E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2018; 6(4): 115-123

www.fisheriesjournal.com
Received: 13-05-2018
Accepted: 16-06-2018

Ousmane Diankha
Université Cheikh Anta Diop (UCAD), Ecole supérieure polytechnique, Laboratoire de Physique de l'Atmosphère et de l'Océan Siméon Fongang (LPAO-SF), BP 5085 Fann, Dakar, Senegal

Correspondence
Ousmane Diankha
Université Cheikh Anta Diop (UCAD), Ecole supérieure polytechnique, Laboratoire de Physique de l'Atmosphère et de l'Océan Siméon Fongang (LPAO-SF), BP 5085 Fann, Dakar, Senegal

Seasonal distribution patterns of fish assemblage in the lagoon of Somone natural reserve of communal interest in Senegal: influence of abiotic factors

Ousmane Diankha

Abstract
Fish assemblage was investigated for patterns in seasonal structure in Somone lagoon, Senegal. Seasonal sampling from three stations with beach seine was performed in 2017. Abiotic factors such as temperature and salinity were measured during each season at all stations. Ecological and trophic classification was carried out in order to determine the fish fauna nature of this lagoon. Multivariate analysis like factorial correspondence analysis (FCA) and hierarchical classification analysis (HCA) were carried out to study temporal organization of fish assemblage. Canonical correspondence analysis (CCA) was performed to assess the influence of abiotic factors on temporal fish assemblage distribution. The fish assemblage of Somone lagoon consisted of 29 species from 19 families. The most abundant species were Mugilidae and Cichlidae species, accounting for 82.87% of total abundance and 87.53% of the total biomass. In terms of ecological and trophic guilds, the fish assemblage was dominated by species with estuarine affinity (19 species representing 94.75% of total individuals and 94.69% of total biomass) and herbivorous species (8 species accounting for 82.80% of total individuals and 87.17% of total biomass). The multivariate analysis indicated that temperature and salinity played an important role on the temporal distribution of fish assemblage in Somone lagoon.

Keywords: Canonical Correspondence Analysis, Fish assemblage, Somone lagoon

Introduction

There is a growing interest on lagoon and estuarine ecosystems due to their ecological and socioeconomic importance. Interface between marine systems and continental environments, lagoons provide a variety of habitat types for many species, function as nursery areas and feeding grounds for marine opportunistic species as well [29, 45, 52]. Some of them support important fishery activities.

However, overfishing, climate change, pollution, lack of management, among other factors, are considered as major concerns for both the structure and the functioning of these sensitive coastal ecosystems [27, 53]. In this context, for their sustainability, it is necessary to understand and protect these critical ecosystems by documenting the communities they support and by investigating the factors that influence the distribution and abundance of associated species.

Therefore, several studies investigating fish assemblage structure were carried out within estuarine and lagoon ecosystems [2, 6, 7, 21, 23, 27, 37, 42, 54, 61, 63,]. Most of these studies suggested that variations in time of fish assemblage could be caused by variation of environmental conditions. The main environmental parameters used to assess habitat conditions on fish assemblage distribution in estuarine ecosystems are temperature, salinity, dissolved oxygen, pH and turbidity.

In Senegal, studies on fish assemblage in lagoon ecosystems are scares. This study dealing with the lagoon of Somone in the Natural Reserve of Communal Interest, aims to describe the fish assemblages in terms of their taxonomic and functional composition and to describe their seasonal variations relative to environmental fluctuations. In this study, fish assemblage patterns were investigated by clustering the different species according to the sampling seasons relative to the similarities in species composition and their abundance. The canonical correspondent analysis was applied to assess environmental influences on temporal fish assemblage distribution.

2. Materials and Methods

2.1 Study area

Somone lagoon is located in Somone Natural Reserve of Communal Interest (RNICS) which encompasses three rural settlements: Guereo, Thiafoura and Sorokhassap (Sindia) and commune of Somone, in the region of Thiès (Fig. 1). The RNICS covering an area of about 7 km^2 was established in 1999. Somone lagoon with a surface of 2.04 km^2, is covered with mangrove, mainly *Rhizophora racemosa* and *Avicennia africana* which serve as nursery areas and feeding grounds for opportunistic marine species [29, 45, 52]. It communicates with the sea via approximatively 0.5 to 3-m-deep channel and receives freshwater from Somone river (Fig. 1). The climate in the RNICS is tropical Sahelo-Sudanian which consists of dry season, cool from November to April, and warm from May to June, and by a short warm and rainy season from July to October. Total annual rainfall is estimated at 760 mm with a maximum (400 mm) in August [12].

2.2 Sampling protocol

Samples were collected at three sampling stations (Fig. 1). At each station, samples were collected in Cold Season (CS) in April, transition Cold to Warm season (CW) in June, Warm Season (WS) in August and transition Warm to Cold season (WC) in December in 2017. The seasons correspond to the four main hydro-climatic periods in Senegal [24, 57, 58]. Fish Sampling was performed using a beach seine. Environmental parameters such as temperature and salinity were measured during each fish sampling with a multi-probe kit. After each fishing haul, fish were identified at 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.

2.3 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 address the assumptions of normality and homogeneity of variance. Species richness (the total number of species caught in each station or during each season) was calculated. Species richness and abundance were compared between station and sampling seasons.

Species were classified according to their habitats and diet preferences. The ecological classification proposed by Albaret [7] was used in this study. This method classified species on several ecological guilds according to their degree of euryhalinity and the characteristics of their bio-ecological cycle in different estuarine environments. Five ecological categories were sampled in the GMPA: Strictly estuarine species (Es), 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, seven trophic guilds were identified: Scavenger or grazer herbivores (he-de), Herbivores mainly feeding on phytoplankton or micro-phytoplankton (he-ph), First level predators mainly benthophagous (p1-bt), First level generalist predators mainly feeding on macro-crustaceans or insects (p1-mc), First level predators mainly feeding on zooplankton (p1-zo), Second level generalist predators mainly feeding on fish, shrimps and crabs (p2-ge) and Second level piscivorous predators mainly feeding on fish (p2-pi) [61].

2.4 Statistical analysis

An ANOVA was used to test for significant differences in environmental variables among seasons. Similar analysis was performed to examine significant difference between species richness, abundance and biomass between seasons. Multivariate analysis techniques such as factorial and automatic classification analysis methods that allow to resume the temporal organization of data from a complex picture whose structure is difficult to pin down clearly [50], were applied here. Factorial correspondence analysis (FCA) was carried out using fish abundance indices to investigate the pattern of species assemblage among seasons. The Hierarchical Classification Analysis (HCA) was also used to group species according to their seasonal affinity or similarity [44]. The dendrograms were performed using the Euclidean distance and the Ward minimum variance clustering method [28].

