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Research Article

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Preliminary Study of Fish Assemblage Structure of the Marine Protected Area of Cayar in Senegal

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Abstract

Since its establishment in 2004, Cayar Marine Protected area (North of Senegal) is characterized by a lack of information on its fish fauna. Therefore, it becomes necessary to characterize the fish fauna of this MPA and its dynamics in time and space for a sustainable management of this conservation area. This present study investigated seasonal and spatial structure of the fish assemblage of Cayar MPA. This study consisted of collaborative seasonal sampling with local communities from six stations within the four main fishing areas with two types of fishing gears, purse seine and long line between 2015 and 2016. Ecological and trophic classification was performed in order to determine the fish fauna nature of this MPA. Multivariate analysis like factorial correspondence analysis and hierarchical classification analysis were carried out to study spatial and seasonal structure of fish assemblage of Cayar MPA. A total of 103 fish species from 45 families were reported. The most abundant species and the richest family were *Pagellus bellottii* and Carangidae, respectively. The fish assemblage was dominated by species of marine affinity and predators. Spatial and seasonal fish assemblages differed both in terms species richness and fish abundance. The highest and lowest species richness and abundance were recorded during the cold season and cold to warm transition period, respectively. A clear separation was found between stations where purse seine and long line were applied, in species composition and abundance. Results from this study might serve as the reference point of the fish assemblage in Cayar MPA. However, further investigation on the environmental variability is needed for a better understanding of the observed fish assemblage organization in time and space.

Keywords

Cayar; Fish assemblage; Marine Protected area; Senegal

Introduction

In the context of climate change and overexploitation several tools have been propose for sustainable fisheries management. A panoply of approaches range from the establishment of biological rest to the implementation of Marine Protected Areas (MPA) has been elaborated. Despite some controversy [1], MPA is worldwide recognized as one of the most efficient fishery management strategies [2-7]. In this sense, during the Fifth World Parks Congress held in South Africa in September 2003, it was exhorted to the Member States to protect at least 5% of their marine territory by 2010. Recent studies suggested that, if applied at broad spatial scales and effectively managed, MPA can potentially reduce absolute levels of fishing pressure and might lead to fish stock and habitats restoration [8-11]. These findings probably led to an increase of this rate to 10% by 2020 at the Conference of Parties on Biodiversity Convention (CBD) in Nagoya (Japan) held in 2010.

Since 2004, the Senegalese government created five new MPA, by Presidential decree of 4 November 2004 in order to respect the commitments made at this Congress in 2003. These MPA, besides Bamboung MPA which benefited of a regular monitoring of its fish assemblage from the closing off of the area until 2012 [12], were suffering from a lack of information about fish assemblage. Aware that regular monitoring of the relative abundance of species within MPA network is essential to assessing their performance as tools for conservation and fishery management [13-15], a seasonal bio-ecological monitoring program was set since 2015 by the Directory of Marine Protected Areas in Senegal. This program was elaborated with the technical support of the research institutions such as CRODT (Centre de Recherche Océanographique de Dakar-Thiaroye) and IUPA (Aquaculture and Fisheries Institute of the University of Dakar). It seeks to describe and to follow the evolution of the fish assemblage in the Senegal MPA. The finality of this program is to dispose sufficient and reliable information to be able to orientate decision making for effective and sustainable management of marine and coastal resources.

Here we present the spatial and temporal fish assemblages relative to their taxon, abundance biomass, ecological and trophic categories of Cayar Marine Protected Area. This study is a first step towards understanding the functioning of biological communities in space and time in Cayar MPA, where fishing activities are authorized and regulated. It exist several techniques that allow to display the association between species assemblage in time and space. In this study, fish assemblage patterns were investigated by clustering the different species according to the sampling seasons and stations relative to the similarities in species composition and their abundance.

Material and Methods

Study area

The Cayar Marine Protected Area (CMPA) is located 58 km North of Dakar in the Grande Côte, between 14°55'6 and 15°01'6 N and 17°10'8 and 17°16'5 W (Figure 1). It covers an area of 171 km^2 and belongs to the maritime domain. It consists of a fishing-MPA where fishing activities are authorized and regulated which is divided in four areas: "Bountoubi", "Tank", "Angleterre" and "Kheurus" (Figure 1). These names were given by local fishers. This partition was based on sociological and ecological criteria. Fishing activities with long line and gillnets are prohibited in the MPA. The other specificity of the CMPA is the presence of a deep canyon (the Canyon of Cayar) playing an important ecological role, the diversity of habitats and the seasonal upwelling which enriches the subsurface waters [16-18].

Sampling protocol

Samples were collected every season between April 2015 and

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December 2016 at six sampling stations (A, B, C, D, E and F) representing the different types of habitats encountered in the MPA. These sampling stations are within the main fishing areas in the MPA. Station A belongs to Bountoubi area, B and D are within Kheurus area, C and E are inside Angleterre area and F belongs to Tank area. The choice of these stations was based on fisher's knowledge and habitat types. The seasons correspond to the four main hydro-climatic periods in Senegal [19-21]: Cold Season (CS) in April, transition Cold to Warm season (CW) in June, Warm Season (WS) in September and transition Warm to Cold season (CW) in December. Sampling was done during daylight hours using two types of fishing gears: a purse seine (length 350 m, height 40 m, 14 mm mesh size) and a bottom long line (length 100 m, height 38 m, with several types of fishhooks). Purse seine was applied at stations where seabed are muddy, sandy-muddy, sandy (A, B and C sampling sites (sandy area), while bottom long line was used to collect data at rocky stations (D, E and F (rocky area). These two devices were used to ensure more exhaustive fish sampling because of the diversity of habitat types (rocky and sandy areas). The fishing haul was considered as the fishing unit in this study. Therefore, 48 fishing hauls were carried out from 2015 to 2016.

After each fishing haul, fish were identified to the species level, counted, sized and weighed by species. In the case of large number of individuals, a sub-sample of 30 individuals per species was analyzed.

Data analysis

The relative abundance indices (AI) and the biomass indices (BI) were calculated as followed:

$$AI = \log \left(\frac{\text{Number of individuals for a given species}}{\text{Number of total individuals}} + 1\right) \quad (1)$$

$$BI = \log\left(\frac{\text{Biomass for a given species}}{\text{Total biomass}} + 1\right) \quad (2)$$

The logarithm function was applied to stabilize the variance. Species richness (the total number of species caught in each station or during each season) was calculated. Species were classified according to their habitats preference and feeding regimes. The ecological classification proposed by Albaret [22] was used in this study. This method classified species on several ecological categories according to their degree of euryhalinity and the characteristics of their bio-ecological cycle in different estuarine environments. Four ecological categories were sampled in the CMPA: Estuarine species from marine origin (Em), Marine-estuarine species (ME), Marine species which are accessory in estuaries (Ma) and Marine species that are occasional in estuaries (Mo). Concerning their feeding behavior, eight categories were identified: Scavenger or grazer herbivores (he-de), Herbivores mainly feeding on phytoplankton or micro-phytoplankton (he-ph), Omnivorous (Om), First level predators mainly feeding on zooplankton (p1-zo), First level predators mainly benthophagous (p1-bt), First level generalist predators mainly feeding on macro-crustaceans or insects (p1-mc), Second level generalist predators mainly feeding on fish, shrimps and crabs (p2-ge) and Second level piscivorous predators mainly feeding on fish (p2-pi).

