# Management Measures for Fisheries in the Marine Protected Area of the National Marine Park of Zakynthos

## Final Report

Dept. of Marine Science, University of Aegean

MedPAN North Project

National Marine Park of Zakynthos

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FRONT PAGE PHOTOS: DIVING TEAM

**MYTILENE 2013**

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# TABLE OF CONTENTS

# I. ABSTRACT

This study contributes to a better understanding of the effects of small scale artisanal fisheries on fish stock status and overall marine biodiversity, both within the limits of the MPA of NMPZ, as well as in the North and Eastern coasts of Zakynthos Island. It also provides insights regarding the effectiveness of management measures, fishermen attitudes, preferences and socio-economic profile. Given that fisheries activities and fish stock conservation is a complex issue encompassing both ecological and socioeconomic aspects, we adopted several methodological approaches in order to address all the main parameters involved. The study includes sampling areas located both inside and outside the MPA. We applied underwater visual census to evaluate composition and status of fish assemblages, on board sampling to assess fish stocks and other parameters related to fisheries, fishermen interviews via questionnaires to collect additional ecological information and investigate socioeconomic parameters, as well as fisheries data from local authorities. The observed overexploitation status of fish populations in all studied areas, and the lack of a marine reserve effect, indicate that current management measures are not sufficient in maintaining fish stocks at a sustainable level, whilst compromising ecosystem stability and fishermen profits. The results also suggest that it is of particular importance to maintain the present legal status of recreational fisheries (i.e. total prohibition of recreational fishing within the MPA), and further increase the effectiveness of enforcement. Although the majority of local professional fishermen that fish in the MPA report a significant reduction in fish size and landings over the last years, current opinions and perceptions regarding the existance of an MPA are primarily negative. Based on our findings, a set of additional management actions are being proposed for the sustainable management of fisheries in the MPA of NMPZ.

# II. INTRODUCTION

## A. MedPAN North Project

The current research action consists part of the MedPAN North project which is co-funded by the European Regional Development Fund and includes 12 partners from 6 European countries bordering the Mediterranean (France, Greece, Italy, Malta, Slovenia and Spain). The aim of the MedPAN North project is to improve Marine Protected Areas (MPA) management effectiveness, including in the marine Natura 2000 sites and to contribute to the establishment of a network of MPAs, as part of the international commitments, and particularly the European commitments in this area. Sustainable management of fisheries in MPA's is an important component of the MedPAN North project actions in which the National Marine Park of Zakynthos (N.M.P.Z) has been involved as a partner of the project. The latter action contains three major thematic sections that for the case of N.M.P.Z. are: i) management actions for artisanal fisheries in the MPA of N.M.P.Z. , ii) management actions for recreational fisheries in the MPA of N.M.P.Z. and iii) promotion and publication actions for fisheries management in the MPA of N.M.P.Z. The Department of Marine Sciences (University of the Aegean) has been assigned to participate in these actions as an external collaborator to the N.M.P.Z. since October of 2012.

## B. Protection Measures and Fisheries

The study concerns the island of Zakynthos situated in the south-eastern part of the Ionian Sea (Western Greece). The Marine Protected Area (M.P.A) of the National Marine Park of Zakynthos (N.M.P.Z) is located at the southernmost part of the island, in the area of Laganas Bay, and comprises of a coastline of 28.7 km in length and a marine area of 89.2 $km^2$. It is characterized as a shallow bay, where the 10 m isobath is met at a distance of 3 km from the coastline, and the 50 m isobath at 6 km (NMPZ, 2008)[1].The marine area of the N.M.P.Z. is divided into three main zones (Fig 1) of different protection status and management regulations regarding both fisheries and maritime traffic. According to the zoning scheme described by the National Government Gazette 906/D/22 - 12 – 1999, and which explicitly defines the MPA of N.M.P.Z., Zone 'Ia' constitutes the entire marine protected area of Laganas Bay. This area is further subdivided into three distinct management zones, namely Zone A, Zone B and Zone C (Dimitriadis et al., 2013). Trawlers, purse seiners and all forms of recreational fishing (including spear fishing) are permanently banned within the limits of Marine Protected Area all year round. Moreover, Zone A is located at the easternmost area of Laganas Bay and covers 8.98% of the total marine area of NMPZ (including the marine area of Strofadia Islands). This is the core zone of the N.M.P.Z. receiving a maximum protection status as a no-take area for 6 months per year. The closure regime of Zone A begins in May (01/05) and ends in October (31/10). During this period fishing practices alongside with any kind of boating activity are strictly prohibited within the limits of this zone. The rest of the year (from October to May) only small scale artisanal fishing is permitted. Zone B is located at the central part of Laganas Bay covering the greatest part of the MPA (40.3% of the total marine protected area, including the marine area of Strofadia Islands). In this area, artisanal small scale fishery is allowed

[1] The marine protected area of Strofadia Islands, located 22 nautical miles south of Zakynhtos island, that is also managed by the management agency of NMPZ, is not included in the present study.

throughout the year, boating activity is allowed with a speed limit restriction of 6 knots, whereas anchoring is not permitted in this area. Zone C, which is located at the western part of Laganas Bay covers 8.3% of the total surface of the MPA, and forms the smallest protection zone in the MPA. Likewise, small scale artisanal fishing is the only acceptable form of fishing in this zone, while boating activity is permitted up to a speed limit of 6 knots. However, there are no restrictions for anchoring in this Zone. Finally, the remaining marine area of 'Ia' zone ('Ia' surface minus the surface of A, B and C zones) forms the 'Peripheral Maritime Zone' which covers 35.81% of the total surface of the MPA and follows the general restrictions that rule zone Ia. The MPA was initially established in 1999 for the protection of the loggerhead turtle *Caretta caretta*, as the area constitutes one of the most important nesting grounds for this species at a Mediterranean scale. For this reason, the management measures that are currently being applied are primarily focused at the protection of the nesting activity of *C. caretta,* and do not specifically regard other key ecosystem components, such as the presence of several important marine species and habitats.

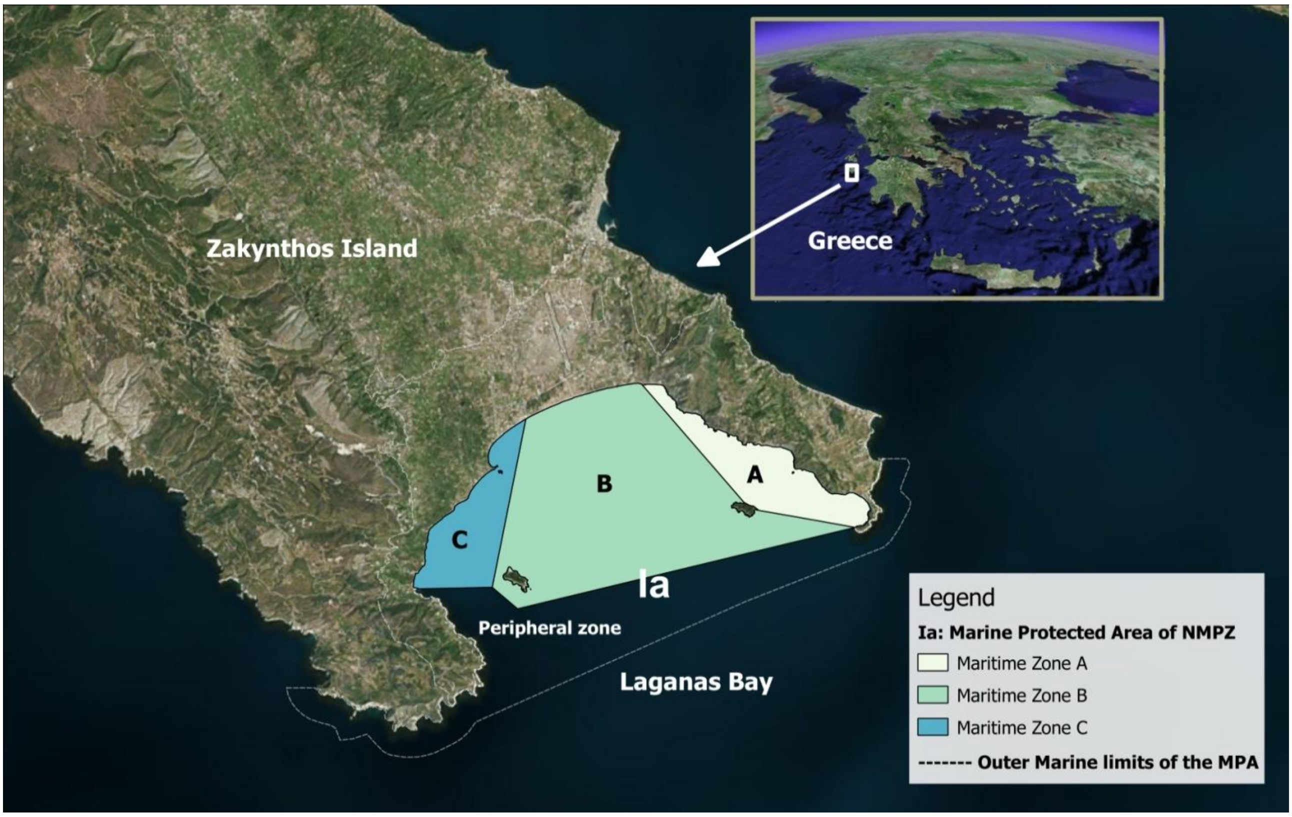



**Fig 1: MPA limits and protection zone coverage in Laganas Bay**

The MPA of N.M.P.Z has been traditionally fished for many decades before the establishment of the MPA, and hosts some of the most important fishing grounds exploited by fishermen in Zakynthos Island (Dimitriadis et al., 2013). All small scale artisanal fishermen are allowed to fish in the MPA without any constrains concerning locality or port of registry. Fishing gears, methods/techniques used in the area are in compliance with the National and International laws and fisheries regulations, but no further restrictions concerning the number of fishing vessels and/or fishermen, fishing yields and gears have been imposed by the management agency of the N.M.P.Z. Finally, surveillance of fisheries in the MPA of N.M.P.Z. is carried out by the navy park rangers with the collaboration of the local port police (marine patrols conducted by both park rangers and port police officers) and it mainly concerns the implementation of the fishing spatial restrictions (no fishing in zone A from May to October) as well as the enforcement of the regulations related to the permitted forms of fishing in the MPA (exclusion of trawlers, purse seiners and recreational fishing).

The Management Agency of the NMPZ in an effort to enhance the involvement of artisanal fishermen in decision-making and governance of the MPA has recently (2012) established a special Fisheries Committee (with participation of the NMPZ staff, the Prefecture of Zakynthos Fisheries Dept., the Dept. of Marine Sciences of the University of the Aegean, the Port Authorities and the local fishermen Association). Under this framework, it is anticipated that decisional power and sense of collaboration among all related bodies will be strengthened in order to reduce long-term conflicts (Dimitriadis et al., 2013). Moreover, this special Fisheries Committee has put forward new management options for the effective safeguarding and enforcement in the MPA. However, all the above actions of the Fisheries Committee are at an initial stage and hence the expected outcomes have not yet been reached.

## C. Fisheries Profile in the MPA of N.M.P.Z.

Fisheries profile in the MPA of N.M.P.Z. has long been a neglected aspect of research, a fact which is emphatically highlighted by the presence of the very few existing publications in this field (e.g. Armenis 2005; Mousoura, 2006; Dimitriadis et al., 2013). In an effort to address this issue, we processed the latest available data (up to 2012) provided by the Local Fisheries Department (Hellenic Ministry of Rural Development and Food) for Zakynthos Island mainly focusing in the area of the MPA of N.M.P.Z..The main findings are briefly presented below.

The artisanal fishing fleet of Zakynthos Island is currently comprised of 235 vessels in total, from which 42 fishing vessels are using reference ports located within the limits of the MPA (22% of the total), while149 are registered in reference ports located outside the MPA of N.M.P.Z. (78% of the total). Zakynthos town port hosts almost 1/4 of the total fishing fleet (49 vessels), followed by Volimes port (16.23% of the fishing fleet). For the case of MPA, 15 vessels are registered in Agios Sostis port, 13 in Lithakia port, 6 in Keri port, 6 in Porto Roma port, whereas the rest of the vessels are using other localities (without established ports). The vast majority of the vessels that comprise the fishing fleet of Zakynthos Island can be classified as small scale coastal fishing boats (97.8%) in contrast to the medium scale fishing vessels (trawlers and purse seiners) which are considerably less (4 vessels). Regarding horsepower, gross tonnage and total length of the fishing vessels that are fishing in the MPA, the mean value was calculated at 25.03HP, 2.07GT and 6.68m for each parameter, respectively. With respect to the preferred fishing gears in Zakynthos Island, the combination of nets and long lines is the most frequently employed fishing practise (97.2% of the fishing fleet). In the area of the MPA, the combined use of nets and long lines constitutes the most popular fishing method (58.62%), followed by the exclusive usage of nets (34.48%) and the exclusive usage of long lines (6.9%). Therefore, fishermen in the MPA of NMPZ are primarily using nets (mostly trammel nets) usually combined with long line fishing.

## D. Objectives

The present study constitutes the first step towards obtaining a better understanding of small scale coastal fisheries in the MPA of N.M.P.Z. Given that fisheries activities and fish stock conservation is a complex issue encompassing both ecological and socioeconomic aspects, we adopted several methodological approaches in order to include all the main parameters involved. In this framework, we used underwater visual census to evaluate fish stock composition and status, on board sampling to assess fish stocks and the related fisheries characteristics, application of questionnaires for both ecological and socioeconomic parameters, as well as collection of fisheries data from local authorities.

**Primary Study Objectives:**

1. Investigate the structure and the status of fish populations related directly or indirectly to fisheries in the MPA of N.M.P.Z. and Zakynthos Island

2. Identify the profile of small scale artisanal fisheries operating within the MPA and in Zakythos Island involving ecological and socioeconomic aspects

3. Examine the possible effects of recreational fisheries in the MPA

4. Evaluate the effectiveness of the MPA in the protection and conservation of the fish stocks related to artisanal small scale fisheries

5. Propose suitable management actions for fisheries in the MPA of NMPZ

**Secondary Study Objectives:**

1. Investigate benthic fauna in the effort to expand current information regarding marine biodiversity in the MPA and Zakynthos Island coast.

2. Create an interactive biodiversity data base for the MPA of NMPZ.

# III. MATTERIALS AND METHODS

## A. Underwater Visual Census (UVC)

Underwater visual census techniques are commonly applied in studies regarding marine reserves, as they allow the acquisition of quantitative and qualitative estimates with a minimum impact on the marine environment. In the present study visual census techniques were applied for the assessment of fish communities, protected and exploited megabenthic species, and benthic biodiversity, in order to investigate potential effects of protection measures inside and outside the boundaries of the National Marine Park of Zakynthos – NMPZ (Fig 1).

Sampling was carried out in three distinct areas around Zakynthos Island (Fig 2) that receive varying levels of protection. Area A: includes stations inside the most strictly protected zone of NMPZ (Park Zone A), receiving a 6 month total protection as a no-take area and a year round prohibition of recreational and medium scale fisheries; Area B: includes stations at a close distance to area A, with a year round prohibition of recreational fisheries; Area C: includes stations lovated in areas outside the NMPZ, where no particular protection measures are in effect.

Underwater visual census was conducted in 28 stations, including 10 stations in area A, 11 in area B, and 7 in area C. A summary of the sampling stations and habitat characteristics is presented in Table 1. Note that stations marked with an asterisk are pilot stations which were only used for the qualitative assessment of biodiversity; they were not considered in any further quantitative analysis regarding fish assemblages.

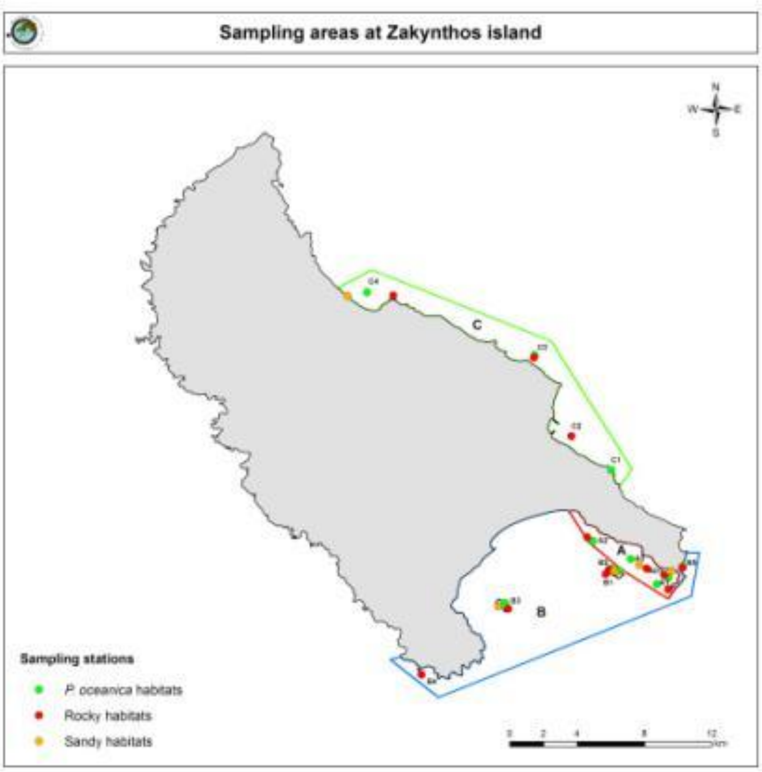



**Fig 2: Map of Zakynthos Island depicting sampling areas. Bullets represent sampling stations and colors denote habitat type; green for *P. oceanica*, red for rock, and yellow for sand. Note that Study Area boundaries in color are different from the N.M.P.Z. zones.**

**Table 1: Sampling effort summary, including stations, habitat types and respective coordinates (in decimal degrees). Note that sampling Area codes differ from the NMPZ zones. Stations marked with an asterisk were not included in the quantitative analysis of fish assemblages.**

| A/A | Station name | Area | NMPZ zones | Latitude | Longitude | Habitat type | Habitat category |
|---|---|---|---|---|---|---|---|
| 1 | AR1 | A | A | 37.695 | 20.98 | Rock | Flat |
| 2 | AP1 | A | A | 37.697 | 20.981 | *P. oceanica* | Meadow - *matte morte* |
| 3 | AR2 | A | A | 37.723 | 20.926 | Rock | Flat highly rugose |
| 4 | AP2 | A | A | 37.721 | 20.93 | *P. oceanica* | Thin meadow - *matte morte* |
| 5 | AR3* | A | A | 37.707 | 20.967 | Rock | Flat highly rugose |
| 6 | AP3* | A | A | 37.712 | 20.956 | *P. oceanica* | Thin meadow |
| 7 | AS3* | A | A | 37.709 | 20.962 | Sand | Continuous |
| 8 | AR1b* | A | A | 37.701 | 20.985 | Rock | Thin meadow |
| 9 | AP1b* | A | A | 37.703 | 20.982 | *P. oceanica* | Meadow |
| 10 | AS1b* | A | A | 37.706 | 20.984 | Sand | Continuous |
| 11 | BR1 | B | B,C,I | 37.701 | 20.939 | Rock | Large boulders (>3m diameter) |
| 12 | BP1 | B | B,C,I | 37.705 | 20.948 | *P. oceanica* | Meadow |
| 13 | BS1* | B | B,C,I | 37.705 | 20.945 | Sand | Continuous |
| 14 | BR2 | B | B,C,I | 37.703 | 20.935 | Rock | Flat highly rugose |
| 15 | BP2 | B | B,C,I | 37.704 | 20.941 | *P. oceanica* | Meadow |
| 16 | BR3 | B | B,C,I | 37.679 | 20.873 | Rock | Large boulders (>3m diameter) |
| 17 | BP3 | B | B,C,I | 37.684 | 20.871 | *P. oceanica* | Meadow |
| 18 | BS3* | B | B,C,I | 37.681 | 20.866 | Sand | Coarse |
| 19 | BR4 | B | B,C,I | 37.647 | 20.818 | Rock | Large boulders (>3m diameter) |
| 20 | BR5 | B | B,C,I | 37.706 | 20.988 | Rock | Large boulders (>3m diameter) |
| 21 | BP5 | B | B,C,I | 37.709 | 20.991 | *P. oceanica* | Large tufts |
| 22 | CP1 | C | Outside NMPZ | 37.759 | 20.941 | *P. oceanica* | Meadow |
| 23 | CR2 | C | Outside NMPZ | 37.777 | 20.913 | Rock | Medium boulders (1-3m diameter) |
| 24 | CR3 | C | Outside NMPZ | 37.818 | 20.886 | Rock | Medium boulders (1-3m diameter) |
| 25 | CP3 | C | Outside NMPZ | 37.819 | 20.887 | *P. oceanica* | Meadow |
| 26 | CR4 | C | Outside NMPZ | 37.846 | 20.79 | Rock | Flat highly rugose |
| 27 | CP4 | C | Outside NMPZ | 37.85 | 20.772 | *P. oceanica* | Thin meadow |
| 28 | CS4* | C | Outside NMPZ | 37.848 | 20.759 | Sand | Continuous |

## 1. Ichthyofauna

### *Sampling Methodology*

Out of the 28 stations sampled, only 19 were used for the analysis of fish assemblages (Fig 3).

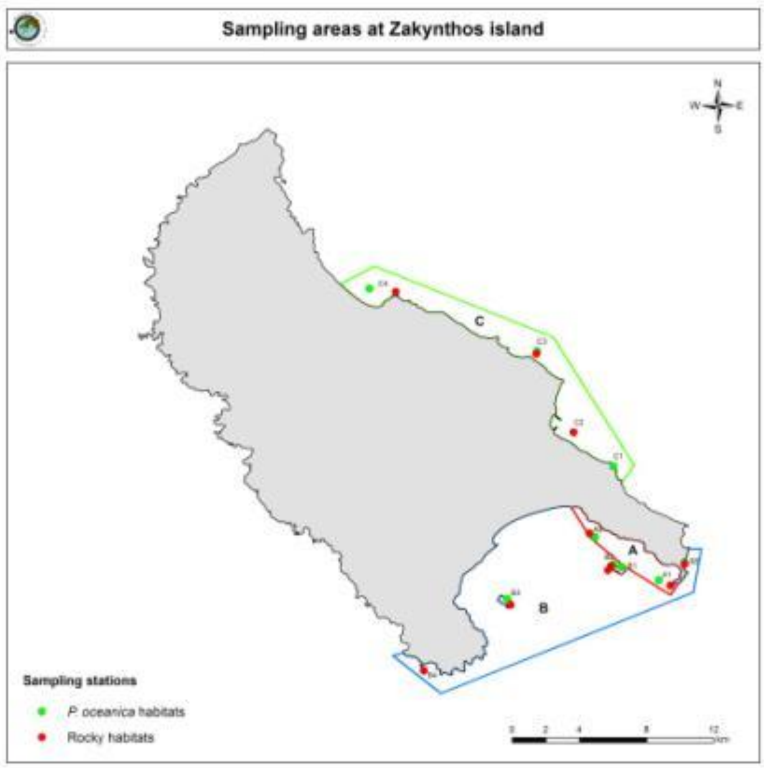



**Fig 3: Map of Zakynthos Island depicting sampling areas and stations. Bullets represent sampling stations considered in the fish data analysis, and colors denote habitat type; green for *P. oceanica*, red for rock, and yellow for sand**

Fish species, size and abundance were assessed through SCUBA diving using standard underwater visual census (Harmelin *et al*., 1995) at depths ranging from 5-15 meters. At each station fish data were recorded along three replicate belt transects of 25 x 5 meters, placed successively at the same depth several meters apart. Moving one way along each transect line at constant speed, the fish observer identified, counted and estimated the size of all fish present within 2.5 meters distance on either side of the transect line. All fish species encountered were recorded, except small cryptic ones (e.g. fish of the families Bleniidae and Gobiidae). Actual numbers of fish were recorded up to 20 individuals, while higher numbers were assigned to separate abundance categories (21-30, 31-50, 51-100, 101-200, 201-500, >500 individuals) as proposed in the existing literature (Harmelin *et al*., 1995; Harmelin-Vivien *et al*., 2008). Two main habitat types were considered, rocky reefs and *Posidonia oceanica* beds, as they represent the most productive habitats in the shallow sublittoral Mediterranean waters (Guidetti 2000; Harmelin-Vivien *et al*., 2005; La Mesa *et al*., 2006; Giakoumi & Kokkoris 2012).

Habitat complexity is one of the main factors contributing to the small scale variability patterns observed in fish communities (García-Charton & Pérez-Ruzafa 2001; García-Charton *et al*., 2004), and may overshadow the reserve effects when protected areas have a simpler topographic profile than the unprotected ones (García-Charton *et al*., 2004). In the present study, habitat complexity was qualitatively assessed at each transect, according to the following habitat categories (5 for rock and 4 for *Posidonia oceanica*, Table 1): 1. rocky flat, 2. rocky flat highly rugose, 3. rocky small boulders (<1m diameter), 4. rocky medium boulders (1-3m diameter), 5. rocky large boulders (>3m diameter), 6. *P. oceanica* meadow, 7. *P. oceanica* thin meadow 8. *P. oceanica* large patches, and 9. *P. oceanica matte morte* (i.e. dead matte).

***Data handling***

Measurements of fish total length were converted to biomass (i.e. wet weight) using the alometric length – weight relationship $W = aL^b$, where L: total length (cm), W: wet weight in grams, a and b: constants obtained from Forese & Pauly (Fishbase) 2000, Moutopoulos & Stergiou 2002, and Giakoumi *et al*., 2011. When values of constants a and b were not available, equivalent values where obtained from cogeneric species of similar maximum total length and body shape. Choice of parameters was based on the proximity of the geographical region to our study area, from which the initial constants were estimated.

Furthermore, fish species were pooled into four main functional groups, based on information regarding their trophic status (Forese & Pauly, 2000), namely zooplanktivores, herbivores, carnivores and apex predators, in order to investigate potential changes in community complexity and shifts in trophic structure as a response to protection (Micheli *et al*., 2004; Guidetti & Sala 2007).

***Data analyses***

Kruskal – Wallis test was used to detect differences in mean species richness, abundance and biomass per 125m$^2$ among sampling stations and areas of different protection status, as well as among different trophic groups. In order to provide a detailed description of the current state of the fish communities, the contribution of the different species to the total biomass and abundance per trophic group was graphically presented. Moreover, the mean abundance and biomass as well as the size structure of selected species/families (i.e. commercial, allochthonous and herbivorous) among the different sampling areas was graphically assessed.

***Response ratio (ln*R*)***

In order to quantify the response of fish assemblages to protection, we used the response ratio ln*R* (Mosquera *et al*., 2000; Micheli *et al*., 2004, Guidetti & Sala 2007). The response ratio is defined as the ratio of the estimated abundance or biomass observed inside and outside the marine reserve, and is generally preferred to other metrics for the study of changes brought about by protection because it is designed to measure relative differences (Goldberg *et al*., 1999; Osenberg *et al*., 1999). The metric is defined as:

$$\ln RR = \ln\left(\frac{\overline{X}^{I}}{\overline{X}^{O}}\right)$$

, where $\overline{X}^{I}$ and $\overline{X}^{O}$ are mean values (of abundance or biomass) estimated inside and outside the marine reserve.

In the present study, we pooled data from both habitat types (i.e. rocky and *P. oceanica* habitats) and calculated the abundance and biomass ratios of the three different areas (i.e. A-B, B-C, and A-C). We estimated the ratios for the different trophic groups, as well as for selected species/families. In order to minimize variability of results due to sampling effort (i.e. number of stations sampled per area), we used weighted values. Positive response ratios indicate greater values for the numerator of the fraction (i.e. the more protected areas), negative response ratios indicate greater values for the denominator of the fraction (i.e. less protected areas), while a zero ratio means that values in both areas are equal.