Canonical correspondence analysis (CCA) was performed to assess the influence of environmental variables on temporal fish assemblage structure [67]. This method (CCA) allows to assess the relative importance of environmental parameters to the distribution of each species. The relative length of the vector indicates the importance of the environmental parameter. More the vector is longer, greater is its influence. Concerning the species, the closer are two species, the more similar is their distribution; for the vectors [54, 67] as well. Species or groups that are highly influenced by two parameters are on the axes generated by the corresponding vectors of these parameters rather than at the end of any single vector [67]. The canonical analysis concerned only the most commonly occurring species (Mugilidae and Cichlidae species) in order to reduce effects of rare species. The Variance Inflation Factors (VIFs) were calculated for all environmental variables in order to detect possible high dimensional collinearities [74]. In fact, it was suggested by these authors that covariates with VIFs >5 are highly collinear.

3. Results

3.1 Fish assemblage

A total of 29 fish species belonging to 19 families from 2,114 specimens with a total biomass of 95.48 kg were identified in Somone lagoon (Table 1). Of the 29 species captured, the Mugilidae (6 species with 43.33% of total abundance and 53.19% of total biomass) and the Cichlidae (2 species with 39.54% and 34.34% of the total abundance and biomass) dominated the fish assemblage (Table 1). *Chelon dumerili* (22.80% of total abundance and 21.81% of total biomass), *Coptodon guineensis* (21.71% and 19.51% of total abundance and biomass) and *Sarotherodon melanotheron* 17.83% of total individuals and 14.83% of total biomass) were the dominant species.

According to their habitat preference, the estuarine species from marine origin (Em) dominated the fish assemblage in terms of species richness, abundance and biomass (10 species representing 50.57% and 56.45% of total abundance and biomass, respectively) (Fig. 2). The strictly estuarine species with 4 species, account for 41.87% of total individuals and

36.15% of total biomass precede the Em species. The marine-estuarine were the second most important ecological guilds in terms of species richness (6 species). The marine-occasionally species (5 species) were the lowest as well as in abundance and biomass (1.42% of total individuals and 0.93% of total biomass).

As for their diet preference, the scavenger or grazer herbivores species (he-de), 8 species accounting for 82.80% of the total abundance and 87.17% of the total biomass, were the most encountered (Fig. 3). Height species were benthophagous (p1-bt), comprising 9.40% of the total specimens and 3.98% of the total biomass. Ten species were second level predators (p2-ge and p2-pi, 5 species each one), but they comprised low number of the fish collected (5.24% of total abundance and 8.09% of total abundance). The omnivorous and phytoplanctivores species represented each by one species were the les abundant, less than 1% of total individuals and biomass.

The distribution of species richness, abundance and biomass was not significantly different among seasons (P >0.05). However, highest species richness (22 species), abundance (48.69% of total individuals) and biomass (37.97%) occurred in WS (Fig. 4). The lowest species richness, abundance and biomass (14 species accounting for 6.91% and 8.61% of total biomass) were recorded in CS. The clustering analysis based on species abundance allowed to identify three different groups (Fig. 5a). The first group (15 species accounting for 61.92% of total individuals and 56.21% of total biomass) was associated with WS (Fig.5b). The second group consisted of the most abundant species in cold and WC (4 species accounting for 27.44% of total abundance and 28.99% of total biomass). The third group with 10 species, accounting 10.64% of total abundance and 14.83% of total biomass, was related to CS and CW.

3.2 Abiotic factors

The studied abiotic factors showed a clear seasonal pattern (Fig. 6). Temperature ranged from 19.51°C in CS to 28.03°C in WS (mean ± SD = 23.41 ± 4.01°C) (Fig. 6a). The differences in temperature between the four sampling seasons were not statistically significant (F=0.07; P=0.80). Salinity varying between 29.14‰ in WC and 45.5‰ in CW (29.83±0.48‰) (Fig. 6b), was not significant between seasons (F=8.09; P=0.09).

3.3 Environmental influence on temporal fish assemblage distribution

The CCA analysis based on species abundance indices revealed that axis 1 (57.06%) and axes 2 (36.36%) explained 93.42% of variance of the seasonal species-environment relation. Temperature and salinity were positively and highly correlated with axis 1 (Fig. 7). According to the relative length of the vectors, both factors played an important environmental in the seasonal distribution of fish species in Somone lagoon, even if the influence of salinity was slightly more important. Temperature was positively and negatively correlated with *Chelon dumerili* and *Neochelon falcipinnis*, respectively. In other words, season distribution of both species was mainly influenced by temperature. *Mugil bananensis* and *Parachelon grandisquamis* were positively and strongly correlated with salinity. *Sarotherodon melanotheron* located near the origin either did not show a strong relation to any of the factors, while *Coptodon guineensis* was strongly influenced by both factors, temperature and salinity. Salinity negatively influenced the abundance distribution of *Mugil curema*.

4 Discussion

4.1 Fish assemblage

Fish assemblage in Somone lagoon was characterized by moderate species diversity, 29 species belonging to 19 families. This species richness can be equal, higher or lesser than that of other lagoon or estuaries: 108 species in St Lucia lagoon [18], more than 70 in Laguna Madre, Texas [35], 26 in Ghar El Melh in Tunisia, 17 in Lake Manzala in Egypt [41], 13 in the Ichkeul Lagoon in Tunisia [62] and 11 in Mellah lagoon [27]. By comparison, in North-West Africa, 153 species from 71 families were identified in Ebrié lagoon in Côte d'Ivoire [5] and 15 fish species were recorded in Nador lagoon in Morocco [37]. However, caution should be taken when comparing fish diversity between these cited studies. In fact, difference in fish diversity could be related to the characteristics of the lagoon (surface area, depth, connection with the sea), hydrological parameters (e.g., tidal range, temperature, salinity etc.), the sampling effort, as well as the fishing gear type [2, 29, 45].

