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SIX YEARS OF MONITORING OF FISH ASSEMBLAGES IN SHALLOW BOTTOMS AROUND THE EMBIEZ ISLANDS AND CAP SICIÉ (FRENCH MEDITERRANEAN SEA)

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ABSTRACT. – Located between the Port-Cros and the Calanques National Parks, the Embiez Islands and the Cap Sicié massif have important natural heritage conservation challenges highlighted by the establishment of three Natura 2000 sites. Coastal ecosystems and associated fish assemblages are subject to various anthropogenic pressures. The fish assemblages of shallow bottoms have been surveyed over the 2012-2017 period by visual censuses in 7 sites, twice a year, in order to assess their structure and temporal changes. The results obtained during these 6 years of monitoring showed that the fish assemblages in this area were diversified and abundant but dominated by a few species of herbivores, mesocarnivores and planktivores. Fish species belonging to higher trophic levels were rare. The fish assemblages of this area differed from those observed in marine protected areas, where appropriate management measures of fishing activities are applied. Fish monitoring following an assemblage approach allowed discussing the efficiency of marine protected area management measures to sustain good functional ecosystem services.

INTRODUCTION

Fish assemblages play a crucial role in the functioning of Mediterranean coastal ecosystems (Sala *et al*. 2012). The Mediterranean Sea has long been overexploited (Vasilakopoulos *et al*. 2014). The most diverse and productive fish assemblages are found in shallow rocky bottoms between the surface and 20 m depth. These environments are the most impacted by human activities. Despite the increasing number of Marine Protected Areas (MPAs), a very small percentage of the coastline is actually efficiently protected (Meinesz & Blanfuné 2015). Consequently, most of these habitats are not subject to specific regulations to protect fish assemblages. Currently, most of the areas considered as MPAs in Europe are under Natura 2000 site classification. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive (92/43/CEE). Along the French Mediterranean coasts, these sites do not usually include strictly protected zones neither regulatory measures of potentially impacting fishing activities (Guidetti *et al*. 2019, Meinesz & Blanfuné 2015).

At West of the City of Toulon (Provence, France), marine areas around the Embiez Islands and the Cap Sicié are managed by three Natura 2000 sites with no regulation measures for fishing activities. Toulon area has a large population, close to 440,000 inhabitants, to which is added the flow of tourists in the summer period. Less than 50 km from either side of Toulon, there are two National Parks including no-take marine reserves. Located to the west, the Calanques National Park was created in 2012 and the benefits of the management measures for the marine environment are becoming conspicuous. To the east of Toulon, Port-Cros National Park, created in 1963, is one of the oldest and well enforced MPA in the Mediterranean Sea, with a multi-use management that generates a strong reserve effect (Astruch *et al*. 2018). Coastal ecosystems and associated fish assemblages are subject to various anthropogenic pressures. The Toulon area is subject to high fishing pressure by both professional and recreational fishermen (including spearfishing and handline fishing). The aim of this study was to perform the first characterization of the fish assemblages present on shallow rocky bottoms of the Natura 2000 sites around the Embiez Islands and Cap Sicié, and to compare them to those encountered in well-established Mediterranean MPAs.

MATERIAL AND METHODS

Study site: The study area is located to the west of Toulon (France, north-western Mediterranean) and extends on three Natura 2000 sites (Fig. 1). Habitat structure is highly diversified with large proportions of seagrass beds (*Posidonia oceanica* (Linnaeus) Delile) and rocky bottoms, and to a lesser extent coralligenous habitats and sandy bottoms.

Visual censuses and sampling design: Data sets were collected by underwater visual censuses (UVC) on transects according to the method developed by Harmelin-Vivien & Harmelin

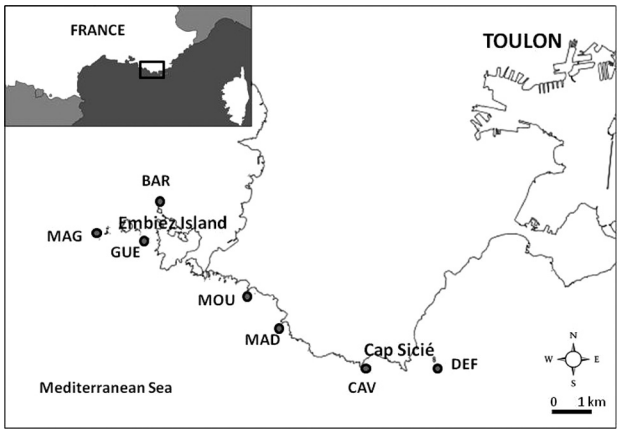

Fig. 1. – Map of study sites west of the City of Toulon. BAR: Basse Renette, MAG: Magons, GUE: Guenaud, MOU: Mouret, MAD: Mal Dormi, CAV: Cap Vieux, DEF: Deux Frères.

