

Research Article

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# Differences in Fish Assemblage Structure Between Taking and No-Taking Protected Areas: The Case of Cayar And Joal-Fadiouth Marine Protected Areas in Senegal

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## Abstract

This work is a preliminary comparative study of fish assemblage between a marine protected area where fishing is banned in Joal-Fadiouth (JFMPA) and a fishing authorized marine protected in Cayar (CMPA). It consisted of seasonal sampling between 2015 and 2016. Trophic classification based on food regime was performed in order to describe the fish fauna of these MPA. Multivariate analysis like factorial correspondence analysis and hierarchical classification analysis were carried out to study the spatial differences of fish assemblages. Both MPA had similar number of species, 103 fish species belonging to 45 families. However, a fundamental difference in terms of fish composition, abundance and biomass were noted. Only 38 fish species were shared by these MPA. In other words, among the 103 fish species found in CMPA 65 were not encountered in JFMPA. The total number of individuals in JFMPA was six time higher, and the biomass in JFMPA was triple of that in CMPA. The fish assemblage of CMPA was dominated in terms of abundance by two second-level predators *Pagellus bellottii* and *Galeoides decadactylus* (12.4%), while in JFMPA the pelagic herbivores *Ethmalosa fimbriata* (34%) dominated the fish assemblage. Our results suggest that management strategy in JFMPA seem to be more efficient than that of CMPA. Therefore, fishing activities in CMPA, even controlled seem to have negative effect on fish abundance.

**Keywords:** Bio-ecological indicators; Grande côte; Multivariate analysis; Petite côte

## Introduction

Aware that marine biodiversity is threatened by overfishing and climate change, the implementation of marine protected areas (MPA) has been proposed as alternative solution [1-6] The government of Senegal committed to implement a network of marine protected areas, with a goal of encompassing 10% of its seas and coastal areas within an effectively managed, ecologically representative and well-connected system of MPA by 2020. Therefore, five MPA (Saint-Louis, Cayar, Joal-Fadiouth, Bamboung and Abene MPA) were implemented in 2004 and two in 2014 (Sangomar and Gandoule MPA). In addition, two new MPA were created, Niamone-Kalounaye and Casa-Balantakounda in 2015 and 2016, respectively.

The implementation of MPA network requires a regular monitoring of the fish assemblage over time and space, is essential to assess their performance as tools for conservation and fishery management [7,8] Excepted Bamboung MPA which benefited of a regular monitoring of its fish assemblage from the closing off of the area until 2012 [9] the other MPA established in 2004 were suffering from a lack of information about their fish assemblage composition, structure and dynamic. Therefore, a seasonal monitoring protocol was set by the directorate responsible for the management of this MPA network in collaboration with technical partners such as CRODT (Centre de Recherche Océanographique de Dakar-Thiaroye) and IUPA (Aquaculture and Fisheries Institute of

the University of Dakar). This protocol seeks to describe and follow the dynamic of the fish assemblage in the Senegal MPA. The finality of this protocol is to dispose sufficient and reliable information to be able to orientate decision making for effective and sustainable management of marine and coastal resources.

The present study aims to compare fish assemblage during the 2015-2016 period between Cayar MPA where fishing activities are authorized but regulated, and Joal-Fadiouth MPA where the extraction of any type of fish species is prohibited. In comparative studies, the management strategy effect on fish assemblages through the creation of an MPA is measured using bio-ecological indicators, which are compared between fished and unfished areas. These bio-ecological indicators are species richness, abundance and biomass, mean size and mean trophic level were used. In this study, multivariate analysis techniques such as factorial correspondence analysis and hierarchical classification methods that allow to resume the spatial organization of fish assemblage were used.

## Material and Methods

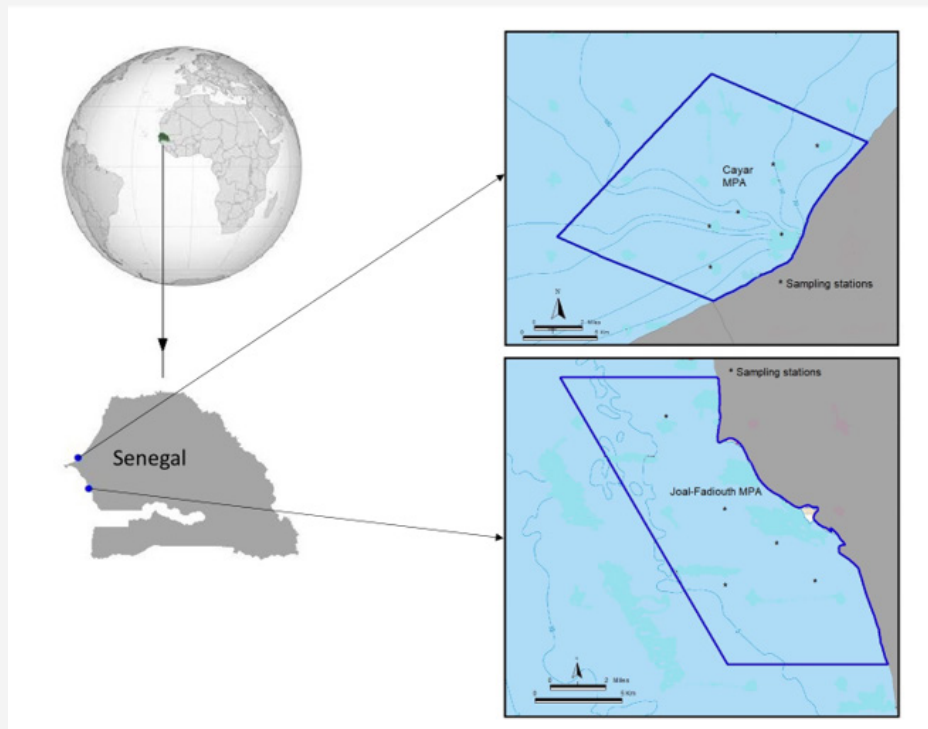
### Study area

The Cayar Marine Protected Area (CMPA) is located 58km 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 1a). It covers an area of 17km<sup>2</sup> and belongs to the maritime domain. It consists of a fishing-MPA where fishing activities are authorized and regulated. 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 [10-12].