***Analysis of community structure***

In order to identify patterns of community structure, MDS and Cluster analysis were employed based on Bray - Curtis similarity index which was calculated from the fourth root transformed abundance and biomass data regarding the different sampling sites per habitat type (i.e. rock and *P. oceanica*). One-Way ANOSIM was used to detect statistical significant differences in sampling sites grouping when abundance, biomass and trophic groups were considered per habitat type, as well as for the pooled habitat types.Two-Way crossed ANOSIM analysis was used in order to detect significant differences of community structure between the sampling areas (A, B and C) across all habitat groups (posidonia and rock), as well as between all the habitat groups across all sampling areas. In this respect, identification of grouping strength (ANOSIM R value) according to habitat and area factor enabled the detection of which of the former had the most powerful effect in community shaping. Simper analysis was employed to evaluate species contribution in the produced dissimilarity of community structure when abundance, biomass and trophic groups were taken into account per habitat type and for pooled habitat types. All community-based analysis was carried out through the use of the statistical package PRIMER v6 as it described and discussed by Clarke & Gorley (2006).

## 2. Megabenthic species

Biodiversity assessment was carried out along the transect lines by a second diver, who followed the fish observer at a distance to minimize disturbance of fish species. Moving along the transect lines, the biodiversity observer estimated the abundance of eight conspicuous megabenthic species, found within a distance of 2.5 meters on each side of the transect line. The specific species were purposefully selected according to their protection and/or exploitation status (Table 2).

**Table 2: The eight megabenthic species considered in the study and their protection/exploitation status***

| SPECIES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| *Arbacia lixula* (Linnaeus, 1758) | | | | | | | | | HF |
| *Charonia variegata* (Lamarck, 1816) | II | | II | | | | | | COL |
| *Hacelia attenuata* Gray, 1840 | | | | | | | | + | |
| *Microcosmus* spp. | | | | | | | | | HF |
| *Ophidiaster ophidianus* (Lamarck, 1816) | II | | II | | | | | | |
| *Paracentrotus lividus* (Lamarck, 1816) | III | | III | VU | | | | | HF |
| *Pinna nobilis* Linnaeus, 1758 | II | IV | II | | + | + | + | | HF/COL/BIOM |
| *Tonna galea* (Linnaeus, 1758) | II | | II | | + | + | + | | HF/COL |

***1. Bern Convention** - Convention on the conservation of European wildlife and natural habitats, Council of Europe, 1979; **2. Habitats Directive 92/43/EEC**; **3. Barcelona Convention** - Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean, 1995; **4. Greek Red Data Book of Threatened Species** (2009); **5. Presidential Decree 67/1981**; **6. Presidential Decree 109/2002**; **7. Presidential Decree 227/2003; 8.** Species that are regionally threatened and included in regional or national lists (OCEANA, 2009); **9.** Exploited species; **II, III, IV.** Appendix/Annex II, III, IV; **VU.** Vulnerable; **HF.** Human Food; **COL.** Collections/Museums; **BIOM.** Used for Biomonitoring.

**Deployment of transect line over rocky habitats**

**The protected purple sea star Ophidiaster ophidianus within the count zone**

**The protected tun shell *Tonna galea***

Additional measurements of width (w) and unburied length (UL) were taken for the encountered individuals of the endangered fan shell Pinna *nobilis*. The total length (Ht) of each individual was estimated using the following equation: Ht = h + UL, where h = 1.79w + 0.5 (García-March *et al*., 2002).

***In situ* morphometric measurements on *Pinna nobilis* shells**

### 3. Biodiversity

Following the quantitative assessment of fish and benthic communities, the benthic observer conducted a qualitative survey to collect information regarding the biodiversity of the area, by means of visual observation and photography. The biodiversity assessment included the presence of cryptic fish species (e.g. Bleniidae and Gobiidae), while special attention was given to the presence of alien, protected and exploited species. The protection/exploitation status of recorded species was determined by reviewing available literature (Chintiroglou *et al*., 2005; Katsanevakis *et al*., 2008; 2011; Thessalou-Legaki & Legakis, 2005).

## B. On Board Sampling (OBS)

### 1. Study area

In order to detect the potential nourishing effects of the current MPA protection measures to the fish stocks, sampling surveys included fishing grounds that are found both inside and outside the MPA. Sampling surveys within the MPA boundaries focused mainly on fishing grounds found at zone A (partial no take zone for 6mothns per year - May to October) or in neighbouring to it after the opening of the fishing period in that zone. Sampling locations outside the MPA included traditional fishing grounds that are found all around Zakynthos Island. All sampling locations correspond to some of the most important fishing grounds that are traditionally being used by local fishermen for over a decade.

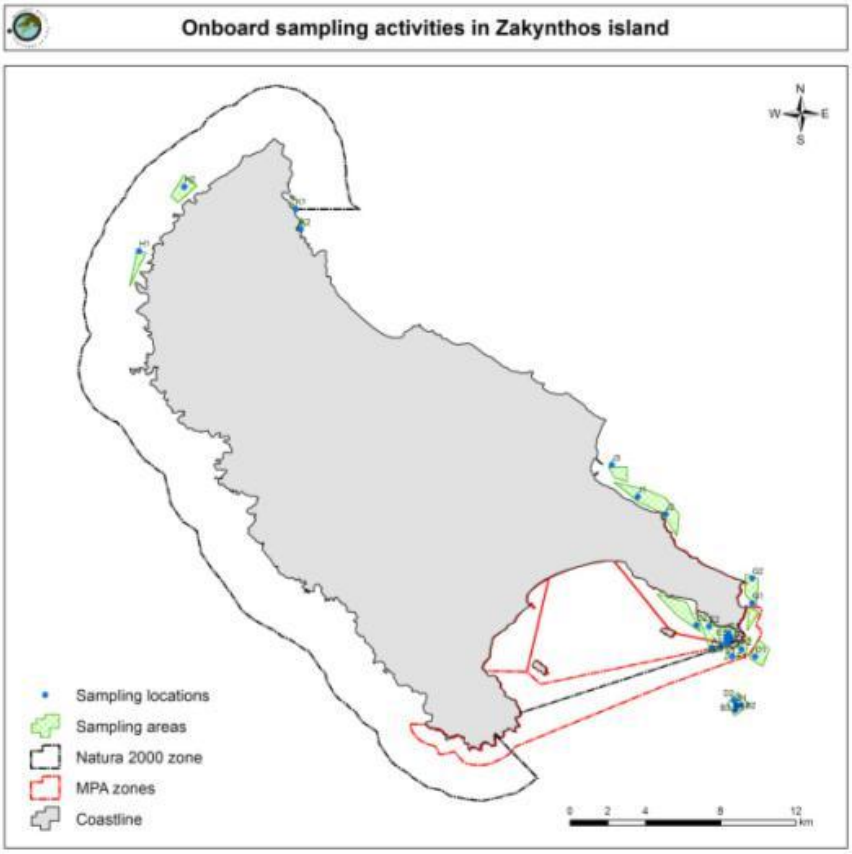



**Fig 4: Sampling locations and fished areas during the sampling period**

## 2. Sampling Design

Catch and effort data were collected from November of 2012 until April of 2013 (after the opening of the fishing period in the partially enforced no take area) onboard artisanal commercial fishing vessels that operate in traditional fishing grounds found both inside and outside the MPA (Fig 4). Three small scale artisanal fishing vessels were involved in the sampling procedure (with similar vessel attributes) that it took place in mixed types of habitats (including the combination of posidonia beds, reefs and sand). Concerning the fishing gear, we used trammel nets which is the most frequently employed fishing gear in Zakynthos Island. For each fishing set, we recorded the date, the geographical position (start and end of fishing set - WGS84 projection system), the length of the nets (m), the fishing duration (hours), the depth (m), and the weather conditions. Thus, a total of 27 fishing sets (13 inside and 14 outside the MPA) and 40100 m of trammel nets were immersed in several traditional fishing grounds across the coastal area of Zakynthos Island, from which 17500m were located within the borders of the MPA and 22600 m outside of them. Fishing depth ranged from 5 to 35m, mesh size of the nets fluctuated between 21 and 36mm, fishing duration (duration that the nets were immersed in the water) ranged from 9 to 20 hours whereas all fishing surveys were conducted with similar weather conditions (Table 3). For each fishing set sampled, catch was identified to species level whereas fish were counted, measured (total body length in cm) and weighted (gr) with portable length and weight meters respectively (Fig 5). Data were inserted in properly designed sampling protocols and then were stored in an electronic data base for further processing.

**Table 3: Detailed list of sampling design and fishing surveys information during the sampling period**

| Site | Latitude | Longitude | Fishing Gear | Mesh size (mm) | Net length (m) | Vessel | Fishing Duration (hours) | Location | Area | Depth (m) | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 37°41.811 | 20°58.410 | Trammel Net | 26 | 1500 | Soulitsa | 17 | Gerakas | Inside MPA | 30 | 1/2/2013 |
| A2 | 37°41.803 | 20°59.485 | Trammel Net | 26 | 1500 | Soulitsa | 17 | Glines | Inside MPA | 30 | 1/2/2013 |
| A3 | 37°41.809 | 21°00.239 | Trammel Net | 21 | 1700 | Soulitsa | 17 | Glines | Inside MPA | 30 | 1/2/2013 |
| B1 | 37°40.199 | 20°59.372 | Trammel Net | 26 | 1500 | Soulitsa | 20 | Ksera Geraka | Outside MPA | 35 | 4/4/2013 |
| B2 | 37°40.205 | 20°59.538 | Trammel Net | 28 | 1700 | Soulitsa | 20 | Ksera Geraka | Outside MPA | 30 | 4/4/2013 |
| B3 | 37°40.055 | 20°59.324 | Trammel Net | 22 | 3000 | Soulitsa | 20 | Ksera Geraka | Outside MPA | 30 | 4/4/2013 |
| C1 | 37°42.253 | 20°59.005 | Trammel Net | 21 | 1000 | Elpis | 10 | Gerakas | Inside MPA | 6 | 9/11/2012 |
| C2 | 37°42.453 | 20°57.840 | Trammel Net | 21 | 1500 | Elpis | 10 | Dafni | Inside MPA | 18 | 9/11/2012 |
| C3 | 37°41.972 | 20°58.934 | Trammel Net | 36 | 400 | Elpis | 10 | Gerakas | Inside MPA | 15 | 9/11/2012 |
| D1 | 37°41.598 | 20°59.997 | Trammel Net | 28 | 1700 | Soulitsa | 20 | Glines | Outside MPA | 25 | 10/4/2013 |
| D2 | 37°40.327 | 20°59.284 | Trammel Net | 26 | 1700 | Soulitsa | 20 | Ksera Geraka | Outside MPA | 25 | 10/4/2013 |
| D3 | 37°40.327 | 20°59.284 | Trammel Net | 30 | 1000 | Soulitsa | 20 | Ksera Geraka | Outside MPA | 30 | 10/4/2013 |
| E1 | 37°41.880 | 20°58.736 | Trammel Net | 26 | 1700 | Soulitsa | 20 | Gerakas | Inside MPA | 15 | 11/4/2013 |
| E2 | 37°42.426 | 20°58.295 | Trammel Net | 28 | 1700 | Soulitsa | 20 | Dafni | Inside MPA | 5 | 11/4/2013 |
| E3 | 37°42.133 | 20°59.086 | Trammel Net | 30 | 1000 | Soulitsa | 20 | Gerakas | Inside MPA | 7 | 11/4/2013 |
| F1 | 37°41.594 | 20°59.164 | Trammel Net | 26 | 1500 | Soulitsa | 12 | Glines | Inside MPA | 20 | 12/3/2013 |
| F2 | 37°42.101 | 20°58.919 | Trammel Net | 28 | 1500 | Soulitsa | 12 | Glines | Inside MPA | 9 | 12/3/2013 |
| G1 | 37°43.136 | 20°59.823 | Trammel Net | 26 | 1500 | Soulitsa | 20 | Porto Roma | Inside MPA | 15 | 13/3/2013 |
| G2 | 37°43.849 | 20°59.795 | Trammel Net | 28 | 1500 | Soulitsa | 20 | Vasilikos | Outside MPA | 17 | 13/3/2013 |
| G3 | 37°42.043 | 20°59.099 | Trammel Net | 21 | 1000 | Soulitsa | 20 | Gerakas | Inside MPA | 12 | 13/3/2013 |
| H1 | 37°52.647 | 20°37.208 | Trammel Net | 22 | 1000 | Oneiro | 9 | Nauagio | Outside MPA | 20 | 17/4/2013 |
| H2 | 37°54.537 | 20°38.763 | Trammel Net | 36 | 1800 | Oneiro | 9 | Ag. Andreas | Outside MPA | 35 | 17/4/2013 |
| J1 | 37°46.088 | 20°55.564 | Trammel Net | 28 | 1500 | Soulitsa | 12 | Argasi | Outside MPA | 23 | 23/1/2013 |
| J2 | 37°45.616 | 20°56.592 | Trammel Net | 26 | 1800 | Soulitsa | 12 | Argasi | Outside MPA | 12 | 23/1/2013 |
| J3 | 37°46.971 | 20°54.581 | Trammel Net | 30 | 1600 | Soulitsa | 12 | Limani Zak | Outside MPA | 15 | 23/1/2013 |
| K1 | 37°54.015 | 20°42.830 | Trammel Net | 36 | 1800 | Oneiro | 9 | Ag. Nikolaos | Outside MPA | 25 | 28/3/2013 |
| K2 | 37°53.437 | 20°43.013 | Trammel Net | 36 | 1000 | Oneiro | 9 | Ksigia | Outside MPA | 15 | 28/3/2013 |

## 3. Statistical Analyses

Species number per sampling site as well as per groups of sampling stations (inside *vs* outside the MPA) was calculated whereas significant differences of mean species number between the sampling groups were detected by means of Mann-Whitney test (Zar,1984).
Evaluation of fish stocks is commonly achieved when data of catch and effort resulting from commercial fishing are combined. So, in order to evaluate the status of the fish stocks, we used Catch Per Unit Effort (CPUE) index as a proxy of the state of the harvested population (FAO, 2006).

**Fig 5: Onboard measurement of the catches with portable length and weight meters**

CPUE was initially calculated as the catch (biomass in gr) per fishing effort for each species separately within each sampling site. In this manuscript we used as estimator of the fishing effort the combination of net length and fishing duration (net x hours) per fishing set. Then, we averaged species CPUE within each fishing set so as to produce species aggregated CPUE across the sampling sites (Myers, 2003; Walters, 2003; but also see Hampton *et al*., 2005). Significance of mean CPUE differences between the groups of sampling sites (inside *vs* outside the MPA) was calculated with the use of Mann - Whitney test (Zar, 1984). Moreover, we gathered information, in close collaboration with the local fishermen, about the current price of each fish (€ / kg) during the sampling period. The price of each fish was multiplied by its respective CPUE so as to calculate the Income Per Unit Effort (IPUE) per species as well as the aggregated IPUE (including all species) per sampling station and per group of sampling stations (inside *vs* outside the MPA) (Stelzenmüller *et al*., 2009).

Further CPUE measurements tottaled by the fishing sites or by the groups of sites that are found inside and outside the MPA were calculated for species aggregated data. In this respect, three CPUE calculation approaches were adopted as it is described and discussed by Pereira et al (2009). These indices were:

$CPUE_1 = [\Sigma(C_i/f_i)]/n$ weighted index of density, (1)

$CPUE_2 = (\Sigma C_i/\Sigma f_i)$ unweighted index of density, (2)

$CPUE_3 = [\Sigma(C_i x f_i)]/[\Sigma(f_i)^2]$ ratio estimator, (3)

where $C_i$ is $i^{th}$ catch (biomass in gr), $f_i$ is its respective fishing effort (net x hours) and n is the number of sampling sites.

Several authors have shown that CPUE is an accurate indicator of fish stock status when the relationship between catch and effort is linear through the origin (strict proportionality) (Lima *et al*., 2000; Petrere *et al*., 2010 and references therein). Therefore, whenever catch is proportional to the effort and the regression line between them statistically goes through the origin of x and y axis, $CPUE_1$, $CPUE_2$ and $CPUE_3$ are considered to be unbiased estimators of the fish stock status. Under this framework, we examined if our catch and effort data were following the normal distribution by means of One-Sample Kolmogorov-Smirnov Test and then we applied regression model and Pearson's correlation index so as to detect proportionality patterns between catch and effort as well as if the regression line pass through the origin of catch and effort axis (Petrere et al., 2010).

In addition, species were assigned to 5 functional (trophic) groups which included herbivores (HE), detritivores (DE) (including also omnivorous species), zooplanktivores (ZP), carnivores (CA) and apex predators (AP) based on the diet and the trophic level of each species provided by data bases (http://www.fishbase.org) and scientific publications (e.g. Micheli *et al*., 2004; Guidetti & Sala, 2007; Giakoumi *et al*., 2012). We further pooled species CPUE data in order to produce functional groups' CPUE and hence to detect significant differences in the mean CPUE for each functional group between the fishing sets that are located inside and outside the MPA by means of Mann-Whitney test.

Finally, we gathered data regarding the body length (cm) of first sexual maturity for each species (Lm) (source: http://www.fishbase.org - Life history tool) which was compared with the measured body length of our catches for all the encountered species. In this respect, 5 body size categories were formulated (0%Lm, Lm<25%, Lm25-50%, Lm50-75% and Lm75-100%) denoting the percent of each species population for which the body length of the measured individuals was lower than Lm threshold. Therefore, the first category incorporated species for which none of the measured individuals was lower that Lm (0%Lm), the second category gathered these species for which the measured body length of their population was from 1 to 25% lower that Lm, the third group incorporated species for which the measured body length of their population was from 26 to 50% lower than Lm, the fourth group consisted of species that the 51 to 75% of the measured body length was lower than LM whereas the last group included the species for which the percentage of the measured body length was 75 to 100% lower than Lm. Finally, we gathered information about the minimum permitted catch size for each species according to European (e.g. EC 1967/2006) and National regulations and then we calculated the percentage of species population's individuals with a body length lower than the minimum permitted size (%<Min Permitted Size).

# C. Questionnaires for Fisheries

## 1. Field Surveys

Within the framework of artisanal fisheries study via questionnaires, personal interviews of 17 fishermen took place from November to December of 2012. Given that the active artisanal fishing fleet in Zakynthos Island at present consists of about 200 registered fishing boats, our sampling effort included almost 9% of the total fishing fleet. The relative low number of questionnaires that we finally managed to collect can be attributed to the lack of collaboration that fishermen exhibited during the study and especially those that are active within the limits of the MPA.

The first subsection of the professional fishing questionnaire aimed at the collection of information regarding basic data for the professional fishing vessel for which the questionnaire was completed.

The four question categories of this subsection were the following: 1) Vessel Category, 2) Vessel's name, 3) Vessel's attributes and 4) Fishing costs of the vessel/annum.
The second subsection of the questionnaire aimed at the collection of data concerning the fishing gear used, the frequency of usage and seasonal variation of usage from the professional fishermen. The third subsection of the questionnaire provided data on the owner and employees of the vessels. The fourth and fifth subsection of the questionnaire included information about the fishing trips and the catches respectively. Finally, the last part of the questionnaire involved the problems and the future perspectives of artisanal fisheries in Zakynthos Island.

### 2. Data Analyses

The obtained data, which we gathered from the questionnaires, were sorted, evaluated and consequently inserted in a properly designed data base. Quantitative data were processed by means of SPSS software whereas for the case of geospatial data (points in maps concerning the fishing grounds, the breeding grounds as well as the areas of high biodiversity) the indicated points in questionnaires' maps were transformed to coordinates (latitude and longitude in WGS84 projection system) and analyzed by means of ArcGIS software.

## D. Data Base and Geo - Base

Database systems are necessary for the management of the biodiversity in local, regional or country level (Poursanidis *et al*., 2008). These systems can store and handle a vast amount of the information for the biodiversity of a protected area, such as the National Marine Park of Zakynthos. A database can store information about the occurrence of nomenclature-species name, geographic data, anatomy, morphology, ecology, habitats, economic importance, conservation status of the species, threats, images of the species and habitats within an area, as point stations or habitat polygons (Piramanayagam, 2007).
The use of a database system is crucial for the management of a protected area, since it provides the suitable platform to acquire answers such as "where do i have a protected / endemic/ rare species of habitat» Combination of the descriptive database with the spatial database enables for the implementation of a vast amount of statistical analysis, visualization of the species on space, creation of distribution maps, use of Species Distribution Modelling to identify the potential distribution of selected species, identification "hot-spots" for the biodiversity and "hot-spots" for urgent actions in cases of declines in the biodiversity (Bianchi *et al*., 2012).

### 1. Descriptive Database

For the needs of the project a descriptive and a geographic database were designed. A database is a structured collection of data, either descriptive or spatial/geographic. For the design of the descriptive database the relational model was selected since it is a simple model that provides flexibility. It organizes data based on two-dimensional arrays known as table relations. The most common language associated with the relational model is the Structured Query Language (SQL). The use of Microsoft Access software provided the appropriate tools to design the database.
The descriptive database was based on the relational system "one/*> many" (Fig 6). This is the most simple and most functional scheme for a database system, as the developer creates relations from the main table (the stations / areas table) with the findings (the biodiversity / habitats tables).

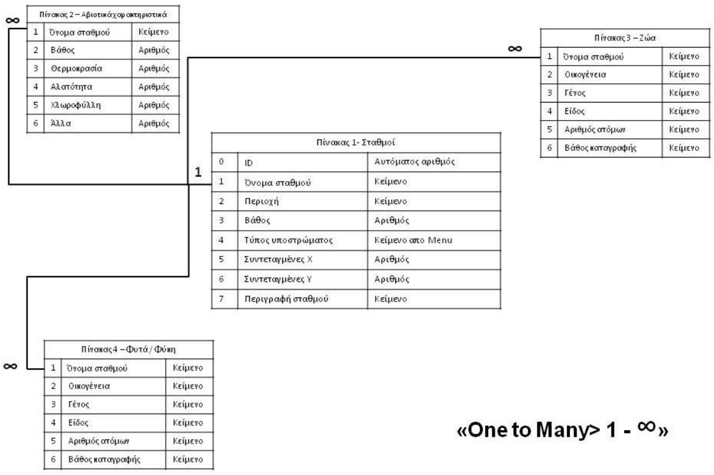



**Fig 6: The structure of the descriptive database**

## 2. Spatial Database

The Spatial database (Geodatabase) has been designed using ESRI's ArcGIS Desktop tools. Is a well known platform for designed geographic databases (ESRI, 2010), maps, running spatial analysis, etc. The geodatabase handle all the spatial data that have been produced during the project (stations, annotations, habitats, bathymetry and spatial datasets) (Fig 7).
Using this geodatabase, the user can visualize the spatial data using an appropriate GIS software, like ArcGIS or even the open source QGIS and using these to produce maps showing the habitats, the sampling stations, hot spots of biodiversity, etc. Also, the MXD (map document) files, which have been created during the project and as results the maps that are included in the report, will accompany this Geodatabase. Using them, the user can update the existing map documents, with new data, when applicable.

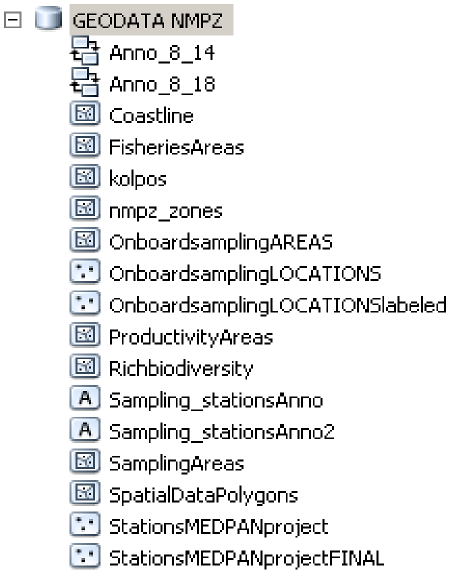



**Fig 7: The data that are included in the Geodatabase**

## E. Recreational Fisheries

Following the scheme which is provided by the National Government Gazette 906/D/22 - 12 - 1999, recreational fishing is strictly prohibited within the limits of the MPA of NMPZ and thus it was not possible to conduct quantitative field surveys in the framework of this study. However, the evaluation of the status of the typically targeted fish species by recreational fishermen enabled us to draw several rough conclusions about the possible effects that recreational fishing may have if this activity was not prohibited.

# IV. RESULTS

## A. Visual Census - Fish Fauna

For the analysis of fish assemblages, data collected from 19 stations were utilized (including 10 from rocky and 9 from *P. oceanica* habitats). More specifically 4 stations were located in area A, 9 in area B, and 6 in area C (for more details see Table 1 in Material and Methods section)

### 1. Fish Diversity

A total of 33 fish species were recorded, including a single sighting of the allochthonous fangtooth moray *Enchelipore anatine* in station BR4 and a single sighting of the relatively rare in the NE Mediterranean *Labrus mixtus* in CR3.

**Table 4: List of fish species/families recorded. 'a' and 'b' are constants used for the estimation of biomass**

| Family/Species name | a | b |
|---|---|---|
| Atherina sp. | 0.0077 | 3.0290 |
| *Boops boops* (Linnaeus, 1758) | 0.0149 | 3.0930 |
| *`Caranx crysos* (Mitchill, 1815) | 0.02200 | 2,730 |
| *Chromis chromis* (Linnaeus, 1758) | 0.0996 | 2.4150 |
| *Coris julis* (Linnaeus, 1758) | 0.0048 | 3.3780 |
| *Diplodus annularis* (Linnaeus, 1758) | 0.0231 | 3.0020 |
| *Diplodus sargus* (Linnaeus, 1758) | 0.0138 | 3.0700 |
| *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817) | 0.0131 | 3.0550 |
| *Enchelycore anatina* (Lowe, 1838) | Not available | Not available |
| *Epinephelus costae* (Steindachner, 1878) | 0.0024 | 3.4400 |
| *Epinephelus marginatus* (Lowe, 1834) | 0.0127 | 3.0850 |
| *Labrus merula* (Linnaeus, 1758) | 0.0105 | 3.0760 |
| *Labrus mixtus* (Linnaeus, 1758) | 0.005 | 3.2570 |
| *Labrus viridis* (Linnaeus, 1758) | 0.0359 | 2.6690 |
| *Mullus surmuletus* (Linnaeus, 1758) | 0.0140 | 2.9540 |
| *Oblada melanura* (Linnaeus, 1758) | 0.0219 | 2.8310 |
| *Sarpa salpa* (Linnaeus, 1758) | 0.0145 | 2.9780 |
| *Sciaena umbra* Linnaeus, 1758 | 0.0352 | 3.0480 |
| *Serranus cabrilla* (Linnaeus, 1758) | 0.0277 | 2.7250 |
| *Serranus scriba* (Linnaeus, 1758) | 0.0095 | 3.1220 |
| *Siganus luridus* (Rüppell, 1829) | 0.0110 | 3.0400 |
| *Sparisoma cretense* (Linnaeus, 1758) | 0.0113 | 3.0520 |
| *Spicara maena* (Linnaeus, 1758) | 0.0104 | 3.0960 |
| *Spicara smaris* (Linnaeus, 1758) | 0.0069 | 3.2470 |
| *Spondyliosoma cantharus* (Linnaeus, 1758) | 0.0339 | 2.8490 |
| *Symphodus cinereus* (Bonnaterre, 1788) | 0.0339 | 2.8490 |
| *Symphodus mediterraneus* (Linnaeus, 1758) | 0.0144 | 3.0120 |
| *Symphodus melanocercus* (Risso, 1810) | 0.0180 | 3.0000 |
| *Symphodus roissali* (Risso, 1810) | 0.0350 | 2.6700 |
| *Symphodus rostratus* (Bloch, 1791) | 0.0031 | 3.4860 |
| *Symphodus tinca* (Linnaeus, 1758) | 0.0278 | 2.7330 |
| *Thalassoma pavo* (Linnaeus, 1758) | 0.0159 | 2.9720 |
| *Trachinotus ovatus* (Linnaeus, 1758) | 0.0220 | 2.7300 |

A list of species recorded, including the parameter values (a and b) used for the length - weight relationship, is presented in Table 4. Rocky reefs show a higher species richness (30 species) than *P. oceanica* habitats (24 species) as shown in Fig 8.