(1975) and Harmelin-Vivien *et al*. (1985), and usually used in most MPAs in the north-western Mediterranean (Harmelin-Vivien & Harmelin 2013). Seven sampling sites were considered in the present study. Fish counts were carried out during spring and autumn on a six-year period (2012-2017). At each site, fish assemblages were assessed on 8 transects of 25 m long and 5 m wide constituting replicates. All fish species, their abundance and size (cm) were recorded. All sites were chosen for their similarity in terms of type of substrates, mainly represented by rocky bottoms and seagrass beds to a lesser extent. Transects were placed between 9 to 16 m depth. Habitat characteristics were recorded on each transect, measured as visual estimates of the cover percentages of rock, boulders, rocky slab, sand, *Posidonia oceanica* bed and coralligenous concretions.

Data analysis: A global data analysis was performed combining all data sets (all years and seasons combined). Fish biomass was obtained from the estimation of wet mass of each individual on the basis of size/mass relationships available in FishBase (Froese & Pauly 2019). Density and abundance were processed for the whole assemblage (all species). Reduced density and abundance were calculated excluding planktivorous species (Centracanthidae, Pomacentridae and the sparid *Boops boops* (Linnaeus, 1758)). Density and biomass were also calculated for target species based on a list of 26 species as done by Astruch *et al*. (2018). Target species mainly belonged to the following fish families: Congridae, Gadidae, Labridae, Moronidae, Mullidae, Sciaenidae, Scorpaenidae, Serranidae, Sparidae and Sphyraenidae. Fish species were classified into 6 trophic groups according to their diet, following Astruch *et al*. (2018). Data being not normalized, differences in mean values were tested with non-parametric Kruskal-Wallis tests.

RESULTS

During these 6 years of monitoring, 48 taxa of coastal fishes have been observed in the study area (Table I). Total number of species encountered per site varied between 29 at Mal Dormi and 40 at Deux Frères (Table II). Mean point diversity in the area was 9.8 species/transect and varied significantly among sites (Kruskal-Wallis test, $p < 0.0001$) with the highest values at Deux Frères and Magnons, and the lowest at Basse Renette. Mean density (for all species combined) for the study area was 211.5 ind/100 m² and varied significantly among sites (Kruskal-Wallis test, $p < 0.0001$) with the maximum value at Deux Frères and the lowest value at Guénaud,

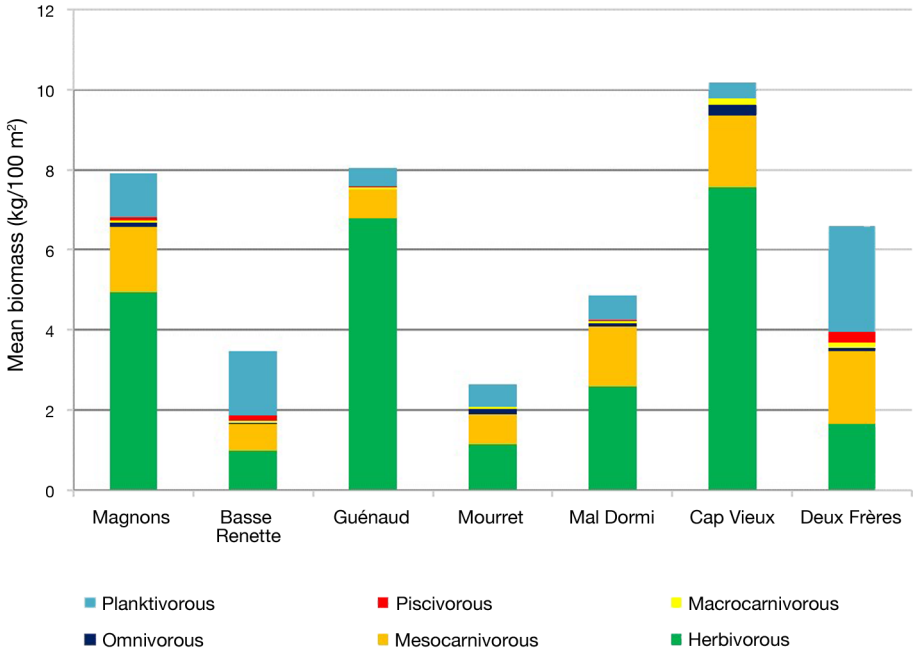

Fig. 2. – Mean biomass (kg/100 m²) of fish assemblages in each site and its distribution between the 6 trophic groups considered.

Table I. – List of the fish species recorded in the study sites located west of the City of Toulon with indication of their exploitation status by fisheries (target or no-target species) and trophic category (Species nomenclature based on International Commission on Zoological Nomenclature).