The most abundant species were the Mugilidae (*Chelon dumerili, Mugil bananensis, Neochelon falcipinnis, Mugil curema* and *Parachelon* grandisquamis) and the Cichlidae (*Coptodon guineensis* and *Sarotherodon melanotheron*) probably due to their high adaptation capacity in high salinity variations [3, 4, 19, 36, 51, 55, 63, 68]. In terms of richness, abundance and biomass, the fish assemblage of Somone lagoon was dominated estuarine species forms of marine origin (Em) whose life cycle is spread across both marine and estuarine environments [8, 25, 26]. Concerning the trophic guilds, herbivores were dominant in terms of species richness, abundance and biomass. Similar results were found in Palmarin Communal Natural Reserve [22]. Sadio *et al.* [61] reported that grazer herbivores were the most abundant in Bamboung marine protected area.

4.2 Spatial and temporal variation of fish assemblage in relation with environmental parameters

The fish assemblages differed among seasons both in terms of fish diversity, abundance and biomass. This temporal variation in total abundance reflects fluctuations in the most dominant species, the Mugilidae and Cichlidae (82.87% of the total sampled species and 87.53% of the total abundance). High abundance of these species within the lagoon might result of high tolerant to fluctuating environmental conditions [19, 36, 51, 63, 68]. In fact, it has been suggested that fish assemblage structure in lagoons and estuaries is influenced by both abiotic and biotic factors [1, 11, 17, 30, 31, 46, 48, 56, 59, 69, 71]. In this study, the CCA revealed that the temporal organization of the fish assemblages in Somone lagoon was greatly influenced by studied abiotic factors, temperature and salinity. These two abiotic factors have been postulated to be important determinants of spatial and temporal assemblage structure [1, 33, 34]. In fact, temperature always affects fish species at different stages of their life cycles, including during spawning and the development and survival of the eggs and larvae, as well as influencing their distribution, diet, migration pattern and schooling behavior [32, 43, 66]. Concerning salinity, several authors suggested that it influences reproduction, larval dispersal and recruitment, geographical distribution, and behavior of many species [10, 14, 17, 38, 64, 65]. As example, it has been showed that juvenile mullets prefer oligohaline waters, while adults prefer euryhaline waters [20]. It's worth highlighting that, even if the abiotic factors tested in this study had an important influence on fish assemblage distribution in Somone lagoon, they could not fully explain the temporal of the assemblage. In fact, it has been suggested that other factors such as aquatic vegetation [1, 39, 60, 70, 73], food availability [15, 40, 59], status of the estuarine mouth (open or intermittently open) [16, 72], and biological interrelationships [49] were associated with fish assemblage structure in other lagoon and estuarine ecosystems.

Table 1: List of the 29 species observed in Somone lagoon in 2017. Percentage of abundance and biomass with the name of the family, species labels, ecological and trophic guilds.

Family	Species	Labels	Ecological guilds	Trophic guilds	Abundance (%)	Biomass (%)
Carangidae	*Caranx hippos*	CHI	ME	p2-ge	0.19	0.02
	Lichia amia	LAM	Ma	p2-ge	0.14	0.21
Cichlidae	*Coptodon guineensis*	CGU	Es	he-de	21.71	19.51
	Sarotherodon melanotheron	SME	Es	he-de	17.83	14.83
Clupeidae	*Ethmalosa fimbriata*	EFI	Em	he-ph	0.14	0.21
Elopidae	*Elops lacerta*	ELA	ME	p2-pi	0.47	1.78
Gerreidae	*Eucinostemus melanopterus*	EME	ME	p1-mc	1.37	0.1
	Gerres nigri	GNI	Es	p1-mc	0.61	0.28
Haemulidae	*Pomadasys Jubelini*	PJU	Em	p1-bt	7	2.77
	Pomadasys incisus	PIN	Ma	p1-bt	1.8	0.42
	Plectorhinchus macrolepis	PMA	Em	p2-ge	0.05	0.1
Lutjanidae	*Lutjanus agennes*	LAG	Ma	p2-pi	1.66	3.56
	Lutjanus dentalus	LDA	Ma	p2-pi	0.19	0.1
	Lutjanus fulgens	LFU	Ma	p2-pi	0.05	0.1
Monodactylidae	*Monodactylus sebae*	MSE	Es	p2-ge	1.75	1.68
Moronidae	*Dicentrarchus punctatus*	DPU	Mo	p2-ge	0.71	0.47
Mugilidae	*Chelon dumereli*	CDU	Em	he-de	22.8	21.81
	Mugil bananensis	MBA	Em	he-de	6.05	9.17
	Neochelon falcipinnis	NFA	Em	he-de	5.96	8.49
	Mugil curema	MCU	Em	he-de	5.16	8.85
	Parachelon grandisquamis	PGR	Em	he-de	2.98	4.35
	Mugil cephalus	MCE	Em	he-de	0.38	0.52
Paralichthyidae	*Syacium micrurum*	SMI	ME	p1-bt	0.19	0.09
Serranidae	*Epinephelus aeneus*	EAE	ME	p2-pi	0.05	0.12
Soleidae	*Synaptura cadenati*	SSP	Mo	p1-bt	0.09	0.15
Sparidae	*Diplodus cervinus*	DCE	Mo	Om	0.43	0.16
	Diplodus vulgaris	DVU	Mo	p1-bt	0.14	0.16
	Diplodus sargus	DSA	Mo	p1-bt	0.05	0.01
Tetraodontidae	*Ephippion guttifer*	EGU	ME	p1-bt	0.05	0.01