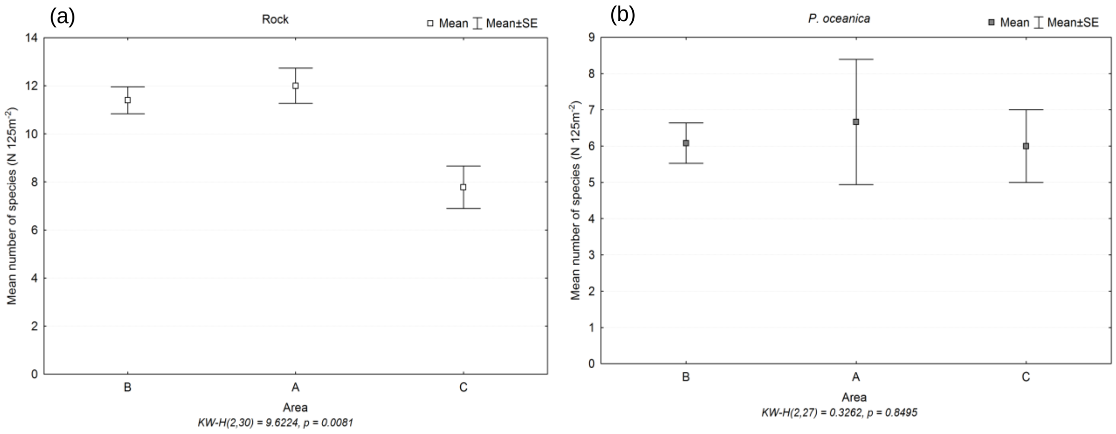



**Fig 8: Mean number and st. error of fish species a) for rock, and b) for *P. oceanica***

The mean number of species differ significantly among areas when considering the rocky habitats (KW test: p = 0.00, Fig 8a), displaying higher values in areas A (12 species/125 m$^{-2}$) and B (11.4 species/125 m$^{-2}$) than C (7.7 species/125 m$^{-2}$). At *P. oceanica* habitats the mean species number does not differ significantly across areas (KW test: p = 0.8475,Fig 8b). The mean and st. error of species richness across different stations, for both rocky and *P. oceanica* habitats, are depicted in (Fig 9)

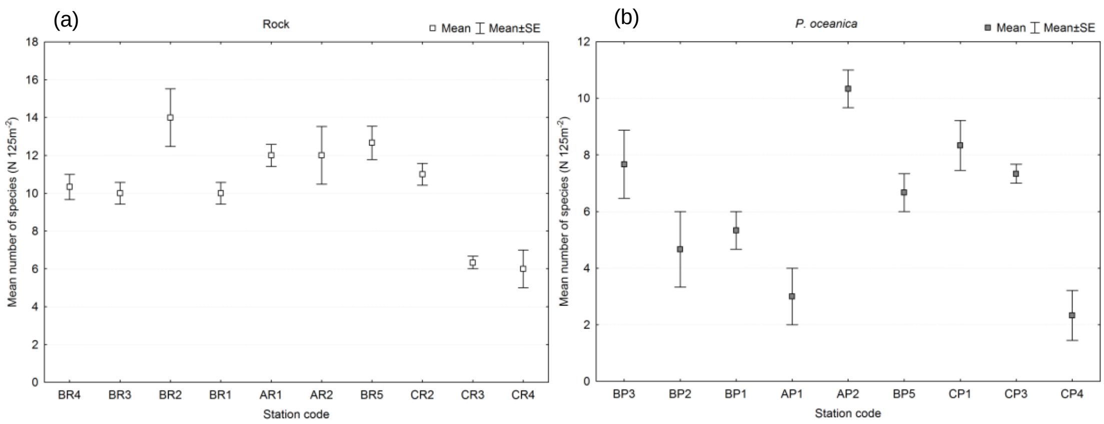



**Fig 9: Mean number and st. error of fish species a) for rock, and b) for *P. oceanica* stations**

At rocky habitats the highest mean number of species richness is recorded in station BR2 (14), BR5 (12.67), AR1 (12), and AR2 (12), and the lowest at CR3 and CR4 (6.3 and 6 species respectively). At *P. oceanica* habitats the mean number of species is higher in stations AP2 (10.3), CP1 (8.3) and lowest at AP1 (3) and CP4 (2.3).

The most diverse trophic group are the carnivores (20 and 17 species at rocky and *P. oceanica* habitats respectively), while the rest of the trophic groups display relatively low species richness (Table 1). The Kruskal-Wallis test shows that in both habitat types the mean number of species per trophic group differs significantly across the different areas for herbivorous and carnivorous fish species (p<0.05), but not for the zooplanktivorous or apex predators (p>0.05) (Table 5).

**Table 5: Number of species per trophic group, and Kruskal-Wallis test statistics across different areas**

| Trophic Group | Number of Species | Test statistic |
|---|---|---|
| **Rocky Habitat** | **30** | |
| Zooplanktivorous | 4 | KW-H(2,30) = 5.6681, p = 0.0588 |
| Herbivorous | 3 | KW-H(2,30) = 8.3911, p = 0.0151 |
| Carnivorous | 19 | KW-H(2,30) = 10.2198, p = 0.0060 |
| Apex predators | 4 | KW-H(2,30) = 3.0899, p = 0.2133 |
| ***P. oceanica* Habitat** | **24** | |
| Zooplanktivorous | 4 | KW-H(2,30) = 0.0621, p = 0.9694 |
| Herbivorous | 2 | KW-H(2,30) = 7.3015, p = 0.0260 |
| Carnivorous | 17 | KW-H(2,30) = 8.9692, p = 0.0113 |
| Apex predators | 1 | KW-H(2,18) = 4.25, p = 0.1194 |

Carnivorous fish display highest mean species richness in areas B (7.6) and A (7.5) at rocky habitats, while at *P. oceanica* species richness is higher in area A (4.3). Although some statistical differences are detected in the mean number of herbivorous fish diversity at both habitats, species richness is generally very low (3 species for rocky and 2 species for *P. oceanica*).

Detailed graphs regarding the mean number of species per sampling station and trophic group according to habitat type can be found in Fig 10.

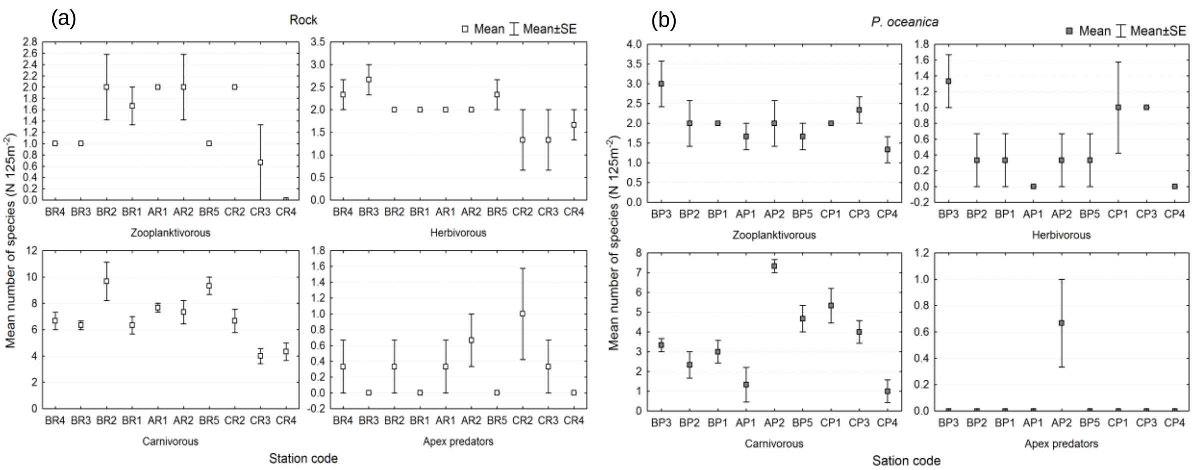



**Fig 10: Mean number and st. error per trophic group a) for rock, and b) for *P. oceanica* stations**

## 2. Fish Abundance

Abundance was overall higher in rocky (total: 9083) than in *P. oceanica* (total: 7247) habitats. Within each habitat type, mean abundance shows significant differences among the different areas ($p<0.00$, Fig 11). In rocky habitats, area A (597/125 $m^2$) displays the highest mean value, followed by area B (288.53/125 $m^2$), and finally area C (130.56/125 $m^2$). In *P. oceanica* habitats, the highest abundance is observed in area B (402.17/125 $m^{-2}$), followed by area C (188.67/125 $m^{-2}$) and finally area A (120.50/125 $m^{-2}$).

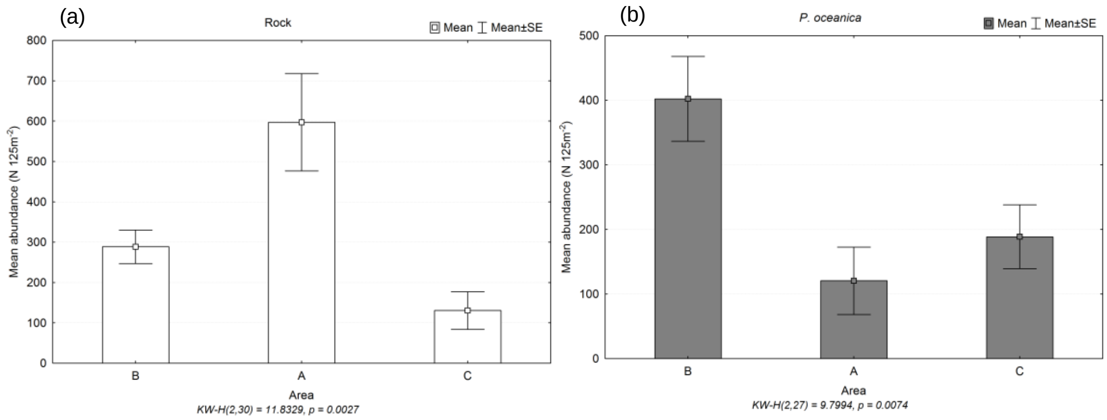



**Fig 11: Mean abundance and st. error per area a) for rock, and b) for *P. oceanica*. K-W test results in italics as footnote**

In rocky habitats (Fig 12a) mean fish abundance is found to be higher in station AR1 (751.33/125 $m^2$), displaying a gradual decrease as distance from area A (i.e. NMPZ zone A) increases, with the lowest value being recorded in CR4 (13.33/125 $m^2$). In *P. oceanica* (Fig 12b) highest mean fish abundance was recorded in station BP3 (627/125 $m^2$), while stations BP1, BP5 and CP1 display also high abundances (between 367-406 individuals/125 $m^2$). In the rest of the stations mean values are below 200/125 $m^{-2}$.

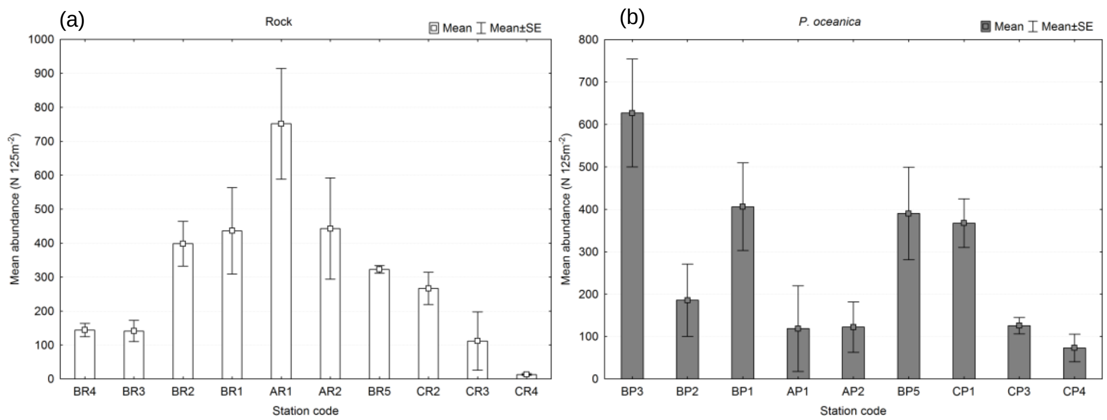



**Fig 12: Mean abundance and st. error of fish species per station a) for rock, and b) for *P. oceanica*. Stations appear according to distance from NMPZ Zone A (i.e. area A), which is located at the centre of the graph**

As expected, biomass values is also higher in rocky (total = 84.054 kg) than in *P. oceanica* habitats (total = 34.98 kg). In rocky habitats, mean values present a significant difference across areas (KW-p<0.00, Fig 13a) with mean values being higher in area A (4854 g /125 $m^2$) and B (2855 g /125$m^2$). In *P. oceanica*, area B (1967 g /125 $m^2$) presents the highest mean biomass value, and biomass of area A is higher than area C. However, these differences are not statistically significant (KW-p>0.05, Fig 13b).

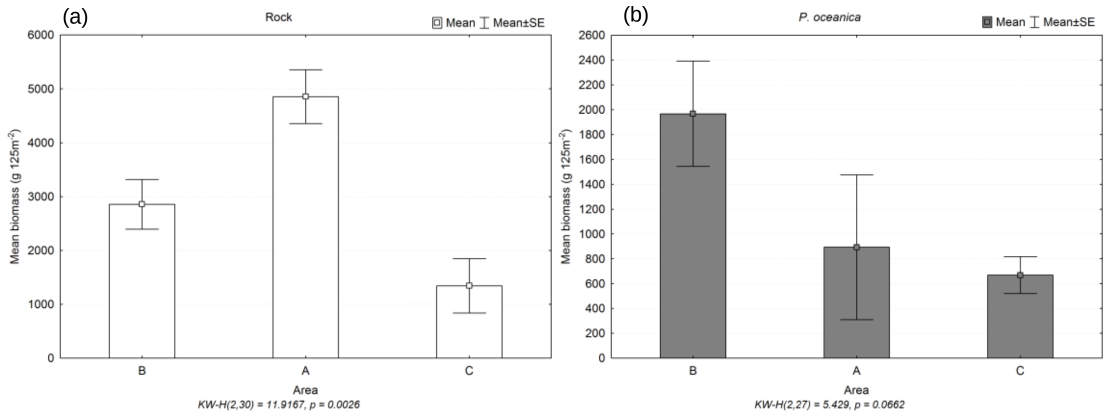



**Fig 13: Mean biomass and st. error per area a) for rock, and b) *P. oceanica*. K-W test results in italics as footnote**

Furthermore, the highest mean biomass values in rocky habitats (Fig 14a) were recorded in stations AR2 (4997.8 g /125 $m^2$) and AR1 (4710.9 g /125 $m^2$), and the lowest in CR3 (1132.3 g /125 $m^2$) and CR4 (308.3 g /125 $m^2$). In *P. oceanica* (Fig 14b), highest biomass was observed in stations BP1 (3016.3 g /125 $m^2$) and BP3 (2540.5 g /125 $m^2$), while the lowest in AP1 (111.94 g /125 $m^2$), CP4 (439.36 g /125 $m^2$) and CP3 (516.39 g /125 $m^2$).

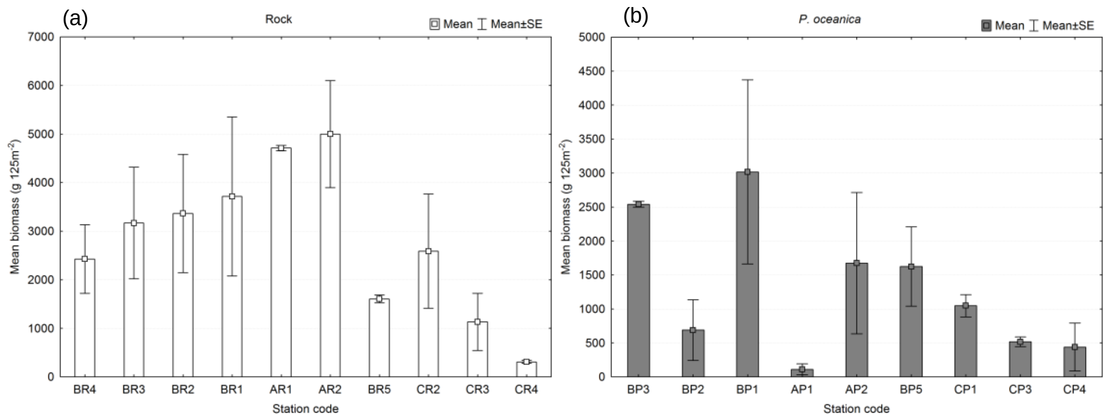



**Fig 14: Mean biomass and st. error of fish species per station a) for rock, and b) *P. oceanica*. Stations appear according to distance from the NMPZ Zone A (i.e. area A), which is located at the centre of the graph**

With regard to trophic groups (Fig 15), zooplanktivores are the most abundant fish in both habitats, mean values being higher in area A (532.5 individuals/125 $m^2$) for rocky, and area B (390.08 individuals/125 $m^2$) for *P. oceanica* habitats. In rocky stations highest abundance was recorded at AR1 (681.67/12 $m^2$), AR2 (383.33/125 $m^2$) and BR1 (376/125 $m^2$), and zero abundance at CR4 (Fig 16a). In *P. oceanica* zooplanktivore abundance is higher in stations BP3 (617.33/125 $m^2$), BP1 (398/125 $m^2$), BP5 (370/125$m^2$), and CP1 (340.67/125 $m^2$) (Fig 16b). The second most abundant group in both habitats are the carnivores, displaying similar mean values in rocky habitats of all areas (A= 47.5, B=42.8, C=48.5 /125 $m^2$) (Fig 15a), but having slightly greater abundance in area C (17/125 $m^2$) of *P. oceanica* habitats (Fig 15b). The highest mean abundance for carnivores was recorded in stations CR2 (124.67125 $m^2$) and BR2 (73.67/125 $m^2$) at rocky habitats (Fig 16a), while in *P. oceanica* stations carnivores are more abundant in CP3 (28.67/125 $m^2$), CP1 (21/125 $m^2$), AP2 (21.3/125 $m^2$), and BP5 (19.6/125 $m^2$) (Fig 16b).

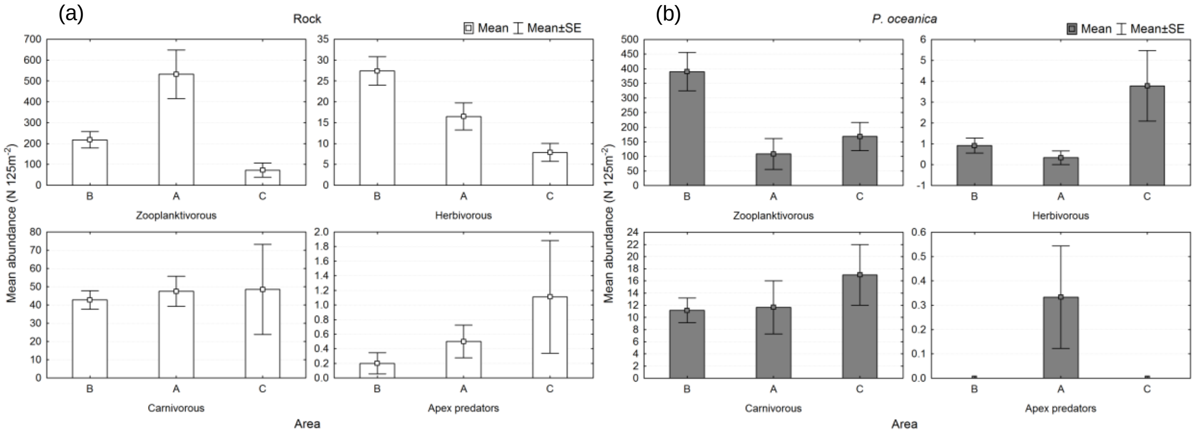



**Fig 15: Mean abundance and st. error of trophic groups per station a) for rock, and b) *P. oceanica***

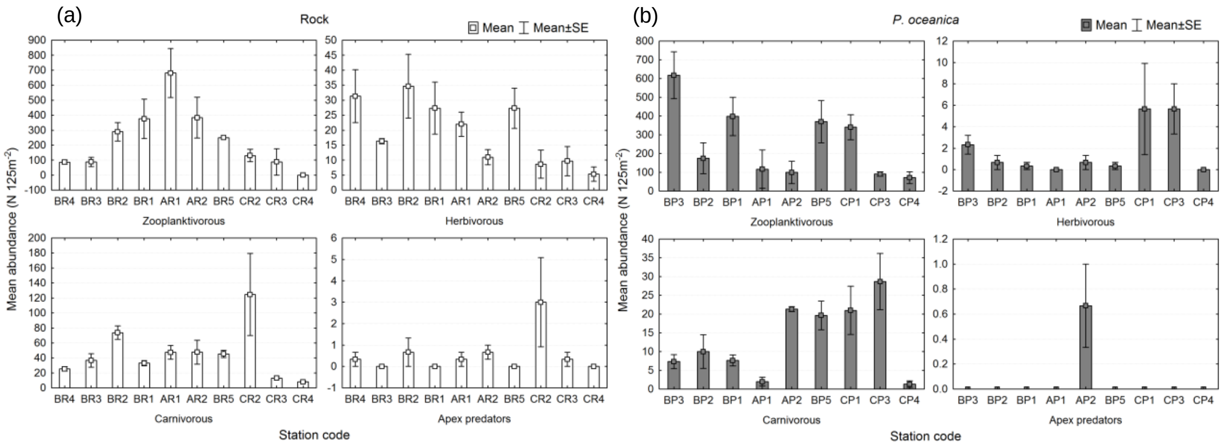



**Fig 16: Mean abundance and st. error of trophic groups per station a) for rock, and b) for *P. oceanica***

Herbivores are the third most abundant trophic group in both habitat types. In rocky areas (Fig 15a), area B (27.4/125 $m^2$) presents the highest mean abundance, while area C (7.89/125 $m^2$) the lowest. The highest mean abundance was recorded in stations BR2 (34.67/125 $m^2$) and BR4 (31.3/125 $m^2$), while the lowest in CR4 (5.3/125 $m^2$) (Fig 16a). In *P. oceanica* stations abundance of herbivorous fish is much lower than in rocks, with the highest mean values being recorded in area C (Fig 15b), and more specifically in CP1 and CP3 (5.6/125 $m^2$ for both stations), while zero values were recorded in AP1 and CP4 (Fig 16b).
Apex predators have very low abundance across all stations and habitat types (Fig 16). Mean values range between 0.2/125 $m^2$ (area B) and 1.1/125$m^2$ (area C) in rocky habitats, with a maximum in CR3. In *P. oceanica* apex predators were only recorded in one station, namely AP2.

## 3. Fish Biomass

Biomass is overall higher in rocky (total: 84.05 kg) than in *P. oceanica* habitats (total: 34.98 kg). In rocky habitats, zooplanktivores and carnivores present the highest mean biomass in area A (2375.14 and 1333.8 g/125 $m^2$ respectively) and the lowest in area C (Fig 17a). Zooplanktivore mean biomass is greater in stations AR1 (2959.8 g/125 $m^2$), AR2 (1790.4 g/125 $m^2$) and BR1 (1639.4 g/125 $m^2$), while carnivores display a greater mean biomass in BR3 (2178 g/125 $m^2$) and

AR2 (1730 g/125 $m^2$) (Fig 18a). In *P. oceanica,* both zooplanktivore and carnivore biomass is greater in area B (Fig 17b). More specifically, zooplanktivores have higher mean biomass in BP3 (2411 g/125 $m^2$) and BP1 (2049 g/125 $m^2$), while highest mean biomass for carnivores was recorded in BP1 (962 g/125 $m^2$) (Fig 18b).

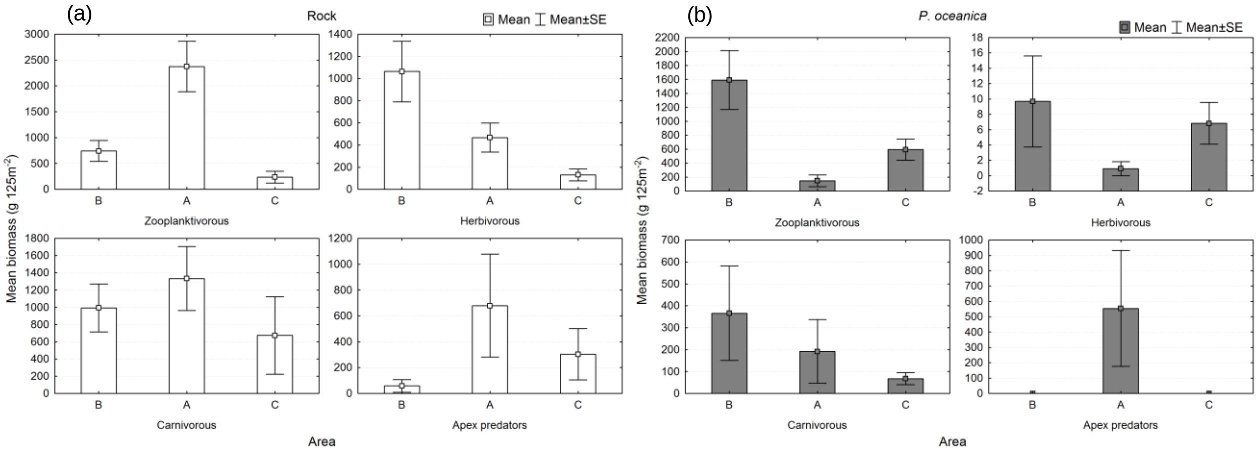



**Fig 17: Mean biomass and st. error of trophic groups per area a) for rock, and b) for *P. oceanica***

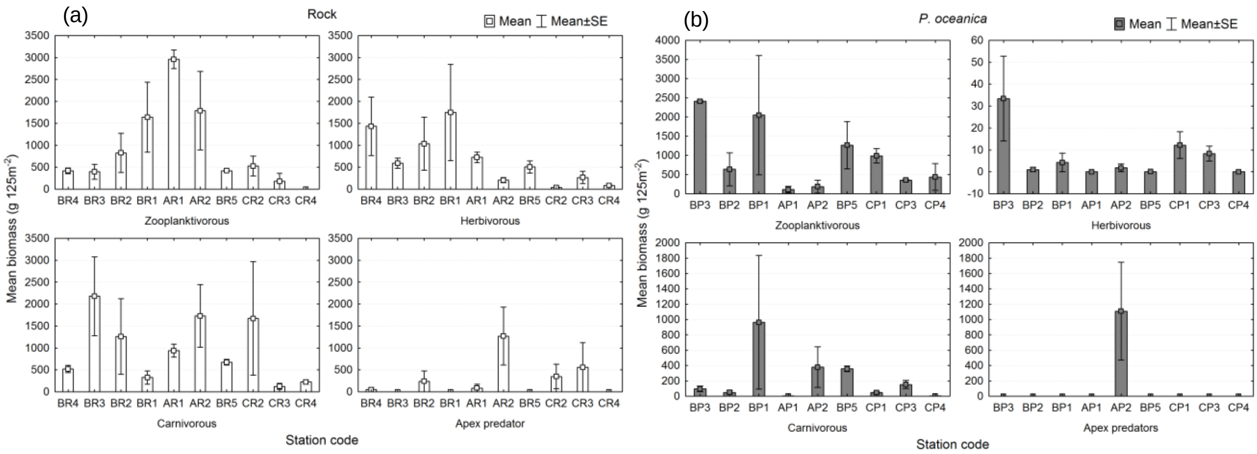



**Fig 18: Mean biomass and st. error trophic groups per station a) for rock, and b) for *P. oceanica* station**

Herbivore biomass in both habitats is higher in area B (Fig 17). In rocky habitats mean herbivore biomass is higher in BR1 (1748.7 g/125 $m^2$) and BR4 (1433.9 g/125 $m^2$) (Fig 18a), while in *P. oceanica* values are quite low across all stations (i.e. below 20 g/125 $m^2$), with only station B3 displaying a higher mean value of 33.4 g/125 $m^2$ (Fig 18b). Apex predators' mean biomass is higher in area A for both habitat types (Fig 17a,b) and appear to be higher in stations AR2 (1271 g/125 $m^2$), and AP1 (1108.6 g/125 $m^2$) (Fig 18a,b). In rocky habitats apex predators have the lowest biomass of all other trophic groups, while in *P. oceanica* habitats they were only recorded in AP2.