Statistical analysis

Multivariate analysis techniques such as factorial and automatic classification analysis methods that allow to resume the spatial and temporal organization of data from a complex picture whose structure is difficult to pin down clearly [23], were applied here. Factorial correspondence analysis (FCA) was carried out using fish abundance indices to investigate the pattern of species assemblage among seasons and stations. The Hierarchical Classification Analysis (HCA) was also used to group species according to their spatial and seasonal affinity or similarity [24,25]. The dendrograms were performed using the Euclidean distance and the Ward minimum variance clustering

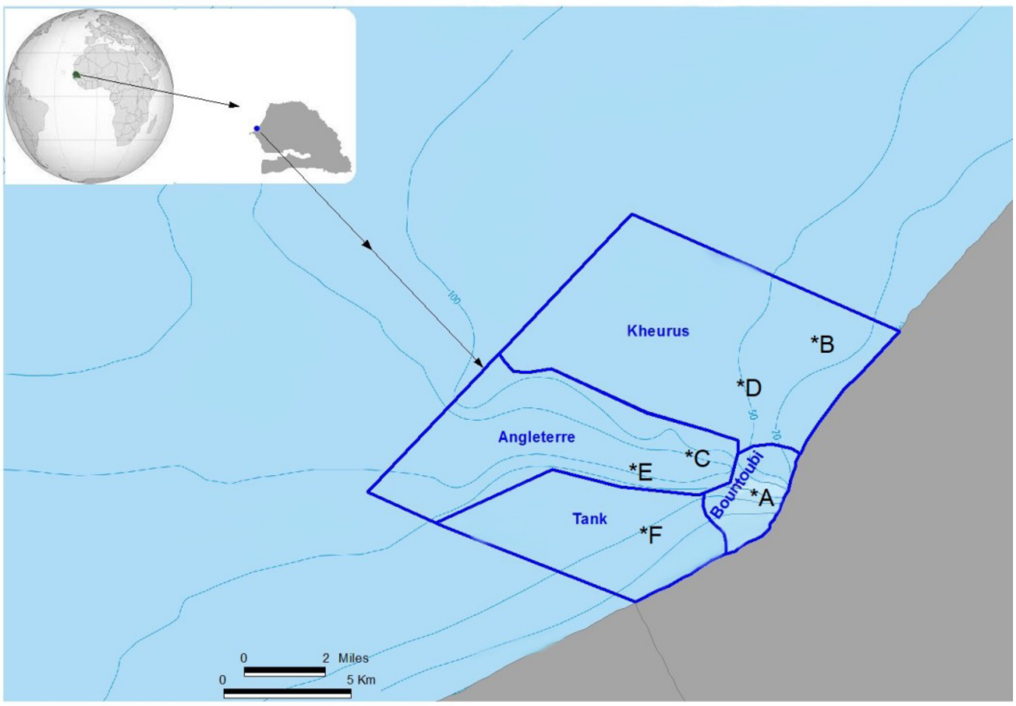

Figure 1: Map of the Cayar Marine Protected area and location of the six sampling stations within the four fishing domains.

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method [26]. These statistical analysis were carried out using R software [27], the ade4, Factoclass libraries [28]. The JLutils library was also used to obtain the best number of groups. The dendrograms of similarity between seasons and between sampling stations were carried out using the pvclust package [29]. This method provides probability values, which refer to an approximately unbiased (AU) or *p*-value. The *p*-value expresses the degree of similarity of seasons or sampling stations. Here, it is considered as significant when equal or more than 95%.

Results

Fish community composition and abundance

From the two years (2015-2016) of seasonal monitoring, 1424 individuals weighting 378.5 kg were collected in the CMPA. A total of 103 species belonging to 45 families were recorded (Table 1). The most abundant species were *Pagellus bellottii* (7.2%), *Caranx crysos* (5.8%), *Galeoides decadactylus* (5.2%), *Decapterus rhonchus* (4.4%), *Sarda sarda* (4.4%), *Pseudupeneus prayensis* (4.3%), *Caranx senegallus* (3.9%), *Cynoglossus senegalensis* (3.8%), *Chelidonichthys gabonensis* (3.6%), *Hemiramphus brasilensis* (3.6%), *Sphyraena guachancho* (3.1%), *Cynoglossus monody* (2.5%), *Lagocephalus laevigatus* (2.2%), *Euthynnus alletteratus* (2.4%), *Sardinella maderensis* (2.4%), *Scorpaena angolensis* (2.4%), *Synaptura punctatissima* (2.4%) and *Selene dorsalis* (2.2%). These eighteen species constituted 66.4% of the total fish number. In terms of family, the Carangidae were the most represented (13 species), followed by the Sparidae (12 species), the Serranidae (7 species), Sciaenidae (4 species), Scombridae (4) and Soleidae (4 species). Nine others families such as Haemulidae, Scorpaenidae, Tetraodontidae, Balistidae, Cynoglossidae, Dasyatidae, Diodontidae, Pomadasyidae, Sphyraenidae and Triglidae composed between two and three species. The 28 remaining families recorded one species only.

Temporal and spatial variation of species richness and abundance and biomass

The seasonal pattern of species richness, abundance and biomass is shown (Figure 2). Higher number of fish species, abundance and biomass were recorded in CS and WS. The lowest species richness and biomass were associated with CW, while lowest fish abundance occurred in WC. Figure 3 shows that there is no clear spatial pattern of species richness. The highest (40) and lowest (24) number of species were observed at stations C and F. However, spatial pattern of fish abundance and biomass was identified with higher values at stations A B and C where purse seine was deployed, and lower at D, E and F where long line were used.

Ecological and trophic structures

Fish assemblage was largely dominated by the marine species occasional in estuarine Mo (51 species representing 40.3% of the total number of individuals and 45.1% of the total biomass) and the marine species accessory in estuarine Ma (25 species accounting for 28.8% and 28.5% of abundance and biomass, respectively) (Figure 4). The marine estuarine species ME with 20 species, 20.3% of the total abundance and 19.7% of the total biomass were the third most represented fish. The estuarine species from marine origin (Em) were the less important in species richness, abundance and biomass (7 species representing 122 individuals and 6.7% of the total biomass).

In terms of trophic categories, the fish assemblage of Cayar MPA was structured in height groups (Figure 5). The predator species, p1-bt (43 species, 41.9% of the total number of individuals and 30.4% of the total biomass), p2-ge (27 species, 36.5% of the total number of individuals and 34.4% of the total biomass) and p2-pi (14 species, 11.4% of the total number of individuals and 21% of the total biomass) were the most encountered species in the CMPA. The size of the most

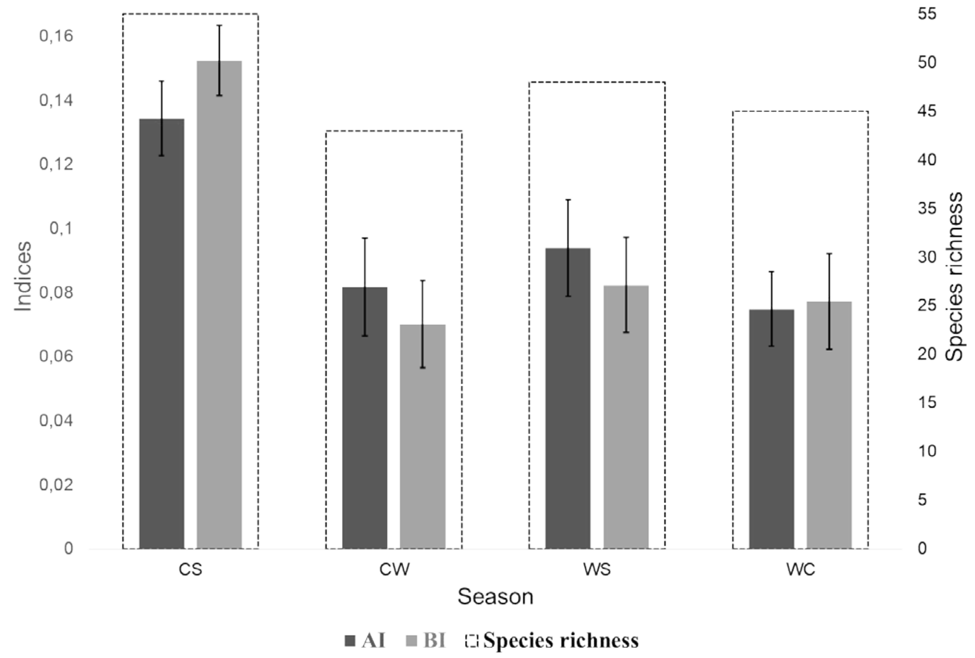

Figure 2: Seasonal variations of species richness, abundance and biomass. CS= Cold season, CW= transition from Cold to Warm season, WS= Warm season and WC= transition from Warm to Cold season. AI = abundance indices and BI=biomass.

