentex gibbosus	DEP	***	-	-	***
	Pagellus belottii	PAR	-	***	***	-
	Pagrus caeruleostictus	BSC	**	-	***	***
Sphyraenidae	*Sphyraena guagancho*	YRU	***	***	***	***
Stromateidae	*Stromateus fiatola*	STF	***	***	***	***
Trichuiridae	*Trichuirus lepturus*	LHT	***	***	***	***
Triglidae	*Chelidonichthys capensis*	GUC	-	***	-	-
Zeidae	*Zeus faber*	JOD	-	-	**	-

(***) = constant species; (**) = accessory species, (-) = absence.

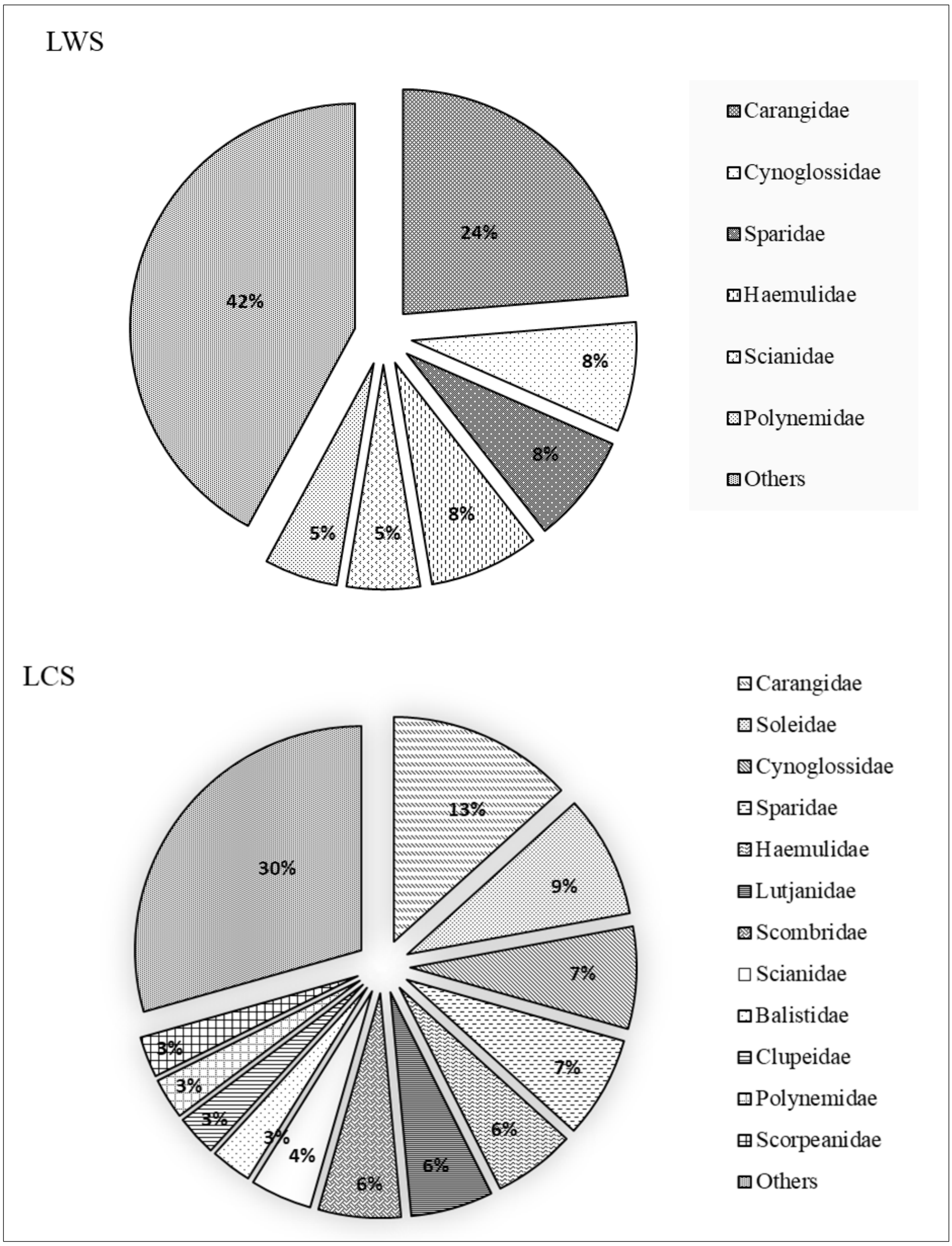

Figure 2 Proportion in number of species of the different families of fish from trawler catches according to the long warm season (LWS) and long cold season (LCS)