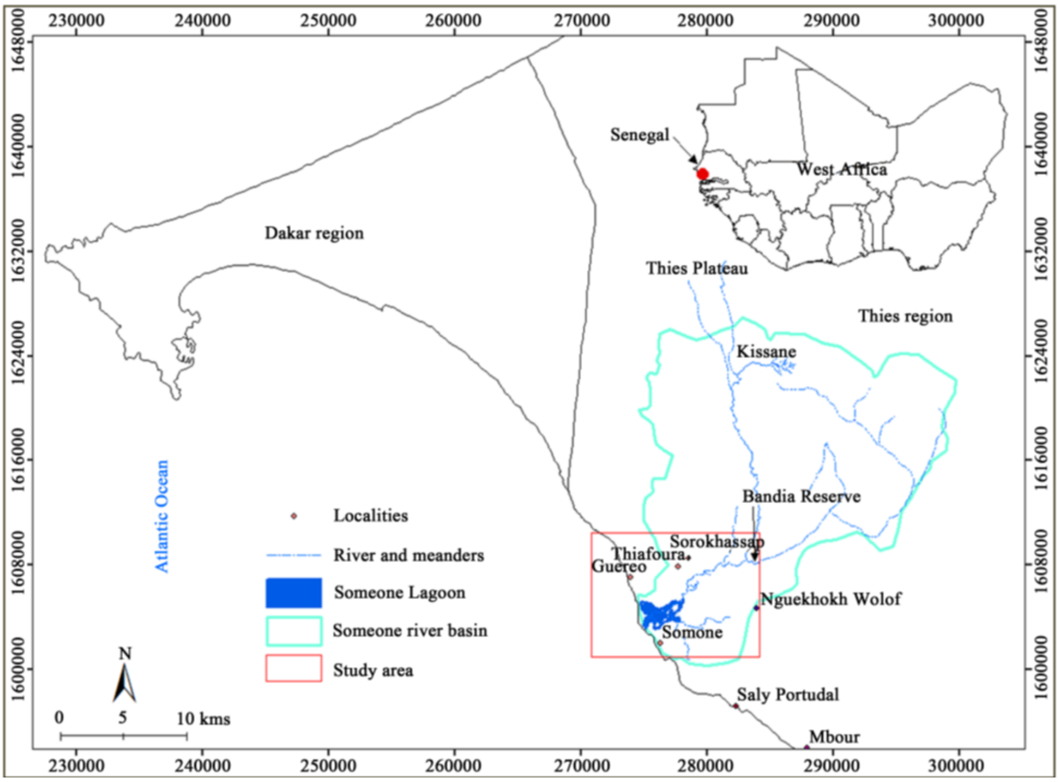

Fig 1: Location of the study area (Barry *et al*. [12]).

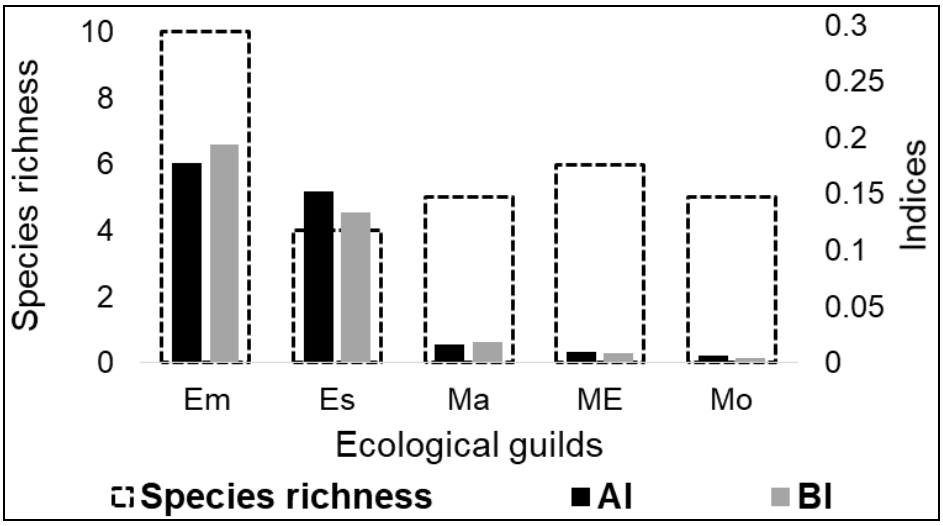

Fig 2: Species richness abundance and biomass of the different ecological and trophic guilds in Somone lagoon. AI = abundance indices; BI= biomass indices. Es = Strictly estuarine species, Em = Estuarine species from marine origin, ME = Marine-Estuarine species, Ma = Marine species, accessory in estuaries and Mo = Marine species, occasional in estuaries (Albaret *et al*., 1999) [7].

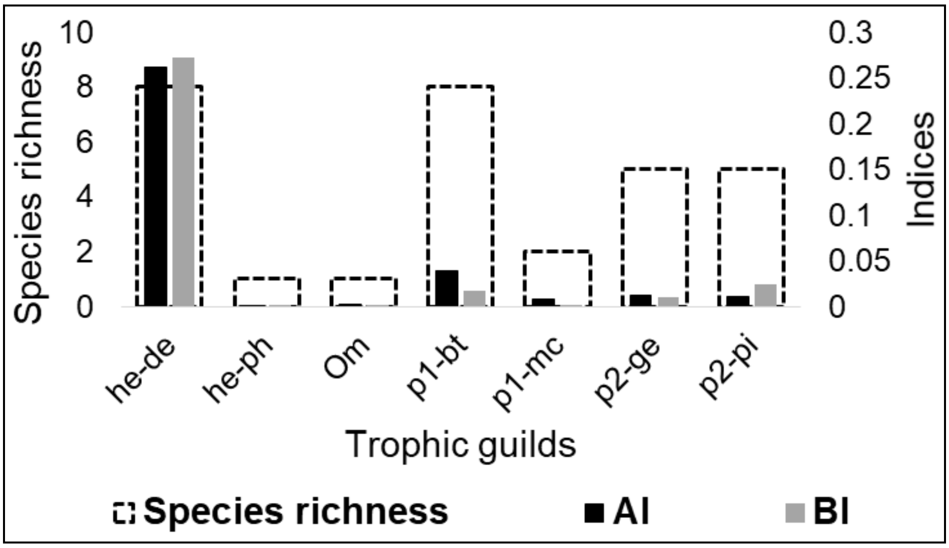

Fig 3: Species richness abundance and biomass of the different ecological and trophic guilds in Somone lagoon. AI = abundance indices; BI= biomass indices. he-de = scavenger or grazer herbivores, he-ph = herbivores mainly feeding on phytoplankton or micro-phytoplankton, Om = omnivorous species, p1-bt = 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.

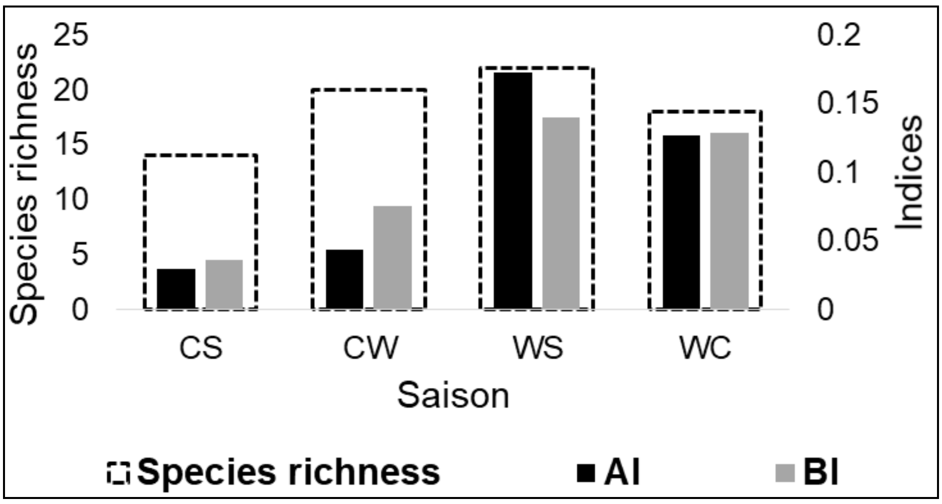

Fig 4: Temporal fluctuations in species richness, abundance and biomass in Somone lagoon in 2017. CS= Cold season; CW transition season from Cold to Warm season; WS= Warm season; WC transition from Warm to season Cold.