The Joal-Fadiouth Marine Protected Area (JFMPA) is located 144 km South of Dakar in the Petite Côte, 14°06' and 13°13' N and 16°47' et 16°53' W (Figure 1b). The JFMPA boasts a rich succession of marine, coastal, estuarine, lagoon and savanna ecosystems (the Botanic reserve of Ngazobil). This gives it various and varied habitats including seagrasses, sand beaches, mangroves, bolongs, and sandy and rocky islets [13]. It covers fish spawning and nursery areas, the habitat of manatees and areas important for sea turtle nesting. In addition to this diversity of natural habitats, the favorable hydrodynamic conditions and the presence of upwelling is a favorable environment for resources.

### Sampling Protocol

Samples were collected every season between April 2015 and December 2016 at six sampling stations in CMPA and at five in JFMPA (Figure 1ab). The seasons correspond to the four main hydro-climatic periods in Senegal: Cold Season (CS) between January to May, transition Cold to Warm season (CW) in June, Warm Season (WS) between July to October and transition Warm to Cold season (CW) between November to December. Sampling was done during daylight hours. In CMPA, a purse seine (length 350m, height 40m, 14mm 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 is muddy, sandy-muddy, and sandy, while bottom long line was used at rocky stations. These two devices were used to ensure exhaustive fish sampling because of the diversity of habitat types (rocky and sandy areas). In JFMPA, the depth is less than 10m, therefore only a purse seine of 250m length, 20m height and 14 mm mesh size were used. The fishing haul was considered as the fishing unit in this study, with 88 hauls from 2015 to 2016.



**Figure 1:** Location of the two study sites (Cayar MPA and Joal-Fadiouth MPA), MPA limits and position of the sampling stations.

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:

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

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

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 feeding regimes. 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 benthophageous (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) [14].

## 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 [15] were applied here. Factorial correspondence analysis (FCA) was carried out using fish abundance indices to investigate the pattern of species assemblage among seasons and space. The Hierarchical Classification Analysis (HCA) was also used to group species according to their spatial and seasonal affinity or similarity [16,17]. The dendrograms were performed using the Euclidean distance and the Ward minimum variance clustering method [18] These statistical analyses were carried out using R software (R Core Team 2014), the ade4, Factoclass libraries [19].

## Results

Fish assemblage composition, structure, abundance and biomass.

**Table 1:** List of the 103 fish species with their abundance and biomass (express in %) sorted trophic and ecological categories in CMPA.

Species	Code	Families	Trophic categories	Abundance (%)	Biomass
					(%)
<i>Ablennes hians</i>	ABH	Belonidae	p2-pi	0,07	0,01
<i>Alutera punctata</i>	ALP	Monacanthidae	he-ph	0,07	0,01
<i>Caranx senegalus</i>	CAS	Carangidae	p2-ge	3,93	0,01
<i>Cephalopholis taeniops</i>	CET	Serranidae	p2-pi	0,07	0,01
<i>Chelidonichthys cuculus</i>	CHC	Triglidae	p1-bt	0,28	0,01
<i>Chelidonichthys gabonensis</i>	CHG	Triglidae	p1-bt	3,65	0,01
<i>Chilomycterus reticulatus</i>	CHR	Diodontidae	p1-bt	0,07	0,01
<i>Chloroscombrus chrysurus</i>	CCR	Carangidae	p1-mc	0,35	0,01
<i>Diplodus vulgaris</i>	DIV	Sparidae	p1-bt	0,14	0,01
<i>Ephippion guittifer</i>	EPG	Tetraodontidae	p1-bt	0,14	0,01
<i>Epinephelus aeneus</i>	EPA	Serranidae	p2-pi	0,91	0,01
<i>Epinephelus goreensis</i>	EGO	Serranidae	p1-bt	0,77	0,01
<i>Euthynnus alletteratus</i>	EUA	scombridae	p2-ge	2,46	0,01
<i>Gymnothorax maderensis</i>	GYM	Muraenidae	p1-bt	0,14	0,02
<i>Mugil cephalus</i>	MUC	Mugilidae	he-de	1,12	0,01
<i>Paraprist oclineatum</i>	PAO	Haemulidae	p1-bt	0,98	0,01
<i>Pomadasys perotaei</i>	POP	Haemulidae	p1-bt	0,21	0,01
<i>Scomberomorus tritor</i>	SCT	scombridae	p2-pi	0,21	0,01
<i>Synaptura cadenati</i>	SYC	Soleidae	p1-bt	0,77	0,01
<i>Trachinotus ovatus</i>	TRO	Carangidae	p2-ge	1,54	0,01
<i>Xyrichtys novacula</i>	XYN	Labridae	p1-bt	0,42	0,00
<i>Decapterus rhonchus</i>	DER	Carangidae	p1-bt	4,42	0,01
<i>Pseudupeneus prayensis</i>	PSP	Mullidae	p1-bt	4,28	0,01
<i>Hemiramphus brasiliensis</i>	HEB	Hemiramphidae	p2-ge	3,58	0,01
<i>Scomber japonicus</i>	SCJ	Scombridae	p2-ge	0,63	0,01

