

Structure and diversity of fish communities in the Hairtail Protected Area of the East China Sea

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Abstract. The data of the Hairtail Protected Area in the East China Sea (ECS) are based according to the accumulated survey data of two seasons trawl, spring and autumn of 2012 and 2013. In results, we were able to identify of 138 kinds of fish species consisting of 17 orders and 57 families which belong to Chondrichthyes (2 taxa) and Osteichthyes (136 taxa). The total number of species in autumn 2012 and 2013 were 95 and 82, respectively. In addition, the total number of species in spring 2012 and 2013 were 67 and 74, respectively. The species with index of relative importance (IRI) greater than 500 were defined as dominant species, a total of 11 species in spring-autumn (2012-2013), which are: Small snakehead (*Channa asiatica*), Branded goby (*Chaeturichthys stigmatias*), Small yellow croaker (*Pseudosciaena polyactis*), Bombay duck (*Harpadon nehereus*), Largehead hairtail (*Trichiurus haumela*), Silver croaker (*Pennahia argentata*), Skinnycheek lanternfish (*Benthosema pterotum*), Vertical striped cardinalfish (*Apogonichthys lineatus*), Mi-iuy croaker (*Miichthys miiuy*), Japanese anchovy (*Engraulis japonicus*), (*Odontamblyopus rubicundus*) and each species are dominant only one seasons except 5 species which is dominant in both seasons annually. Abundance-Biomass Comparison (ABC) curves of the Hairtail Protected Area (HPA) fishes according to the two seasons' fish communities showed that the abundance curve was always above (upper) the biomass curve of each year, indicating that the species composition was less diverse, the species are small size, large abundance, quick sexual maturity and short lifetime (r strategy) and the community structure tended to be unstable.

Key Words: fisheries assessment, species composition, abundance, biomass, seasons trawl.

Introduction. The protecting area is located in the East Coast of China Sea where the depth of water is ranged about 10 ~ 80 meters. In addition, the geographical coordinates is 28°30' ~ 30°30'N and 121°50' ~ 123°40'E. The Hairtail Protected Area (HPA) is around 22,500 square kilometers. In Figure 1, the core zone in the protecting area is plotted in red which can be seen in X3 (30°30'N, 123°10'E), X18 (29°00'N, 122°35'E), X23 (28°30'N, 122°10'E), X24 (28°30'N, 122°30'E), X19 (29°00'N, 122°55'), and X4 (30°30'N, 123°30'E).

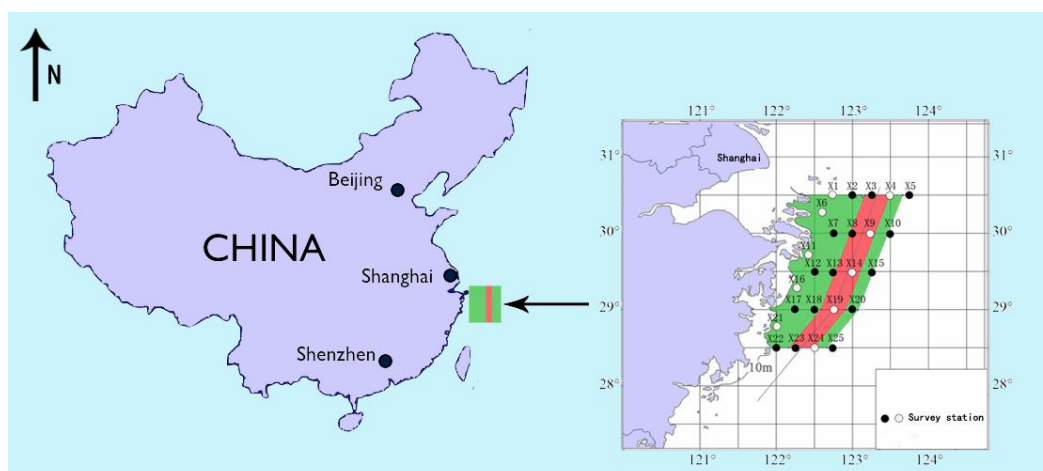


Figure 1. The survey station of Hairtail Protected Area (HPA).