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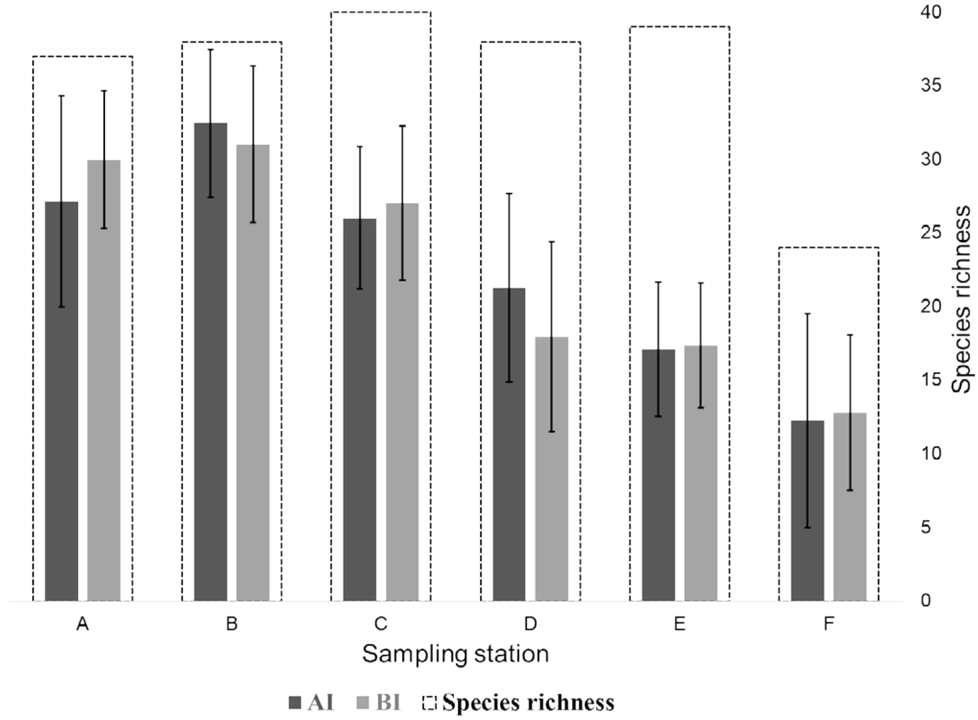

Figure 3: Spatial variations of species richness, abundance and biomass. CS=Cold season, CW=transition from Cold to Warm season, WS=Warm season and WC=transition from Warm to Cold season. AI=abundance indices and BI=biomass.

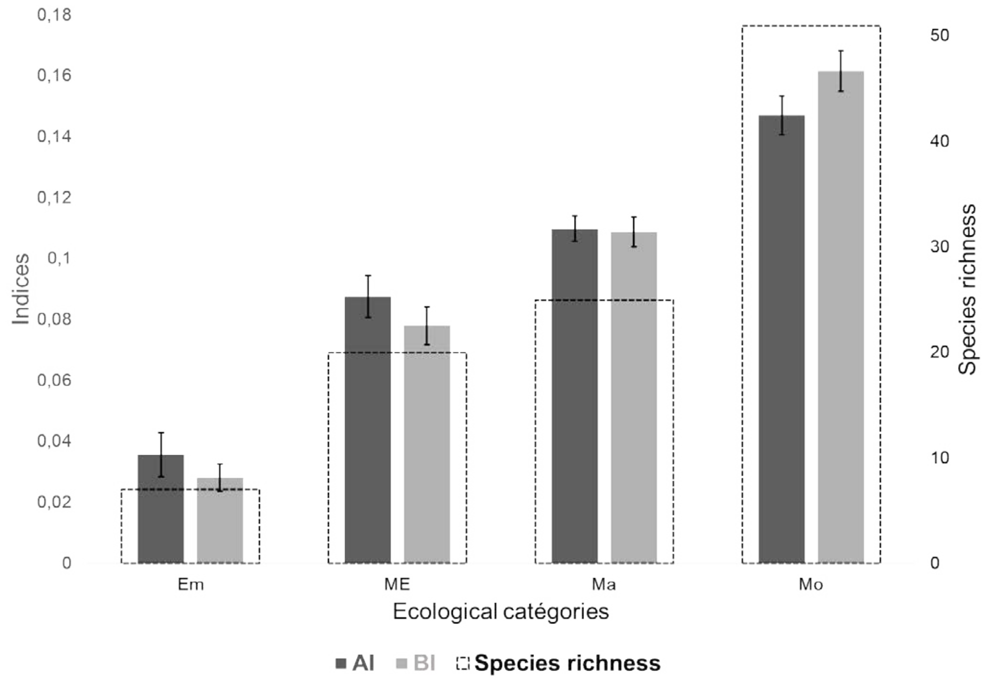

Figure 4: Fish species richness and abundance and biomass indices of the different ecological categories caught in the Cayar Marine Protected Area. AI = abundance indices and BI = biomass indices. Em = Estuarine species from marine origin, ME = Marine-Estuarine species, Ma = Marine species, accessory in estuaries and Mo = Marine species, occasional in estuaries [22]. The error bars are the standard errors.

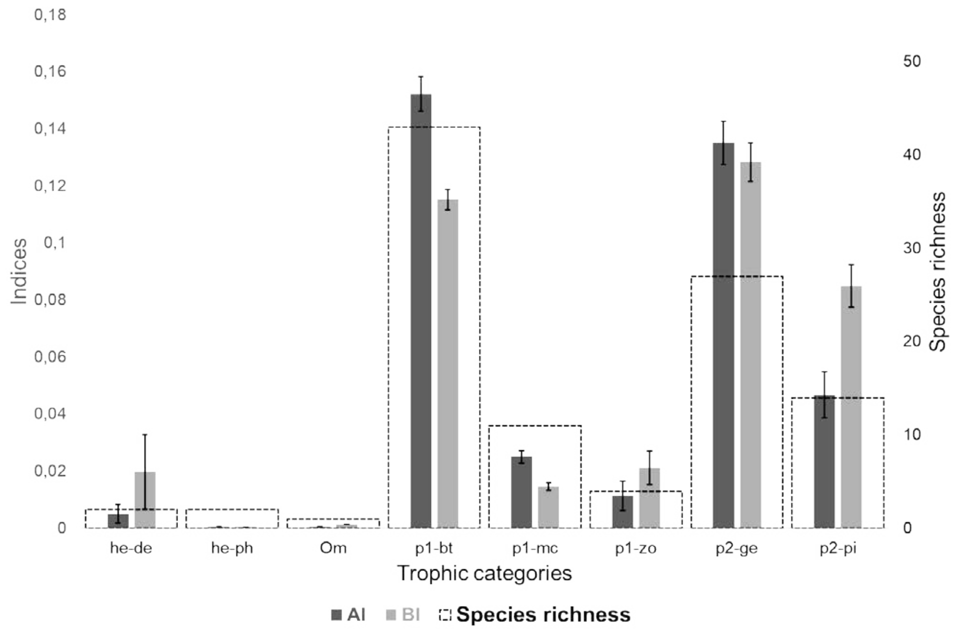

Figure 5: Fish species richness, and abundance and biomass indices of the different trophic categories of Cayar Marine Protected Area. AI = abundance indices and BI = biomass indices. he-de = scavenger or grazer herbivores, he-ph = herbivores mainly feeding on phytoplankton or micro-phytoplankton, p1-zo = first level predators mainly feeding on zooplankton, Om = omnivorous species, p1-bt = first level predators mainly benthophagous (mollusks, cockles, marine worms), p1-mc = first level generalist predators mainly feeding on macro-crustaceans or insects, p2-ge = second level generalist predators mainly feeding on fish, shrimps and crabs, p2-pi = second level piscivorous predators mainly feeding on fish. The error bars are the standard errors.