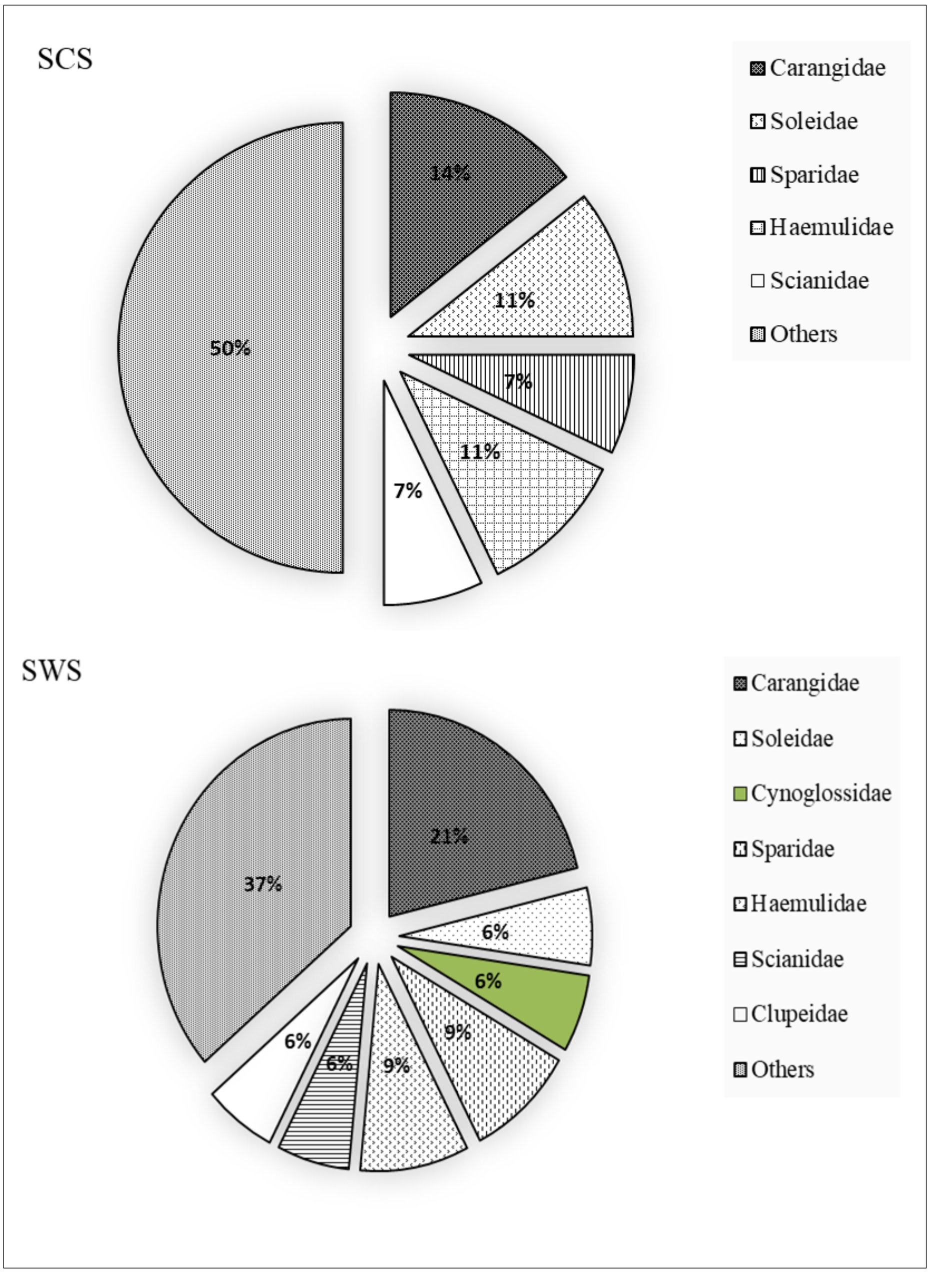

Figure 3 Proportion in number of species of the different families of fish in trawler catches according to the short warm season (SWS) and short cold season (SCS)

3.3. Relative abundance

The evolution of relative abundance presents a variability of species and families according to the seasons. Taking into account the relative abundance by species, *Brachydeteurus auritus* (22.29 %) (Haemulidae) and *Chloroscombrus chrysurus* (18.63 %) (Carangidae) dominate the catches during the short cold season. They are followed by *Sardinella aurita* (8.87 %) (Clupeidae), *Sardinella Maderensis* (7.54 %) (Clupeidae), *Cynoglossus canariensis* (5.76 %) (Cynoglossidae), *Galeoides decadactylus* (4.88 %) (Polynemidae), *Trichiurus lepturus* (4.66 %) (Trichiuridae), *Pseudupeneus prayensis* (4.43 %) (Mulidae) and *Selene dorsalis* (3.55 %) (Carangidae). The other species (n = 24) represent 19.29 % of the total abundance. During the short warm season, the number of *B. auritus* remains high at 31.14 %, followed by *S. maderensis* (13.35 %), *C. chrysurus* (7.93 %), *T. lepturus* (7.54 %). The species *S. dorsalis* and *G. decadactylus* have 5.61 % and 5.22 % respectively. Then come *P. senegalensis* (4.64 %) and *C. canariensis* (3.09 %). The rest of the species (n = 26) represent 21.47 % of the total number (Figure 4).

In the long cold season, *G. decadactylus* has the highest abundance with 17.70 %, followed by *B. auritus* and *B. barbata* with 12.60 % and 12.21 %, respectively. *C. chrysurus*, *P. senegalensis* and *S. aurita* have respective abundances of 8.11

%, 5.11% and 4.10 %. The other species (n = 40) have an abundance of 33.08 %. During the season, *B. barbata* dominates with 25.51 %, followed by *B. auritus* (14.52 %), *C. chrysurus* (6.12%), *P. senegalensis* (5.10 %), *T. lepturus* (4.87 %) and *S. maderensis* (4.16%). *S. guagancho*, *E. lacerta* and *S. aurita* have respective percentages of 3.53 %, 3.45 % and 3.45 %. The rest of the species (n = 31) occupy 25.27 % (Figure 5).