<i>Pagrus caeruleostictus</i>	PAC	sparidae	p1-bt	0,49	0,01
<i>Petrometopon nigri</i>	PEN	Serranidae	p2-ge	0,49	0,01
<i>Pagrus caeruleostictus</i>	PAC	Sparidae	p1-bt	0,35	0,01
<i>Strongylura senegalensis</i>	STS	Belonidae	p2-pi	0,21	0,02
<i>Spherooides spengleri</i>	SPS	Tetraodontidae	p1-bt	0,21	0,00
<i>Acanthurus monroviae</i>	ACM	Acanthuridae	Om	0,14	0,01
<i>Cephalopholis nigri</i>	CEN	Serranidae	p2-ge	0,14	0,00
<i>Sphyraena sphyraena</i>	SSP	Sphyraenidae	p2-pi	0,07	0,03
<i>Sarpa salpa</i>	SSA	sparidae	he-de	0,07	0,01
<i>Trachinotus goreensis</i>	TRG	Carangidae	p2-ge	0,07	0,01
<i>Auxis thazard</i>	AUT	Scombridae	p2-pi	0,07	0,01
<i>Bodianus speciosus</i>	BOS	Carangidae	he-ph	0,07	0,01
<i>Trachinocephalus myops</i>	TRM	Synodontidae	p2-pi	0,07	0,01
<i>Dasyatis centroura</i>	DAC	Dasyatidae	p1-bt	0,07	0,01
<i>Albula vulpes</i>	ALV	Albulidae	p1-bt	0,21	0,02
<i>Balistes punctatus</i>	BAC	Balistidae	p2-ge	0,07	0,01
<i>Balistes carolinensis</i>	BAP	Balistidae	p2-ge	0,77	0,01
<i>Boops boops</i>	BOB	Sparidae	p1-bt	0,28	0,01
<i>Brachydeteurus auritus</i>	BRA	Haemulidae	p1-mc	1,05	0,01
<i>Campogramma glaycos</i>	CAG	Carangidae	p2-pi	0,77	0,01
<i>Cantharus cantharus</i>	CAC	Sparidae	p1-bt	0,07	0,01
<i>Cephalocanthus volitans</i>	CEV	Dactylopteridae	p1-mc	0,28	0,01
<i>Cynoglossus monodi</i>	CYM	Cynoglossidae	p1-bt	2,53	0,01
<i>Cynoglossus senegalensis</i>	CYS	Cynoglossidae	p1-bt	3,79	0,01
<i>Dasyatis margarita</i>	DAM	Dasyatidae	p1-bt	0,07	0,02
<i>Decapterus punctatus</i>	DEP	Carangidae	p1-bt	0,07	0,01
<i>Dentex canariensis</i>	DEC	Sparidae	p1-bt	0,42	0,01
<i>Dentex macrophthalmus</i>	DEM	Sparidae	p1-bt	0,42	0,01
<i>Diagramma mediterraneus</i>	DIM	Haemulidae	p1-mc	0,84	0,01
<i>Dicologlossa cuneata</i>	DIC	Soleidae	p1-bt	0,21	0,01
<i>Diodon holocanthus</i>	DIH	Diodontidae	p1-bt	0,07	0,00
<i>Diplodus senegalensis</i>	DIS	Sparidae	p1-bt	0,70	0,01
<i>Drepane africana</i>	DRA	Drepaneidae	p1-mc	0,07	0,00
<i>Eucinostemus melanopterus</i>	EUM	Gerreidae	p1-mc	1,76	0,01
<i>fistularia tabacaria</i>	FIT	Fistulariidae	p2-pi	0,77	0,02
<i>Galeoides decadactylus</i>	GAD	Polynemidae	p2-ge	5,20	0,01
<i>Lagocephalus laevigatus</i>	LAL	Tetraodontidae	p2-ge	2,53	0,01
<i>Lethrinus atlanticus</i>	LEA	Lethrinidae	p1-bt	0,07	0,01
<i>Lichia amia</i>	LIA	Carangidae	p2-ge	0,14	0,01
<i>Merluccius senegalensis</i>	MES	Merlucciidae	p2-pi	0,21	0,01
<i>Mycteroperca rubra</i>	MYR	Serranidae	p2-ge	0,07	0,02
<i>Pagellus bellottii</i>	PAB	Sparidae	p2-ge	7,16	0,01
<i>Pomadasys incisus</i>	POI	Haemulidae	p1-bt	0,91	0,01
<i>Pseudotolithus senegalensis</i>	PSS	Sciaenidae	p2-ge	0,28	0,01
<i>Pteroscion peli</i>	PTP	Sciaenidae	p1-mc	0,07	0,01
<i>Sardinella maderensis</i>	SAM	Clupeidae	p1-zo	2,46	0,01
<i>Selene dorsalis</i>	SED	Carangidae	p2-ge	2,25	0,01
<i>Sphyraena guachancho</i>	SPG	Sphyraenidae	p2-pi	3,09	0,01