Moreover, the core zone is about 7,200 square kilometers where as the outer zone which also considered as the experimental area is about 15,300 square kilometers. Therefore, the HPA was set up by the Ministry of Agriculture of China on December 2008 with 22,500 square kilometers as a result of total sea area from the inner to outer zone of the protected area. A total of 44 species and some others are collected from within the protected area. These fishes are commercially important and highly targeted as well in the conservation area. For example, these fishes include hairtail (*Trichiurus haumela*), large yellow croaker (*Larimichthys crocea*), small yellow croaker (*Larimichthys polyactis*), Atlantic mackerel (*Scomber scombrus*), scad (*Decapterus maruadsi*), white pomfret (*Pampus argenteus*), elongate ilisha (*Ilisha elongata*), Japanese Spanish mackerel (*Scomberomorus niphonius*) and so on.

Material and Method

Sampling sites. The East China Sea (ECS) is a typical epicontinental sea and part of the western Pacific Ocean bordered by China, South Korea and Japan. It covers an area of 770,000 km² (Zheng et al 2003), of which 65% has a water depth less than 200 m. In this investigation twenty five sampling station (X1 to X25) of HPA were selected from May, November 2012 (spring and autumn) and May, November 2013 (spring and autumn), based on fishery resources of main fishing grounds in the region of the East Sea (27° 00'-31° 00'N, 121° 30' -126° 30' E) around 22,500 km² (Figure 2).

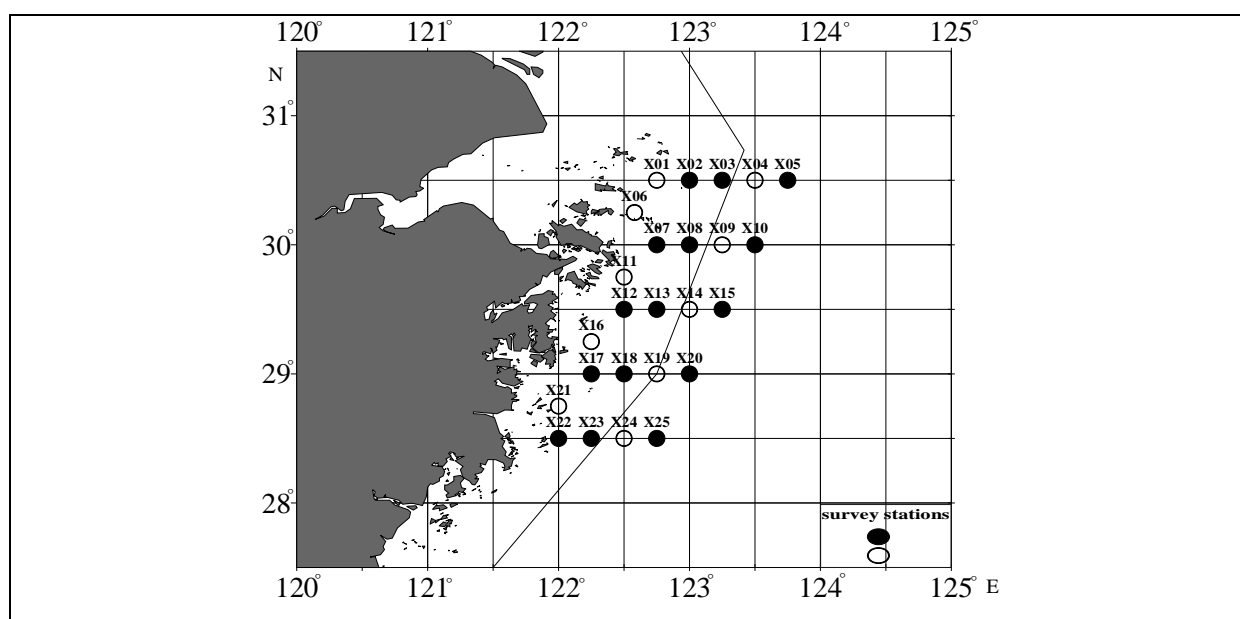


Figure 2. Location of sampling stations in the East China Sea of Hairtail Protected Area (HPA).

Sampling method. We sampled fish and measured environmental variables at each station using a boat and net. Research boat is "Zhepuyu 34256", length of the ship is 28 m, and molded breadth is 6.2 m. Molded depth is 2.6 m, tonnage is 123 t, and main motor power is 183.8 kW. We collected all fish samples at each region using a net: the circumference of bottom trawl's net mouth is about 50 m, the length of net body is 48 m, mesh size is 2.5 cm, lengths of headline and footline are 30 m and 37 m respectively. Trawling was performed for 1h at every station, at average speed of 5.5 Km/h in each zone. Samples which caught by bottom trawling were placed into boxes and the iced cabin, then species were identified, weight and body length measured, and some other common measurements were completed in laboratory using electronic weighing scales with a precision of 0.1 g and a ruler with an accuracy of 1 mm.