Families	Species	Target species	Trophic category
Apogonidae	*Apogon imberbis*		Planktivorous
Carangidae	*Seriola dumerili*	X	Piscivorous
	Trachurus trachurus		Macrocarnivorous
Centracanthidae	*Spicara sp.*		Planktivorous
Gadidae	*Phycis phycis*	X	Mesocarnivorous
Labridae	*Coris julis*	X	Mesocarnivorous
	Labrus merula	X	Mesocarnivorous
	Labrus mixtus	X	Mesocarnivorous
	Labrus viridis	X	Mesocarnivorous
	Symphodus cinereus		Mesocarnivorous
	Symphodus doderleini		Mesocarnivorous
	Symphodus mediterraneus	X	Mesocarnivorous
	Symphodus melanocercus		Mesocarnivorous
	Symphodus melops		Mesocarnivorous
	Symphodus ocellatus		Mesocarnivorous
	Symphodus roissali		Mesocarnivorous
	Symphodus rostratus		Mesocarnivorous
	Symphodus tinca	X	Mesocarnivorous
	Thalassoma pavo		Mesocarnivorous
Mugilidae	*Mugilidae sp.*		Omnivorous
Mullidae	*Mullus surmuletus*	X	Mesocarnivorous
Muraenidae	*Muraena helena*	X	Macrocarnivorous
Pomacentridae	*Chromis chromis*		Planktivorous
Sciaenidae	*Sciaena umbra*	X	Mesocarnivorous
Scorpaenidae	*Scorpaena maderensis*		Macrocarnivorous
	Scorpaena notata		Macrocarnivorous
	Scorpaena porcus		Macrocarnivorous
	Scorpaena scrofa	X	Piscivorous
Serranidae	*Anthias anthias*		Planktivorous
	Epinephelus costae	X	Piscivorous
	Epinephelus marginatus	X	Piscivorous
	Serranus cabrilla	X	Macrocarnivorous
	Serranus hepatus		Macrocarnivorous
	Serranus scriba	X	Macrocarnivorous
Sparidae	*Boops boops*		Planktivorous
	Dentex dentex	X	Piscivorous
	Diplodus annularis		Mesocarnivorous
	Diplodus cervinus	X	Mesocarnivorous
	Diplodus puntazzo	X	Omnivorous
	Diplodus sargus	X	Mesocarnivorous
	Diplodus vulgaris	X	Mesocarnivorous
	Oblada melanura		Omnivorous
	Pagellus acarne	X	Macrocarnivorous
	Pagrus pagrus	X	Macrocarnivorous
	Sarpa salpa		Herbivorous
	Sparus aurata	X	Mesocarnivorous
	Spondyliosoma cantharus	X	Mesocarnivorous
Sphyraenidae	*Sphyraena viridensis*	X	Piscivorous

with respectively 291.7 ind/100 m^2 and 153.3 ind/100 m^2. Among the 48 species observed, 5 of them represented more than 85 % of the total density. The most abundant species were *Chromis chromis* (Linnaeus, 1758), *Coris julis* (Linnaeus, 1758), *Sarpa salpa* (Linnaeus, 1758), *Spicara* sp. and *Boops boops*. When we excluded planktivorous species, the mean reduced density was 60.8 ind/100 m^2 in the study area. For target species (26 species out of the 48 observed in the study area) the mean density was 40.9 ind/100 m^2 and the mean biomass was 1.41 kg/100 m^2.

The mean biomass for all sites was 6.24 kg/100 m^2 when all species were considered and 5.19 kg/100 m^2 for the reduced biomass (without planktivorous species). Fish assemblages were dominated by herbivorous species which contributed mainly to the significant fluctuation of biomass between sites (Kruskal-Wallis test, $p < 0.0001$) (Fig. 2). *Sarpa salpa* was the only herbivorous species recorded in the study area and accounted for 59 % of the mean total biomass. Piscivorous fishes were represented by 6 species and accounted for 1.25 % of the biomass. Among the carnivorous species observed in the area, two serranids, the dusky grouper *Epinephelus marginatus* (Lowe, 1834) and *E. costae* (Steindachner, 1878), and the Sciaenidae *Sciaena umbra* (Linnaeus, 1758) are concerned by a moratorium banning angling and spearfishing. During this six-year study, 20 dusky groupers were observed. Among them, several individuals were probably observed several times during the different counting campaigns, which lowered the actual number of groupers present in this area. Only one individual of *E. costae* was observed. A total of 17 individuals of *Sciaena umbra* was observed in only 2 out of the 7 sites investigated: 16 individuals were observed at Cap Vieux during the different UVC campaigns and 1 individual was observed at Mouret.

Table II. – Characteristics of fish assemblages in the study sites located west of Toulon and in well-established Mediterranean MPAs.