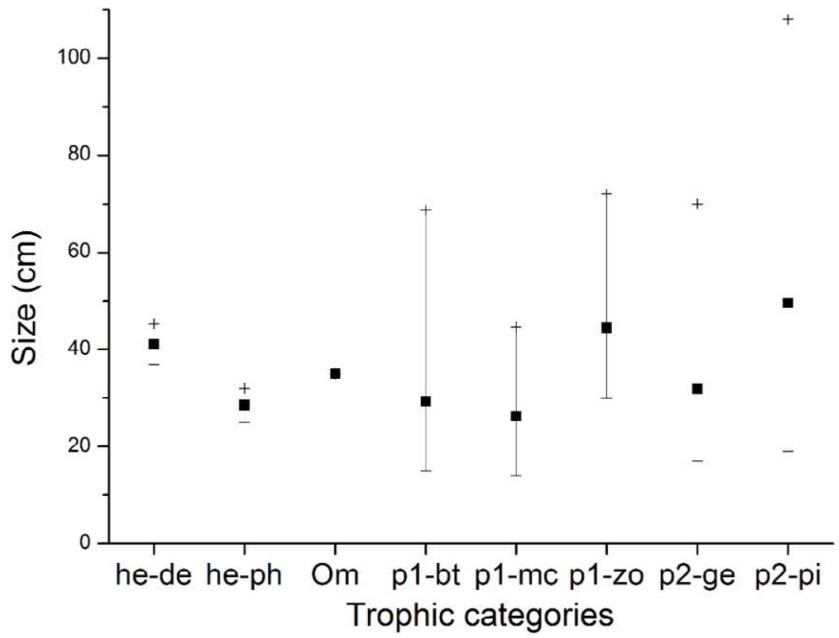

Figure 6: Fish size structure of the different trophic categories of Cayar Marine Protected Area. AI = abundance indices and BI = biomass indices. (+) and (-) are the maximum and the minimum sizes, respectively. The black squares correspond to the mea sizes. he-de = scavenger or grazer herbivores, he-ph = herbivores mainly feeding on phytoplankton or micro-phytoplankton, p1-zo = first level predators mainly feeding on zooplankton, Om = omnivorous species, p1-bt = first level predators mainly benthophagous (mollusks, cockles, marine worms), p1-mc = first level generalist predators mainly feeding on macro-crustaceans or insects, p2-ge = second level generalist predators mainly feeding on fish, shrimps and crabs, p2-pi = second level piscivorous predators mainly feeding on fish. The error bars are the standard errors.

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Table 1: List of the 103 fish species with their abundance and biomass (express in %) sorted trophic and ecological categories and by group according to their seasonal abundance.

Species	Code	Families	Trophic categories	Ecological categories	Abundance (%)	Biomass (%)	Group
Ablennes hians	ABH	Belonidae	p2-pi	ME	0,07	0,01	Group 1
Alutera punctata	ALP	Monacanthidae	he-ph	Mo	0,07	0,01	Group 1
Caranx senegallus	CAS	Carangidae	p2-ge	ME	3,93	0,01	Group 1
Cephalopholis taeniops	CET	Serranidae	p2-pi	Mo	0,07	0,01	Group 1
Chelidonichthys cuculus	CHC	Triglidae	p1-bt	Ma	0,28	0,01	Group 1
Chelidonichthys gabonensis	CHG	Triglidae	p1-bt	Ma	3,65	0,01	Group 1
Chilomycterus reticulatus	CHR	Diodontidae	p1-bt	Mo	0,07	0,01	Group 1
Chloroscombrus chrysurus	CCR	Carangidae	p1-mc	ME	0,35	0,01	Group 1
Diplodus vulgaris	DIV	Sparidae	p1-bt	Mo	0,14	0,01	Group 1
Ephippion guittifer	EPG	Tetraodontidae	p1-bt	ME	0,14	0,01	Group 1
Epinephelus aeneus	EPA	Serranidae	p2-pi	ME	0,91	0,01	Group 1
Epinephelus goreensis	EGO	Serranidae	p1-bt	Mo	0,77	0,01	Group 1
Euthynnus alletteratus	EUA	scombridae	p2-ge	Ma	2,46	0,01	Group 1
Gymnothorax maderensis	GYM	Muraenidae	p1-bt	Mo	0,14	0,02	Group 1
Mugil cephalus	MUC	Mugilidae	he-de	ME	1,12	0,01	Group 1
Paraprist octlineatum	PAO	Haemulidae	p1-bt	Ma	0,98	0,01	Group 1
Pomadasys perotaei	POP	Haemulidae	p1-bt	Em	0,21	0,01	Group 1
Scomberomorus tritor	SCT	scombridae	p2-pi	Ma	0,21	0,01	Group 1
Synaptura cadenati	SYC	Soleidae	p1-bt	Mo	0,77	0,01	Group 1
Trachinotus ovatus	TRO	Carangidae	p2-ge	Ma	1,54	0,01	Group 1
Xyrichtys novacula	XYN	Labridae	p1-bt	Mo	0,42	0,00	Group 1
Decapterus rhonchus	DER	Carangidae	p1-bt	ME	4,42	0,01	Group 2
Pseudupeneus prayensis	PSP	Mullidae	p1-bt	Mo	4,28	0,01	Group 2
Hemiramphus brasilensis	HEB	Hemiramphidae	p2-ge	Em	3,58	0,01	Group 2
Scomber japonicus	SCJ	Scombridae	p2-ge	Ma	0,63	0,01	Group 2
Pagrus caeruleostictus	PAC	sparidae	p1-bt	Ma	0,49	0,01	Group 2
Petrometopon nigri	PEN	Serranidae	p2-ge	Mo	0,49	0,01	Group 2
Pagrus caeruleostictus	PAC	Sparidae	p1-bt	Ma	0,35	0,01	Group 2
Strongylura senegalensis	STS	Belonidae	p2-pi	Em	0,21	0,02	Group 2
Sphoeroides spengleri	SPS	Tetraodontidae	p1-bt	Mo	0,21	0,00	Group 2
Acanthurus monroviae	ACM	Acanthuridae	Om	Mo	0,14	0,01	Group 2
Cephalopholis nigri	CEN	Serranidae	p2-ge	Mo	0,14	0,00	Group 2
Sphyraena sphyraena	SSP	Sphyraenidae	p2-pi	ME	0,07	0,03	Group 2
Sarpa salpa	SSA	sparidae	he-de	Ma	0,07	0,01	Group 2
Trachinotus goreensis	TRG	Carangidae	p2-ge	Mo	0,07	0,01	Group 2
Auxis thazard	AUT	Scombridae	p2-pi	Mo	0,07	0,01	Group 2
Bodianus speciosus	BOS	Carangidae	he-ph	Mo	0,07	0,01	Group 2
Trachinocephalus myops	TRM	Synodontidae	p2-pi	Mo	0,07	0,01	Group 2
Dasyatis centroura	DAC	Dasyatidae	p1-bt	Em	0,07	0,01	Group 2
Albula vulpes	ALV	Albulidae	p1-bt	Mo	0,21	0,02	Group 3
Balistes punctatus	BAC	Balistidae	p2-ge	Mo	0,07	0,01	Group 3
Balistes carolinensis	BAP	Balistidae	p2-ge	Mo	0,77	0,01	Group 3
Boops boops	BOB	Sparidae	p1-bt	Mo	0,28	0,01	Group 3
Brachydeteurus auritus	BRA	Haemulidae	p1-mc	ME	1,05	0,01	Group 3
Campogramma glaycos	CAG	Carangidae	p2-pi	Mo	0,77	0,01	Group 3
Cantharus cantharus	CAC	Sparidae	p1-bt	Mo	0,07	0,01	Group 3
Cephalocanthus volitans	CEV	Dactylopteridae	p1-mc	Ma	0,28	0,01	Group 3
Cynoglossus monodi	CYM	Cynoglossidae	p1-bt	Mo	2,53	0,01	Group 3
Cynoglossus senegalensis	CYS	Cynoglossidae	p1-bt	Em	3,79	0,01	Group 3
Dasyatis margarita	DAM	Dasyatidae	p1-bt	Em	0,07	0,02	Group 3
Decapterus punctatus	DEP	Carangidae	p1-bt	ME	0,07	0,01	Group 3
Dentex canariensis	DEC	Sparidae	p1-bt	Mo	0,42	0,01	Group 3
Dentex macrophtalmus	DEM	Sparidae	p1-bt	Mo	0,42	0,01	Group 3
Diagramma mediterraneus	DIM	Haemulidae	p1-mc	Mo	0,84	0,01	Group 3
Dicologoglossa cuneata	DIC	Soleidae	p1-bt	Mo	0,21	0,01	Group 3
Diodon holocanthus	DIH	Diodontidae	p1-bt	Mo	0,07	0,00	Group 3