Data analysis. In this paper, fish and environment data were evaluated by the

univariate and multivariate methods. The index of relative abundance of fish species was the Capture Per Unit of Effort (CPUE) in terms of number of individuals and biomass. The dominant species was calculated by the Index of Relative Importance (IRI) (Pinkas et al 1971) with this formula: $IRI = (N\% + W\%) F$

N = Total number of individuals of all species (%), W = weight of a species as a percentage of the total weight of all species, F = frequency of a species that appears in the station.

Abundance- biomass comparison curves (ABC curves) based on abundance and biomass of species allow viewing if communities are dominated by small individuals or individuals of high body mass.

Additionally, the sampling stations we used the software SURFER8 to make maps. The ABC curves were performed using the PRIMER5™ (Plymouth Routines in Multivariate Ecological Research, Plymouth, UK). We calculated all the data by EXCEL software.

Results and Discussion

Species composition. According to the survey analysis in the HPA a total of 138 kinds of fishes (species) in spring–autumn consisting of 17 orders and 57 families were identified which belong to Chondrichthyes (2 taxa) and Osteichthyes (136 taxa), with the different seasons, we have fish species number autumn 2012 (95 species) > autumn 2013 (82 species) > spring 2013 (74 species) > spring 2012 (67 species). Two kinds of cartilaginous fish belonging to 2 orders (Rajiformes and Myliobatiformes), two families (Dasyatidae, Rajidae); like Ocellate spot skate (*Okamejei kenojei*) and Whip stingray (*Dasyatis akajei*); 138 species of hard bony fish belonging to 15 orders, 57 families; Perciformes have the most species 57 kinds, followed by Pleuronectiformes 23 kinds, then Anguilliformes with 12 kinds, Scorpaeniformes and Tetraodontiformes are 9 kinds, Clupeiformes are 8 kinds, Gadiformes, Syngnathiformes, Aulopiformes, Ophidiiformes and Lophiiformes are 3 kinds, Zeiformes, Myctophiformes, Siluriformes, and Gasterosteiformes are one kinds (Table 1).

Table 1
List of fish species in the catches of the Hairtail Protected Area in the ECS (spring–autumn)

<i>Phylum</i>	<i>Order</i>	<i>Family number</i>	<i>Species number</i>
Osteichthyes	Perciformes	20	57
	Pleuronectiformes	5	22
	Anguilliformes	6	12
	Scorpaeniformes	6	9
	Tetraodontiformes	3	9
	Clupeiformes	2	8
	Gadiformes	2	3
	Syngnathiformes	2	3
	Aulopiformes	1	3
	Ophidiiformes	1	3
	Lophiiformes	3	3
	Zeiformes	1	1
	Myctophiformes	1	1
	Siluriformes,	1	1
	Gasterosteiformes	1	1
Chondrichthyes	Rajiformes	1	1
	Myliobatiformes	1	1
Total	17	57	138

The dominant species. The index of relative importance (IRI) considering study the

number of individual species, biomass composition, frequency of a species that appears in the area and other information, has been widely used to study feeding ecology and dominant species composition of fish. Based on the size of the index, was determined the importance of fish species in the community. IRI values greater than 500 are the dominant species; IRI value of 100–500 common species; IRI value of 10–100 for the general kinds, IRI value from 1–10 between the rare species and IRI value less than 1 for the rare species. Table 2 shows the IRI of the HPA in the ECS during spring and autumn (2012–2013) of the dominant species.

Table 2

IRI of the Hairtail Protected Area in the ECS during spring and autumn (2012–2013) of the dominant species