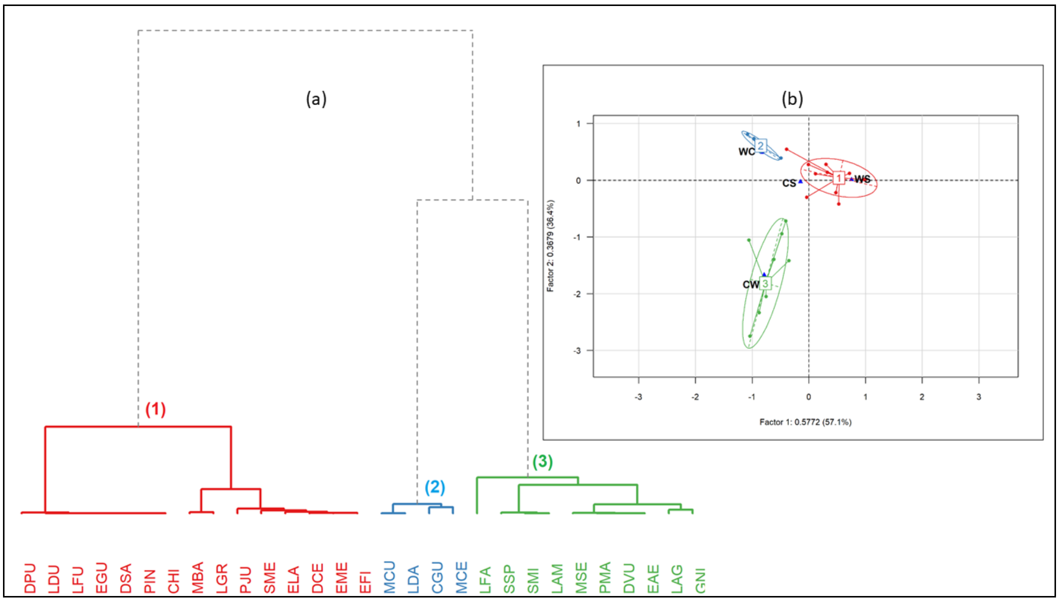

Fig 5: Factorial correspondence analysis (FCA) performed using seasonal abundance of fishes: a) is the dendrogram showing the groups of species, b) is the correspondence between groups and seasons. CS = Cold season, CW = Cold to Warm transition, WS = Warm season and WC = Warm to Cold transition. See Table 1 for species labels.

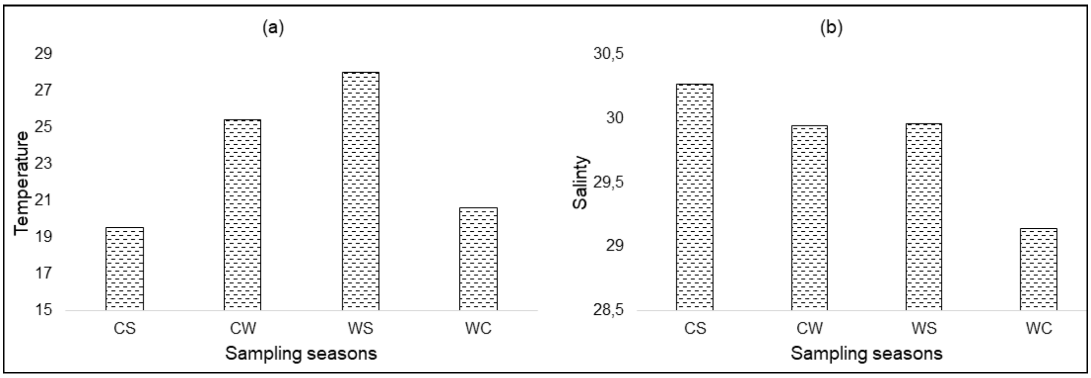

Fig 6: Temporal fluctuations of abiotic factors in 2017 Somone lagoon. CS= Cold season; CW transition season from Cold to Warm season; WS= Warm season; WC transition from Warm to season Cold.

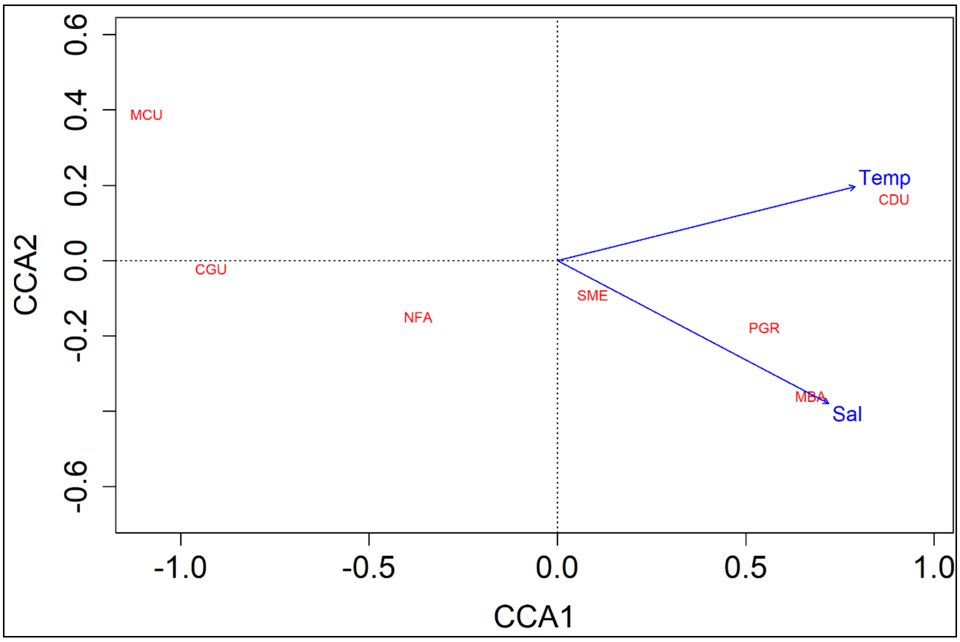

Fig 7: Plot of canonical correspondence analysis relating season, fish taxa abundance and abiotic factors correlated with axes; response variables (species abundance) are plotted by species, arrows represent quantitative explanatory variables (environmental variables: Temp = temperature, Sal = salinity. See Table 1 for species labels.