Summarizing the above analysis with regard to the main community characteristics, fish abundance is generally found to be higher in rocky (total: 9085 fish) than in *P. oceanica* habitats (total: 7247 fish). In rocky habitats fish abundance is found to be greater in stations located close to Zone A of the NMPZ (i.e. study area A), gradually declining in stations located further away from this zone (Fig 19a). In *P. oceanica*, abundance in overall higher in stations of area B (Fig 19b).

In both habitats the most abundant fish are the zooplanktivores, representing 78.4% of total abundance in rock and 94.4% in *P. oceanica*. Carnivorous and herbivorous fish are more abundant in rock (15% and 4.9% respectively) than in *P. oceanica* (6.4% and 0.65, respectively), while a really low number of apex predators was recorded in both habitats presenting only 0.2% and 0.03% of the total abundance in rock and *P. oceanica* respectively.

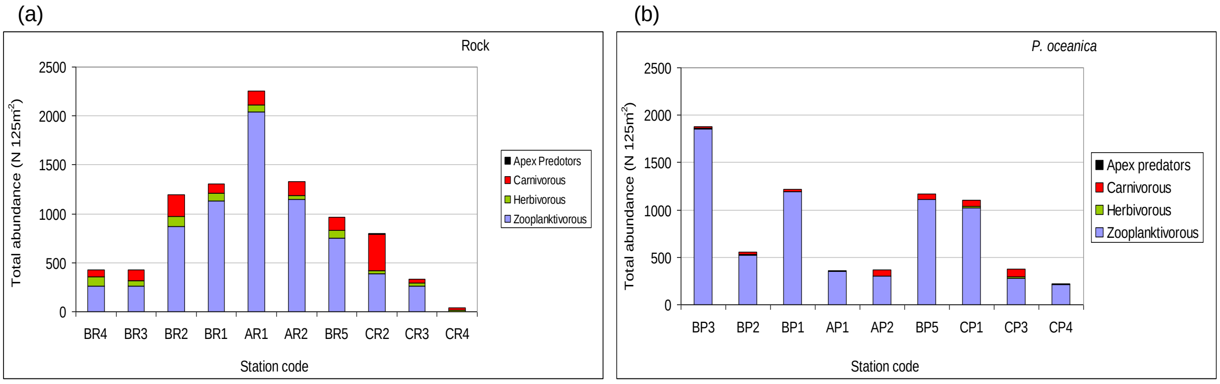



**Fig 19: Total fish abundance per station a) for rock, and b) for *P. oceanica*. Different colors denote trophic status. Stations appear according to distance from Zone A (area A), which is located at the centre of the graph**

Similarly, fish biomass is overall higher in rocky (total: 84.05 kg) than in P. oceanica habitats (total: 34.98 kg). In rocky habitats total fish biomass is highest at stations of area A and B and lowest at stations of area C (Fig 20a), while in P. oceanica biomass is greater in area B (Fig 20b). The contribution of the different trophic groups with regard to biomass appears to be different to that of abundance. Although zooplanktivorous fish have the greatest contribution in total biomass of the *P. oceanica* habitats (i.e. 72%), in rocky habitats total biomass is more evenly distributed, with carnivores presenting the greatest biomass (34.4%), followed by zooplanktivores (32.7%) and herbivores (23.7%). Apex predator biomass is still very low in both habitat types, contributing by 9% in total biomass of rocky and 9.5 in *P. oceanica* habitats.

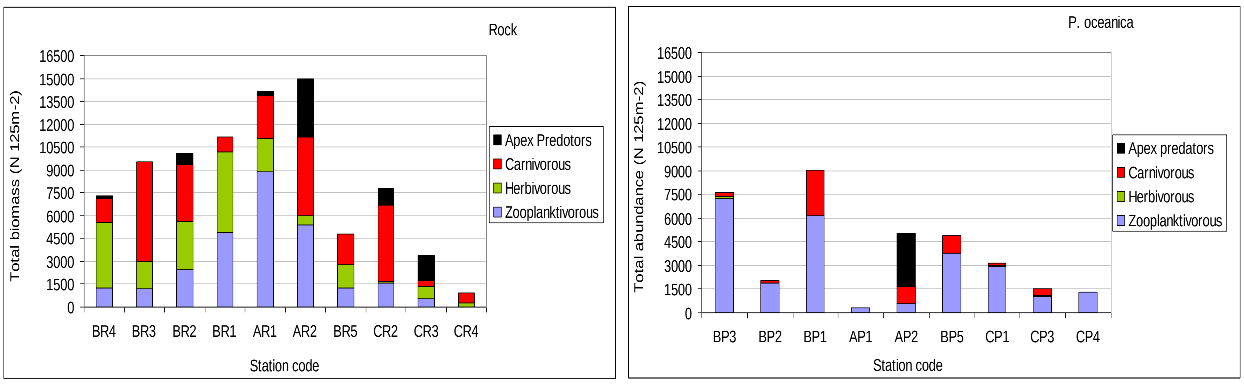



**Fig 20: Total fish abundance per station a) for rock, and b) for *P. ocenica*. Different colors denote trophic status. Stations appear according to distance from Zone A (area A), which is located at the centre of the graph**

## 4. Species Contribution to Overall Abundance & Biomass

In rocky habitats, *C. chromis* is the most abundant of all species, accounting for 72% of total abundance and 29% of total fish biomass, and is therefore responsible for the dominance of zooplanktivorous fish in most areas and stations (Fig 21a, Fig 22b). *S. luridus*, accounting for 3.6% of total abundance and 16.6% of total biomass, is the most commonly recorded herbivorous fish, which alongside with *S. cretense* (2.7% abundance and 6.5% biomass) outnumber the populations of *S. salpa* in the study sites (Fig 21b, Fig 22b). The most numerous carnivorous fish are *C. julis*

(2.7%), *D. sargus* (2.4%), *T. pavo* (1.8%), *S. scriba* (1.26%) and *D. vulgaris* (1.04%), but the former has the highest biomass of all carnivorous fish (14.4% total biomass) (Fig 21c, Fig 22c). With regard to apex predators, in rocky habitats the most common species is *E. costae*, but its total abundance accounts for less than 0.2% of the total fish abundance recorded (Fig 21d). Furthermore, although abundance of *E. marginatus* is also very low (0.068%) it represents the highest biomass (6%) in this trophic group (Fig 21d, Fig 22d).

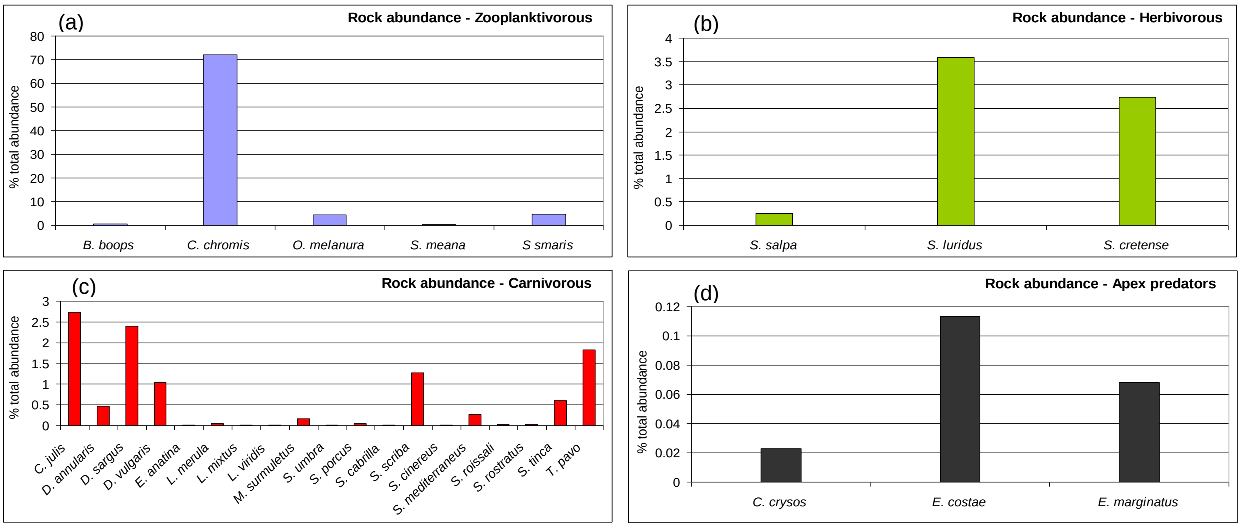



**Fig 21: Contribution of the different species per trophic group to the overall fish abundance in rocky habitats**

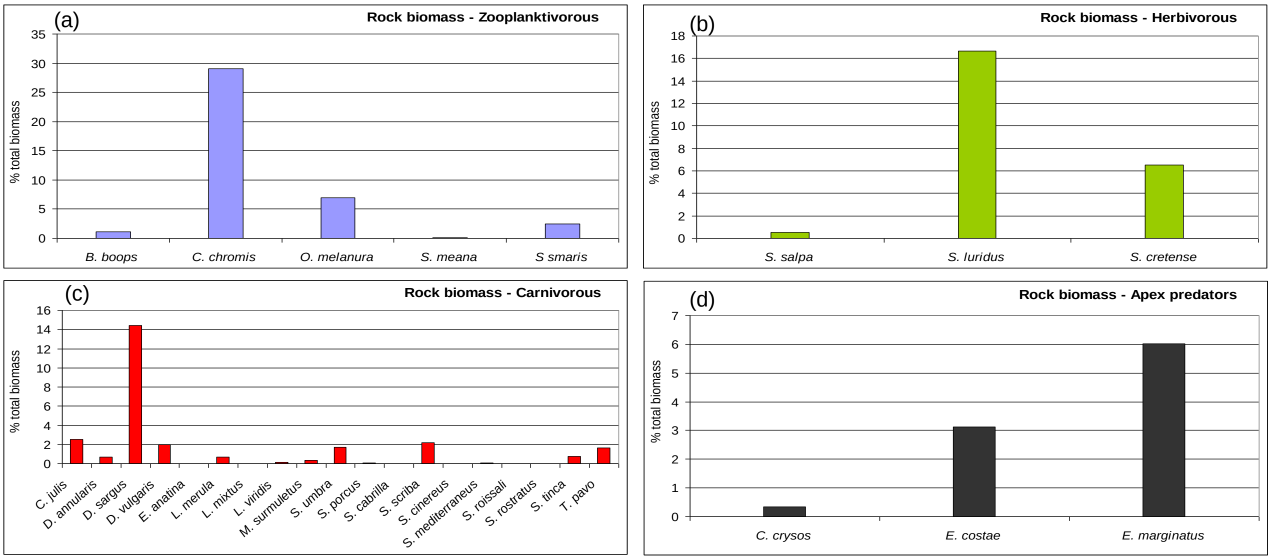



**Fig 22: Contribution of the different species per trophic group to the overall fish biomass in rocky habitats**

In *P. oceanica* habitats, the zooplanktivorous fish *C. chromis* and *S. smaris* are the species with the greatest contribution to the overall abundance and biomass (Fig 23a, Fig 24a). Furthermore, *S. luridus* is the most important herbivorous fish both in terms of abundance (0.6%) and biomass (0.33%) (Fig 23b, Fig 24b). From the carnivorous group, *C. julis* is the most abundant (2.1%), while *S. umbra* displays the highest biomass (7.8%) (Fig 23c, Fig 24c). *E. marginatus* is the only species representing apex predators in *P. oceanica* habitats with a total abundance of 0.027% and a total biomass of 9.6% (Fig 23d, Fig 24d).

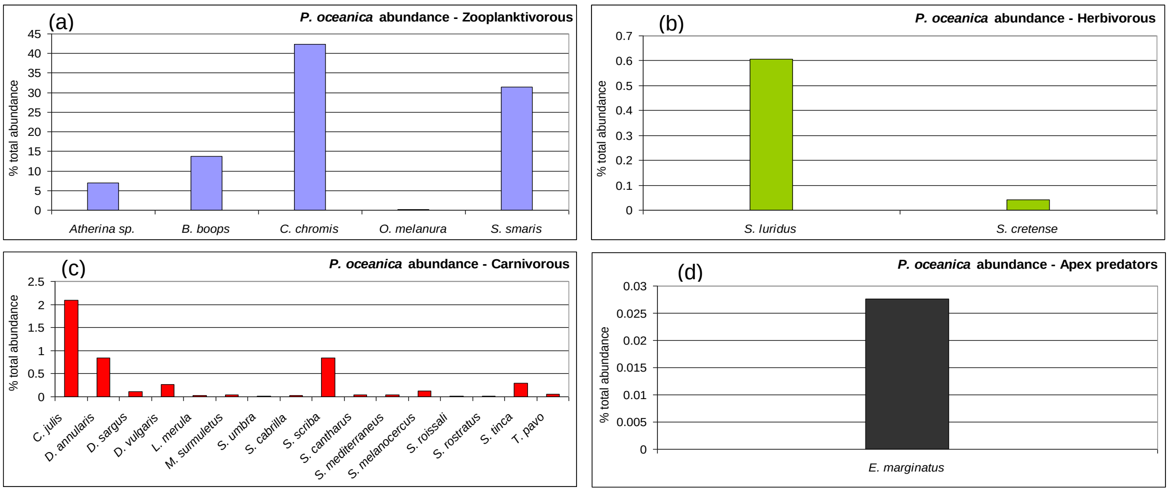



**Fig 23: Contribution of the different species per trophic group to the overall fish abundance in *P. oceanica* habitats**

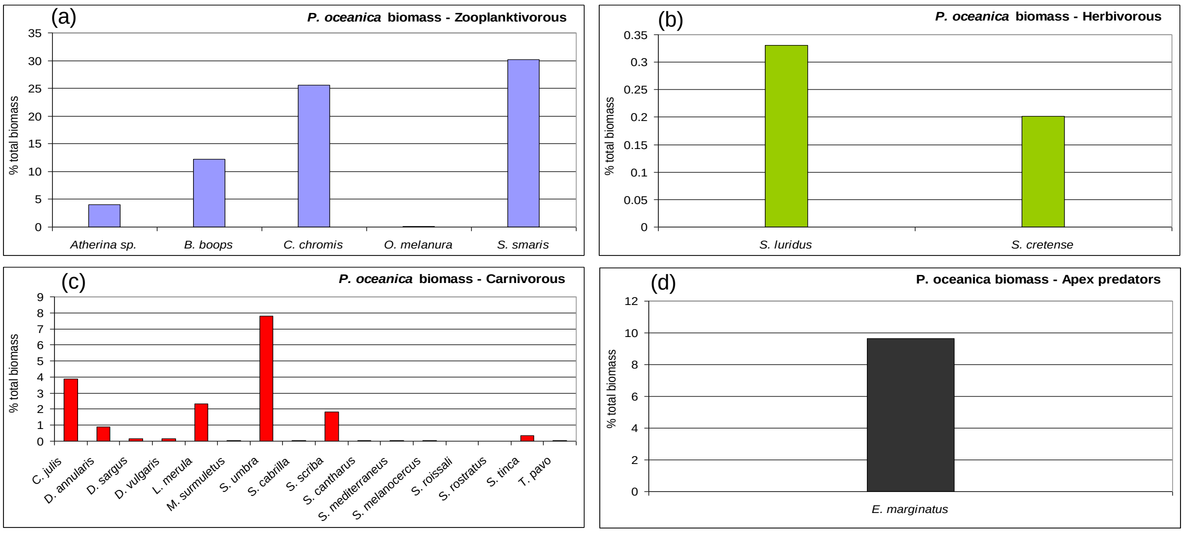
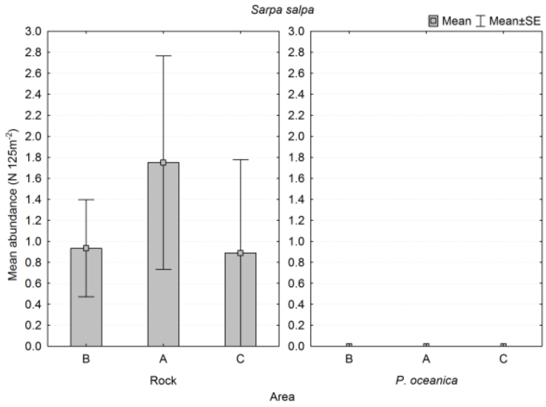
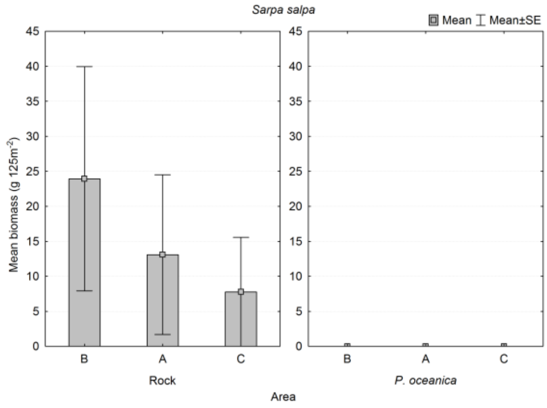


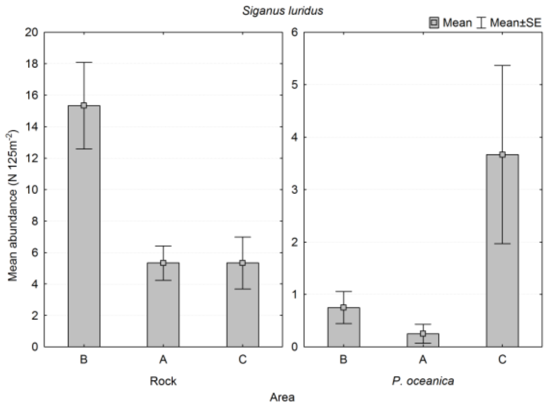

**Fig 24: Contribution of the different species per trophic group to the overall fish biomass in *P. oceanica* habitats**

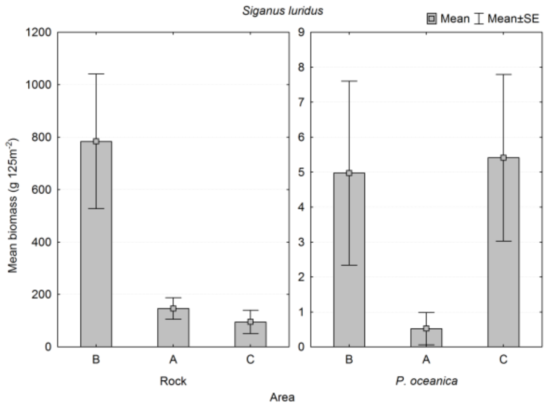
## 5. Abundance & Biomass for Selected Species/Families

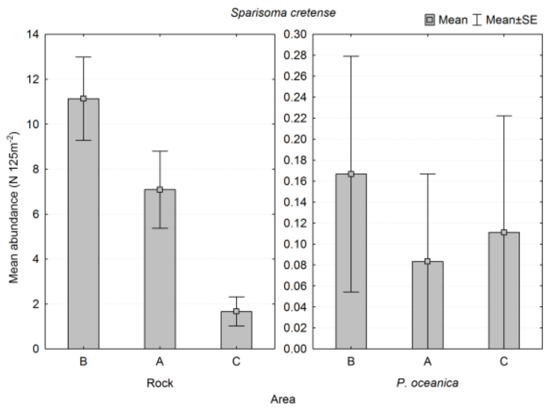
The mean abundance and biomass recorded across the different sampling areas for selected species (i.e. commercial, allochthonous and herbivorous) is displayed in the following set of graphs (composite Fig 25). Species of extremely low abundance or biomass, but of similar body size were grouped and presented graphically at the family level.

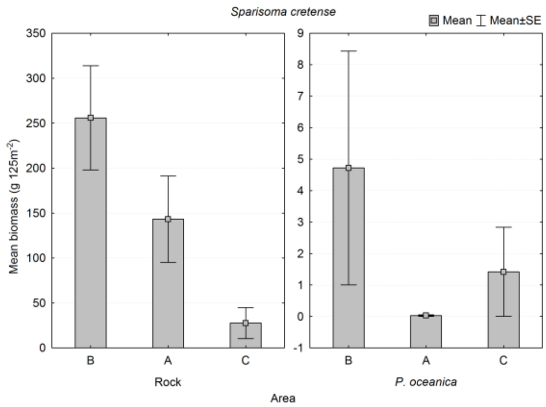

Sarpa salpa
Mean Mean±SE
Mean abundance (N 125m$^{-2}$)
Rock
P. oceanica
Area

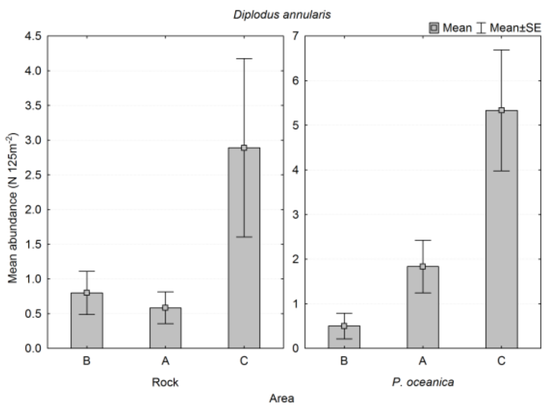

Sarpa salpa
Mean Mean±SE
Mean biomass (g 125m$^{-2}$)
Rock
P. oceanica
Area

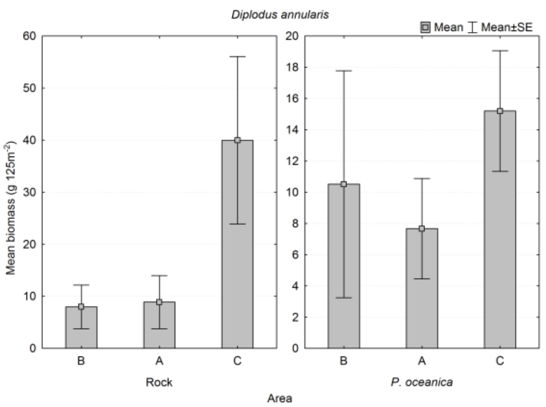

Siganus luridus
Mean Mean±SE
Mean abundance (N 125m$^{-2}$)
Rock
P. oceanica
Area

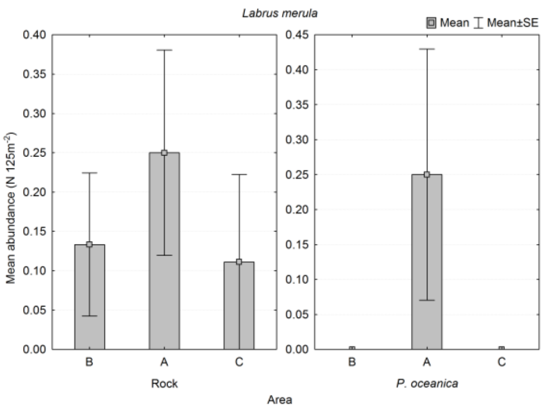

Siganus luridus
Mean Mean±SE
Mean biomass (g 125m$^{-2}$)
Rock
P. oceanica
Area

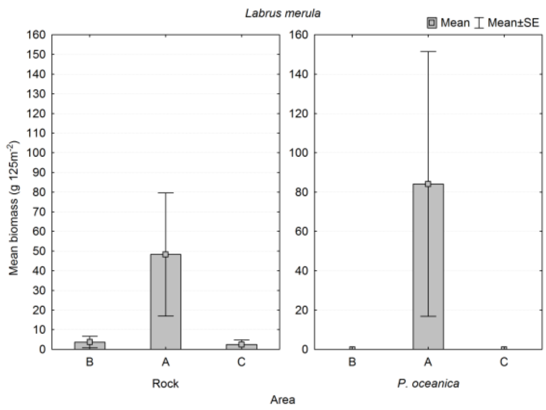

Sparisoma cretense
Mean Mean±SE
Mean abundance (N 125m$^{-2}$)
Rock
P. oceanica
Area

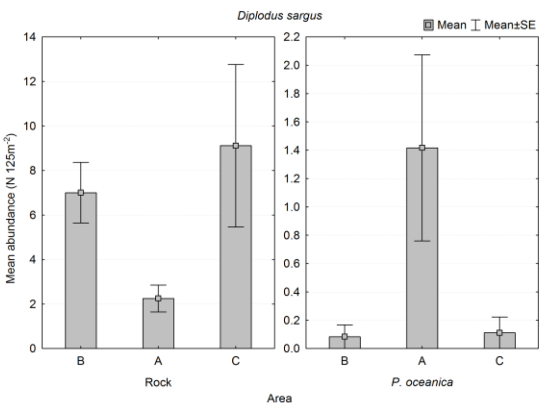

Sparisoma cretense
Mean Mean±SE
Mean biomass (g 125m$^{-2}$)
Rock
P. oceanica
Area

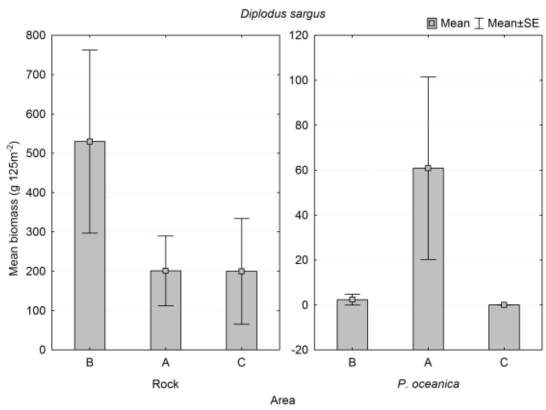

Diplodus annularis
Mean Mean±SE
Mean abundance (N 125m$^{-2}$)
Rock
P. oceanica
Area

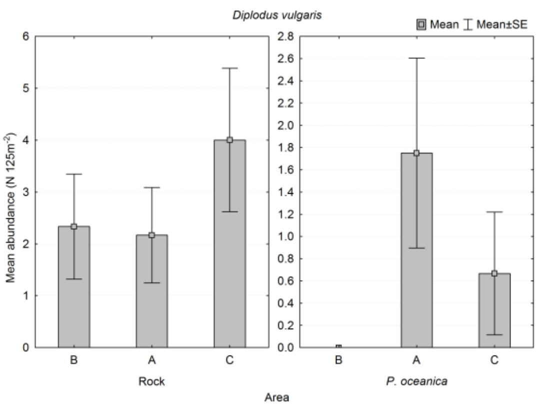

Diplodus annularis
Mean Mean±SE
Mean biomass (g 125m$^{-2}$)
Rock
P. oceanica
Area