Diplodus senegalensis	DIS	Sparidae	p1-bt	Mo	0,70	0,01	Group 3
Drepane africana	DRA	Drepaneidae	p1-mc	ME	0,07	0,00	Group 3
Eucinostemus melanopterus	EUM	Gerreidae	p1-mc	Ma	1,76	0,01	Group 3
fistularia tabacaria	FIT	Fistulariidae	p2-pi	Mo	0,77	0,02	Group 3
Galeoides decadactylus	GAD	Polynemidae	p2-ge	ME	5,20	0,01	Group 3
Lagocephalus laevigatus	LAL	Tetraodontidae	p2-ge	Ma	2,53	0,01	Group 3
Lethrinus atlanticus	LEA	Lethrinidae	p1-bt	Mo	0,07	0,01	Group 3
Lichia amia	LIA	Carangidae	p2-ge	Ma	0,14	0,01	Group 3
Merluccius senegalensis	MES	Merluciidae	p2-pi	Mo	0,21	0,01	Group 3
Mycteroperca rubra	MYR	Serranidae	p2-ge	Mo	0,07	0,02	Group 3
Pagellus bellottii	PAB	Sparidae	p2-ge	Mo	7,16	0,01	Group 3
Pomadasys incisus	POI	Haemulidae	p1-bt	Ma	0,91	0,01	Group 3
Pseudotolotus senegalensis	PSS	Sciaenidae	p2-ge	Ma	0,28	0,01	Group 3
Pteroscion peli	PTP	Sciaenidae	p1-mc	ME	0,07	0,01	Group 3
Sardinella maderensis	SAM	Clupeidae	p1-zo	ME	2,46	0,01	Group 3
Selene dorsalis	SED	Carangidae	p2-ge	ME	2,25	0,01	Group 3
Sphyraena guachancho	SPG	Sphyraenidae	p2-pi	ME	3,09	0,01	Group 3
Trachinus radiatus	TRR	Trachinidae	p1-bt	Ma	0,84	0,01	Group 3
Umbrina canariensis	UMC	Sciaenidae	p1-bt	Mo	0,14	0,01	Group 3
Uranoscopus scaber	URS	Uranoscopidae	p2-ge	ME	1,62	0,01	Group 3
Botus bodas	BBO	Soleidae	p1-bt	Mo	0,56	0,00	Group 4
Brotula barbata	BRB	Ophidiidae	p1-bt	Mo	0,21	0,01	Group 4
Caranx crysos	CCA	Carangidae	p1-bt	Mo	5,83	0,01	Group 4
Chromis chromis	CRC	Pomacentridae	p1-bt	Ma	0,07	0,00	Group 4
Chylomecterus reticulatus	CRE	Diodontidae	p1-bt	Mo	0,35	0,01	Group 4
Coryphaena hippurus	COH	Coryphaenidae	p2-ge	Ma	0,28	0,01	Group 4
Cynoponticus ferox	CYF	Muraenesocidae	p2-ge	Ma	0,07	0,02	Group 4
Dentex congoensis	DCO	Sparidae	p2-ge	Ma	0,07	0,00	Group 4
Diplodus cervinus	DCE	Sparidae	p1-mc	Mo	0,42	0,01	Group 4
Echeneis naucrates	ECN	Echeneidae	p1-zo	Mo	0,07	0,01	Group 4
Erythrocles monodi	ERM	Emmelichthyidae	p1-zo	ME	0,07	0,01	Group 4
Exocoetus volitans	EXV	Exocoetidae	p1-mc	Ma	0,56	0,01	Group 4
Fodiator acutus	FOA	Exocoetidae	p1-mc	Ma	0,21	0,01	Group 4
Palinurichtus pringlei	PAP	Stromateidae	p1-zo	Mo	0,07	0,02	Group 4
Pentheroscion Mbizi	PEM	Sciaenidae	p2-ge	Mo	0,07	0,01	Group 4
Plectorhynchus mediterraneus	PLM	Haemulidae	p2-ge	Em	0,63	0,01	Group 4
Pomadasys rogerii	POR	Haemulidea	p1-bt	Mo	0,21	0,01	Group 4
Sarda sarda	SAS	Scrombridae	p2-pi	Mo	4,42	0,01	Group 4
Scorpaena angolensis	SCA	Scorpaenidae	p1-bt	Ma	2,46	0,01	Group 4
Scorpaena normani	SCN	Scorpaenidae	p1-bt	Ma	0,07	0,01	Group 4
Scorpaena notata	SNO	Scorpaenidae	p2-ge	Ma	1,12	0,00	Group 4
Scyris alexandrinus	SAL	Carangidae	p2-ge	ME	0,21	0,01	Group 4
Serranus cabrilla	SEC	Serranidae	p2-ge	Mo	1,05	0,01	Group 4
Syacium micrurum	SYM	Bothidae	p1-bt	ME	1,62	0,01	Group 4
Synaptura punctatissima	SYP	Soleidae	p1-bt	Mo	2,39	0,01	Group 4
Trichiurus lepturus	TRL	Trichiuridae	p2-pi	Mo	0,42	0,02	Group 4

abundant trophic categories, p1-bt varied between 15- and 66 cm (Figure 6). The size of second level generalist predators (p2-ge) ranged from 17 to 70 cm. The piscivorous species (p2-pi) had the largest size class varying between 19 and 108 cm. The he-de, he-ph and Om species the less abundant with less than 1% of the total abundance, showed narrower range size classes.