<i>Species</i>	<i>W%</i>	<i>N%</i>	<i>F%</i>	<i>IRI</i>
Spring (2012)				
<i>Chaeturichthys stigmatias</i>	17.5	26.4	84	3692.3
<i>Channa asiatica</i>	4.8	28.5	36	1196.2
<i>Harpadon nehereus</i>	10.5	3.5	68	951.7
<i>Apogonichthys lineatus</i>	15.7	6.0	40	870.5
<i>Trichiurus haumela</i>	3.6	6.3	64	634.4
<i>Engraulis japonicus</i>	0.5	9.2	56	544.4
Autumn (2012)				
<i>Channa asiatica</i>	3.8	65.3	60	4145.3
<i>Apogonichthys lineatus</i>	6.9	13.4	72	1460.1
<i>Harpadon nehereus</i>	14.8	2.2	72	1224.5
<i>Chaeturichthys stigmatias</i>	4.8	6.5	64	723.5
Spring (2013)				
<i>Chaeturichthys stigmatias</i>	6.7	40.7	88	4175.2
<i>Pseudosciaena polyactis</i>	9.7	6.0	64	1003.1
<i>Apogonichthys lineatus</i>	9.0	6.2	48	731.5
<i>Odontamblyopus rubicundus</i>	6.5	9.5	40	636.9
<i>Engraulis japonicus</i>	2.9	6.9	56	546.0
<i>Harpadon nehereus</i>	7.4	1.6	60	537.3
Autumn (2013)				
<i>Benthoosema pterotum</i>	1.6	38.9	48	1946.3
<i>Apogon lineatus</i>	9.5	24.6	52	1776.8
<i>Miichthys miiuy</i>	21.0	0.5	56	1203.8
<i>Pennahia argentata</i>	10.1	4.0	56	790.5
<i>Harpadon nehereus</i>	7.1	5.6	52	657.5

W% - percentage weight, N% - percentage number of individuals, F% - percentage frequency.

IRI \geq 500 represent the dominant species, there are 11 species: small snakehead (*Channa asiatica*), branded goby (*Chaeturichthys stigmatias*), small yellow croaker (*Pseudosciaena polyactis*), Bombay duck (*Harpadon nehereus*), largehead hairtail (*Trichiurus haumela*), silver croaker (*Pennahia argentata*), skinnycheek lanternfish (*Benthoosema pterotum*), Verticalstriped cardinalfish (*Apogonichthys lineatus*), Mi-iuy croaker (*Miichthys miiuy*), Japanese anchovy (*Engraulis japonicus*), and *Odontamblyopus rubicundus*. Divided according to the different seasons, the analysis revealed that each species are dominant only one seasons, except 5 species: *Harpadon nehereus* and *Apogonichthys lineatus* appeared in spring and autumn of each year, *Chaeturichthys stigmatias* which appeared in spring (2012-2013) and autumn (2012), *Channa asiatica* and *Engraulis japonicus* which appeared in spring (2012-2013) and autumn 2012.

Index of abundance-biomass comparison (ABC curves). The comparison of the cumulative frequency or dominance curves (ABC curves) based on abundance and biomass of species allow viewing if communities are dominated by small individuals or

individuals of high body mass. For this purpose, distributions in abundance and biomass can be presented on the same graph (Warwick 1986; Warwick et al 1987; Warwick & Clarke 1991). The Abundance-Biomass comparison curves based on the principle that at steady state, an environment is healthy, when biomass curve is above the abundance curve; the assembly is dominated by species with K strategy (large size, moderate abundance, long life, slow growth).

Conversely, an environment is disturbed, when the curve of abundance is above that of the biomass, the assembly is dominated by species with r strategy (small size, large abundance, short lifetime, quick sexual maturity, larvae dispersed all year).

The graphical representation of abundance-biomass comparison curves allows establishing eventual temporal evolution and to know if individuals of the dominant species are small observed and high abundance or high observed size and low abundance. In the HPA during the two seasons, the abundance curve is above the biomass curve in spring-autumn of each year, indicating a strong dominance of species whose individuals are numerous and low body mass (Figures 3 & 4).