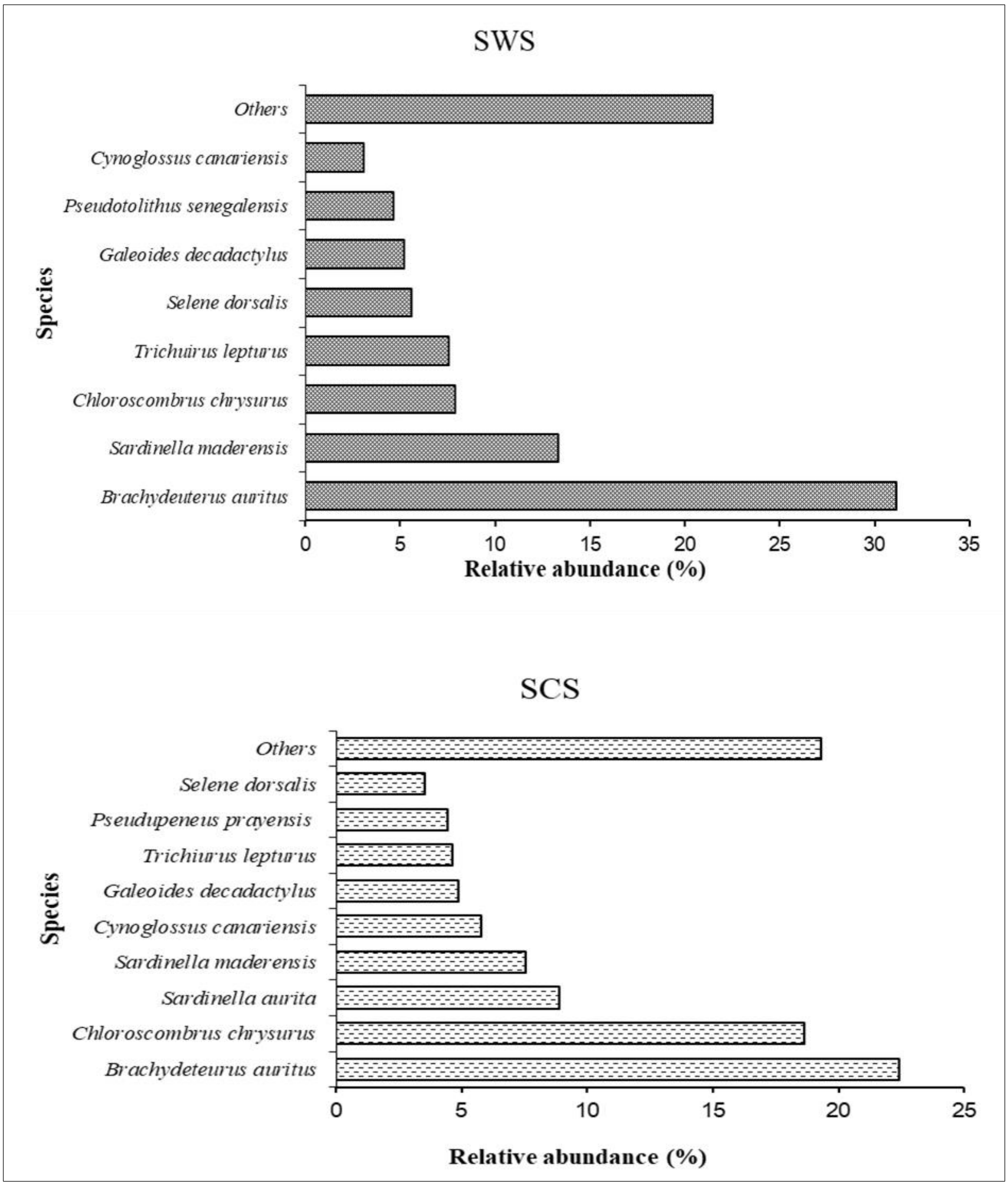

Figure 4 Relative abundance of the main fish species in trawler catches according to the short warm season (SWS) and short cold season (SCS)