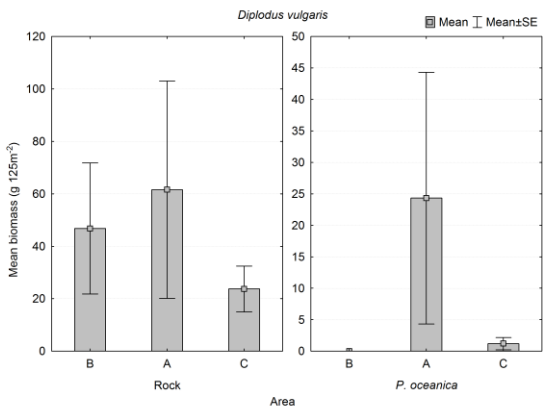

Labrus merula
Mean Mean±SE
Mean abundance (N 125m$^{-2}$)
B A C
Rock
P. oceanica
Area

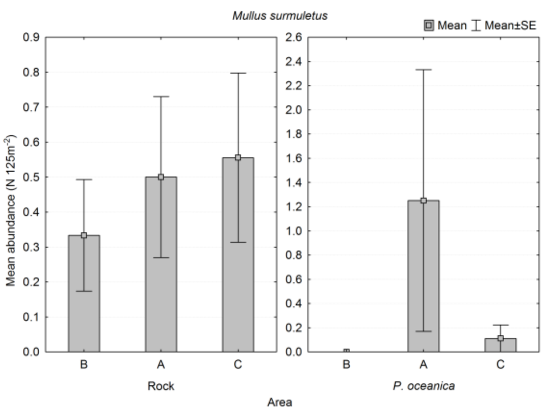

Labrus merula
Mean Mean±SE
Mean biomass (g 125m$^{-2}$)
B A C
Rock
P. oceanica
Area

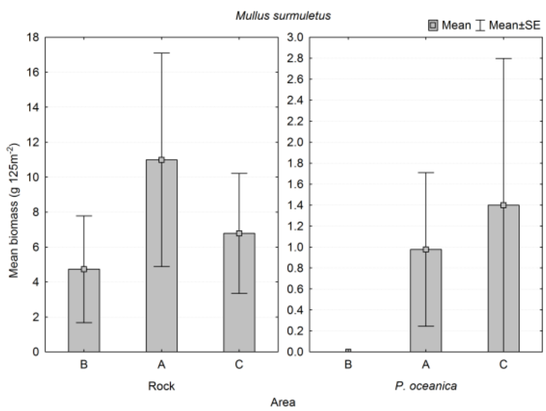

Diplodus sargus
Mean Mean±SE
Mean abundance (N 125m$^{-2}$)
B A C
Rock
P. oceanica
Area


Diplodus sargus
Mean Mean±SE
Mean biomass (g 125m$^{-2}$)
B A C
Rock
P. oceanica
Area


Diplodus vulgaris
Mean Mean±SE
Mean abundance (N 125m$^{-2}$)
B A C
Rock
P. oceanica
Area


Diplodus vulgaris
Mean Mean±SE
Mean biomass (g 125m$^{-2}$)
B A C
Rock
P. oceanica
Area


Mullus surmuletus
Mean Mean±SE
Mean abundance (N 125m$^{-2}$)
B A C
Rock
P. oceanica
Area


Mullus surmuletus
Mean Mean±SE
Mean biomass (g 125m$^{-2}$)
B A C
Rock
P. oceanica
Area

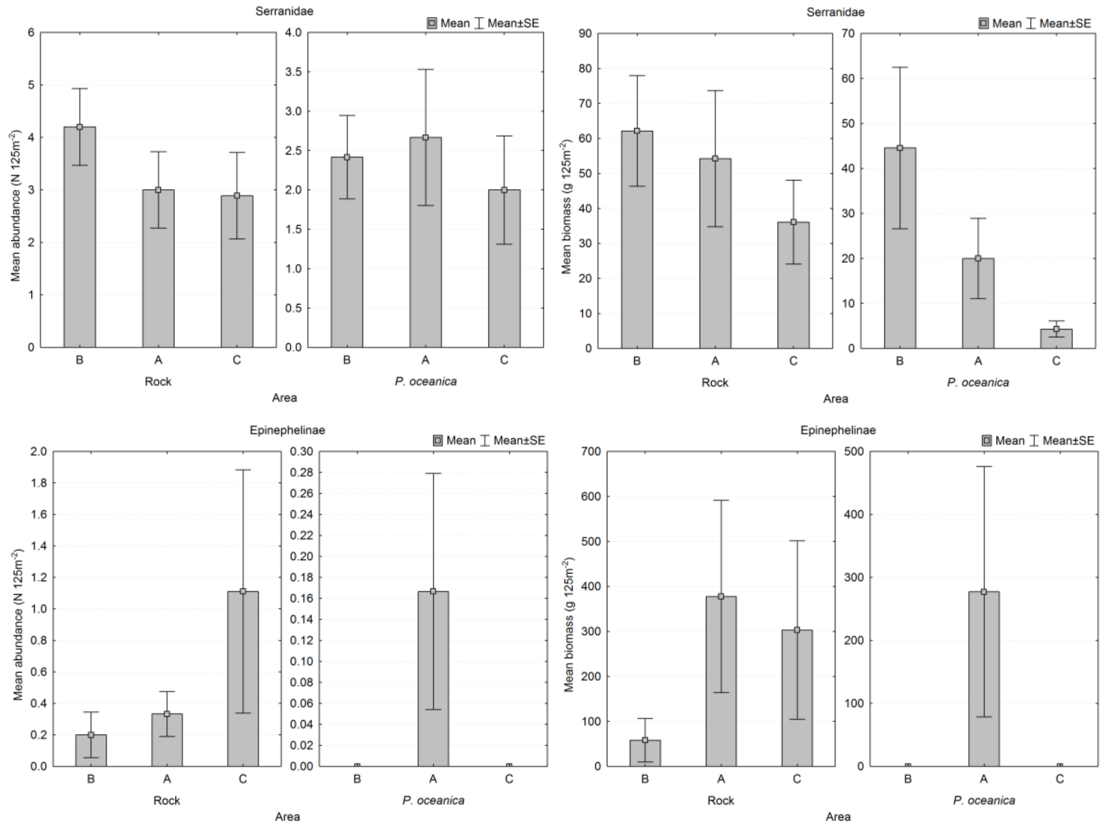



**Fig 25: Mean abundance and biomass of selected species/families per area (both habitats pooled)**

## 6. Response Ratio (Ln *R*) for Rocky Habitats

The response of fish communities to protection, estimated as the natural log response ratio (ln*R*) of density and biomass per set of areas (i.e. A/B, B/C and A/C), shows that protection has a positive effect to the overall fish community. The non-logarithmic weighted ratio of the total abundance of fish is estimated to be 1.02 times higher in area A than area B ($\ln R_{ab}$ = 0.02), while abundance in area B is 3.1 times higher than in area C ($\ln R_{bc}$ = 1.13) (Table 6). Similarly total biomass is estimated to be 1.3 times higher in area A than B ($\ln R_{ab}$ = 0.26), and biomass in area B is 4.5 times higher than C ($\ln R_{bc}$ = 1.51).

**Table 6: The results of the Ln*R* ratio across different areas for abundance and biomass (all habitats and stations pooled)**

| ln*R* | Abundance | Biomass |
|---|---|---|
| $\ln R_{ab}$ | 0.02 | 0.26 |
| $\ln R_{bc}$ | 1.13 | 1.51 |
| $\ln R_{ac}$ | 1.15 | 1.77 |

When ln*R* was estimated for the different trophic groups, the resulting ratios reveal the existence of a positive response to protection, at least with regard to the two areas found at the two opposite ends of protection measures, namely areas A/C (Fig 26). Furthermore, for most trophic groups ln*R* indicates higher values in areas A and B than C, while the A/B ratio suggests similar values of fish biomass and abundance in the two areas (i.e. values close to 0). The only exception is the case of apex predators, which display lower ratios in area B both from area A and C.

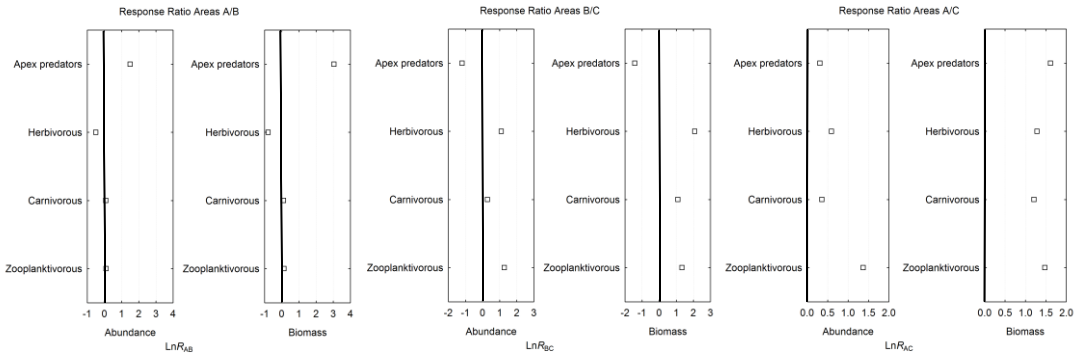



**Fig 26: Response of fish trophic groups to protection, measured as the natural log response ratio (ln*R*) of density and biomass per set of areas A/B, B/C and A/C**

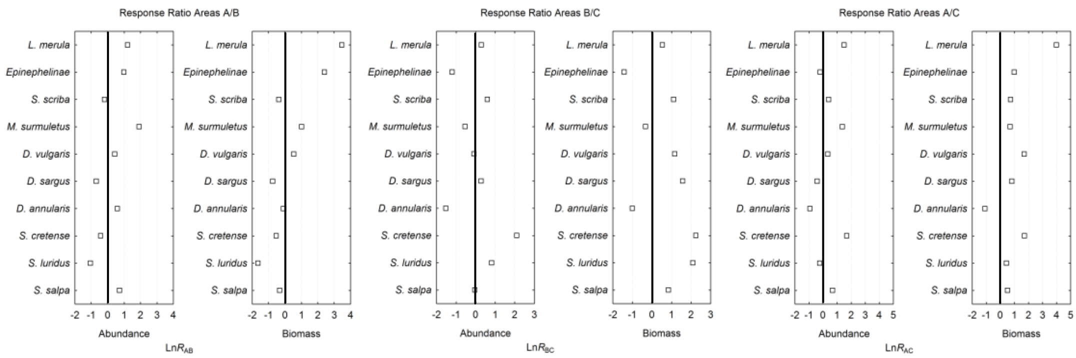



**Fig 27: Response of selected fish species to protection, measured as the natural log response ratio (ln*R*) of density and biomass per set of areas A/B, B/C and A/C**

With regard to the logarithmic response ratio analysis for the ten selected species of particular interest (i.e. herbivorous, allochthonous and commercial), not all species respond in the same way to protection (Fig 27). For example, the herbivorous fish *S. salpa, S. luridus* and *S. cretense* display a different response, with *S. cretense* and *S. luridus* having highest abundance and biomass in area B, and *S. salpa* (although with a weaker response) presenting higher abundance in area A, and greater biomass in area B.

The logarithmic ratio of abundance and biomass is highest in area B for *D. sargus*, area C for *D. annularis*, and area A for *D. vulgaris* and *M. surmuletus*. *S. scriba* displays almost no response to the different protection status of the three areas, while *L. merula* has the strongest response displaying highest abundance and biomass in area A. Finally, response ratio for abundance of groupers is similar between area A and C, being higher than area B. Yet, the biomass ratio is increased in area A, suggesting an increase in fish size.

## 7. Size Structure of Selected Species

The size structure of selected species (i.e. herbivorous, allochthonous and commercial) recorded in the three areas is provided in the following set of figures, for future reference (Fig 28).

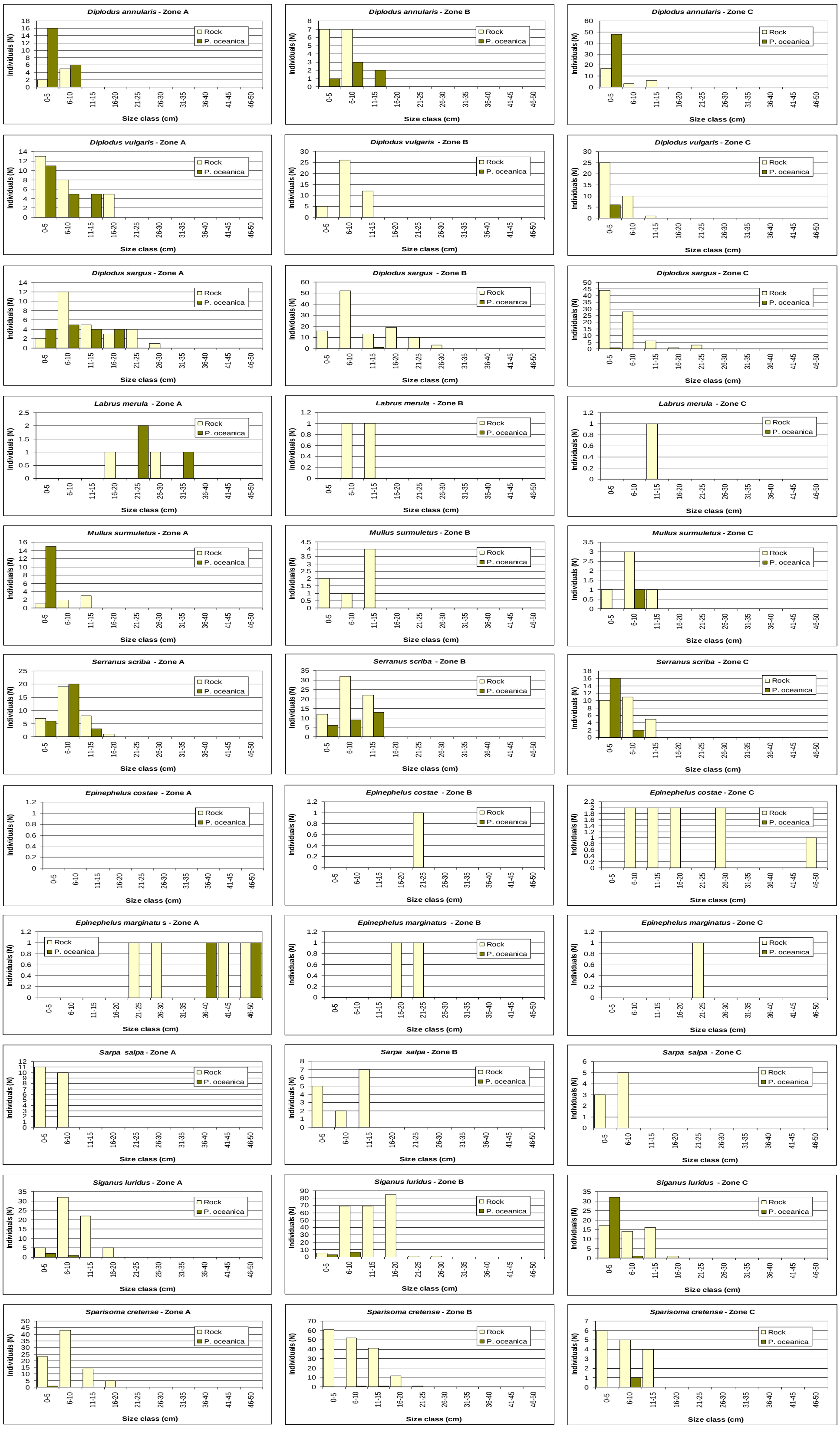



**Fig 28: Size structure of selected species (i.e. herbivorous, allochthonous and commercial) recorded**

## 8. Community Structure and Patterns

### *Abundance based patterns*

MDS and Cluster analyses results based on species abundance data revealed a clear pattern of community structure differentiation for fish assemblages when different types of habitats are compared (posidonia *vs* rock habitat - Fig 29). On the other hand, when the different zones were compared, a less visible pattern of stations' grouping according to their community structure was detected since all the formulated groups of areas are presenting high values of structure similarity (higher than 65% in all cases).

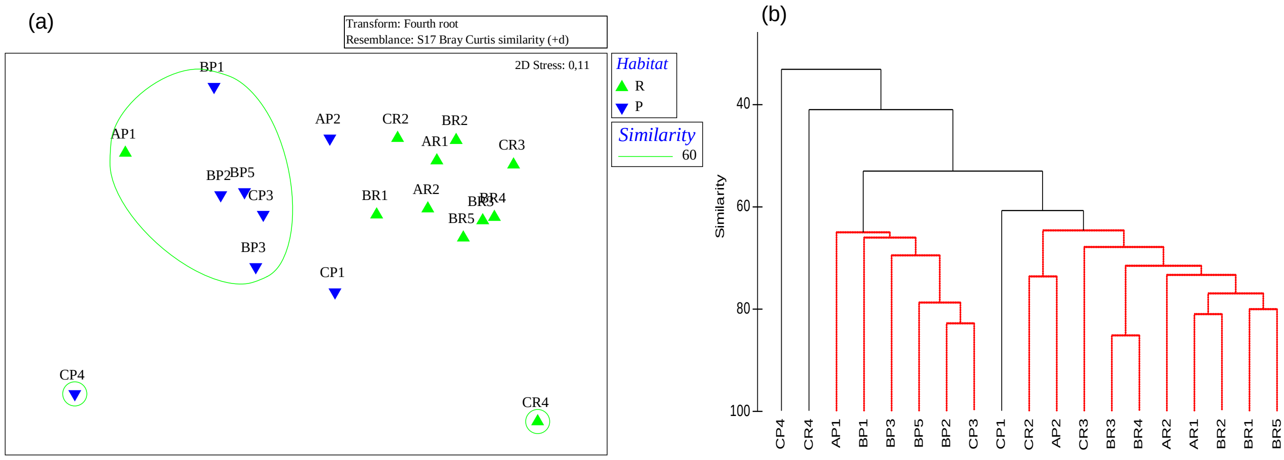



**Fig 29: Community structure of fish assemblages based on species abundance as it was evidenced by (a) MDS and (b) Cluster analyses**

Results from the Two-Way crossed ANOSIM analysis, suggested statistically significant differences of community structure between the sampling areas (A, B and C) across all habitat groups (posidonia and rock) ($R = 0{,}338$, $p < 0.01$) as well as between all the habitat groups across all sampling areas ($R = 0.683$, $p<0.01$). These findings are in line with MDS and Cluster analyses results, since strength of community separation, expressed as the R value of the ANOSIM test, was two times bigger when habitat effect is taken into account in comparison to the effect of the different zones that include the sampling stations.

### *Abundance based patterns on rocky habitats*

When only rocky habitat is considered, MDS and Cluster analysis revealed a pattern of spatial grouping of the sampling areas in terms of their community structure. In this sense, two major groups of areas were detected, one including the stations located in areas A and B and a second one gathering the stations found in area C, at a dissimilarity level of 30% (Fig 30). Even though, the formulated groups of areas presented high similarity in their community structure, significance of areas grouping was achieved as it was evidenced by one way ANOISIM results ($R = 0.364$, $p<0.05$).

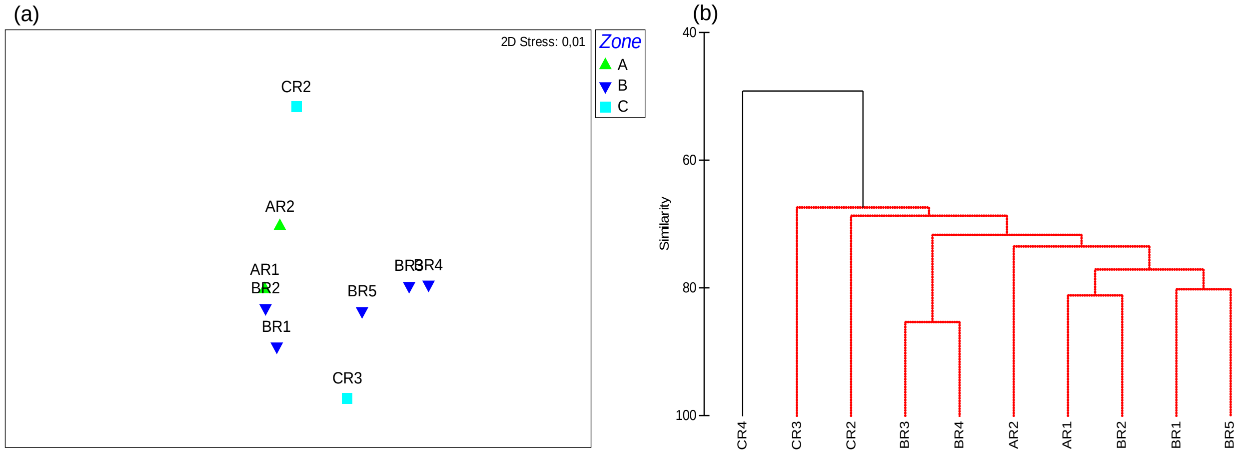



**Fig 30: Community structure of rocky habitat of fish assemblages based on species abundance as it was evidenced by (a) MDS and (b) Cluster analyses**

SIMPER analysis results (Tables 7-9) reveal the main species responsible for the observed community structure and thus for the produced area grouping. In this respect, when area A and B are compared (Table 7), the observed average dissimilarity (27.98%) was mainly attributed to abundance fluctuation, rather than species exclusive present to only one area, of 8 species *(Oblada melanura, Spicara smaris, Boops boops, Chromis chromis, Symphodus mediterraneus, Epinephelus marginatus, Sarpa salpa, Labrus merula)* which accounted for the 50% of this dissimilarity. Moreover, all the above species had higher average abundance values in Area A, with the exception of *Sarpa salpa* and *Symphodus mediterraneus.* Comparison of areas A and C suggested an enhanced level of community dissimilarity (39.93%) which however was mainly attributed to abundance variation of species with low or none commercial value such as *Chromis chromis*, *Spicara smaris*, *Boops boops*, *Thalassoma pavo*, *Symphodus tinca* and *Coris julis* (Table 8). The highest level of community dissimilarity was noted at the comparison of areas B and C (40.34%) whereas the species which were mainly responsible for the produced dissimilarity are *Chromis chromis*, *Thalassoma pavo*, *Spicara smaris*, *Coris julis*, *Oblada melanura*, *Symphodus mediterraneus* and *Symphodus tinca* (Table 9).

**Table 7: Species abundance contribution to the produced dissimilarity of community structure when areas A and B are compared**

| Average dissimilarity = 27.98% | AREA A | AREA B | | | | |
|---|---|---|---|---|---|---|
| Species | Av.Abund | Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
| ***Oblada melanura*** | 1.89 | 0.96 | 2.4 | 2.1 | 8.57 | 8.57 |
| ***Spicara smaris*** | 0.92 | 0.9 | 2.25 | 1.06 | 8.04 | 16.6 |
| ***Boops boops*** | 1,01 | 0 | 2.16 | 0.94 | 7.72 | 24.32 |
| ***Chromis chromis*** | 4.6 | 3.68 | 2.01 | 1.31 | 7.19 | 31.51 |
| ***Symphodus mediterraneus*** | 0 | 0.89 | 1.81 | 1.68 | 6.48 | 38 |
| ***Epinephelus marginatus*** | 0.83 | 0.18 | 1.47 | 1.99 | 5.26 | 43.25 |
| ***Sarpa salpa*** | 0 | 0.66 | 1.43 | 1.12 | 5.12 | 48.37 |
| ***Labrus merula*** | 0.76 | 0.18 | 1.37 | 2.31 | 4.89 | 53.26 |
| ***Diplodus annularis*** | 0.9 | 0.64 | 1 | 1.12 | 3.58 | 56.84 |
| ***Mullus surmuletus*** | 0.92 | 0.5 | 0.97 | 1.08 | 3.48 | 60.32 |
| ***Symphodus roissali*** | 0.45 | 0.15 | 0.93 | 1 | 3.31 | 63.63 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Caranx crysos*** | 0.45 | 0 | 0.92 | 0.94 | 3.29 | 66.92 |
| ***Labrus viridis*** | 0.38 | 0 | 0.81 | 0.94 | 2.9 | 69.82 |
| ***Thalassoma pavo*** | 1.36 | 1.7 | 0.79 | 1.07 | 2.84 | 72.66 |
| ***Symphodus rostratus*** | 0.38 | 0.3 | 0.79 | 0.94 | 2.81 | 75.47 |
| ***Siganus luridus*** | 1.59 | 1.97 | 0.76 | 2.38 | 2.73 | 78.2 |
| ***Symphodus tinca*** | 1.26 | 1.16 | 0.74 | 1.56 | 2.65 | 80.84 |
| ***Diplodus vulgaris*** | 1.31 | 1.14 | 0.7 | 1.3 | 2.51 | 83.36 |
| ***Scorpaena porcus*** | 0 | 0.33 | 0.64 | 0.76 | 2.28 | 85.64 |
| ***Diplodus sargus*** | 1.43 | 1.55 | 0.57 | 1.39 | 2.05 | 87.69 |
| ***Spicara meana*** | 0 | 0.31 | 0.55 | 0.47 | 1.97 | 89.66 |
| ***Sparisoma cretense*** | 1.74 | 1.8 | 0.49 | 1.4 | 1.76 | 91.43 |

**Table 8: Species abundance contribution to the produced dissimilarity of community structure when areas A and C are compared**

| Average dissimilarity = 39.93% | AREA A | AREA C | | | | |
|---|---|---|---|---|---|---|
| Species | Av.Abund | Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
| ***Chromis chromis*** | 4.6 | 1.91 | 6.78 | 1.39 | 16.97 | 16.97 |
| ***Spicara smaris*** | 0.92 | 0.98 | 2.92 | 1.12 | 7.3 | 24.27 |
| ***Boops boops*** | 1.01 | 0 | 2.49 | 0.9 | 6.23 | 30.5 |
| ***Thalassoma pavo*** | 1.36 | 0.41 | 2.45 | 1.61 | 6.14 | 36.63 |
| ***Symphodus tinca*** | 1.26 | 0.3 | 2.42 | 1.44 | 6.06 | 42.7 |
| ***Coris julis*** | 1.81 | 0.97 | 2.39 | 1.09 | 5.98 | 48.67 |
| ***Oblada melanura*** | 1.89 | 1.6 | 2.28 | 5.49 | 5.7 | 54.38 |
| ***Sparisoma cretense*** | 1.74 | 1.08 | 1.64 | 1.63 | 4.1 | 58.47 |
| ***Epinephelus marginatus*** | 0.83 | 0.25 | 1.48 | 1.38 | 3.72 | 62.19 |
| ***Epinephelus costae*** | 0 | 0.68 | 1.45 | 1.23 | 3.64 | 65.83 |
| ***Labrus merula*** | 0.76 | 0.25 | 1.23 | 1.24 | 3.07 | 68.9 |
| ***Sarpa salpa*** | 0 | 0.43 | 1.2 | 0.64 | 3.01 | 71.91 |
| ***Diplodus sargus*** | 1.43 | 1.48 | 1.19 | 1.53 | 2.98 | 74.89 |
| ***Spicara meana*** | 0 | 0.5 | 1.17 | 0.65 | 2.92 | 77.81 |
| ***Caranx crysos*** | 0.45 | 0 | 1.05 | 0.9 | 2.63 | 80.44 |
| ***Symphodus roissali*** | 0.45 | 0 | 1.05 | 0.9 | 2.63 | 83.07 |
| ***Mullus surmuletus*** | 0.92 | 0.61 | 0.98 | 0.96 | 2.44 | 85.52 |
| ***Labrus viridis*** | 0.38 | 0 | 0.94 | 0.9 | 2.34 | 87.86 |
| ***Diplodus annularis*** | 0.9 | 1.19 | 0.89 | 2.01 | 2.24 | 90.1 |

**Table 9: Species abundance contribution to the produced dissimilarity of community structure when areas B and C are compared**

| Average dissimilarity = 40.34% | AREA B | AREA C | | | | |
|---|---|---|---|---|---|---|
| Species | Av.Abund | Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
| ***Chromis chromis*** | 3.68 | 1.91 | 4.95 | 1.03 | 12.26 | 12.26 |
| ***Thalassoma pavo*** | 1.7 | 0.41 | 3.34 | 1.88 | 8.29 | 20.55 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Spicara smaris*** | 0.9 | 0.98 | 3.06 | 0.97 | 7.58 | 28.13 |
| ***Coris julis*** | 1.71 | 0.97 | 2.43 | 1.09 | 6.01 | 34.14 |
| ***Oblada melanura*** | 0.96 | 1.6 | 2.38 | 1.17 | 5.91 | 40.05 |
| ***Symphodus tinca*** | 1.16 | 0.3 | 2.29 | 1.69 | 5.68 | 45.73 |
| ***Symphodus mediterraneus*** | 0.89 | 0 | 2.23 | 1.62 | 5.52 | 51.25 |
| ***Sparisoma cretense*** | 1.8 | 1.08 | 1.9 | 1.95 | 4.72 | 55.97 |
| ***Diplodus annularis*** | 0.64 | 1.19 | 1.79 | 1.23 | 4.44 | 60.41 |
| ***Sarpa salpa*** | 0.66 | 0.43 | 1.67 | 1.12 | 4.13 | 64.54 |
| ***Spicara meana*** | 0.31 | 0.5 | 1.5 | 0.79 | 3.71 | 68.25 |
| ***Epinephelus costae*** | 0.15 | 0.68 | 1.47 | 1.25 | 3.64 | 71.89 |
| ***Diplodus sargus*** | 1.55 | 1.48 | 1.45 | 1.29 | 3.61 | 75.49 |
| ***Siganus luridus*** | 1.97 | 1.49 | 1.27 | 1.62 | 3.14 | 78.63 |
| ***Mullus surmuletus*** | 0.5 | 0.61 | 1.2 | 1.12 | 2.96 | 81.6 |
| ***Scorpaena porcus*** | 0.33 | 0.25 | 1.01 | 0.91 | 2.49 | 84.09 |
| ***Diplodus vulgaris*** | 1.14 | 1.29 | 0.92 | 1.55 | 2.27 | 86.36 |
| ***Labrus merula*** | 0.18 | 0.25 | 0.81 | 0.81 | 2 | 88.36 |
| ***Epinephelus marginatus*** | 0.18 | 0.25 | 0.74 | 0.81 | 1.83 | 90.19 |

### *Abundance based patterns on P. oceanica habitat*

MDS and Cluster analyses results based on species abundance data suggested that there was no profound pattern of stations grouping since sampling stations from area C were grouped with stations form areas B and A (Fig 31). ANOSIM test results further sustained the latter outcome since stations grouping with respect to areas A, B and C was weak and not significant (One-way ANOSIM: R= 0.322, p>0.05). Therefore, it's reasonable to assume that fish assemblages' structure in *Posidonia oceanica* beds is well homogenized across all the zones of the study areas.