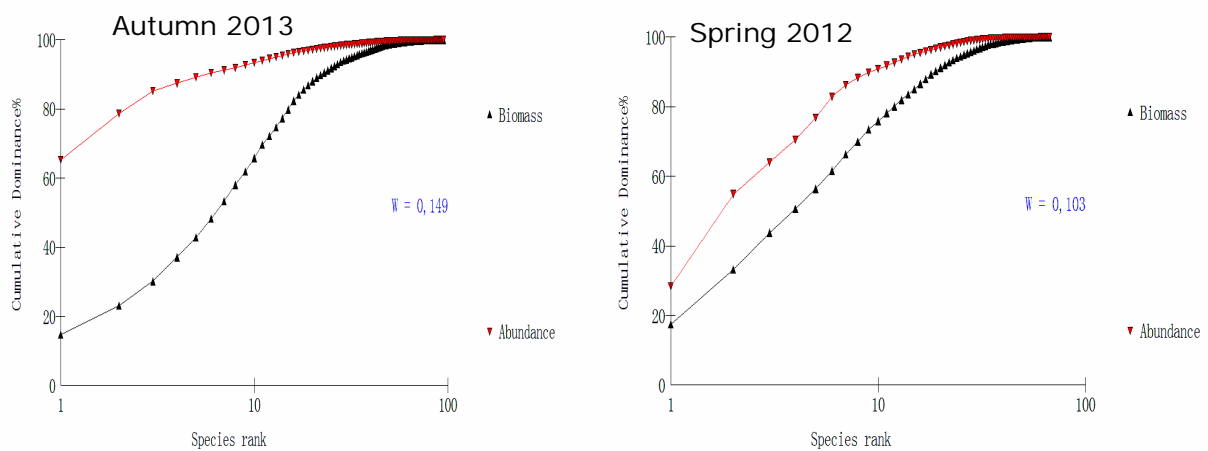


Figure 3. ABC curves and W value of fishery in Hairtail Protected Area in spring–autumn (2012).

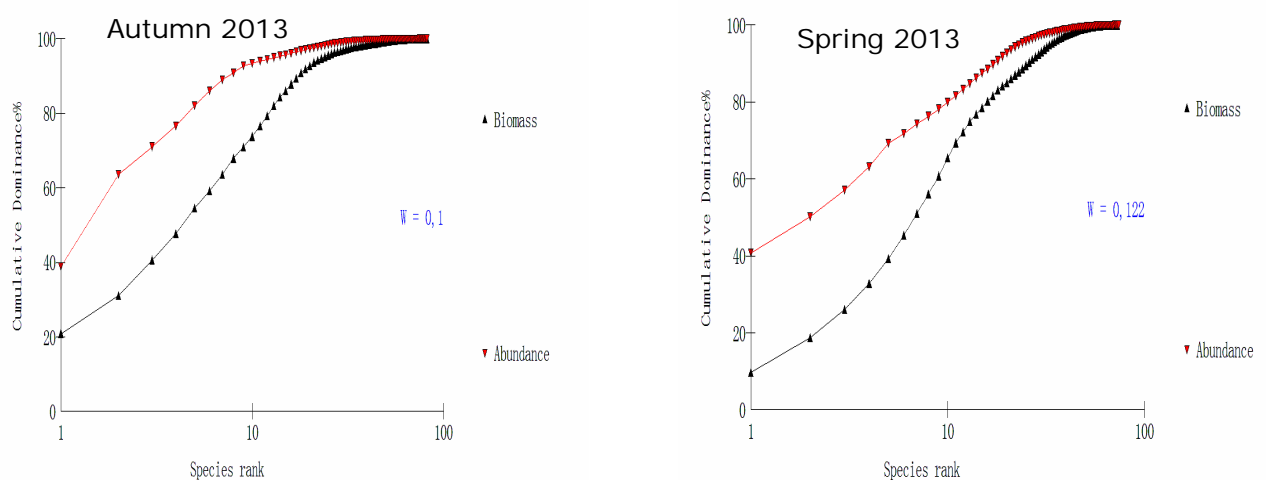


Figure 4. ABC curves and W value of fishery in Hairtail Protected Area in spring–autumn (2013).

According to the different seasons (spring-autumn) the HPA is characterized by dominant species whose fish individuals are more numerous in proportion and the community is essentially composed of small fish individuals, indicating that the fish community structure in this area tends to be unstable (r strategy). The W value of each season was positive and $0.1 \leq W \leq 0.149$, lowest in autumn 2013 and highest in autumn 2012. The cumulative dominance % annual abundance of each assembly varies during the two years analyzed without showing trend.

Discussion

Changes in fish composition. The fishery survey station located in the HPA of the ECS is one of the most important fishery resources in abundance and biomass of fish, and there are many economic fish spawning grounds and juvenile feeding grounds. According to the bottom trawling data, two years (2012-2013) surveys were sampled in two seasons (spring-autumn). Results of the survey give us a total of 138 taxa throughout the two years; although some stations are not sampled i.e. four stations in 2012 and seven stations in 2013, because of climate problems or environmental factors and we didn't use the trawling net for these regions, thus we observed the most variety of fish appear during autumn of each years with 95 kinds in 2012 and 82 kinds in 2013. Contrary to the autumn, the fish composition is decreased annually in spring (2012-2013). Compared to the investment report of the department of fishery resources of Zhejiang Marine Fishery Research Institute (ZMFRI 2011) in the HPA in summer and autumn, 197 species were identified in 2011 greater than two years surveys in the same area in autumn-spring. This may be due to the anthropological factors, the increase in the fishing effort and overfishing phenomenon, adverse consequences of environmental changes brought about, a significant decline of some species fishery production and even rare species, to the migration of the species in other areas, but also with the relevant sampling methods and sampling time and so on.