	Alpha diversity per site	Point diversity per transect	Mean density (all species) (ind/100 m²)	Mean reduced density (ind/100 m²)	Mean density (Target species) (ind/100 m²)	Mean biomass (All species) (kg/100 m²)	Mean reduced biomass (kg/100 m²)	Mean biomass (Target species) (kg/100 m²)
Magnons	34	11.3	224.0	61.9	39.8	7.91	6.83	1.82
Basse Renette	34	8.6	222.3	29.9	20.9	3.48	1.84	0.83
Guénaud	31	9.2	153.3	45.4	28.8	8.04	7.59	0.76
Mourret	31	9.2	176.3	69.1	42.4	2.64	2.07	0.77
Mal Dormi	29	10.5	211.9	72.2	51.7	4.86	4.25	1.52
Cap Vieux	33	8.3	200.9	87.3	57.8	10.19	9.78	1.89
Deux Frères	40	12.1	291.7	60.1	45.2	6.60	3.97	2.22
Total area	**48**	**9.8**	**211.5**	**60.8**	**40.9**	**6.24**	**5.19**	**1.41**
BIOMEX (1) Inside MPA		10.1-14.1		48.9-90.9			3.6-22.6	
BIOMEX Outside MPA		7.7-13.9		25.2-78.6			0.56-3.2	
Port-Cros (2) (Rocky reefs 5-15 m depth)	23-34	10.7-16.7	158.4		37.5	6.58		4.74

(1) Harmelin-Vivien *et al.* 2008
(2) Astruch *et al.* 2018

DISCUSSION

Substrate type and depth are generally the main factors affecting fish assemblage composition (García-Charton & Pérez-Ruzafa 2001). Although all sites were chosen for their similarity in terms of substrate type and depth, some habitat differences might generate inter-sites variations in the fish assemblages' parameters recorded in the study area. Globally, West Toulon fish assemblages were well diversified with a high alpha diversity and a point diversity slightly lower than those encountered in well-established MPAs in the north-western Mediterranean Sea, such as around the Port-Cros archipelago (Astruch *et al*. 2018) and in the six MPAs studied in the BIOMEX project (Harmelin-Vivien *et al*. 2008). Values of mean density and mean biomass for all species combined and excluding planktivorous species in West Toulon sites were similar to those encountered in other well-established MPAs.

Pyramids of biomass of fish assemblages in West Toulon sites were dominated by herbivorous fishes (*Sarpa salpa*), while highest trophic level fishes including piscivorous species were scarce. On the contrary, the reverse situation with biomass pyramids of fishes dominated by high trophic level (macrocarnivores and piscivores) were encountered around Port-Cros Island MPA in similar conditions of habitat and depth (Astruch *et al*. 2018) and in other well-established reserves, approaching a pristine situation (Sala *et al*. 2012).

Target species were poorly represented in term of biomass in West Toulon area and among them the carnivorous species were particularly under-represented. Fish assemblages were largely dominated by species without economic interest in terms of density and biomass. *S. salpa* seemed to benefit from the low predation pressure to proliferate. This situation can have consequences on the whole ecosystem induced by a possible overgrazing of macroalgae (Pinnegar *et al*. 2000, Guidetti 2007, Vergés *et al*. 2009). In contrast, around Port-Cros Island, target species represented a high proportion of the total fish biomass, resulting from an effective management (Astruch *et al*. 2018). The strong differences observed between these two geographically close areas raises the question: does the West Toulon area have suitable habitats for fish assemblages like those of Port-Cros? No scientific data allows estimating the previous state of fish assemblages in this area. Fortunately, the film archive "*Par 18 m de fond*" was shot around the Embiez Islands in 1942. This film highlights that less than 80 years ago, fish assemblages in this area have seemed to be very productive and dominated by piscivorous species. The images shot in this film contrasted drastically with the current situation. In a few decades, fishing activities have sharply increased in this area, mainly for recreational fishing (angling and spear-fishing) (Font & Lloret 2014). Fish assemblages were also affected by the loss of habitats (particularly nurseries) and diverse anthropogenic pressures (pollution, over-frequentation, tourism activities, noise, etc.). This study highlighted that fish assemblages in the West of Toulon appeared to be disturbed and likely affected by fishing activities although the area is classified Natura 2000 site. In addition, even species concerned by special regulations such as groupers or *Sciaena umbra* were rare

and exhibited escape behavior, which suggested illegal spearfishing activities and poaching. Natura 2000 sites are designated to protect a certain number of habitats but not specifically to protect coastal fish assemblages. Without any particular regulation of fishing activities, Natura 2000 sites do not effectively protect fish assemblages and target species, and consequently ecosystem-wide conservation (Meinesz & Blanfuné 2015, Guidetti *et al*. 2019). This area needs thus more effective management measures, such as the implementation of no-take areas, to protect the fish assemblages, which play a key role in the functioning of ecosystems. This would complement and reinforce the benefits of the actions supported by N2000.

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