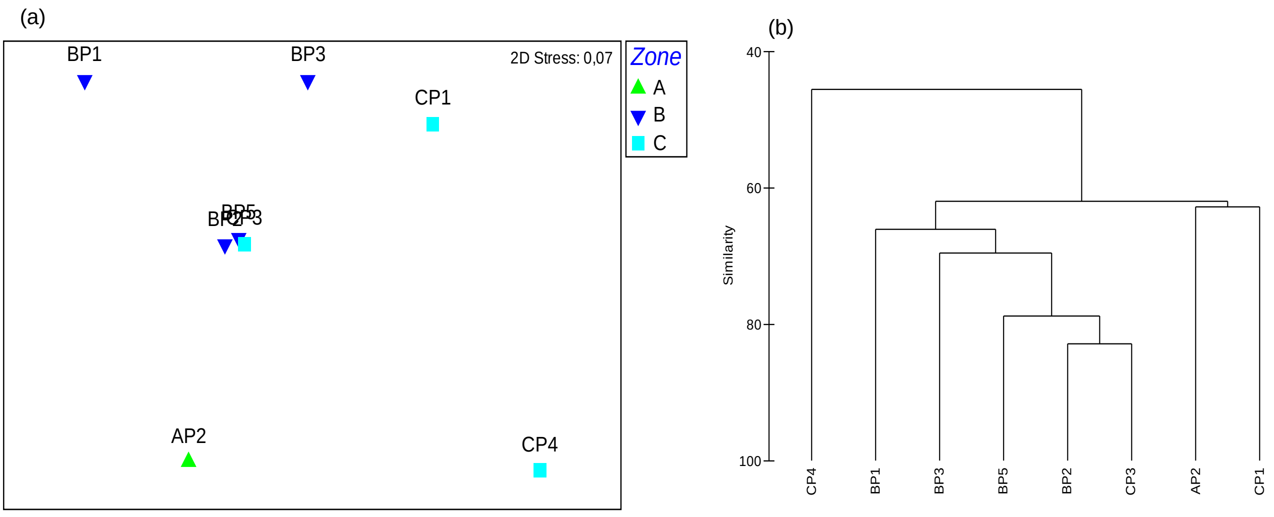



**Fig 31: Community structure of fish assemblages in *P. oceanica* habitat based on species abundance as it was evidenced by (a) MDS and (b) Cluster analyses**

### *Biomass based patterns*

MDS and Cluster analyses results based on species biomass data pointed out the existence of profound differences in community structure between the examined types of habitats (Fig 32). In this respect, two major groups of stations were formulated at 60% similarity level. The first one gathered the sampling stations deriving exclusively from rocky habitats while the second one included sampling station exclusively belonging to *Posidonia oceanica* habitat. A less profound pattern of stations grouping was detected when the different sampling areas were considered, a fact which was mainly governed by the differences in community structure between the pairs A - B and B-C.

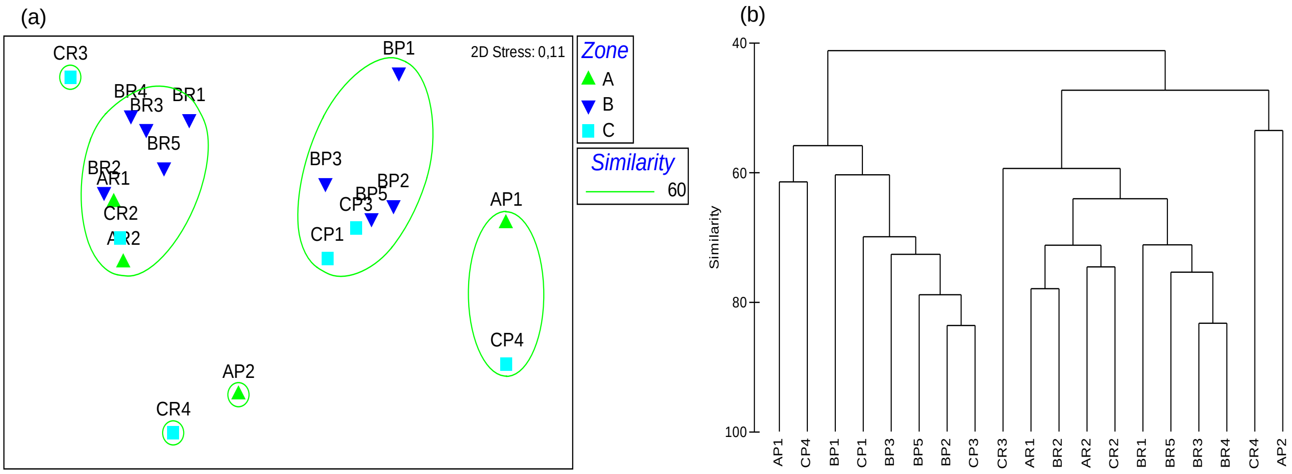



**Fig 32: Community structure of fish assemblages in *P. oceanica* habitat based on species abundance as it was evidenced by (a) MDS and (b) Cluster analyses**

Results from the Two-Way crossed ANOSIM analysis, revealed statistically significant differences of community structure between the sampling areas (A, B and C) across all habitat groups (posidonia and rock) (R = 0,409, p <0.001) as well as between all the habitat groups across all sampling areas (R = 0.869, p<0.001). These finding are in line with MDS and Cluster analyses results, since strength of community difference, expressed as the R value of the ANOSIM test, was two times bigger when habitat effect was compared to zoning effect. Therefore, differences in community structure patterns are primarily driven by habitat variation without though ignoring the zoning effect which seemed to play a secondary but still significant role.

### *Biomass based patterns on Rocky habitats*

Results of community structure patterns of fish assemblages on rocky habitats deriving by species biomass data suggested a spatial grouping of stations belonging to areas A and B at a similarity level of 60% (Fig 33). At higher similarity levels (around 70%), a further grouping of sampling stations was detected clearly distinguishing sites of area B from the ones of area A.

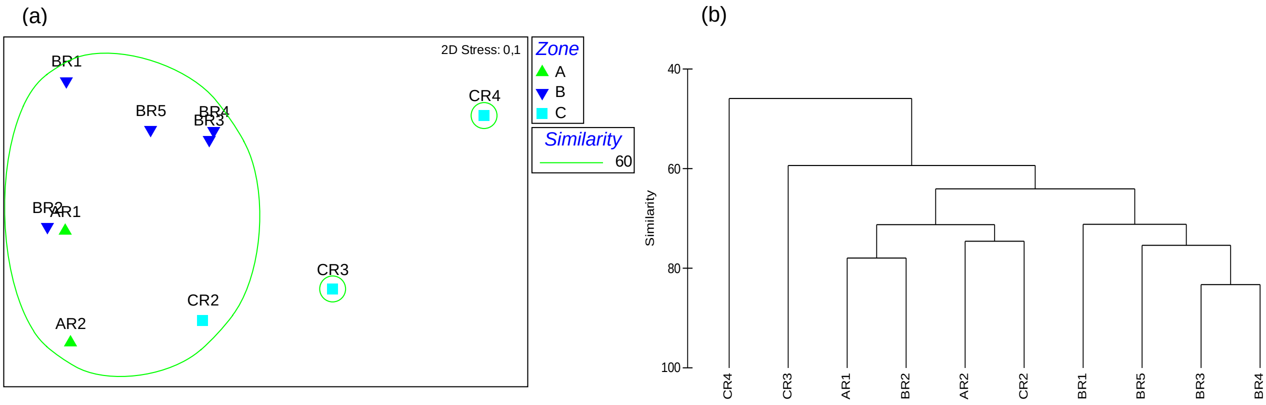



**Fig 33: Community structure of fish assemblages in rocky habitat based on species biomass as it was evidenced by (a) MDS and (b) Cluster analyses**

One - way ANOSIM results have also confirmed the aforementioned grouping since significant differences of community structure were evidenced with respect to the sampling areas (R = 0.498, p<0.001).

SIMPER analysis results regarding species contribution to the observed community dissimilarity between areas A and B have shown a rather low average dissimilarity (34.35%) which was mainly attributed to biomass variation of *Epinephelus marginatus*, *Spicara smaris*, *Oblada melanura*, *Labrus merula* and *Chromis chromis* as well as to the exclusive presence of *Caranx crysos* and *Boops boops* in area A (Table 10). Higher level of community dissimilarity was observed (44.83%) when areas A and C were compared (Table 11). The produced dissimilarity was mainly attributed to the higher abundance values of *Chromis chromis*, *Epinephelus marginatus*, *Spicara smaris*, *Labrus merula* and *Oblada melanura* in area A as well as in the exclusive presence of *Epinephelus costae* in area C. Similar level of community dissimilarity (44.58%) was detected when areas B and C were considered (Table 12). The observed dissimilarity between these areas was mainly attributed to the enhanced mean biomass values of *Chromis chromis*, *Thalassoma pavo*, *Diplodus sargus*, *Siganus luridus* and *Coris julis* in area B as well as of *Epinephelus costae* and *Oblada melanura* in area C.

**Table 10: Species biomass contribution to the produced dissimilarity of community structure when areas A and B are compared**

| Average dissimilarity = 34.35% | AREA A | AREA B | | | | |
|---|---|---|---|---|---|---|
| Species | Av.Biomass | Av.Biomass | Av.Diss | Diss/SD | Contrib% | Cum.% |
| ***Epinephelus marginatus*** | 4.51 | 0.79 | 4 | 1.98 | 11.63 | 11.63 |
| ***Spicara smaris*** | 3.68 | 0.82 | 2.91 | 2.34 | 8.47 | 20.1 |
| ***Oblada melanura*** | 4.01 | 1.64 | 2.58 | 1.58 | 7.51 | 27.61 |
| ***Labrus merula*** | 2.88 | 0.42 | 2.53 | 2.37 | 7.37 | 34.98 |
| ***Boops boops*** | 2.09 | 0 | 2.09 | 0.94 | 6.09 | 41.07 |
| ***Chromis chromis*** | 6.64 | 5.03 | 1.67 | 1.88 | 4.86 | 45.92 |
| ***Caranx crysos*** | 1.57 | 0 | 1.59 | 0.94 | 4.62 | 50.54 |
| ***Sarpa salpa*** | 0 | 1.42 | 1.46 | 1.1 | 4.25 | 54.79 |
| ***Siganus luridus*** | 3.82 | 5.12 | 1.36 | 1.46 | 3.96 | 58.75 |
| ***Diplodus sargus*** | 4.41 | 4.08 | 1.34 | 1.11 | 3.89 | 62.64 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Diplodus annularis*** | 1.98 | 0.95 | 1.24 | 1.73 | 3.6 | 66.24 |
| ***Labrus viridis*** | 1.22 | 0 | 1.22 | 0.94 | 3.55 | 69.79 |
| ***Mullus surmuletus*** | 2.05 | 0.95 | 1.19 | 1.31 | 3.45 | 73.24 |
| ***Thalassoma pavo*** | 2.07 | 2.7 | 1.11 | 1.54 | 3.22 | 76.46 |
| ***Symphodus mediterraneus*** | 0 | 1.03 | 1.03 | 1.76 | 3.01 | 79.46 |
| ***Diplodus vulgaris*** | 3.21 | 2.4 | 0.96 | 1.38 | 2.8 | 82.26 |
| ***Sciaena umbra*** | 0 | 0.94 | 0.82 | 0.47 | 2.38 | 84.65 |
| ***Sparisoma cretense*** | 3.7 | 3.88 | 0.78 | 1.29 | 2.28 | 86.93 |
| ***Symphodus roissali*** | 0.72 | 0.24 | 0.72 | 1 | 2.11 | 89.03 |
| ***Serranus scriba*** | 3.04 | 2.65 | 0.64 | 1.4 | 1.86 | 90.89 |

**Table 11: Species biomass contribution to the produced dissimilarity of community structure when areas A and C are compared**

| Average dissimilarity = 44.83% | AREA A | AREA C | | | | |
|---|---|---|---|---|---|---|
| Species | Av.Biomass | Av.Biomass | Av.Diss | Diss/SD | Contrib% | Cum.% |
| ***Chromis chromis*** | 6.64 | 2.56 | 4.82 | 1.65 | 10.75 | 10.75 |
| ***Epinephelus marginatus*** | 4.51 | 1.02 | 4.1 | 1.5 | 9.14 | 19.89 |
| ***Epinephelus costae*** | 0 | 2.96 | 3.19 | 1.24 | 7.11 | 27.01 |
| ***Spicara smaris*** | 3.68 | 1.34 | 3.12 | 1.45 | 6.95 | 33.96 |
| ***Labrus merula*** | 2.88 | 0.55 | 2.64 | 2.3 | 5.89 | 39.85 |
| ***Oblada melanura*** | 4.01 | 2.96 | 2.42 | 1.59 | 5.39 | 45.23 |
| ***Boops boops*** | 2.09 | 0 | 2.36 | 0.9 | 5.26 | 50.49 |
| ***Diplodus sargus*** | 4.41 | 2.81 | 2.26 | 1.07 | 5.04 | 55.53 |
| ***Symphodus tinca*** | 2.42 | 0.59 | 2.16 | 1.77 | 4.83 | 60.36 |
| ***Coris julis*** | 3.12 | 1.36 | 2.12 | 1.33 | 4.72 | 65.08 |
| ***Thalassoma pavo*** | 2.07 | 0.4 | 1.91 | 1.43 | 4.26 | 69.34 |
| ***Caranx crysos*** | 1.57 | 0 | 1.79 | 0.9 | 4 | 73.35 |
| ***Sparisoma cretense*** | 3.7 | 2.21 | 1.7 | 1.56 | 3.8 | 77.14 |
| ***Diplodus vulgaris*** | 3.21 | 2 | 1.4 | 1.49 | 3.13 | 80.27 |
| ***Labrus viridis*** | 1.22 | 0 | 1.37 | 0.9 | 3.06 | 83.34 |
| ***Siganus luridus*** | 3.82 | 2.88 | 1.21 | 1.69 | 2.71 | 86.05 |
| ***Mullus surmuletus*** | 2.05 | 1.18 | 1.08 | 1.02 | 2.42 | 88.47 |
| ***Sarpa salpa*** | 0 | 0.73 | 0.93 | 0.65 | 2.08 | 90.54 |

**Table 12: Species biomass contribution to the produced dissimilarity of community structure when areas C and B are compared**

| Average dissimilarity = 44.58% | AREA B | AREA C | | | | |
|---|---|---|---|---|---|---|
| Species | Av.Biomass | Av.Biomass | Av.Diss | Diss/SD | Contrib% | Cum.% |
| ***Chromis chromis*** | 5.03 | 2.56 | 3.74 | 1.08 | 8.39 | 8.39 |
| ***Epinephelus costae*** | 0.54 | 2.96 | 3.69 | 1.34 | 8.27 | 16.66 |
| ***Thalassoma pavo*** | 2.7 | 0.4 | 3.22 | 2.22 | 7.22 | 23.88 |
| ***Diplodus sargus*** | 4.08 | 2.81 | 3.17 | 1.2 | 7.11 | 30.99 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Siganus luridus*** | 5.12 | 2.88 | 3.13 | 1.92 | 7.02 | 38.01 |
| ***Oblada melanura*** | 1.64 | 2.96 | 2.75 | 1.31 | 6.18 | 44.19 |
| ***Coris julis*** | 2.97 | 1.36 | 2.53 | 1.24 | 5.68 | 49.87 |
| ***Symphodus tinca*** | 2.12 | 0.59 | 2.29 | 1.63 | 5.14 | 55.01 |
| ***Sparisoma cretense*** | 3.88 | 2.21 | 2.28 | 2.47 | 5.12 | 60.12 |
| ***Diplodus annularis*** | 0.95 | 2.27 | 2.15 | 1.4 | 4.82 | 64.94 |
| ***Spicara smaris*** | 0.82 | 1.34 | 2.06 | 1.06 | 4.61 | 69.55 |
| ***Sarpa salpa*** | 1.42 | 0.73 | 1.86 | 1.16 | 4.17 | 73.73 |
| ***Epinephelus marginatus*** | 0.79 | 1.02 | 1.7 | 0.82 | 3.81 | 77.54 |
| ***Symphodus mediterraneus*** | 1.03 | 0 | 1.43 | 1.71 | 3.2 | 80.74 |
| ***Mullus surmuletus*** | 0.95 | 1.18 | 1.28 | 1.09 | 2.87 | 83.61 |
| ***Sciaena umbra*** | 0.94 | 0 | 1.08 | 0.48 | 2.41 | 86.02 |
| ***Scorpaena porcus*** | 0.35 | 0.6 | 1.06 | 0.91 | 2.38 | 88.4 |
| ***Diplodus vulgaris*** | 2.4 | 2 | 1.01 | 1.42 | 2.26 | 90.67 |

### *Biomass based patterns on Posidonia oceanica habitats*

Community structure of the sampling stations located along *Posidonia oceanica* habitat did not present a clear spatial pattern as it was proved by MDS plots (Fig 34) and One-Way ANOSIM test results with respect to areas A, B and C (R = 0,277; p>0.05).

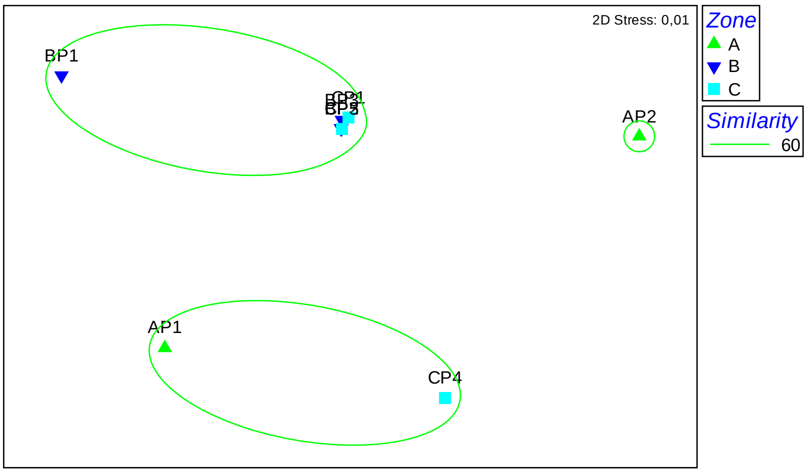



**Fig 34: Community structure of fish assemblages in *Posidonia oceanica* habitat based on species biomass as it was evidenced by MDS analysis**

### *Feeding guilds - Biomass based patterns*

Community structure based on feeding guilds biomass was carried out by means of MDS and Cluster analysis so as to capture patterns of the trophic complexity of fish assemblages with respect to habitat and zoning effect. Our results suggested high levels of similarity in feeding guilds patterns of the sampling stations located at rocky habitats and *Posidonia oceanica* ones correspondingly. In this respect, stations grouping according to community feeding status indicated a clear separation between the examined habitats, thus underlining the importance of habitat effect in the trophic complexity of species aggregations (Fig 35). However, the grouping of the sampling stations related to the habitat effect was met to a similarity level of 70%, therefore indicating that the observed differences in the feeding status of fish community were not vast. A less obvious grouping pattern of feeding guilds spatial distribution was observed between the examined areas mainly separating area A from area B as well as area B from area C. Results from the Two-Way crossed ANOSIM analysis, suggested statistically significant differences of community structure between the sampling areas (A, B and C) across all habitat groups (posidonia and rock) (R = 0,433, p <0.01) as well as between all the habitat groups across all sampling areas (R = 0.856, p<0.01). In this sense, habitat effect is primarily responsible for the observed feeding guilds' pattern whereas area effect is less prominent and mainly attributed to differences in the trophic structure between the pairs of areas A and B as well as B and C.

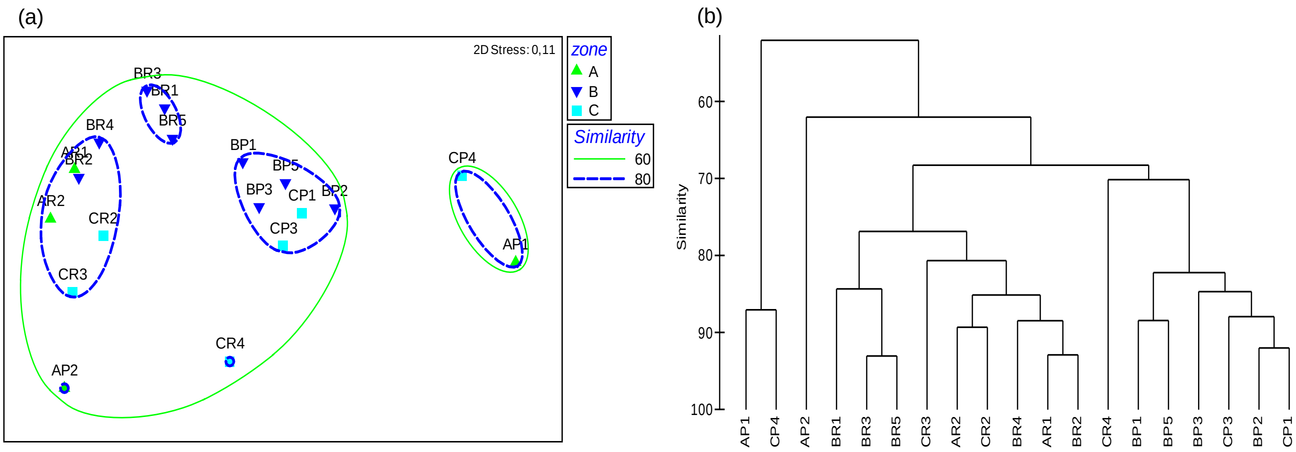



**Fig 35: Feeding structure of fish assemblages based on the biomass of each feeding guild as it was evidenced by (a) MDS and (b) Cluster analyses**

### *Feeding structure in rocky habitats*

When only rocky habitats are examined, MDS and Cluster analysis revealed high similarity in the trophic structure of fish assemblages between the different areas under consideration. The most apparent differentiation involved the areas B and C which however was met at a similarity level around 80% (Fig 36). One - way ANOSIM results (R=0,465; p<0.01) sustained the latter findings since a significant difference in feeding guilds distribution pattern was noted between areas A, B and C, mainly attributed to the difference between the pair of areas B and C.
SIMPER analysis results suggested that the produced mean dissimilarity in feeding guilds structure between areas A and B (Average dissimilarity = 19.78) was mainly attributed to the higher mean biomass in area A of the apex predators and the zooplanktivorous fish which accounted for the 73.79% of cumulative contribution (46.52 and 27.27% respectively) to the total dissimilarity (Table 13). In the case where area A and area C are compared, the produced dissimilarity was mainly attributed to zooplanktivorous fish and to apex predators each contributing to the overall dissimilarity (24.35%) with 38.14% and 29.2% correspondingly. The average biomass of all the examined trophic groups was higher in area A than in area C. Finally, the trophic groups which were mainly responsible for the observed average dissimilarity between areas B and C (Average dissimilarity = 26.62%) were found to be apex predators and herbivores accounting for almost 60% of the total dissimilarity.