In addition, fishery species composition in autumn (2012-2013) has the most important fish species than spring in the HPA which can be explained by the closure of the fishery in summer and allow species to have a good biological rest to facilitate the reproduction of the species and increase the abundance and biomass in autumn, but also the waters of southern Zhejiang coastal upwelling exists throughout the year, the upwelling of nutrient-rich bottom increase the number of fish species and the temperature decrease in autumn.

Changes of dominant species. The survey in the HPA found that the IRI values greater than 500 fish were the dominant species. There are 11 kinds, according to the different seasons the dominant species in spring and autumn 2012 have 82.9% of the total biomass, in 2013 (spring-autumn) have 92.6% of the total biomass. The analysis revealed that each species are dominant only one or two seasons of each year except 2 species which are dominant in 2012-2013 during spring-autumn such as *Harpadon nehereus* and *Apogonichthys lineatus*. Based on the IRI, changes of dominant species were greater in 2012 than in 2013 with species as *Channa asiatica*, *Pseudosciaena polyactis*, *Trichiurus haumela*, *Chaeturichthys stigmatias*, *Apogonichthys lineatus*, *Engraulis japonicus* and *Harpadon nehereus* have a significant IRI. Because of the surge in fishing intensity a part of fisheries resources tend to their decline. Referring to history, the dominant species of high economic value have changed dramatically in the 1960s. The dominant species such as: *Trichiurus haumela*, *Larimichthys crocea*, *Pennahia argentata* etc. began to decline in 1980s and *Scomber scombrus*, *Pampus argenteus* and other large pelagic fish resources increased significantly at the end of 1990s. However, *Engraulis japonicus*, *Bregmaceros maccllellandii*, and other low-value fish became the dominant species (Luzhan Hui et al 2009; Zhu et al 1994). The survey of ZMFRI in 2011 showed that three species are dominant during autumn such as *Chaeturichthys stigmatias*, *Harpadon nehereus*, and *Apogonichthys lineatus*. Compared to the seasonal changes of dominant species, we can see a significant increase in autumn of each year than in spring. Reasons may be due to the summer closed fishing area in the ECS between July 1st and August 31st each year

(Cheng et al 2007). Therefore, the fisheries resources have increased significantly, reflecting the incubation period of the effect of the conservation of fishing resources is obvious.

Changes in community stability. ABC curves showed that the HPA fishes according to the two seasons fish communities subjected various interferences, the community structure tended to be unstable. The abundance-biomass graph during the two seasons (spring–autumn), showed that the abundance curve is above (upper) the biomass curve of each year, indicating that the species composition was less diverse, the species are small size, large abundance, quick sexual maturity and short lifetime (r strategy) would correspond to a system adapted to the existence of disturbances. Disturbances are defined here by the mortality due to hydroclimatic environment and human activities (pollution, overexploitation) (Blanchard & Boucher 2001), but also by the fishing pressure on demersal fish stocks is generally maximum for large individuals of K strategy. Thus, the proportion of r strategy species should theoretically increase with the intensity of the exploitation of the K strategy species in spring and autumn (Jennings & Kaiser 1998). Moreover, the time scale of the study of two years, it is noted that in the HPA there is no changes in the proportion of individuals in each season and the main types of communities are basically composed of a relatively small individual fish. This may be due to the sampling method, or the trawl mesh used.

Conclusions. This study on the HPA has allowed us to note that during the two years (2012-2013) and two seasons (spring-autumn) species composition decreases. Through the analysis, it is clear that abundance is greater than the biomass which means catching small species is high but also the size and weight of the fish decreases. Therefore, HPA must be taken into account in its various aspects, because associated with the influences of environmental factors that insert into an overall mutation, they will affect without none doubt the community of fish in the HPA. It is the reason why we encourage other more specific studies to be conducted on the influences of environmental factors on the structure and spatial dynamics of the community of species in the HPA to feed this reflection.

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