5. Conclusion

Overall this study, the first, revealed that moderate species richness composed of five ecological guilds and seven trophic guilds, was the general features of Somone lagoon. The most abundant species were species with high adaptation capacities in strong salinity variations. The temporal organization of fish assemblage in this lagoon was greatly influenced by both temperature and salinity. Results from this study might serve as the reference point of the fish assemblage in Somone lagoon.

Acknowledgement

We would like acknowledge the members of the Management Comity of the RNICS and Fishermen for their active collaboration. We are also thankful to the research institutions such as CRODT (Centre de Recherche Océanographique de Dakar-Thiaroye) and IUPA (Aquaculture and Fisheries Institute of the University of Dakar) for their support in the elaboration and the setting of this monitoring protocol.

References

1. Akin S, Winemiller KO, Gelwick, FP. Seasonal and temporal variation in fish and macrocrustecean assemblage structure in Mad Island Marsh Estuary, Texas. Estuarine, Coastal and Shelf Science. 2003; 57:269-282. http://dx.doi.org/10.1016/S0272-7714(02)00354-2.
2. Akin S, Buhan E, Winemiller KO, Yilmaz H. Fish assemblage structure of Koycegiz Lagoon–Estuary, Turkey: Spatial and temporal distribution patterns in relation to environmental variation. Estuarine, Coastal and Shelf Science. 2005; 64(4):671-684. http://dx.doi.org/10.1016/j.ecss.2005.03.019.
3. Albaret JJ. Les peuplements de poissons de la Casamance (Sénégal). Revue d’Hydrobiologie Tropicale. 1987; 20:291-310.
4. Albaret JJ, Ecoutin JM. Communication mer-lagune : impact d’une réouverture sur l’ichtyofaune de la lagune Ebrié (Côte d’Ivoire). Revue d’Hydrobiologie Tropicale. 1989; 22:71-81.
5. Albaret JJ. Les poissons : biologie et peuplement. In : Environnement et ressources aquatiques de Côte d’ivoire. Tome II - Les milieux lagunaires, Paris, Durand J.R. Dufour P. Guiral D. Et Zabi S.G.F (Edit.), 1994, 239-279.
6. Albaret JJ, Diouf PS. Diversité des poissons des lagunes et des estuaires ouest-africains. In : Teugels G.G. (ed.), Guégan Jean-François (ed.), Albaret Jean-Jacques (ed.). Biological diversity in African fresh- and brackish water fishes : geographical overviews : PARADI symposium = Diversité biologique des poissons des eaux douces et saumâtres d'Afrique : synthèses géographiques : symposium PARADI. Annales du Musée Royal d'Afrique Centrale. Sciences Zoologiques. 1994; 275:165-177.
7. Albaret JJ. Les peuplements des estuaires et des lagunes. In : Les Poissons Des Eaux Continentales Africaines : Diversité, Biologie, Écologie, Utilisation Par L'Homme (Eds. Lévèque C, Paugy D). IRD, Paris, 1999, 325.
8. Albaret JJ, Simier M, Sadio O. Suivi biologique des peuplements de poissons d'une aire protégée en zone de mangrove: le bolong de Bamboung (Sine-Saloum, Senegal. Narou Heuleuk (Oceanium/AFD/IRD), Dakar, 2005, 80. http:/horizon.documentation.ird.fr/exl-doc/pleins_textes/divers12-05/010055094.pdf.
9. Anger K. Effects of temperature and salinity on the larval development of the Chinese mitten crab Eriocheir sinensis (Decapoda: Grapsidae). Marine Ecology Progress Series. 1991; 72:103-110.
10. Anger K. Salinity tolerance of the larvae and first juveniles of a semi terrestrial grapsid crab, Armases miersii (Rathbun). Journal of Experimental Marine Biology and Ecology. 1996; 202:205-223.
11. Araùjo FG, Bailey RG, Williams WP. Spatial and temporal variations in fish populations in the upper Thames estuary. Journal of Fish Biology. 1999; 55:836-853. http://dx.doi.org/10.1006/jfbi.1999.1042.
12. Barry NY, Traore VB, Ndiaye ML, Isimemen O, Celestin H, Sambou B. Assessment of Climate Trends and Land Cover/Use Dynamics within the Somone River Basin, Senegal. American Journal of Climate Change. 2017; 6:513-538.
13. http://dx.doi.org/10.4236/ajcc.2017.63026
14. Barletta M, Barletta-Bergan A, Saint-Paul U, Hubold G. The role of salinity in structuring the fish assemblages in a tropical estuary. Journal of Fish Biology. 2005; 66:45-72.
15. Barry JP, Yoklavich MM, Cailliet GM, Ambrose DA, Antrim BS. Trophic ecology of the dominant fishes in Elkhorn Slough, California, 1974-1980. Estuaries. 1996: 19:115-118.
16. Bell KNI, Cowley PD, Whitfield K. Seasonality in frequency of marine access to an intermittently open estuary: implications for recruitment strategies. Estuarine, Coastal and Shelf Science. 2001; 52:327-337. http://dx.doi.org/10.1006/ecss. 2000-0709
17. Blaber SJM, Blaber TG. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology. 1980; 17:143-162.
18. Blaber SJM. Fish communities of South East African coastal lakes. In: Lévêque, C., Bruton, M.N., Ssentongo, G.W. (Eds.), Biology and Ecology of African Freshwater Fishes, Travaux et Documents, ORSTOM, Paris. 1988; 216:351-362.
19. Charles-Dominique E, Albaret JJ. African shads, with emphasis on the West African Shad Ethmalosa fimbriata. American Fisheries Society Symposium. 2003; 35:27-48.
20. Cardona L. Effects of salinity on the habitat selection and growth performance of Mediterranean Flathead Grey Mullet Mugil cephalus (Osteichthyes, Mugilidae). Estuarine, Coastal and Shelf Science. 2000; 50:727-737. http://dx.doi.org/10.1006/ecss.1999.0594
21. Day Jr JW, Hall CAS, Kemp MW, Yanez-Arancibia A. Estuarine Ecology. John Wiley and Sons, New York. 1989, 576.
22. Diankha O. Fish assemblage structure of Natural Reserve of Palmarin (Senegal): influence of environmental variations on spatial and temporal distribution. In press, 2018.
23. Diouf PS. Les peuplements de poissons des milieux estuariens de l’Afrique de l’ouest: l’exemple de l’estuaire hypersalin du Sine-Saloum, ORSTOM, Paris. Thèse de doctorat, Université Montpellier II, Montpellier. Thèses et Documents Microfiches, 1996; 156 :267. http://horizon.documentation.ird.fr/exldoc/pleins_textes/pleins_textes_7/TDM_7/010008130.pdf.
24. Domain F. Contribution à la connaissance de 1 'écologie des poissons démersaux du plateau continental sénégalo-mauritanien. Les ressources démersales dans le contexte