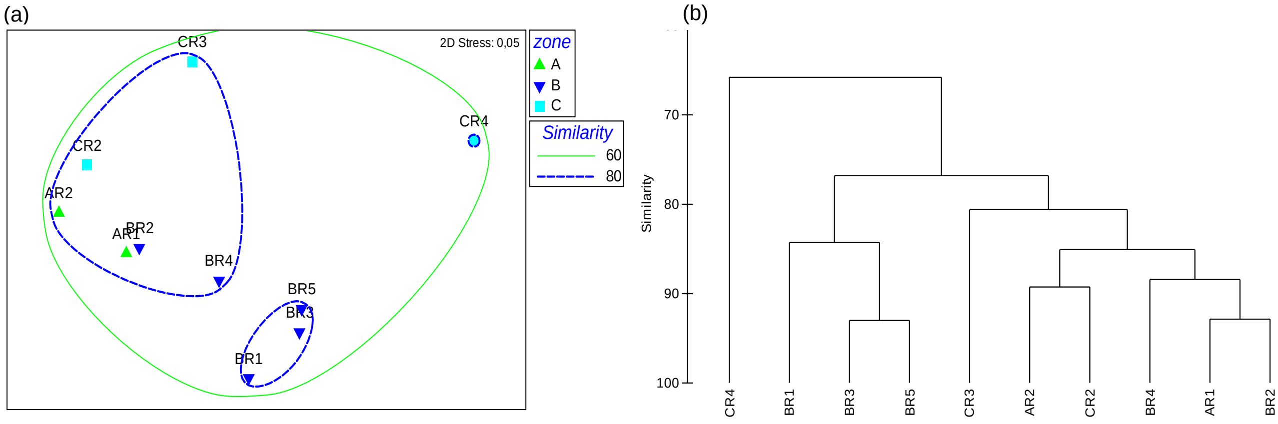



**Fig 36: Trophic structure of fish assemblages based on the biomass of each feeding guild in rocky habitats as it was evidenced by (a) MDS and (b) Cluster analyses**

**Table 13: Trophic groups contribution to the produced dissimilarity of the feeding structure when different areas are compared**

| Average dissimilarity = 19.78 % | AREA A | AREA B | | | | |
|---|---|---|---|---|---|---|
| Species | Av.Biomass | Av.Biomass | Av.Diss | Diss/SD | Contrib% | Cum.% |
| **AP** | 4.82 | 1.32 | 9.2 | 1.7 | 46.52 | 46.52 |
| **ZP** | 7.22 | 5.12 | 5.4 | 2.41 | 27.27 | 73.79 |
| **HE** | 4.49 | 5.59 | 3.12 | 1.56 | 15.79 | 89.57 |
| **CA** | 5.5 | 5.33 | 2.06 | 1.55 | 10.43 | 100 |
| Average dissimilarity = 24.35% | AREA A | AREA C | | | | |
| Species | Av.Biomass | Av.Biomass | Av.Diss | Diss/SD | Contrib% | Cum.% |
| **ZP** | 7.22 | 4.05 | 9.29 | 1.52 | 38.14 | 38.14 |
| **AP** | 4.82 | 3.06 | 7.11 | 1.03 | 29.2 | 67.35 |
| **CA** | 5.5 | 4.06 | 4.09 | 1.63 | 16.8 | 84.14 |
| **HE** | 4.49 | 3.19 | 3.86 | 1.52 | 15.86 | 100 |
| Average dissimilarity = 26.62% | AREA B | AREA C | | | | |
| Species | Av.Biomass | Av.Biomass | Av.Diss | Diss/SD | Contrib% | Cum.% |
| **AP** | 1.32 | 3.06 | 8.1 | 1.3 | 30.42 | 30.42 |
| **HE** | 5.59 | 3.19 | 7.65 | 2.49 | 28.74 | 59.16 |
| **ZP** | 5.12 | 4.05 | 6.19 | 1.48 | 23.26 | 82.42 |
| **CA** | 5.33 | 4.06 | 4.68 | 1.37 | 17.58 | 100 |

### *Feeding structure in Posidonia oceanica habitats*

In the case of *Posidonia oceanica* habitat, sampling stations did not present any profound pattern of the trophic structure with respect to the three sampling areas (Fig 37). One - way ANOSIM results did not also pointed at the direction of significant differences in the trophic structure between the examined areas (A, B and C) (R = 0.385; p>0.05).

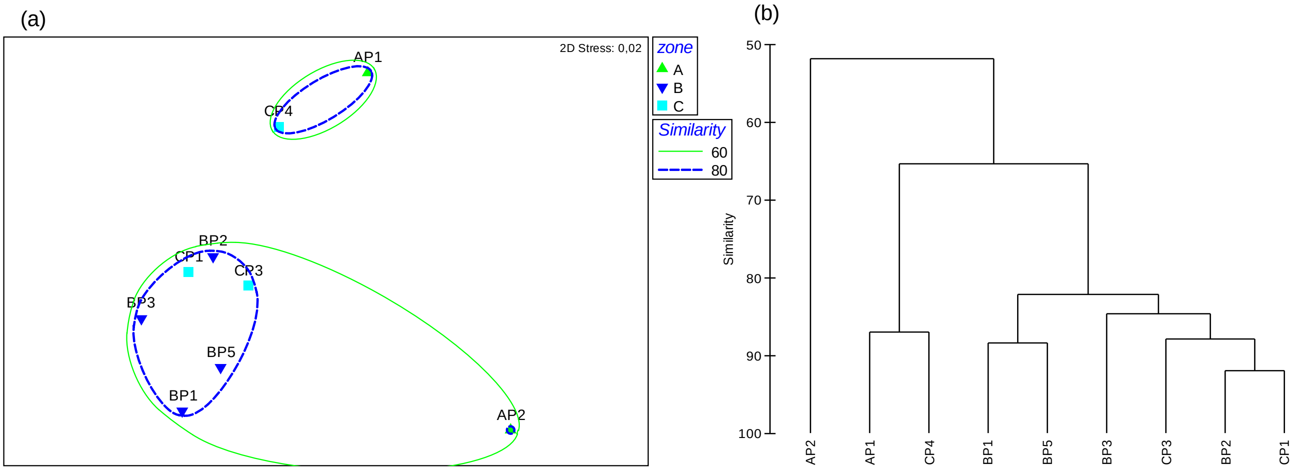



**Fig 37: Trophic structure of fish assemblages based on the biomass of each feeding guild in *Posidonia oceanica* habitats as it was evidenced by (a) MDS and (b) Cluster analyses**

## B. Visual Census - Benthic Fauna

### 1. Megabenthic Fauna

All selected megabenthic species were recorded in area B, while 6 and 5 of them were encountered in areas A and C respectively. The species *C. variegata*, *A. lixula* and *P. lividus* were found only in rocky habitats while *T. galea* was encountered only in *P. oceanica* habitats. The rest of the species were found in both habitat types. The gastropods *C. variegata* and *T. galea* were found only in area B. The rest of the species were recorded in all areas except for *Microcosmus* sp. which was not encountered in area C. The highest species richness among the surveyed rocky habitats was found for area B (7 species) while among the *P. oceanica* habitats for area A (4 species) (Fig 38). The stations presenting the highest species richness were BR1 and BR1 (5 species) for the rocky habitats (Fig 39a), and AP1 (3 species) for the *P. oceanica* habitats (Fig 39b).

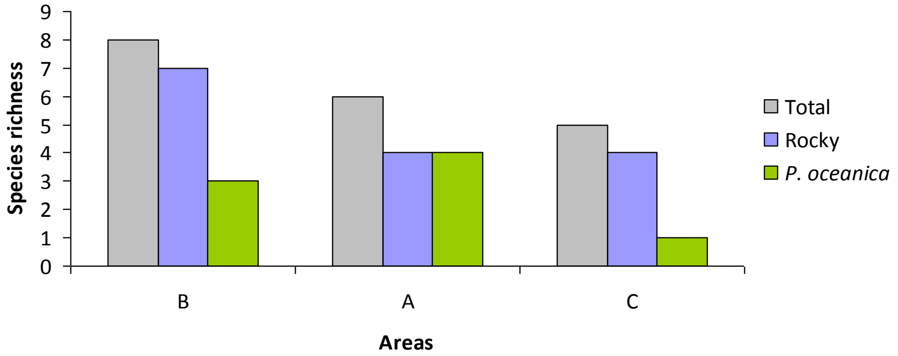



**Fig 38: Species encountered in the surveyed transects of the study areas**

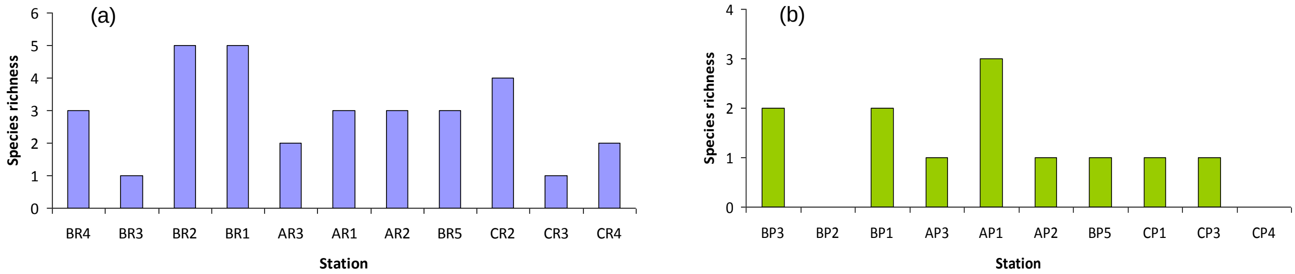



**Fig 39: Number of species encountered in a) rock, and b) *P. oceanica* stations**

## 2. Abundance of Selected Species

### *Pinna nobilis*

The fan shell *P. nobilis* was recorded in 7 stations of *P. oceanica*, and in only 2 rocky stations situated in area B (Fig 40). The highest mean abundance per 125 $m^2$ was found in the *P. oceanica* station BP1 (6 individuals, st. error 2.646 (Fig 40b), while area B presented the highest mean abundance values in both habitat types (Fig 41).

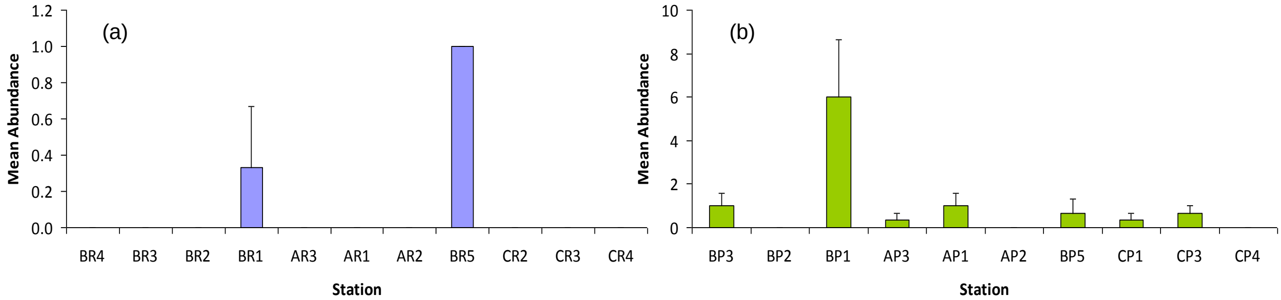



**Fig 40: Mean abundance *of P. nobilis* per 125 $m^2$ for a) rock, and b) *P. oceanica* stations**

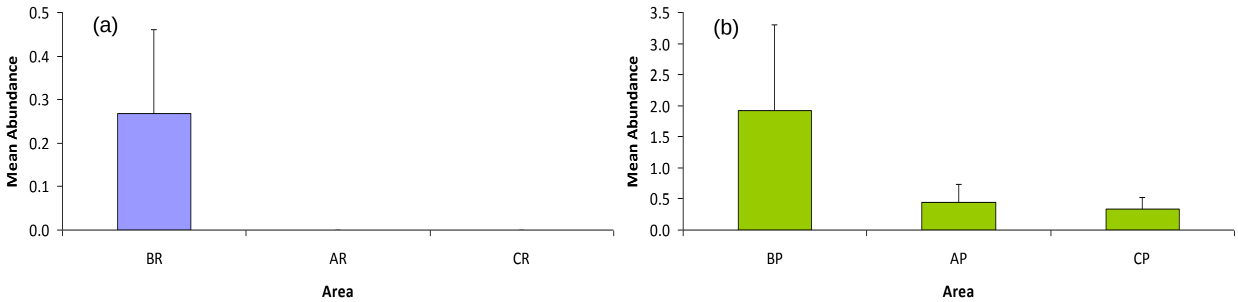



**Fig 41: Mean abundance of P. nobilis per area for a) rock, and b) *P. oceanica* habitats**

### *Ophidiaster ophidianus*

The purple starfish *O. ophidianus* was recorded in 7 rocky and only 2 *P. oceanica* stations (Fig 42). The highest mean abundance per 125 $m^2$ for rocky stations was found in BR2 (1.333 individuals, st. error 0.667) while the two *P. oceanica* stations has the same mean abundance (0.333

individuals, st. error 0.333). The highest mean abundance of the species was found in area B for rocky stations and A for *P. oceanica* habitats (Fig 43).

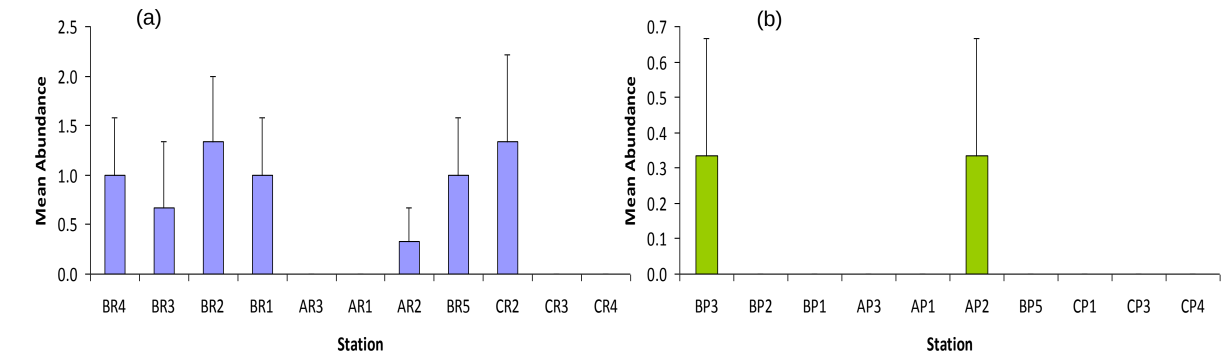



**Fig 42: Mean abundance of O. ophidianus per 125 m$^2$ for a) rock, and b) *P. oceanica* stations**

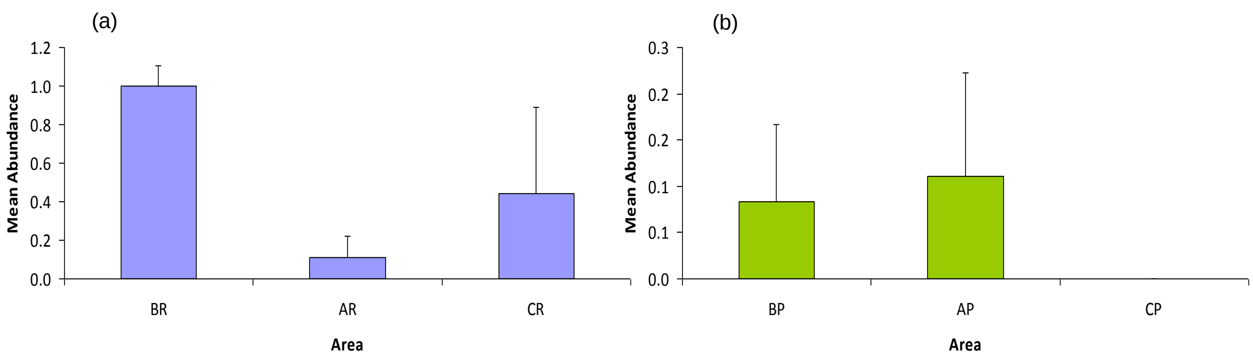



**Fig 43: Mean abundance of *O. ophidianus* per area a) for rock, and b) for *P. oceanica***

### *Hacelia attenuata*

The smooth starfish *H. attenuata* was recorded in rocky habitats of all three areas, while in *P. oceanica* habitats it was only observed in area A (Fig 44). It was recorded in 5 stations of rocky habitats and only one station (AP1) of *P. oceanica* habitats (Fig 45). The highest mean abundance per 125 m$^2$ was observed at rocky habitats, and more specifically in CR2 (1 individual, st. error 0.577).

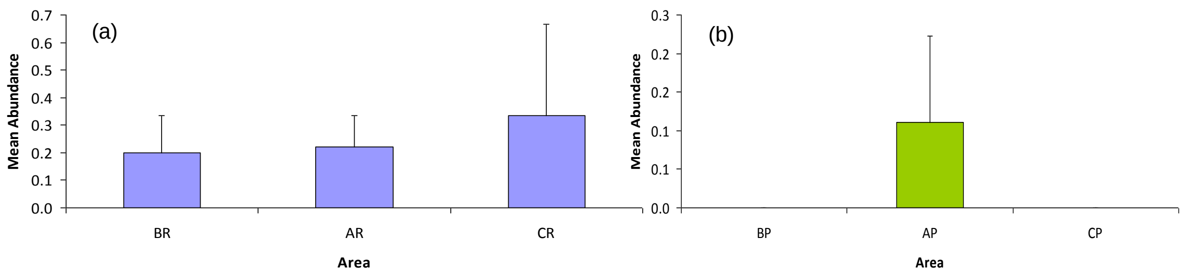



**Fig 44: Mean abundance of *H. attenuata* per area for a ) rock, and b) *P. oceanica* habitats**

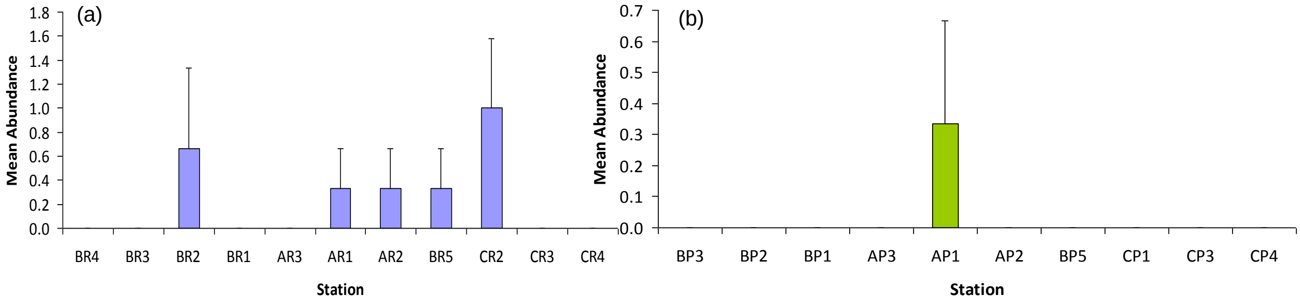



**Fig 45: Mean abundance of *H. attenuata* per 125 m$^2$ for a) rock, and b) *P. oceanica* stations**

### *Sea urchins*

The black sea urchin *Arbacia lixula* and the purple sea urchin *Paracentrotus lividus* were both found in rocky stations of all areas while none of them was encountered in *P. oceanica* stations. The highest mean abundance of *A. lixula* was recorded in BR2 (3 individuals, st. error 1), and in CR2 for *P. lividus* (40 individuals, st. error 16.823) (Fig 46). Across all areas, the highest mean abundance of *A. lixula* was found in areas B and C (Fig 47a), while area C displayed the highest mean abundance of *P. lividus* (Fig 47b).

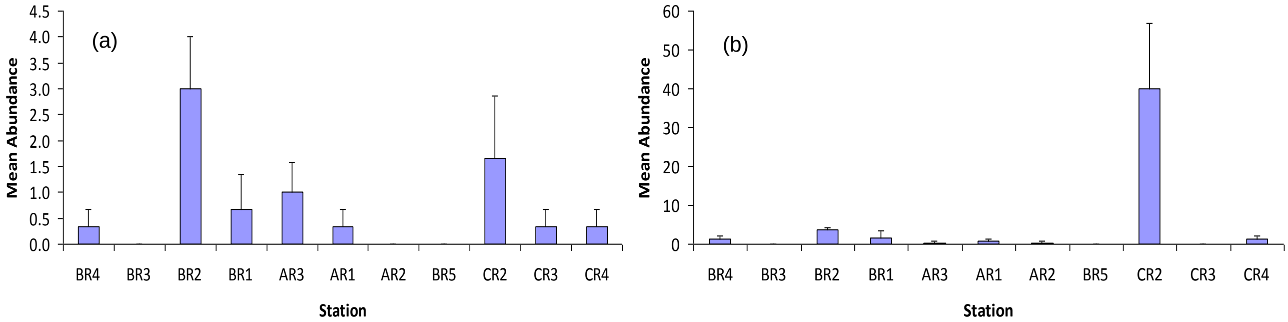



**Fig 46: Mean abundance of a) *A.* lixula, and b) *P. lividus* per 125 m$^2$ in rocky stations**

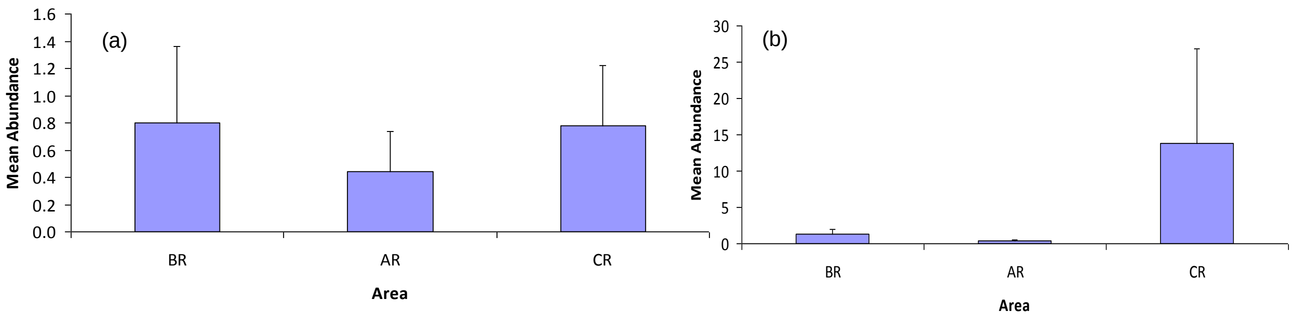



**Fig 47: Mean abundance of a) *A. lixula*, and b) *P. lividus* in rocky habitats per area**

The gastropods *C. variegata* and *T. galea* were encountered only in stations BR2 and BP1 respectively and had the same value of mean abundance per 125 $m^2$ (0.333 individuals, st. error 0.333). The edible tunicates of the genus *Microcosmus* were recorded only in stations BR2 and AP1 and had the same value of mean abundance per 125 $m^2$ (0.667 individuals, st. error 0.667 for BR2 and 0.333 for AP1).

### 3. Population study of *Pinna nobilis*

A total of 34 individuals of the fan shell *P. nobilis* were encountered. Most of them (79.4%) were recorded in area B (4 in rocky habitats and 23 in *P. oceanica* meadows). In areas A and C *P. nobilis* was encountered in low numbers only in *P. oceanica* habitats (4 and 3 individuals respectively). The majority of the individuals (88%) were found in *P. oceanica* meadows and only 0.2% in rocky habitats (Fig 48).

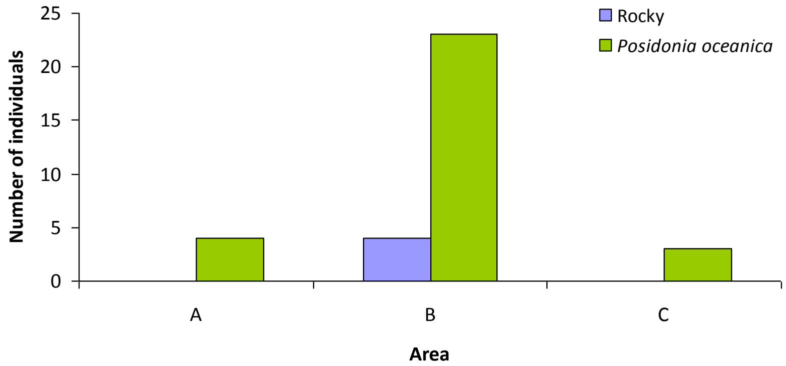



**Fig 48: Number of individuals of *P. nobilis* for rocky and *P. oceanica* habitats of the surveyed areas**

The width distribution of all encountered specimens is presented in Fig 49. Width size ranges from 7 - 30 cm with minimum values found in area A and maximum in area B, while mean width is 17.4 cm (st. error 0.678, N=34). The larger individuals in terms of width were found mainly in *P. oceanica* habitats of areas B and C, while the only individuals found in rocky habitats were in area B (Fig 50).

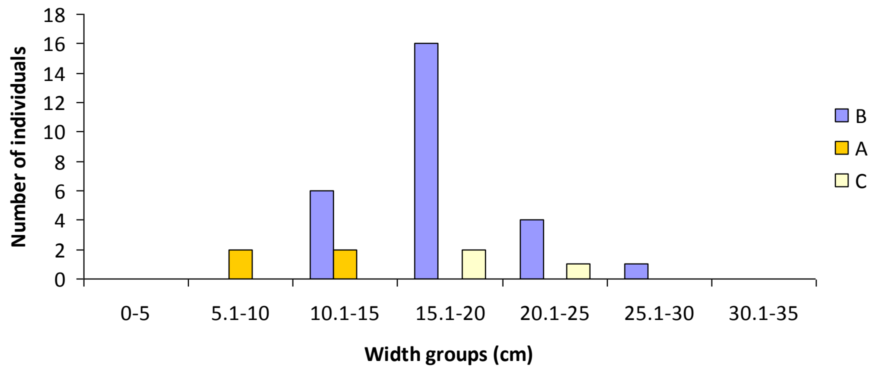



**Fig 49: Width distribution of all *P. nobilis* individuals. Colors denote different sampling areas**

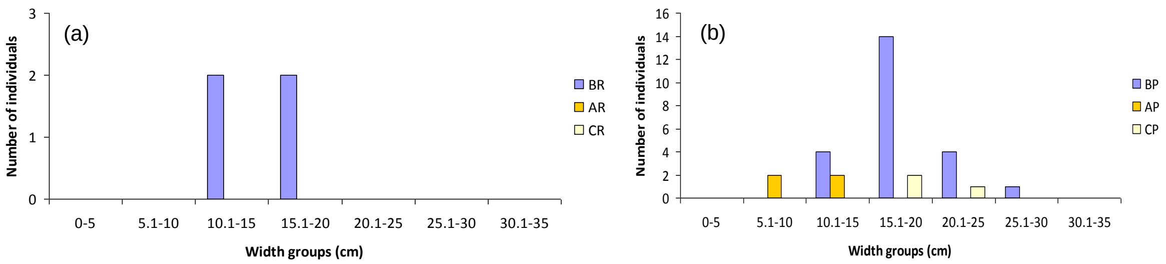



**Fig 50: Width distribution of *P. nobilis* individuals encountered per area in a) rocky habitats, and b) *P. oceanica* habitats. Colors denote different sampling areas**

The total length (Ht) of all encountered specimens is presented in Fig 51. The total length of the encountered specimens ranges from 21.03 - 87.20 cm, with minimum values recorded in area A, maximum in area B, and a mean total length of 53.5 cm (st. error 2.341, N=34). The larger individuals of the species were found mainly in *P. oceanica* habitats of areas B and C (Fig 52).