<i>Trachinus radiatus</i>	TRR	Trachinidae	p1-bt	0,84	0,01
<i>Umbrina canariensis</i>	UMC	Sciaenidae	p1-bt	0,14	0,01
<i>Uranoscopus scaber</i>	URS	Uranoscopidae	p2-ge	1,62	0,01
<i>Botus bodas</i>	BBO	Soleidae	p1-bt	0,56	0,00
<i>Brotula barbata</i>	BRB	Ophidiidae	p1-bt	0,21	0,01
<i>Caranx crysos</i>	CCA	Carangidae	p1-bt	5,83	0,01
<i>Chromis chromis</i>	CRC	Pomacentridae	p1-bt	0,07	0,00
<i>Chylomecterus reticulatus</i>	CRE	Diodontidae	p1-bt	0,35	0,01
<i>Coryphaena hippurus</i>	COH	Coryphaenidae	p2-ge	0,28	0,01
<i>Cynoponticus ferox</i>	CYF	Muraenesocidae	p2-ge	0,07	0,02
<i>Dentex congoensis</i>	DCO	Sparidae	p2-ge	0,07	0,00
<i>Diplodus cervinus</i>	DCE	Sparidae	p1-mc	0,42	0,01
<i>Echeneis naucrates</i>	ECN	Echeneidae	p1-zo	0,07	0,01
<i>Erythrocles monodi</i>	ERM	Emmelichthyidae	p1-zo	0,07	0,01
<i>Exocoetus volitans</i>	EXV	Exocoetidae	p1-mc	0,56	0,01
<i>Fodiator acutus</i>	FOA	Exocoetidae	p1-mc	0,21	0,01
<i>Palinurichthys pringlei</i>	PAP	Stromateidae	p1-zo	0,07	0,02
<i>Pentheroscion Mbizi</i>	PEM	Sciaenidae	p2-ge	0,07	0,01
<i>Plectorhynchus mediterraneus</i>	PLM	Haemulidae	p2-ge	0,63	0,01
<i>Pomadasys rogerii</i>	POR	Haemulidae	p1-bt	0,21	0,01
<i>Sarda sarda</i>	SAS	Scrombridae	p2-pi	4,42	0,01
<i>Scorpaena angolensis</i>	SCA	Scorpaenidae	p1-bt	2,46	0,01
<i>Scorpaena normani</i>	SCN	Scorpaenidae	p1-bt	0,07	0,01
<i>Scorpaena notata</i>	SNO	Scorpaenidae	p2-ge	1,12	0,00
<i>Scyris alexandrinus</i>	SAL	Carangidae	p2-ge	0,21	0,01
<i>Serranus cabrilla</i>	SEC	Serranidae	p2-ge	1,05	0,01
<i>Syacium micrurum</i>	SYM	Bothidae	p1-bt	1,62	0,01
<i>Synaptura punctatissima</i>	SYP	Soleidae	p1-bt	2,39	0,01
<i>Trichiurus lepturus</i>	TRL	Trichiuridae	p2-pi	0,42	0,02

**Table 2:** List of the 105 fish species with their abundance and biomass (express in %) sorted trophic categories in JFMPA.

Especies	Code	Families	Trophic categories	Abundance (%)	Biomass (%)
<i>Ablennes hians</i>	AHI	Belonidae	p2-pi	0,38	0,23
<i>Acreichthys tomentosus</i>	ATO	Monacanthidae	p1-ge	6,67	0,00
<i>Albula vulpes</i>	AUL	Albulidae	p1-bt	0,15	2,01
<i>Alectis alexandrinus</i>	ARI	Carangidae	p1-mc	1,78	0,02
<i>Arius africanus</i>	ACA	Ariidae	p2-ge	0,51	0,67
<i>Arius parkii</i>	AAR	Ariidae	p2-ge	0,59	0,04
<i>Balistes caprisicus</i>	BIS	Balistidae	p1-bt	1,57	0,04
<i>Batrachoides liberiensis</i>	BEN	Batrachoididae	p2-ge	1,16	0,03
<i>Bodianus speciosus</i>	BIO	Labridae	p1-bt	0,24	0,29
<i>Brachideuterus auritus</i>	BRI	Haemulidae	p1-mc	3,12	0,12
<i>Campogramma glaycos</i>	CAY	Carangidae	p1-pi	9,09	0,00
<i>Caranx crysos</i>	CRY	Carangidae	p1-bt	1,05	0,05
<i>Caranx hypos</i>	CHY	Carangidae	p2-ge	0,89	0,02
<i>Chaetodipterus gorensis</i>	CEN	Ephippidae	p1-mc	1,38	1,30
<i>Cynoglossus cadenati</i>	CEN	Cynoglossidae	p1-bt	0,71	0,19
<i>Cynoglossus senegalensis</i>	CEN	Cynoglossidae	p1-bt	0,38	0,13