Spatial and temporal organization of fish assemblage

The Factorial Correspondence Analysis (FCA) carried out on the seasonal abundance species table showed that the 1-2 factorial plane explained 75.3% of the total inertia (42.0% for axis 1 and 33.3% for axis 2). Therefore, results obtained from the first two axes were plotted. The Hierarchical Classification Analysis (HCA) method allowed to classify species in four groups relative to their seasonal abundance (Figure 7a). The projection of these groups on the factorial plan 1-2 shows that these groups were clearly distinct (Figure 7b). The first group (21 species accounting for 18.3% of the total number of individuals and 20.1% of the biomass) was associated with WC (Table 1). The second group consisted of the most abundant species in CW (19 species accounting for 15.8% of the total abundance and 12.1% of the biomass). The third group with 37 taxa, 42.3% and 43.1% of the total abundance and biomass species, respectively was related to CS. The last group gathering 26 fish representing 23.5% of the total numbers and 24.3% of the total weight was constituted of species preferring the WS. The pvclust plot shows that seasons can be classed in two groups (Figure 7c). The first group consisted of WS, while the

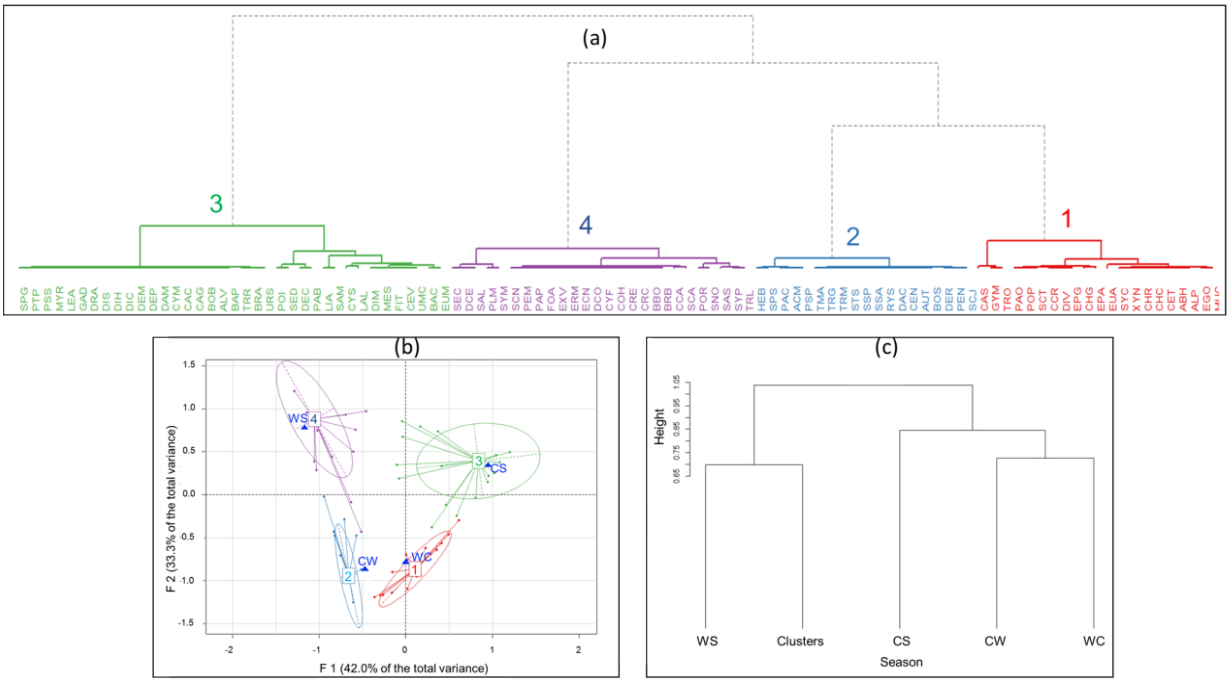

Figure 7: Factorial correspondence analysis (FCA) performed using seasonal abundance indices (AI) of fishes from the Cayar marine protected area: a) is the dendrogram showing the groups of species, b) is the correspondence between groups and seasons and c) is the dendrogram showing similarities between the sampling seasons. CS = Cold season, CW = Cold to Warm transition, WS = Warm season and WC = Warm to Cold transition. See Table 1 for species labels.

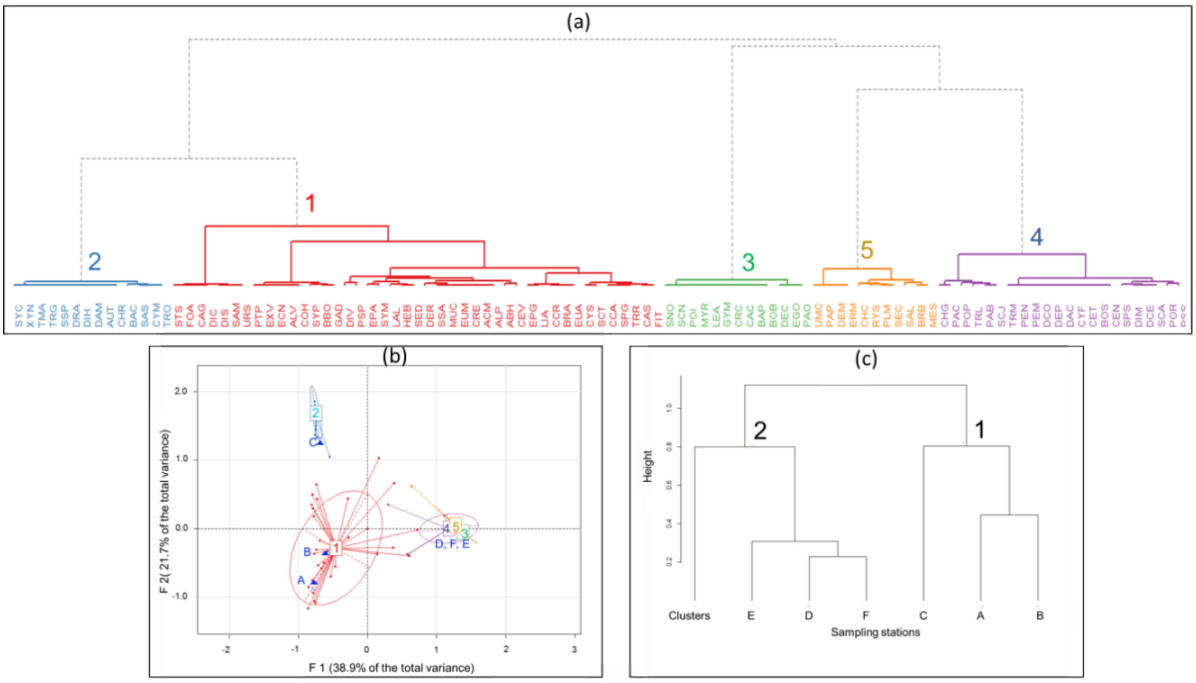

Figure 8: Factorial correspondence analysis (FCA) performed using spatial abundance indices (AI) of fishes from the Cayar marine protected area: a) the dendrogram showing the groups of species, b) the correspondence between groups and sampling stations, c) the dendrogram showing similarities between the sampling stations (Table 2).

Table 2: List of the 103 fish species sorted by group according to their spatial abundance.