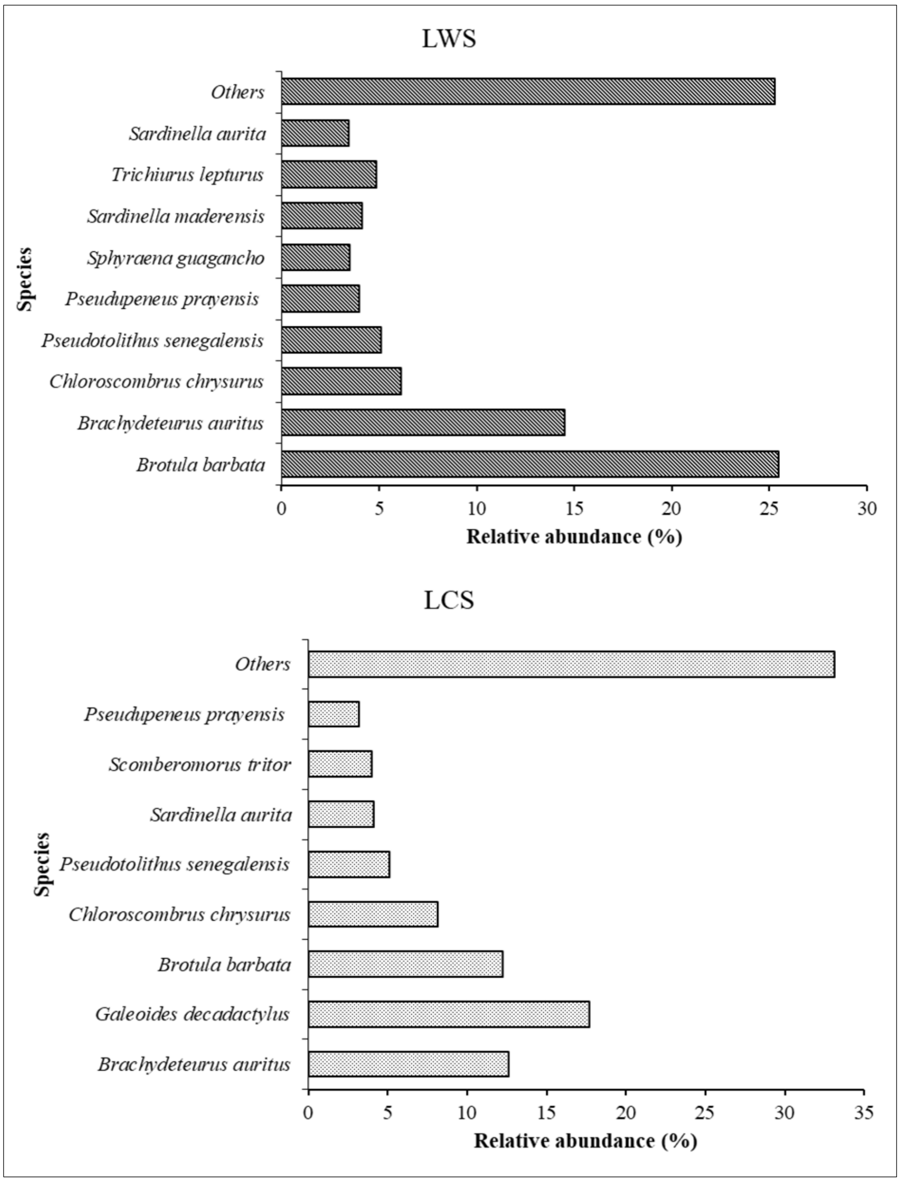

Figure 5 Relative abundance of the main fish species in trawler catches according to the long warm season (LWS) and long cold season (LCS)

3.4. Frequency of occurrence

The classification of species according to their frequency of occurrence allowed them to be grouped into the categories of constant and accessory species (Table 2). The small warm and cold seasons recorded species with frequencies of occurrence greater than or equal to 50 %. These species are called constant species. These are 30 species including *Brachydeteurus auritus* (100 %), *Chhloroscombrus chrysurus* (100 %), *Drepane africana* (50 %) and 34 species including *Galeoides decadactylus* (100 %), *Pomadasys incisus* (100 %), *Drepane Africana* (50 %).

In the long warm season, more than half of the species are constant (28) against 15 accessory species encountered. These are among others, *Branchiostegus semifasciatus* (75 %), *Caranx hippos* (50 %), *Brachydeteurus auritus* (100 %), *Brotula barbata* (100 %) and *Alectis alexandrinus* (25 %), *Baliste capriscus* (25 %), *Tylosurus crocodilys* (25 %).