du Gal fe de Guinée. Thèse doct. d'état, Uni v. Paris VI Mus. nat. Hist. nat. Froese R, 1980, 342.

25. Ecoutin JM, Sadio O, Simier M, Raffray J, Tito de Morais L. Comparaison des peuplements de poissons d'une aire protégée en zone de mangrove (le bolong de Bamboung, Sine Saloum, Senegal) avec les peuplements de deux sites proches non protégés de l'exploitation halieutique. 2012, 67. Report on Contract CSRP/AFD/C11/2011. Dakar. http://www.documentation.ird.fr/hor/fdi:010056414.
26. Ecoutin JM, Simier M, Albaret JJ, Laë R, Raffray J, Sadio O *et al*. Ecological field experiment of short-term effects of fishing ban on fish assemblages in a tropical estuarine MPA. Ocean and Coastal Management. 2014; 100:74-85.
27. Embarek R, Amara R, Kara MH. Fish assemblage structure in shallow waters of the Mellah Lagoon (Algeria): Seasonal and spatial distribution patterns and relation to environmental parameters. Acta Ichthyologica. Piscatoria. 2017; 47(2):133-144.
28. Faye D. Assessment of the Recovering Effects of Protected Areas Using a Multiple Functional Approaches: The Bamboung Model (Senegal, West Africa). International Journal of Biology. 2015; 7:37-58.
29. Franco A, Franzoi P, Torricelli P. Structure and functioning of Mediterranean lagoon fi sh assemblages: A key for the identification of water body types. Estuarine, Coastal and Shelf Science. 2008; 79(3):549-558. http://dx.doi.org/10.1016/j.ecss.2008.05.011
30. Garcia AM, Vieira JP, Winemiller KO. Dynamics of the shallow-water fish assemblage of the Patos Lagoon estuary (Brazil) during cold and warm ENSO episodes. Journal of Fish Biology. 2001; 59:1218-1238. http://dx.doi.org/10.1006/jfbi.2001.1734
31. Gelwick FP, Akin S, Arrington DA, Winemiller KO. Fish assemblage structure in relation to environmental variation in a Texas Gulf coastal wetland. Estuaries. 2001; 24:285-296.
32. Gordoa A, Maso M, Voges L. A case study in D. Halpern. Satellite Oceanography and Society (Amsterdam, The Netherlands: Elsevier) Satellites and Fisheries: The Namibian hake. 2000, 193-205.
33. Grioche A, Koubbi P, Harlay X. Spatial patterns of ichthyoplankton assemblage along the eastern English Channel French coast during the Spring 1995. Estuarine, Coastal and Shelf Science. 1999; 49:141-152. http://dx.doi.org/10.1006/ecss.1999.0483
34. Hagan SM, Able KW. Seasonal changes of the pelagic fish assemblage in a temperate estuary. Estuarine, Coastal and Shelf Science. 2003; 56(1):15-29. http://dx.doi.org/10.1016/S0272.7714(02)00116-6
35. Hedgpeth JW. Ecological aspects of the Laguna Madre, a hypersaline estuary. In: Lauff, G.H. (Ed.), Estuaries, American Association for the Advancement of Science, Washington. 1967; 83:407-419.
36. Hotos GN, Vlahos N. Salinity tolerance of Mugil cephalus and Chelon labrosus (Pisces: Mugilidae) fry in experimental conditions. Aquaculture. 1998; 167:329-338.
37. Jaafour S, Yahyaoui A, Sadak A, Bacha M, Amara R. Fish assemblages of a shallow Mediterranean lagoon (Nador, Morocco): An analysis based on species and functional guilds. Acta Ichthyologica. Piscatoria. 2015; 45(2):115-124.
38. Kantoussan J, Ecoutin JM, Simier M, Tito de Morais L, Laë R. Effects of salinity on fish assemblage structure: An evaluation based on taxonomic and functional approaches in the Casamance estuary (Senegal, West Africa). Estuarine, Coastal and Shelf Science. 2012; 123:152-162.
39. Killgore KJ, Morgan II RP, Rybicki NB. Distribution and abundances of fishes associated with submerged aquatic plants in Potomoc River. North American Journal of Fisheries Management. 1989; 9:101-111.
40. Kneib RT. Early life stages of resident nekton in intertidal marshes. Estuaries. 1997; 20:214-230.
41. Kraïem MM, Chouba L, Ramdani M, Ahmed MH, Thompson JR, Flower RJ. The fish fauna of three North African lagoons: specific inventories, ecological status and production. Hydrobiologia. 2009; 622(1):133-146. http://dx.doi.org/10.1007/s10750-008-9679-3
42. Kupschus S, Tremain D. Associations between fish assemblages and environmental factors in nearshore habitats of subtropical estuary. Journal of Fish Biology. 2001; 58:1383-1403.
43. Laevastu T, Hayes ML. Fishing News (books) (Oxford, U.K.). Fisheries Oceanography and Ecology. Fishing News Books Ltd. 1981, 199.
44. Legendre P, Legendre L. Numerical ecology. Elsevier, Amsterdam. 1998, 852.
45. Maci S, Basset A. Composition, structural characteristics and temporal patterns of fish assemblages in non-tidal Mediterranean lagoons: A case study. Estuarine, Coastal and Shelf Science. 2009; 83(4):602-612. http://dx.doi.org/10.1016/j.ecss.2009.05.007
46. Maes J, Van Damme PA, Taillieu A, Ollevier F. Fish communities along an oxygen-poor salinity gradient (Zeeschelde Estuary, Belgium). Journal of Fish Biology. 1998; 52:534-546. http://dx.doi.org/10.1006/jfbi.1997.0602
47. Marchand J. The influence of seasonal salinity and turbidity maximum variations on nursery function of the Loire estuary (France). Netherlands Journal of Aquatic Ecology. 1993; 27:427-436.
48. Marshall S, Elliott M. Environmental influences on the fish assemblages of the Humber Estuary, U.K. Estuarine, Coastal and Shelf Science. 1998; 46:175-184. http://dx.doi.org/10.1006/ecss.1997.0268
49. Martino EJ, Able KW. Fish assemblages across the marine to low salinity transition zone of a temperate estuary. Estuarine, Coastal and Shelf Science. 2003; 56:969-987, http://dx.doi.org/10.1016/S0272-7714(02)00305-0
50. Morineau A, Lebart L. Specific c1ustering algorithms for large data sets and implementation in SPAD Software: Classification as a tool of research. North Holland, Amsterdam, The Netherlands, 1986.
51. Panfili J, Mbow A, Durand J-D, Diop K, Diouf K, Thior D *et al*. Influence of salinity on the life-history traits of the West African black-chinned tilapia (Sarotherodon melanotheron): comparison between the Gambia and Saloum estuaries. Aquatic Living Resources. 2004; 17:65-74.
52. Pérez-Ruzafa A, Marcos C. Fisheries in coastal lagoons: An assumed but poorly researched aspect of the ecology and functioning of coastal lagoons. Estuarine, Coastal and Shelf Science. 2012; 110:15-31. http://dx.doi.org/10.1016/j.ecss.2012.05.025
53. Pitcher TJ, Cheung WWL. Fisheries: hope or despair?