Species	Code	Families	Trophic categories	Ecological categories	Abundance (%)	Biomass (%)	Group
Ablennes hians	ABH	Belonidae	p2-pi	ME	0,07	0,01	Group 1
Acanthurus monroviae	ACM	Acanthuridae	Om	Mo	0,14	0,32	Group 1
Albula vulpes	ALV	Albulidae	p1-bt	Mo	0,21	1,33	Group 1
Alutera punctata	ALP	Monacanthidae	he-ph	Mo	0,07	0,06	Group 1
Botus bodas	BBO	Soleidae	p1-bt	Mo	0,56	0,22	Group 1
Brachydeteurus auritus	BRA	Haemulidae	p1-mc	ME	1,05	0,58	Group 1
Campogramma glaycos	CAG	Carangidae	p2-pi	Mo	0,77	1,88	Group 1
Caranx crysos	CCA	Carangidae	p1-bt	Mo	5,83	1,66	Group 1
Caranx senegallus	CAS	Carangidae	p2-ge	ME	3,93	2,50	Group 1
Cephalocanthus volitans	CEV	Dactylopteridae	p1-mc	Ma	0,28	0,50	Group 1
Chloroscombrus chrysurus	CCR	Carangidae	p1-mc	ME	0,35	0,15	Group 1
Chylomecterus reticulatus	CRE	Diodontidae	p1-bt	Mo	0,35	1,23	Group 1
Coryphaena hippurus	COH	Coryphaenidae	p2-ge	Ma	0,28	0,30	Group 1
Cynoglossus senegalensis	CYS	Cynoglossidae	p1-bt	Em	3,79	3,17	Group 1
Decapterus rhonchus	DER	Carangidae	p1-bt	ME	4,42	3,32	Group 1
Dicologoglossa cuneata	DIC	Soleidae	p1-bt	Mo	0,21	0,09	Group 1
Diplodus senegalensis	DIS	Sparidae	p1-bt	Mo	0,70	0,32	Group 1
Diplodus vulgaris	DIV	Sparidae	p1-bt	Mo	0,14	0,20	Group 1
Echeneis naucrates	ECN	Echeneidae	p1-zo	Mo	0,07	0,02	Group 1
Ephippion guittifer	EPG	Tetraodontidae	p1-bt	ME	0,14	0,43	Group 1
Epinephelus aeneus	EPA	Serranidae	p2-pi	ME	0,91	1,26	Group 1
Eucinostemus melanopterus	EUM	Gerreidae	p1-mc	Ma	1,76	0,48	Group 1
Euthynnus alletteratus	EUA	scombridae	p2-ge	Ma	2,46	4,07	Group 1
Exocoetus volitans	EXV	Exocoetidae	p1-mc	Ma	0,56	0,39	Group 1
fistularia tabacaria	FIT	Fistulariidae	p2-pi	Mo	0,77	1,21	Group 1
Fodiator acutus	FOA	Exocoetidae	p1-mc	Ma	0,21	0,03	Group 1
Galeoides decadactylus	GAD	Polynemidae	p2-ge	ME	5,20	3,49	Group 1
Hemiramphus brasilensis	HEB	Hemiramphidae	p2-ge	Em	3,58	1,32	Group 1
Lagocephalus laevigatus	LAL	Tetraodontidae	p2-ge	Ma	2,53	4,70	Group 1
Lichia amia	LIA	Carangidae	p2-ge	Ma	0,14	0,08	Group 1
Mugil cephalus	MUC	Mugilidae	he-de	ME	1,12	4,51	Group 1
Pseudupeneus prayensis	PSP	Mullidae	p1-bt	Mo	4,28	2,88	Group 1
Pteroscion peli	PTP	Sciaenidae	p1-mc	ME	0,07	0,04	Group 1
Sardinella maderensis	SAM	Clupeidae	p1-zo	ME	2,46	2,48	Group 1
Sarpa salpa	SSA	sparidae	he-de	Ma	0,07	0,16	Group 1
Scomberomorus tritor	SCT	scombridae	p2-pi	Ma	0,21	0,69	Group 1
Selene dorsalis	SED	Carangidae	p2-ge	ME	2,25	0,79	Group 1
Sphyraena guachancho	SPG	Sphyraenidae	p2-pi	ME	3,09	3,96	Group 1
Strongylura senegalensis	STS	Belonidae	p2-pi	Em	0,21	0,33	Group 1
Syacium micrurum	SYM	Bothidae	p1-bt	ME	1,62	0,30	Group 1
Synaptura punctatissima	SYP	Soleidae	p1-bt	Mo	2,39	0,63	Group 1
Trachinus radiatus	TRR	Trachinidae	p1-bt	Ma	0,84	0,40	Group 1
Uranoscopus scaber	URS	Uranoscopidae	p2-ge	ME	1,62	2,34	Group 1
Auxis thazard	AUT	Scombridae	p2-pi	Mo	0,07	0,09	Group 2
Balistes punctatus	BAC	Balistidae	p2-ge	Mo	0,07	0,21	Group 2
Chilomycterus reticulatus	CHR	Diodontidae	p1-bt	Mo	0,07	0,94	Group 2
Cynoglossus monodi	CYM	Cynoglossidae	p1-bt	Mo	2,53	2,04	Group 2
Dasyatis margarita	DAM	Dasyatidae	p1-bt	Em	0,07	0,47	Group 2
Diodon holocanthus	DIH	Diodontidae	p1-bt	Mo	0,07	0,05	Group 2
Drepane africana	DRA	Drepaneidae	p1-mc	ME	0,07	0,02	Group 2
Sarda sarda	SAS	Scrombridae	p2-pi	Mo	4,42	9,49	Group 2
Sphyraena sphyraena	SSP	Sphyraenidae	p2-pi	ME	0,07	1,27	Group 2
Synaptura cadenati	SYC	Soleidae	p1-bt	Mo	0,77	0,33	Group 2
Trachinotus goreensis	TRG	Carangidae	p2-ge	Mo	0,07	0,15	Group 2
Trachinotus maxillosus	TMA	Carangidae	p2-ge	Mo	0,07	0,26	Group 2
Trachinotus ovatus	TRO	Carangidae	p2-ge	Ma	1,54	0,69	Group 2
Xyrichtys novacula	XYN	Labridae	p1-bt	Mo	0,42	0,13	Group 2

Balistes carolinensis	BAP	Balistidae	p2-ge	Mo	0,77	1,95	Group 3
Boops boops	BOB	Sparidae	p1-bt	Mo	0,28	0,09	Group 3
Cantharus cantharus	CAC	Sparidae	p1-bt	Mo	0,07	0,08	Group 3
Chromis chromis	CRC	Pomacentridae	p1-bt	Ma	0,07	0,01	Group 3
Dentex canariensis	DEC	Sparidae	p1-bt	Mo	0,42	0,36	Group 3
Epinephelus goreensis	EGO	Serranidae	p1-bt	Mo	0,77	0,76	Group 3
Gymnothorax maderensis	GYM	Muraenidae	p1-bt	Mo	0,14	0,72	Group 3
Lethrinus atlanticus	LEA	Lethrinidae	p1-bt	Mo	0,07	0,06	Group 3
Mycteroperca rubra	MYR	Serranidae	p2-ge	Mo	0,07	0,83	Group 3
Paraprist octlineatum	PAO	Haemulidae	p1-bt	Ma	0,98	0,66	Group 3
Pomadasys incisus	POI	Haemulidae	p1-bt	Ma	0,91	0,61	Group 3
Scorpaena normani	SCN	Scorpaenidae	p1-bt	Ma	0,07	0,03	Group 3
Scorpaena notata	SNO	Scorpaenidae	p2-ge	Ma	1,12	0,39	Group 3
Bodianus speciosus	BOS	Carangidae	he-ph	Mo	0,07	0,06	Group 4
Cephalopholis nigri	CEN	Serranidae	p2-ge	Mo	0,14	0,04	Group 4
Cephalopholis taeniops	CET	Serranidae	p2-pi	Mo	0,07	0,03	Group 4
Chelidonichthys gabonensis	CHG	Triglidae	p1-bt	Ma	3,65	1,66	Group 4
Cynoponticus ferox	CYF	Muraenesocidae	p2-ge	Ma	0,07	0,16	Group 4
Dasyatis centroura	DAC	Dasyatidae	p1-bt	Em	0,07	0,26	Group 4
Decapterus punctatus	DEP	Carangidae	p1-bt	ME	0,07	0,08	Group 4
Dentex congoensis	DCO	Sparidae	p2-ge	Ma	0,07	0,03	Group 4
Diagramma mediterraneus	DIM	Haemulidae	p1-mc	Mo	0,84	0,31	Group 4
Diplodus cervinus	DCE	Sparidae	p1-mc	Mo	0,42	0,88	Group 4
Pagellus bellottii	PAB	Sparidae	p2-ge	Mo	7,16	6,00	Group 4
Pagrus caeruleostictus	PAC	sparidae	p1-bt	Ma	0,84	0,89	Group 4
Pentheroscion Mbizi	PEM	Sciaenidae	p2-ge	Mo	0,07	0,06	Group 4
Petrometopon nigri	PEN	Serranidae	p2-ge	Mo	0,49	0,22	Group 4
Pomadasys perotaei	POP	Haemulidae	p1-bt	Em	0,21	0,20	Group 4
Pomadasys rogerii	POR	Haemulidea	p1-bt	Mo	0,21	1,08	Group 4
Pseudotolotus senegalensis	PSS	Sciaenidae	p2-ge	Ma	0,28	0,83	Group 4
Scomber japonicus	SCJ	Scombridae	p2-ge	Ma	0,63	0,69	Group 4
Scorpaena angolensis	SCA	Scorpaenidae	p1-bt	Ma	2,46	1,09	Group 4
Sphoeroides spengleri	SPS	Tetraodontidae	p1-bt	Mo	0,21	0,04	Group 4
Trachinocephalus myops	TRM	Synodontidae	p2-pi	Mo	0,07	0,04	Group 4
Trichiurus lepturus	TRL	Trichiuridae	p2-pi	Mo	0,42	0,49	Group 4
Brotula barbata	BRB	Ophidiidae	p1-bt	Mo	0,21	1,00	Group 5
Chelidonichthys cuculus	CHC	Triglidae	p1-bt	Ma	0,28	0,17	Group 5
Dentex macrophtalmus	DEM	Sparidae	p1-bt	Mo	0,42	0,21	Group 5
Erythrocles monodi	ERM	Emmelichthyidae	p1-zo	ME	0,07	0,13	Group 5
Merluccius senegalensis	MES	Merluciidae	p2-pi	Mo	0,21	0,84	Group 5
Palinurichtus pringlei	PAP	Stromateidae	p1-zo	Mo	0,07	2,38	Group 5
Plectorhynchus mediterraneus	PLM	Haemulidae	p2-ge	Em	0,63	0,96	Group 5
Rypticus saponaceus	RYS	Serranidae	p1-mc	Mo	0,35	0,06	Group 5
Scyris alexandrinus	SAL	Carangidae	p2-ge	ME	0,21	0,83	Group 5
Serranus cabrilla	SEC	Serranidae	p2-ge	Mo	1,05	0,53	Group 5
Umbrina canariensis	UMC	Sciaenidae	p1-bt	Mo	0,14	0,24	Group 5