<i>Dasyatis margarita</i>	DAR	Dasyatidae	p1-bt	0,11	1,13
<i>Decapterus punctatus</i>	DTA	Carangidae	p2-ge	0,42	0,11
<i>Dicentrarchus punctatus</i>	DTA	Moronidae	p2-ge	0,60	0,14
<i>Diplodus bellottii</i>	DOT	Sparidae	p1-bt	2,00	4,32
<i>Diplodus cervinus</i>	DVI	Sparidae	Om-ge	1,14	0,03
<i>Diplodus sargus cadenati</i>	DEN	Sparidae	p1-ge	1,98	0,01
<i>Diplodus vulgaris</i>	DGA	Sparidae	p1-bt	2,11	0,01
<i>Echeneis naucrates</i>	ERA	Echeneidae	p1-zo	1,00	0,01
<i>Elops lacerta</i>	ECE	Elopidae	p2-pi	0,40	1,45
<i>Ephippion guttifer</i>	ETI	Tetraodontidae	p1-bt	0,05	7,12
<i>Ephippion goreensis</i>	EEN	Ephippidae	p1-mc	1,04	0,02
<i>Ephippus luppei</i>	EUP	Ephippidae	p1-mc	0,24	0,13
<i>Epinephelus aeneus</i>	EEN	Serranidae	p2-pi	0,44	0,29
<i>Epinephelus erythrurus</i>	ERU	Serranidae	p2-ge	1,67	0,00
<i>Ethmalosa fimbriata</i>	ERI	Clupeidae	he-ph	34,05	37,50
<i>Eucinostomus melanopterus</i>	ETE	Gerreidae	p1-mc	0,64	10,49
<i>Evynnis ehrenbergii</i>	EER	Sparidae	p2-ge	0,84	0,36
<i>Fodiator acutus</i>	FCU	Exocoetidae	p1-ge	4,23	0,01
<i>Galeoides decadactylus</i>	GTY	Polynemidae	p2-ge	1,56	0,46
<i>Gerres nigri</i>	GNI	Gerreidae	p1-mc	2,14	0,48
<i>Gymnura altavela</i>	GAV	Gymnuridae	p1-bt	4,00	0,00
<i>Halobatrachus didactylus</i>	HTY	Batrachoididae	p2-ge	1,29	0,04
<i>hemiramphus brasiliensis</i>	hEN	Hemiramphidae	p2-ge	1,09	0,95
<i>Heteromycteris proboscideus</i>	HID	Soleidae	p1-ge	0,33	0,05
<i>Hippocampus kuda</i>	H K	Syngnathidae	p1-zo	10,00	0,00
<i>Ilisha africana</i>	IIC	Pristigasteridae	p1-zo	8,76	0,04
<i>Lagocephalus laevigatus</i>	LGA	Tetraodontidae	p2-ge	0,15	1,01
<i>Lichia amia</i>	L A	Carangidae	p2-ge	0,07	1,83
<i>Lichia vadigo</i>	LAD	Carangidae	p2-ge	2,00	0,00
<i>Liza bananensis</i>	LEN	Mugilidae	he-de	1,00	0,25
<i>Liza dumerili</i>	LER	Mugilidae	he-de	0,23	5,60
<i>Liza falcipinnis</i>	LIN	Mugilidae	he-de	0,82	0,40
<i>Liza grandisquamis</i>	LUA	Mugilidae	he-de	0,78	1,16
<i>Lutjanus agennes</i>	LEN	Lutjanidae	p2-ge	0,51	0,02
<i>Monacanthus chinensis</i>	MEN	Monacanthidae	Om	3,33	0,00
<i>Monodactylus sebae</i>	MSE	Monodactylidae	p2-ge	1,16	0,04
<i>Mugil bananensis</i>	MEN	Mugilidae	he-de	0,83	3,04
<i>Mugil cephalus</i>	MHA	Mugilidae	he-de	0,77	0,27
<i>Mugil curema</i>	MUR	Mugilidae	he-de	0,39	0,44
<i>Mycteroperca rubra</i>	MRU	Serranidae	p2-ge	1,30	0,01
<i>Nicholsina usta collettei</i>	NET	Scaridae	he-de	2,73	0,08
<i>Nicholsina usta usta</i>	N U	Scaridae	he-de	0,27	1,22
<i>Oreochromis niloticus</i>	OTI	Cichlidae	he-de	1,59	0,17
<i>Pagellus bellottii</i>	POT	Sparidae	Om	0,21	0,30
<i>Pagrus caeruleostictus</i>	PIC	Sparidae	p2-ge	1,74	0,02
<i>Pomadasys incisus</i>	PCI	Haemulidae	p1-bt	3,04	2,57
<i>Plectorhinchus macrolepis</i>	PLE	Pomadasyidae	p2-ge	0,16	0,10
<i>Pomadasys jubelini</i>	PEL	Haemulidae	p1-bt	0,87	0,57