Marine Pollution Bulletin, 2013; 74:506-516. http://dx.doi.org/10.1016/j.marpolbul.2013.05.045
54. Pombo L, Elliott M, Rebelo JE. Environmental influences on fish assemblage distribution of an estuarine coastal lagoon, Ria de Aveiro (Portugal). Scienta Marina. 2005; 69(1):143-159.
55. Potter IC, Beckley LE, Whitfield AK, Lenanton RCJ. Comparisons between the role played by estuaries in the life cycles of fishes in temperate western Australia and southern Africa. Environmental Biology of Fishes. 1990; 28:143-178.
56. Rakocinski CF, Lyczkowski-Shulz J, Richardson SL. Ichthyoplankton assemblage structure in Mississippi Sound as revealed by canonical correspondence analysis. Estuarine, Coastal and Shelf Science. 1996; 43:237-257. http://dx.doi.org/10.1006/ecss.1996.0067
57. Rebert JP. Hydrobiologie et dynamique des eaux du plateau continental sénégalais. Documents scientifiques no 89, CRODT, Dakar. 1983, 99.
58. Rossignol M, Aboussouan MT. Hydrologie marine côtière de la presqu'île du Cap-Vert. Contribution à l'étude de la productivité des eaux, Documents Scientifiques CRODT. 1965; 2 :166.
59. Rozas LP, Hackney CT. Use of oligohaline marshes by fishes and macrofaunal crustaceans in North Carolina. Estuaries. 1984; 7:213-224.
60. Rozas LP, Minello TJ. Nekton use of salt marsh, seagrass, and non-vegetated habitats in a south Texas estuary (USA). Bulletin of Marine Science. 1998; 63:481-501.
61. Sadio O, Simier M, Ecoutin JM, Raffray J, Lae R, Tito de Morais L. Effect of a marine protected area on tropical estuarine fish assemblage: Comparison between protected and unprotected sites in Senegal. Oceanography and Coastal Management. 2015; 116:257-269.
62. Sellami R, Chaouachi B, Ben Hassine OK. Impacts anthropiques et climatiques sur la diversité ichtyque d’une lagune méditerranéenne (Ichkeul, Tunisie). Cybium. 2010; 34(1):5-10.
63. Simier M, Blanc L, Aliaume C, Diouf PS, Albaret JJ. Spatial and temporal structure of fish assemblages in an inverse estuary, the Sine Saloum system Senegal. Estuarine, Coastal and Shelf Science. 2004; 59:69-86.
64. Smyth K, Mazik K, Elliott M. Behavioural effects of hypersaline exposure on the lobster Homarus gammarus (L) and the crab Cancer pagurus (L). Journal of Experimental Marine Biology and Ecology. 2014; 457:208-214.
65. Spivak ED, Cuesta JA. The effect of salinity on larval development of Uca tangeri (Eydoux, 1835) (Brachyura: Ocypodidae) and new findings of the zoeal morphology. Scientia Marina. 2009; 73:297-305.
66. Sund PN, Balcburn M, Wiliams Tuna. Their Environment in the Pacific Ocean: A Review Oceanography, Oceanography and Marine Biology: An Annual Review. 1981; 19:443-512.
67. Ter Braak CJF. Canonical correspondence analysis: A new eigenvector technique for multivariate direct gradient analysis. Ecology. 1986; 67(5):1167-1179. http://dx.doi.org/10.2307/1938672
68. Vidy G. Estuarine and mangrove systems and the nursery concept: which is which? The case of the Sine Saloum system (Senegal). Wetlands Ecology and Management. 8:37-51.
69. Weinstein MP, Weiss SL, Walters MF. Multiple determinants of community structure in shallow marsh habitats, Cape Fear River Estuary, North Carolina, USA. Marine Biology. 1980-2000; 58:227-243.
70. West RJ, King RJ. Marine, brackish, and freshwater fish communities in vegetated and bare shallows of an Australian coastal river. Estuaries. 1996; 19:31-41.
71. Whitfield AK. Ichthyofaunal assemblages in estuaries: a South African case study. Reviews in Fish Biology and Fisheries. 1999; 9:151-186.
72. Young GC, Potter IC, Hyndes GA, de Lestang S. The ichthyofauna of an intermittently open estuary: implications of bar breaching and low salinities on faunal composition. Estuarine, Coastal and Shelf Science. 1997; 45:53-68. http://dx.doi.org/10.1006/ecss.1996.0165
73. Zimmerman RJ, Minello TJ. Densities of Penaeus aztecus, Penaeus setiferus and other natant macrofauna in a Texas salt marsh. Estuaries. 1984; 7:421-433.
74. Zuur AF, Elena NI, Chris SE. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution. 2010; 1:3-14.