second were constituted of CS, CW and WC. The second group was divided in two subgroups with no significant similarity (86% less than 95% the threshold of similarity). The elements (CW and WC) of the second subgroup similar at 26%, were not significantly correlated.

The FCA performed on the spatial abundance fish species data table revealed that factors 1 and 2 (representing the first and second axes) were responsible for 38.9% and 21.7% of the inertia, respectively. The application of HCA method suggested presence of five groups according to their spatial abundance (Figure 8a). The species of the first group (43 species, 61.7% and 54.8% of the total abundance and biomass, respectively, Table 2) was associated with stations A and B (Figure 8b). The second group with 14 species and responsible for 10.3% of the total number of individuals and 16.1% of the biomass, aggregated the encountered species at C. The species of groups 3, 4 and 5 (regrouping respectively 13, 22 and 11 species, accounting for 5.7%, 18.5% and 3.6% of the abundance respectively, and 6.5%, 15.1% and 0.7% of the total biomass) were inherent to E, D, and F, respectively. Spatial cluster revealed two assemblages (Figure 8c). The first consisted of A, B and C association and the second were composed by E, F and D. Each group was split in two subgroups. In the subgroup of first group, C was similar to the couple A and B at 100%, while A and B show a similarity of 95%. The second subgroup consisted of a similarity between E and D and F at 99%. The couple D and F showed a resemblance of 96%.

Discussion

Species richness

This study provides preliminary insight of fish assemblage of CMPA, characterized by high species richness with 103 fish species belonging to 45 families. Similar study based on artisanal landing data from 2013-2015 identified 86 fish species belonging to 33 families in this MPA [30]. In the whole Sine-Saloum estuarine, it was reported 114 species, over a two-year sampling period involving several fishing techniques and with additional observations from small-scale and game fisheries [31]. In the Bamboung MPA created in 2004 as Cayar MPA, where the extraction of any type of organism is prohibited, the species richness was 72 fish species from 2003-2012 [32]. However, caution is needed when comparing fish composition in distinct ecosystems [33], because several factors have to be considered. This high species diversity in the Cayar MPA might be due to the canyon which plays a predominant role in limiting the intensity of migration of several demersal species [16] and the seasonal upwelling that favors the development of phytoplankton ensuring almost all the primary production and the functioning of the trophic network [34].

Ecological and trophic categories

The fish species assemblage of CMPA was only composed of the marine gradient ecological categories (Em, ME, Ma and Mo). As expected, the marine affinity species Ma and Mo were the richest (76 species, 69% of the species richness) and the most abundant (69.1% and 72.0% of the total abundance and biomass), while the estuarine affinity species represented by 32 species accounted for 30.9% and 28.0% for the total abundance and biomass. These results were not surprising because marine affinity categories were generally caught in poly-mixoeuhaline waters from 18 to 40 PSU [22]. The estuarine affinity species often colonized tropical and subtropical estuarine and lagoon zones [22,35]. The predators (84 species, 98.5% and 94.9% of the total abundance and biomass) colonized the CMPA. Similar results were obtained in Bamboung MPA where predators were the dominant species after the implementation of the fishing regulation [35].

Spatial and temporal of fish assemblage structure

Fish assemblage structure of Cayar MPA showed marked differences between seasons in terms of fish diversity, abundance and biomass. The highest fish assemblage in terms of species richness, abundance and biomass were associated with cold season, while a second peak of species richness, abundance and biomass occurred in warm season. The lowest species richness, abundance and biomass were observed during the cold to warm transition period. This differed markedly among seasons might be partially explained by the temporal migration of several demersal fishes modulated by the seasonal variations of the upwelling intensity [20,36], which reaches its maximum of productivity in cold season [17,37]. Species like *Pagellus bellottii, Galeoides decadactylus, Cynoglossus senegalensis, Sphyraena guachancho, Cynoglossus monody* and *Lagocephalus laevigatus* were mainly responsible for the abundance and biomass peak in CS. The minor peak of species richness in group 4 could be imputed to the canyon which acts as barrier to the migration of some demersal species [16] and presence of species that prefer warm waters. The non-significant similarity obtained between seasons suggests that the temporal sampling strategy applied here seems relevant.

As revealed by the hierarchical clustering analysis, the spatial of fish assemblage structure of the Cayar MPA, was heterogeneous. The first group consisted of highest species composition, abundance and biomass were associated with A and B. In contrast, the lowest species richness, abundance and biomass were obtained in group 5 related to station F. The spatial organization of the fish assemblages in this study is thought to be influenced by the two different types of fishing gear used because purse seine was not adaptable for rocky stations (D, E and F). This hypothesis is consolidated by the dendrogram of similarity between sampling stations which showed two groups where similarity between stations was highly significant. The first group consisted of stations where purse seine was used, while the second group gathering stations where fishing was operated with long line. However, several studies suggested that spatio-temporal fish assemblage organization in aquatic ecosystems is influenced by both abiotic and biotic environmental components [38-45]. The two principle factors especially suspected as the most determinant in the control of spatial and temporal assemblage structure are temperature and salinity [44,46,47].

Conclusion

High species richness consisted of four ecological categories and eight trophic categories were identified in the Cayar MPA after two years of seasonal monitoring. The three most abundant species were *Pagellus bellottii, Caranx crysos* and *Galeoides decadactylus*. The species of marine affinity and the predators dominated the fish assemblage. The fish assemblage structure of Cayar MPA was marked by clear spatio-temporal pattern. Several study postulated that fish assemblage organization in time and space is influenced by abiotic and biotic factor. Therefore, future investigations integrating environmental variables might give better understanding of spatial and temporal fish assemblage of Cayar MPA. Results from this study will serve as reference point for future work on the effect of the marine protected area on marine life.

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