<i>Pomadasys perotaei</i>	POT	Haemulidae	p1-bt	1,34	0,63
<i>Pomadasys rogeri</i>	POG	Haemulidae	p1-bt	1,09	0,06
<i>Pomadasys stridens</i>	PID	Haemulidae	p1-ge	1,00	0,01
<i>Psettodes belcheri</i>	PCH	Psettodidae	p2-ge	0,33	0,10
<i>Pseudotolithus senegallus</i>	PAL	Sciaenidae	p2-ge	0,36	0,79
<i>Pseudupeneus prayensis</i>	PEN	Mullidae	p1-bt	1,23	0,65
<i>Rachycentron canadum</i>	RNA	Rachycentridae	(vide)	1,00	0,01
<i>Remora remora</i>	REM	Echeneidae	p1-mc	0,39	0,06
<i>Rhinobatos rhinobatos</i>	RBA	Rhinobatidae.	p1-bt	0,25	0,06
<i>Sardinella maderensis</i>	SEN	Clupeidae	p1-zo	2,38	0,47
<i>Sarotherodon melanotheron</i>	SHE	Cichlidae	he-ph	0,39	4,85
<i>Scorpaena laevis</i>	SAE	Scorpaenidae	p2-ge	0,34	0,02
<i>Scorpaena plumieri</i>	SMI	Scorpaenidae	p1-ge	12,50	0,00
<i>Scorpaena scrofa</i>	SCR	Scorpaenidae	p2-ge	2,00	0,01
<i>Scorpaena stephanica</i>	SAN	Scorpaenidae	p1-ge	4,65	0,01
<i>Scyacium micrurum</i>	SRU	Paralichthyidae	p1-bt	11,11	0,00
<i>Selene dorsalis</i>	SSA	Carangidae	p1-mc	5,77	0,00
<i>Serranus scriba</i>	SCR	Serranidae	p1-ge	0,40	0,40
<i>Solea senegalensis</i>	SEN	Soleidae	p1-ge	0,91	0,01
<i>Sphoeroides marmoratus</i>	SRA	Tetraodontidae	Om	0,66	0,15
<i>Sphoeroides spengleri</i>	SGL	Tetraodontidae	p1-bt	9,30	0,00
<i>Sphyraena afra</i>	S A	Sphyraenidae	p2-pi	0,51	0,36
<i>Sphyraena barracuda</i>	SAC	Sphyraenidae	p2-pi	0,05	0,34
<i>Sphyraena guachancho</i>	SAN	Sphyraenidae	p2-pi	0,09	0,35
<i>Stephanolepis hispidus</i>	SPI	Monacanthidae	p1-bt	1,43	0,24
<i>Strongylura senegalensis</i>	SEN	Belonidae	p2-pi	1,12	0,01
<i>Syacium micrurum</i>	SRU	Paralichthyidae	p1-bt	1,45	0,02
<i>Synaptura cadenati</i>	SEN	Soleidae	p1-bt	0,47	0,23
<i>Synaptura lusitanica lusitanica</i>	SAN	Soleidae	p1-bt	0,62	0,06
<i>Tilapia guineensis</i>	TEN	Cichlidae	he-de	0,36	0,27
<i>Torpedo nobiliana</i>	TLI	Torpedinidae	p1-pi	0,31	0,05
<i>Trachinocephalus myops</i>	TMY	Synodontidae	p2-pi	3,64	0,00
<i>Trachinotus maxillosus</i>	TLO	Carangidae	p2-ge	10,00	0,00
<i>Trachinotus ovatus</i>	TVA	Carangidae	p2-ge	3,64	0,00
<i>Trichiurus lepturus</i>	TTU	Trichiuridae	p2-pi	0,25	0,03
<i>Tylosorus crocodilus</i>	TDI	Belonidae	p2-pi	0,56	0,21
<i>Umbrina canariensis</i>	UEN	Sphyraenidae	p1-bt	1,47	0,07
<i>Vomer setapinnis</i>	VIN	Carangidae	p1-ge	2,00	0,02

A total of 1424 individuals weighting 378.5kg composed of 103 fish species which belong to 45 families were recorded in the CMPA (Table 1). In JFMPA 8780 individuals with 1268.5kg composed of 103 fish species classified in 45 families were sampled (Table 2). Of the 103 species identified in CMPA, 65 were not encountered in JFMPA. Both MPA had only 38 species in common.

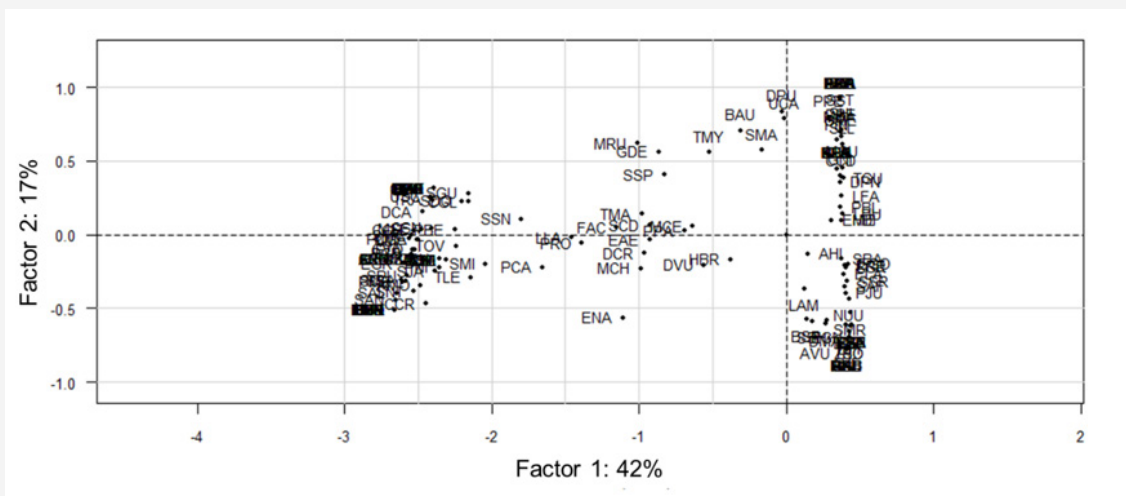
The most abundance species in CMPA were *Pagellus bellottii* (7.2%), *Caranx crysos* (5.8%), *Galeoides decadactylus* (5.2%) and *Sarda sarda* (4.4%), while in JFMPA *Ethmalosa fimbriata*, *Diplodus bellottii*, *Pomadasys incisus* and *Eucinostomus melanopterus* with

34%, 12%, 11% and 9% were the most represented species. In terms of families the Carangidae (13 species), followed by the Sparidae (12 species) and the Serranidae (7 species) were the most represented in CMPA. In JFMPA, the Carangidae, Haemulidae, Mugilidae, Sparidae with 11, 7, 7 and 7 species respectively, were the richest in terms of species diversity.