The constant species obtained in the long cold season have a number of 43 of which are *Acanthurus monroviae* (75 %), *Chaetodipterus goreensis* (50 %), *Epinephelus aenus* (100 %) etc. The other 26 species are accessory. However, in all seasons, the number of constant species is higher than that of accessory species.

3.5. Shannon-Weaver diversity and equitability indices

Table 3 illustrates the seasonal variations of Shannon diversity (H') and equitability (E) index. The Shannon index varies between 2.59 and 3.18 while equitability values range between 0.71 and 0.78. Analysis of variance (ANOVA) did not show any significant difference between seasons ($p > 0.05$). Thus, the population is diverse and all species present have non-significant differences in abundance between seasons.

Table 3 Seasonal variation of Shannon diversity (H') and equitability (E) indices of fish species from trawler catches. LCS = long cold season, SCS = short cold season, LWS = long warm season, SWS = short warm season

	SCS	LWS	LCS	SWS
Shannon (H')	2.64	2.83	3.18	2.59
Equitability (E)	0.78	0.74	0.75	0.73

3.6. Bray-Curtis similarity index

The Bray-Curtis dissimilarity matrix allowed us to order the seasons according to their similarity. Thus, the taxonomic composition between the small seasons and the large seasons are close to each other. But the small warm season and the small cold season are the closest, thus reflecting a strong analogy as to their specific composition (Figure 6).

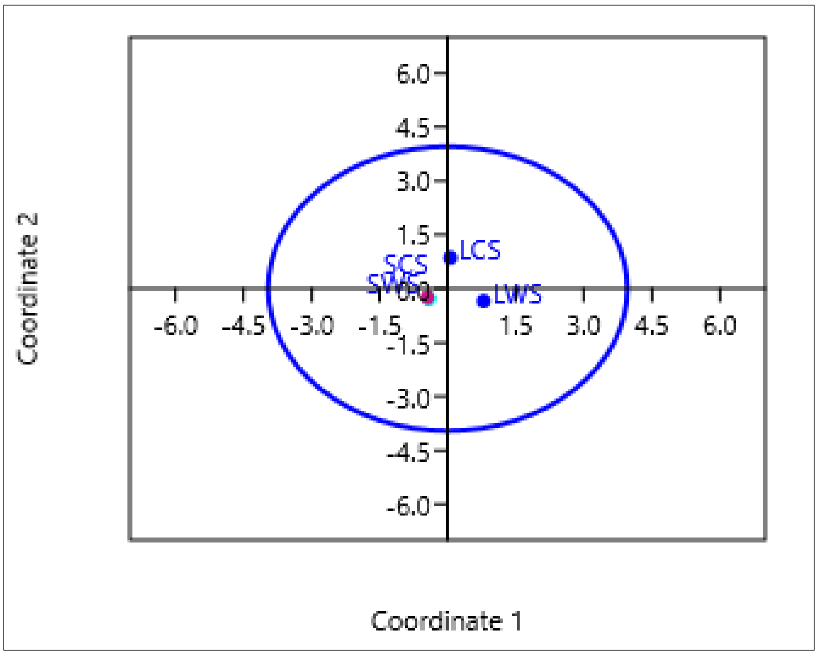

Figure 6 Analysis of principal coordinates between seasons made by the Bray-Curtis distance