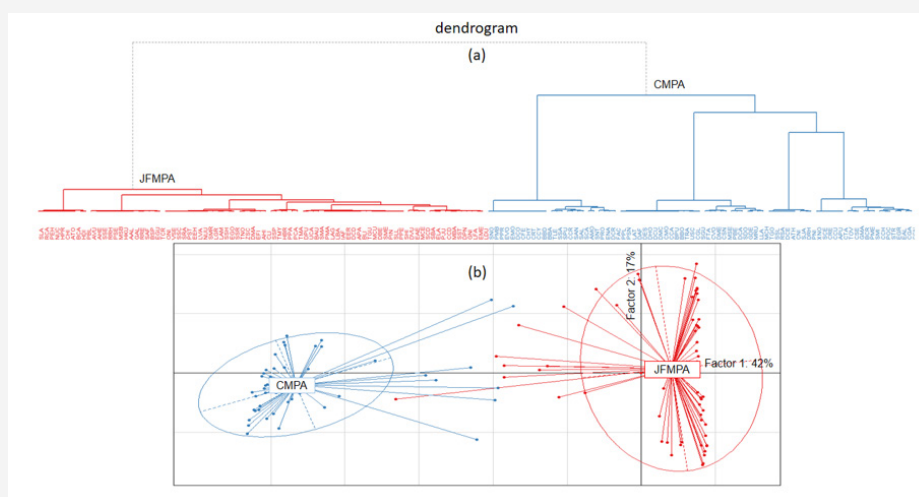
The FCA analysis based on seasonal species abundance showed that the 1-2 factorial plan support 59.0% of the total variance (42.0% for axis 1 and 17.0% for axis 2). The projection of mean points showed a clear spatial and temporal difference in fish assemblage

of both MPA (Figure 2). This observation was confirmed by the HCA method allowing to classify species in two groups relative to their seasonal abundance (Figure 3a). The projection of these groups on the factorial plan 1-2 showed that these groups were clearly

distinct (Figure 3b). The first group (blue color) consisted of the most abundant species in CMPA and the second group (red color) gathered most abundant species in JFMPA.



**Figure 2:** Factorial correspondence analysis (FCA) on Cayar MPA (CMPA) and Joal-Fadiouth (JFMPA): projection 165 species on the 1-2 factorial plane.



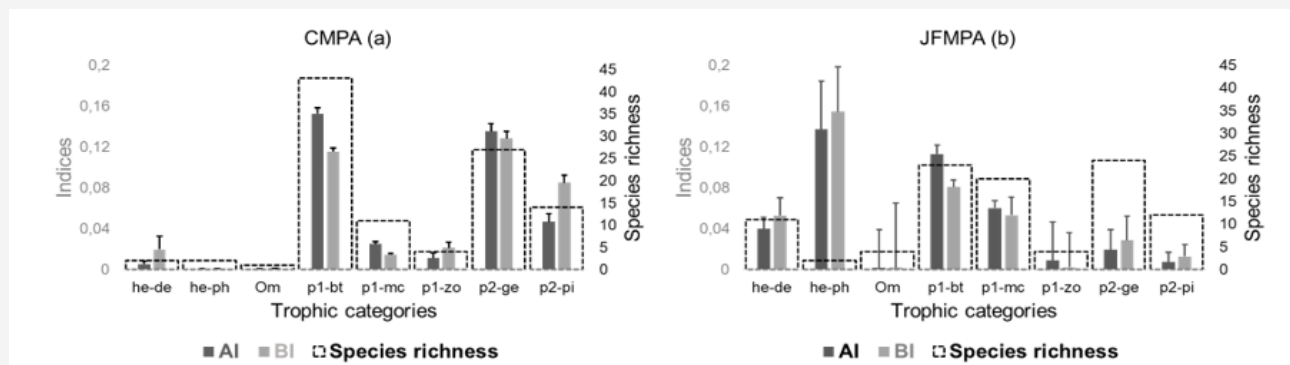
**Figure 3:** Factorial correspondence analysis (FCA) performed using abundance indices (AI) of fishes from the Cayar and Joal-Fadiouth marine protected areas: a) is the dendrogram showing the groups of species, b) is the correspondence between groups and. See Table 1 for species labels.

## Trophic Structures

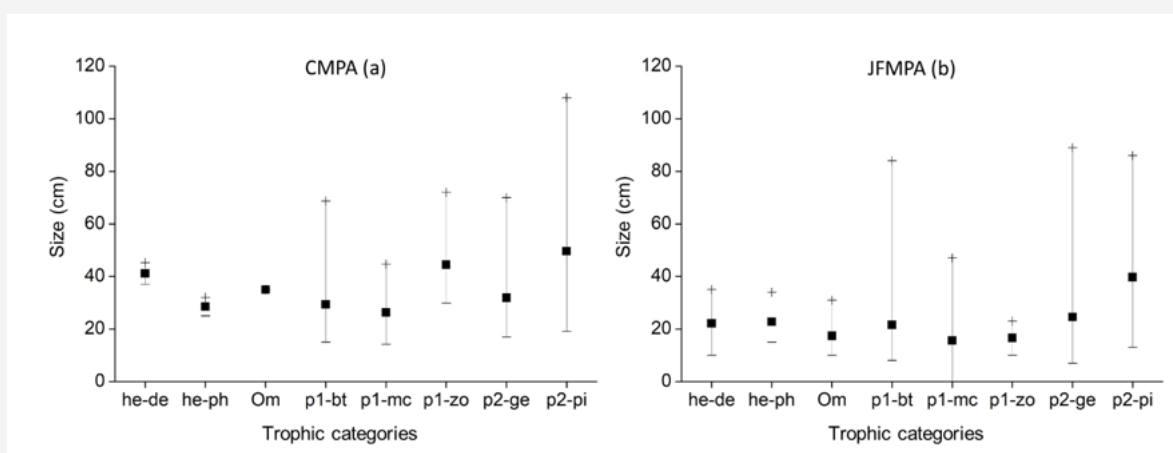
In both MPA the same trophic categories were observed (Figure 4ab). As for species richness, p1-bt (43 species), p2-ge (27 species) and p2-pi (14 species) were the most encountered species in the CMPA (Figure 4a). In JFMPA, the predator p2-ge, p1-bt and p1-mc with 24, 23 and 20 taxa were the represented in terms of species diversity (Figure 4b). As regards to abundance, in CMPA the trophic categories p1-bt, p2-ge and p2-pi represented 89.8% of the total number of individuals with 41.9%, 36.5% and 11.4% of the total number of individuals. In JFMPA the he-ph (36.8% of the total number of individuals), p1-bt (29.5% of total individuals) and p1-mc (14.8%) were the most abundant. Concerning biomass, the trio p1-bt, p2-ge and p2-pi accounted for 85.8% of the total biomass