4. Discussion

The seasonal variation of species richness showed a significant diversity during the long cold season compared to the other seasons. Indeed, the temperature obtained during the cold season (26.24 ± 1.73 °C) is lower than that obtained in the other three seasons. Thus, the high number of species encountered in the long cold season would be due to the upwelling phenomenon that characterizes the cold period. During upwelling, deep cold waters rich in minerals and nutrients constitute a food source for many species. Our results are similar to those of [20]. These authors mentioned that small variations in water temperature can influence the abundance of fish species. Thus, the rise of water to the surface causes a high concentration of fish species [20]. This situation would result in the massive presence of different species in the catches during the cold season. The species diversity of Carangidae in each season is important. Indeed, Carangidae form one of the largest families of bony fishes, which enjoy a wide distribution throughout the world and are represented by about 140 species belonging to 32 genera [21]. Their wide distribution and great diversity could explain the high representativeness of this family in the catches. [21] in their work in Indian waters found results similar to ours. Sixty species of fish of this family were recorded. The species caught by trawlers have a varied distribution depending on the seasons. Thus, some were harvested in one season, among these, *Acanthurus monroviae, Synapturichthys kleinii* in the long cold season, *Zeus faber*, *Caranx crysos* in the long warm season, *Chelidonichthys capensis*, *Ecinostomus melanopterus* short cold season and *Alectis ciliaris* in the short warm season. This would reflect the seasonal nature of these species. On the other hand, others have been recorded in all seasons: *Brachydeuterus auritus, Brotula barbata*, *Caranx senegallus*, *Chloroscombrus chrysurus*, *Cynoglossus canariensis*, *Dentex angolensis*, *Drepane africana*, *Galeoides decadactylus*, *Pseudupeneus prayensis, Selene dorsalis, Trichiurus lepturus.* These species common to the four seasons would indicate their tolerance and adaptation to variations in environmental parameters. Indeed, taxa common to different habitat characteristics are ecologically less demanding taxa [22].

The seasonal evolution of relative abundance showed a high percentage of Haemulidae at the family and species level including *Brachydeuterus auritus*. Our results are similar to those of [23]. In their study on the structure of fish species diversity in the ivorian EEZ, these authors showed that Haemulidae are the most abundant and *B. auritus* dominates the population in terms of numerical abundance. Similarly, *Brachydeuterus auritus* is one of the most abundant and widespread semi-pelagic fish species in the waters of Côte d'Ivoire [24]. Also, in bottom trawl catches, semi-pelagic species including *Brachydeuterus auritus* are very important in the Gulf of Guinea [25].

The seasonal occurrence frequency showed a dominance of constant species in all seasons. The high number of constant species would translate into a good adaptation to environmental conditions and variations in physicochemical parameters. Indeed, some species have a large margin of tolerance to environmental factors. This is the case of *Brachydeuterus auritus* which is able to adapt to rapid temperature changes [26].

Diversity indices vary between 2.59 and 3.18 for Shannon and 0.73 and 0.78 for equitability. This clearly reflects a diversity of species and the equi -distribution of numerical abundance between these species according to the seasons. Similarly, no significant difference was observed between the diversity indices by season. This would be due to the fact that a large number of species are common to the four seasons indicating their tolerance and adaptation to variations in environmental parameters. These results are comparable to those of [17] and [27]. Indeed, these authors observed a fairly good organization of the ichthyological population in the Solomougou dam lake and in the Aghien-Potou lagoon complex. Also, the results of the seasonal variation of numerical abundance clearly reflect this organization since it showed a variability of species and rich in terms of individuals.

The Bray-Curtis dissimilarity index analysis showed a great similarity between the short cold season and short warm season. This could be explained by the fact that these two seasons are subject to almost identical temperatures. This observation is supported by the statistical test (ANOVA) which did not show any significant difference between the small cold season and the small hot season. These similar temperatures would therefore influence the distribution of species. Similarly, among the physicochemical parameters, temperature is an excellent parameter for species distribution [20].

5. Conclusion

This study highlights the influence of seasons on the ichthyological diversity of trawler catches in Côte d'Ivoire. Species richness is at its highest in the long cold season. As for the study of relative species abundances, *Brachydeuterus auritus* is dominant in all catches. Constant species are abundant in landings in each season. In addition, ichthyological diversity remains high in relation to the calculated diversity indices. Furthermore, the Bray-Curtis index showed a similarity between the species of the two short seasons. This information will constitute an important database for researchers and decision-makers in the implementation of sustainable management measures for aquatic resources in ivorian marine waters and in the development of trawler fishery development plans.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest regarding the conduct of this study.

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