in CMPA, while in JFMPA he-ph, p1-bt and p1-mc were responsible for 75.7% of the total biomass. The size structure of the different encountered trophic categories in both MPA is presented (Figure 5ab). Mean and minimum sizes of predators, herbivorous and omnivorous species were higher in CMPA. However, maximum sizes of species belonging to p1-bt, p1-mc and p2-ge were lesser in CMPA. In CMPA the most abundant categories, p1-bt and p2-ge had the largest size classes varying between 15-66 cm and 17-70 cm, respectively (Figure 5a). Concerning JFMPA, the most important category in terms of abundance (he-ph) consisted of species whose sizes ranged from 15 to 34cm (Figure 5b). As for predator species with the highest species richness such as p1-bt, p1-mc and p2-ge, size classes varied between 8-84cm, 5-47cm and 8-89 cm, respectively.





**Figure 4:** Fish species richness (number of species), and abundance and biomass indices of the different trophic categories: a) Cayar Marine Protected Area (CMPA) and b) Joal-Fadiouth Marine Protected Area (JFMPA). AI = abundance index and BI = biomass index. Error bars are the standard deviations. 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 deviations.



**Figure 5:** Fish size structure of the different trophic categories: a) Cayar Marine Protected Area (CPMA) and b) Joal-Fadiouth Marine Protected Area (JFPMA). (+) and (-) are the maximum and the minimum sizes, respectively. The black squares correspond to the mean sizes. Abbreviations used here are as in Figure 4.

## Discussion

### Comparative analysis of fish composition

Patterns in spatial composition and fish assemblage structure depend on the taxonomic identity or functional group [20]. In this preliminary study, patterns derived from taxonomic and trophic analyses were driven by species' spatial distribution. Unexpectedly, results from study suggested that fish assemblages of CMPA and JFMPA were almost identical in terms of species number. However, in terms of species composition dramatic difference was noted, more than 50% of encountered species in CMPA were absent in JFMPA, and vice versa. It's worth highlighting that caution is needed when comparing fish composition in distinct ecosystems because several factors must be considered [21]. Even if both MPA are enriched by a seasonal upwelling which favors the development of phytoplankton ensuring almost all the primary production and the functioning of the trophic network [22], their ecosystems are different. High fish diversity in CMPA might be due to the canyon which contributes to high fish diversity by limiting the intensity of migration of several demersal species [23]. In JFMPA, high species

richness, could be attributed to the large mangrove network which is a nursery area for many species [24] and to the favorable oceanographic conditions (high retention associated with high productivity) [25].

### Comparative Analysis of Fish Abundance and Biomass

In terms of abundance and biomass notable differences were observed between these MPA. In JFMPA, abundance and biomass were six and three times higher. Similar results were found in several studies from other areas [26,27]. This high abundance and biomass in JFMPA were partially due to high presence of *Ethmalosa fimbriata* which accounted for 34% of the total number of individuals and 37% of the total biomass. This species only is twice higher than total number of individuals caught in CMPA. The fact that any type of fish extraction is prohibited in JFMPA explains this difference in terms of abundance and biomass between these conservation areas. Fishery activities are very intense within CMPA, especially that of purse seine. Therefore, this human extraction, although controlled seems to reduce fish abundance in CMPA.

## Comparative Analysis of Trophic Categories

The fish assemblage of CMPA were dominated, in terms of species richness and abundance, by first level predators mainly feeding in benthophageous, while generalist predators were more dominant in biomass. The dominance of p1-bt is primary due to the high catch of *Cynoglossus senegalensis* and *Pseudupeneus prayensis* accounting for 7.4% of the total number of individuals. In JFPMA, second level generalist predators dominated in species richness, while herbivore species mainly feeding on phytoplankton or micro-phytoplankton were more important as well as in terms of abundance and biomass. The higher abundance and biomass of herbivore species is due to the high proportion of the clupeid *Ethmalosa fimbriata*. Similar results were found by [12] comparing the fish assemblage between a protected area and an exploited site in Sine Saloum estuarine. They showed that even if same trophic groups were identified in both sites, difference in species richness, abundance and biomass was observed between the two sites. In terms of size structures, notable differences were observed between trophic categories in both MPA. Mean sizes of all trophic categories were highest in CMPA. This dichotomy in size structure could be explained by the fact that JFMPA is located in nurseries areas [19]. [25] This may explain the abundance of small fish sizes in this MPA.

## Conclusion

Overall this study shows fundamental differences between CMPA and JFMPA in terms of species composition, abundance and biomass. Although both MPA have similar number of species and families, the highest fish abundance and biomass was recorded in JFMPA. These results seem to reflect the positive effect of fishing ban within JFMPA, even if fish extraction is regulated in CMPA. As prohibiting fishing activities within CMPA might be unfeasible, reducing total fishing effort, especially that of purse seine, through conventional fisheries management measures is necessary. Otherwise, small-scale no-take area should be set within CMPA.

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## Conflict of Interest

No conflict of interest.

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