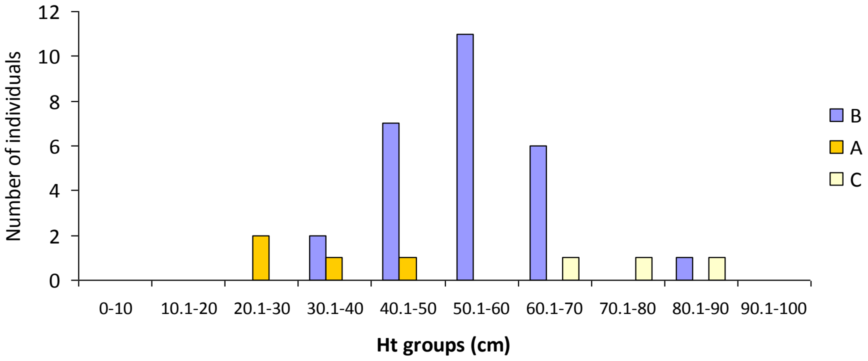



**Fig 51: Total length (Ht) distribution of *P. nobilis* individuals per area.**

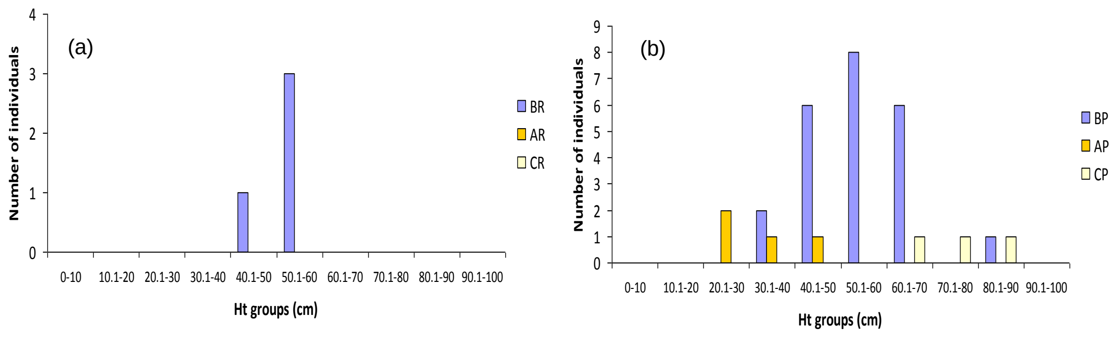



**Fig 52: Height distribution of *P. nobilis* individuals encountered per area in a) rocky habitats, and b) *P. oceanica* habitats. Colors denote different sampling areas**

# C. Visual Census - Biodiversity assessment

## 1. Overall Biodiversity

In total, 134 species belonging to 4 taxonomic groups of marine flora and 9 of marine fauna were recorded during the fieldwork (Fig 53). The majority of the species belonged to Actinopterygii (44), followed by Mollusca (26), Porifera (17) and Echinodermata (10). The rest of the taxonomic groups included less than 10 species each. Rocky habitats presented the highest species richness (116), followed by *P. oceanica* (85), and sandy habitats (24).

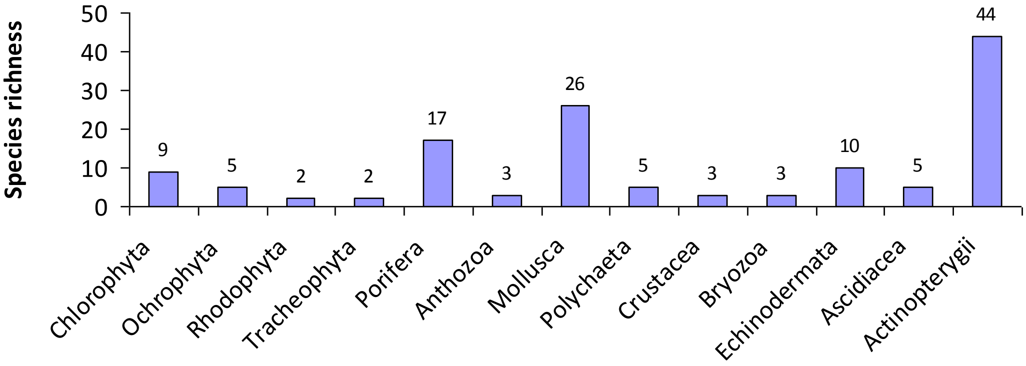



**Fig 53: Species richness per taxonomic group in the study area**

Area B presented the highest species richness (103), followed by areas C (87) and A (78) (Fig 54). Rocky habitats of all areas had a higher species richness (90 species in B, 67 in A and C - Fig 55) than those covered by *P. oceanica* (55 in B, 49 in A and 40 in C - Fig 56), while sandy stations presented the lowest values (13 in B, 11 in A and 5 in C - Fig 57). Area B presented the highest species richness for all habitat types. Rocky stations of areas A and C harboured the same number of species (67), while species richness of sandy habitats in area A was two times bigger than this of area C (11 *vs.* 5 species).

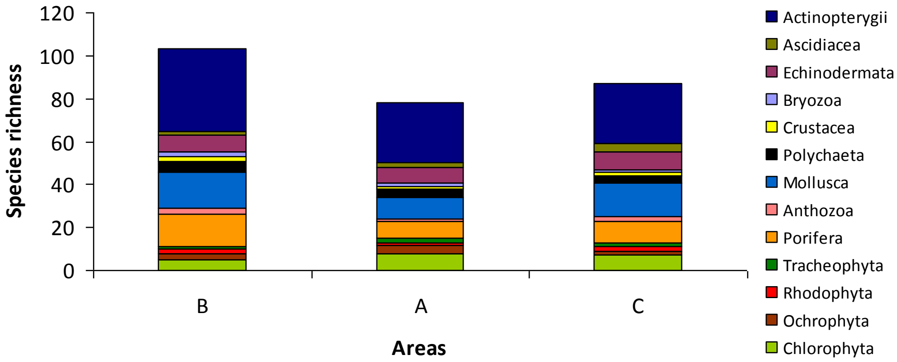



**Fig 54: Species richness per area for all the taxonomic groups**

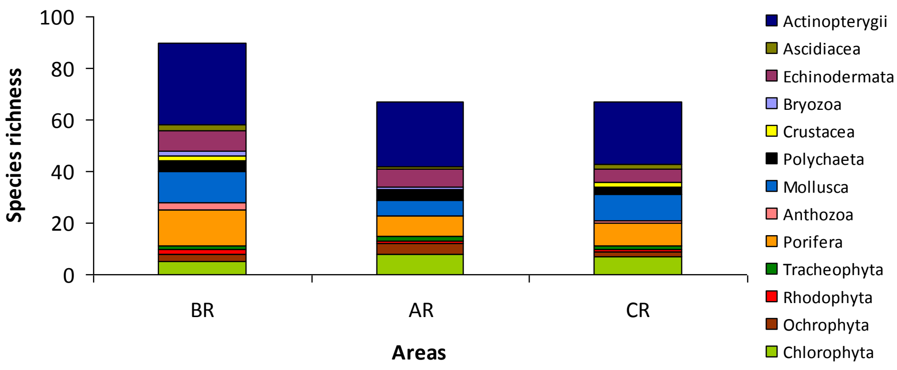



**Fig 55: Species richness in rocky habitats per area for all the taxonomic groups**

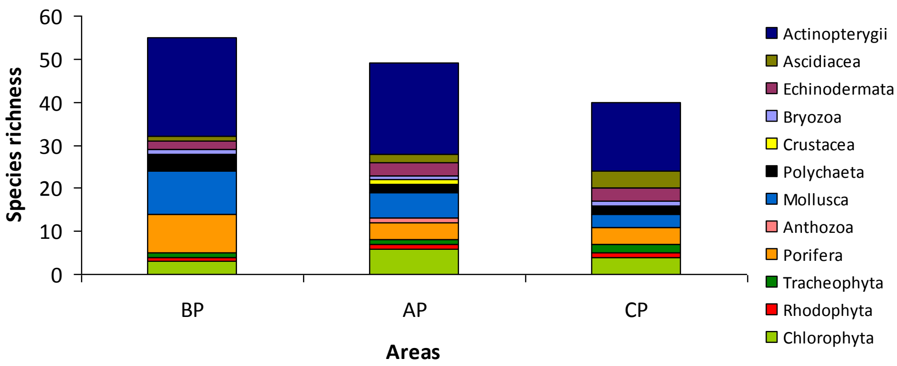



**Fig 56: Species richness in *P. oceanica* habitats per area for all the taxonomic groups**

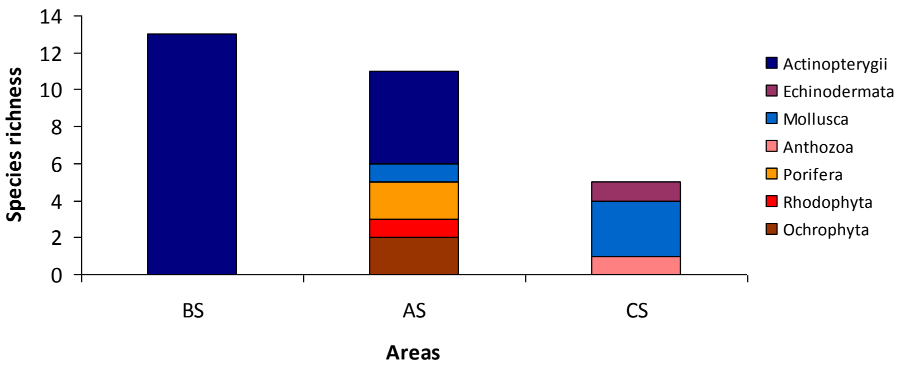



**Fig 57: Species richness in sandy habitats per area for all the taxonomic groups**

Stations BR2 and BR1 presented the highest species richness (59 and 50 species respectively) among rocky stations, followed by AR2 (43), CR2 (42) and BR4 (41) (Fig 58). The aforementioned stations also presented the highest species richness among all stations.

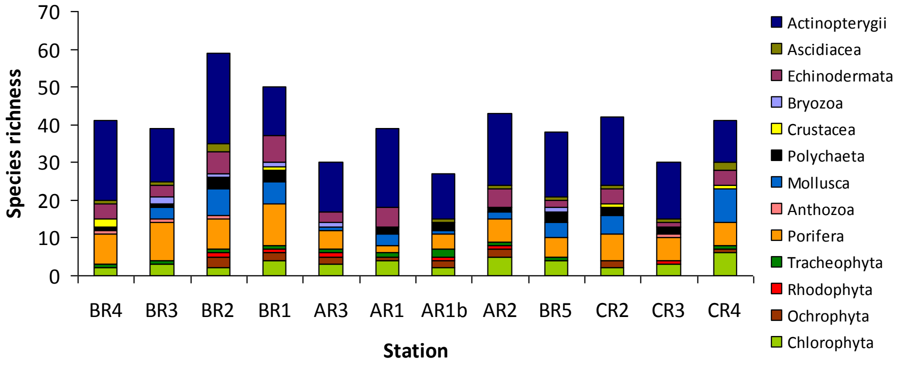



**Fig 58: Species richness in rocky stations for all the taxonomic groups**

Station BP3 had the highest species richness (41) among stations with *P. oceanica* habitats, followed by AP2 (28), CP1 (27), AP3 (26) and CP3 (24) (Fig 59). Sandy stations presented very low values of species richness, with only BS3 and AS3 harbouring over 10 species (12 and 11 respectively - Fig 60).

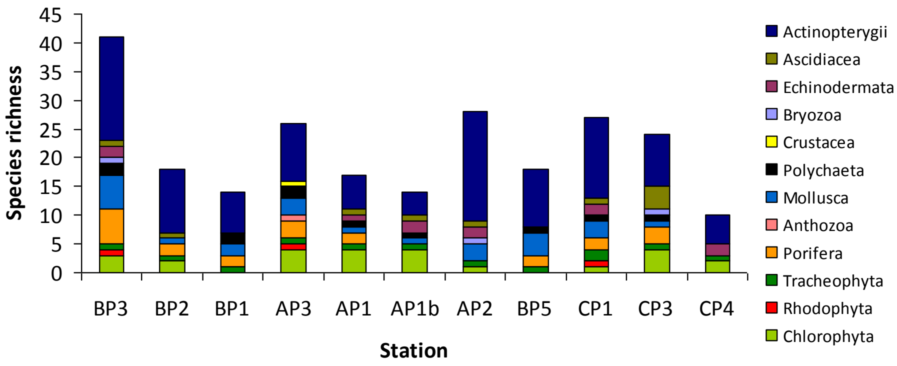



**Fig 59: Species richness in stations covered by *P. oceanica* habitats for all the taxonomic groups**

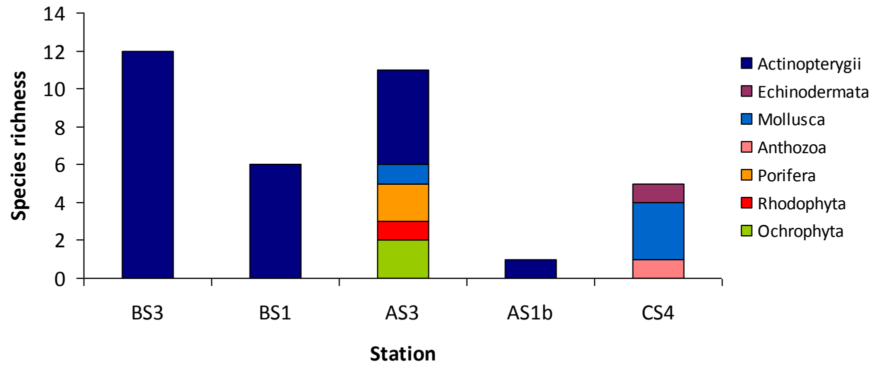



**Fig 60: Species richness in sandy stations for all the taxonomic groups**

## 2. Protected Species

With regard to species protected by international, EU or national legislation, a total of 27 species were recorded throughout the study areas (Table 14). The highest number of protected species was recorded in area B (20), while 18 protected species were found in C and 15 in A (Fig 61). The same pattern was observed for the rocky habitats of the three areas, with 18, 14 and 12 protected species for areas B, C, and A respectively. *P. oceanica* habitats supported 10, 8 and 5 protected species for areas B, A and C respectively. One protected species was reported for the sandy habitats of areas A, B and C.

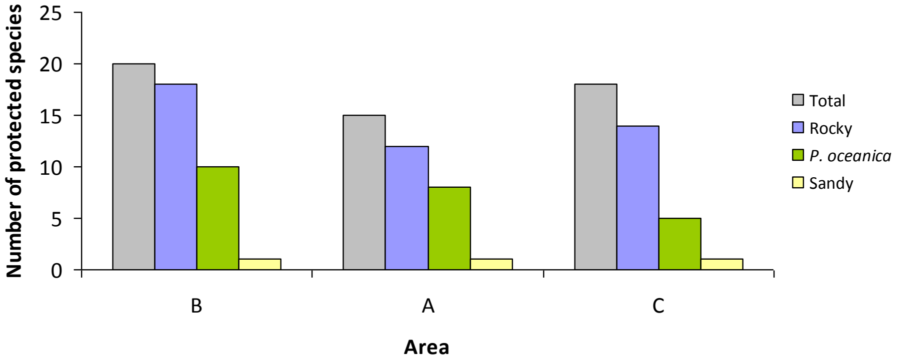



**Fig 61: Number of protected species per area for all the habitat types.**

In rocky habitats, the highest number of protected species was recorded in stations BR2 and CR2 (10), BR1 (9), BR4, AR2 and CR4 (8) (Fig 62). In *P. oceanica* habitats, the highest number of protected species was recorded in stations BP3, BP1 and AP2 (6), followed by AP3, BP5 and CP1 (5) (Fig 63).

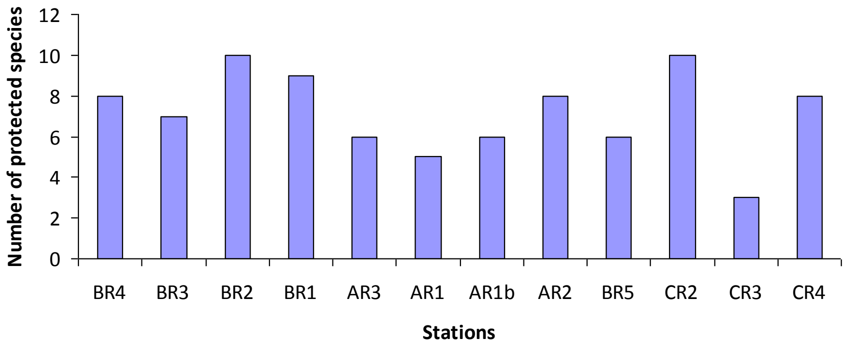



**Fig 62: Number of protected species for stations covered by rocky habitats**

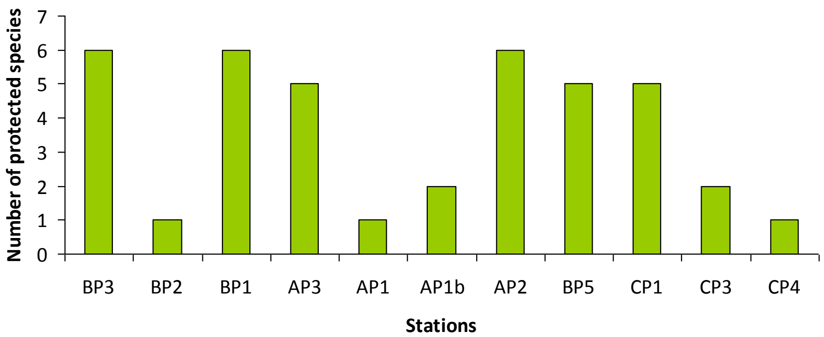



**Fig 63: Number of protected species for stations covered by *P. oceanica* habitats**

**Table 14: Species protected by international, EE and national legislation that are found in the study area**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ochrophyta** | | | | | | | | | | |
| *Cystoseira spinosa* Sauvageau, 1912 | I | | | II | | | | | | |
| **Thracheophyta** | | | | | | | | | | |
| *Cymodocea nodosa* (Ucria) Ascherson, 1870 | I | | | | | | | | | |
| * *Posidonia oceanica* (Linnaeus) Delile, 1813 | I | | | II | | | | | | |
| **Porifera** | | | | | | | | | | |
| *Aplysina aerophoba* Nardo, 1833 | | | | II | | | | | | |
| *Sarcotragus foetidus* Schmidt, 1862 | | | | II | | | | | | |
| **Anthozoa** | | | | | | | | | | |
| *Balanophyllia (Balanophyllia) europaea* (Risso, 1826) | | | | | IIB | DD | | | | |
| *Madracis pharensis* (Heller, 1868) | | | | | IIB | LC | | | | |
| **Gastropoda** | | | | | | | | | | |
| *Bolinus brandaris* (Linnaeus, 1758) | | | | | | | | | | + |
| *Charonia variegata* (Lamarck, 1816) | II | | | II | | | | | | |
| *Erosaria spurca* (Linnaeus, 1758) | II | | | II | | | | + | | |
| *Haliotis tuberculata* Linnaeus, 1758 | | | | | | | | | | + |
| *Hexaplex trunculus* (Linnaeus, 1758) | | | | | | | | | | + |
| *Tonna galea* (Linnaeus, 1758) | II | | | II | | | | + | + | + |
| **Bivalvia** | | | | | | | | | | |
| *Arca noae* Linnaeus, 1758 | | | | | | | | | | + |
| *Ostrea* sp. | | | | | | | | + | | |
| *Pinna nobilis* Linnaeus, 1758 | II | | IV | II | | | | + | + | + |
| *Pinna rudis* Linnaeus, 1758 | II | | | II | | | | | | |
| *Spondylus gaederopus* Linnaeus, 1758 | | | | | | | | | + | + |
| **Echinodermata** | | | | | | | | | | |
| *Ophidiaster ophidianus* (Lamarck, 1816) | II | | | II | | | | | | |
| *Paracentrotus lividus* (Lamarck, 1816) | III | | | III | | | VU | | | |
| **Actinopterygii** | | | | | | | | | | |
| *Caranx crysos* (Mitchill, 1815) | | | | | | LC | | | | |
| *Epinephelus costae* (Steindachner, 1878) | | | | | | DD | | | | |
| *Epinephelus marginatus* (Lowe, 1834) | III | | | III | | EN | | | | |
| *Euthynnus alletteratus* (Rafinesque, 1810) | | + | | | | | | | | |
| *Sciaena umbra* Linnaeus, 1758 | III | | | III | | | | | | |
| *Sparisoma cretense* (Linnaeus, 1758) | | | | | | | | + | | |
| *Xyrichtys novacula* (Linnaeus, 1758) | | | | | | | | + | | |

**1. Bern Convention** - Convention on the conservation of European wildlife and natural habitats, Council of Europe, 1979; **2. UNCLOS** - United Nations Convention on the Law of the Sea; **3. Habitats Directive 92/43/EEC**; **4. Barcelona Convention** - Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean, 1995; **5. CITES** - Convention on International Trade in Endangered Species of Wild fauna and flora, 1973, Council Regulation EC 338/97; **6. IUCN Red List of Threatened Species**; **7. Greek Red Data Book of Threatened Species** (2009); **8. Presidential Decree 67/1981**; **9. Presidential Decree 109/2002**; **10. Presidential Decree 227/2003; I, II, III, IV.** Appendix/Annex I, II, III, IV; **B.** Species of Appendix B of the regulation applying CITES in the EC; ***.** Priority habitat for *P. oceanica* meadows; **DD.** Data Deficient; **LC.** Least Concern; **VU.** Vulnerable; **EN.** Endangered.

## 3. Exploited Species

In the study sites, a total of 15 invertebrate and 1 tunicate species (*Microcosmus* sp.), considered as exploited by human for several purposes, were recorded (Table 15). Most species were observed in rocky habitats (13) followed by *P. oceanica* habitats (9), while only *Bolinus brandaris* was found in the sandy station CS4. In areas B and C, 12 exploited species were found (9 and 8 in rocky; 7 and 3 in *P. oceanica* habitats of the two areas respectively - Fig 64). In area A 9 exploited species were recorded (7 in rocky and 4 in *P. oceanica* habitats).

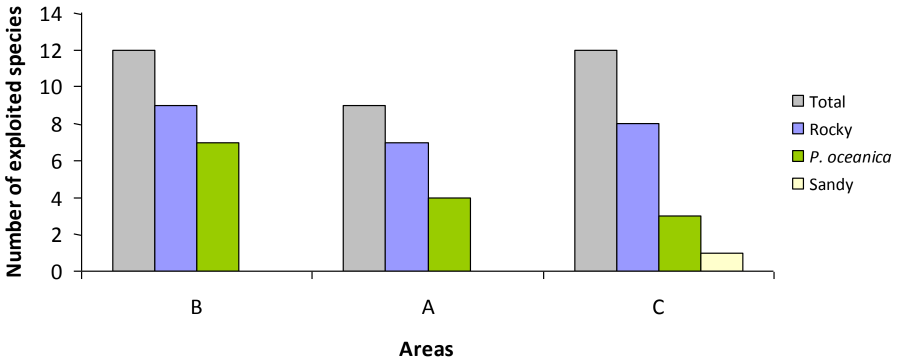



**Fig 64: Number of exploited species per area for all habitat types.**

The rocky stations presenting the highest number of exploited species were CR4 (7), BR2 (6), CR2 (6), BR1 (5) and AR1 (4) (Fig 65). Among the stations covered by *P. oceanica* habitats, the highest number of exploited species was found in BP3 (4), BP5 (4) and CP1 (3) (Fig 66).

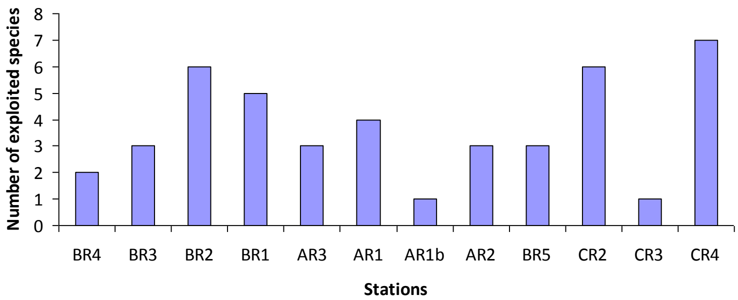



**Fig 65: Number of exploited species for stations covered by rocky habitats**

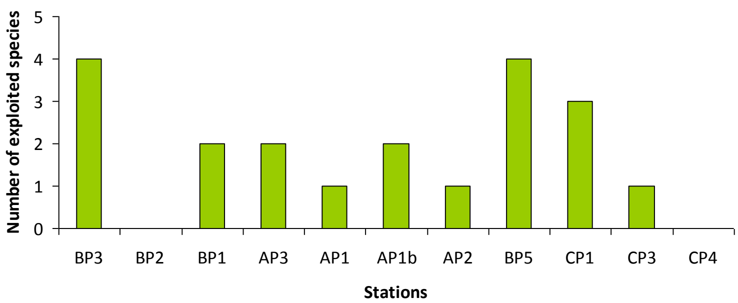



**Fig 66: Number of protected species for stations covered by *P. oceanica* habitats**

**Table 15: Exploited species encountered in the surveyed areas**

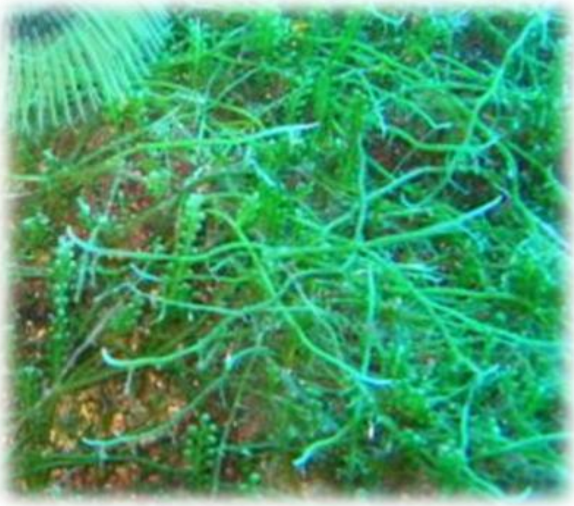
| Species | Human Food | Collections/Museums | Fishing Bait | Jewellery | Biomonitoring |
|---|---|---|---|---|---|
| *Arbacia lixula* (Linnaeus, 1758) | + | | | | |
| *Arca noae* Linnaeus, 1758 | + | | | | |
| *Bolinus brandaris* (Linnaeus, 1758) | + | | | | |
| *Bolma rugosa* (Linnaeus, 1767) | | + | | + | |
| *Cerithium vulgatum* Bruguière, 1792 | | | + | | |
| *Charonia variegata* (Lamarck, 1816) | | + | | | |
| *Erosaria spurca* (Linnaeus, 1758) | | + | | | |
| *Haliotis tuberculata* Linnaeus, 1758 | + | | | | |
| *Hexaplex trunculus* (Linnaeus, 1758) | + | | | | |
| *Microcosmus* sp. | + | | | | |
| *Octopus vulgaris* Cuvier, 1797 | + | | | | |
| *Ostrea* sp. | + | | | | |
| *Paracentrotus lividus* (Lamarck, 1816) | + | | | | |
| *Pinna nobilis* Linnaeus, 1758 | + | + | | | + |
| *Spondylus gaederopus* Linnaeus, 1758 | + | + | | | |
| *Tonna galea* (Linnaeus, 1758) | + | + | | | |

## 4. Alien Species

Four alien species were recorded in the study area (Fig 67):

- The highly invasive chlorophyte *Caulerpa racemosa var. cylindracea* (Sonder) Verlaque, Huisman & Boudouresque, 2003 was found in both rocky and *P. oceanica* habitats of the three areas.
- The rabbitfish *Siganus luridus* (Rüppell, 1829) was found in both rocky and *P. oceanica* habitats of the three areas. In rocky habitats the species accounts for 3.6% of total fish abundance and 16.6% of total fish biomass and is the most commonly recorded herbivorous fish. It has been observed to form small schools of fish along with the parrotfish *S. cretense*, which is the second most abundant herbivorous fish in all areas (2.7% abundance and 6.5% biomass). *S. luridus* is the most important herbivorous fish both in terms of abundance (0.6%) and biomass (0.33%) in *P. oceanica* habitats.
- The invasive Sally Lightfoot Crab *Percnon gibbesi* (H. Milne-Edwards, 1853) was encountered only in station BR4. Only one individual was observed across the three transects covered, at a depth of 11 m while several individuals were observed in shallower depths alongside the rocky coastline (up to 2 m).
- The fangtooth moray *Enchelycore anatina* (Lowe, 1838) was also encountered only in station BR4, at a depth of 11 m

In area B, and particularly in station BR4, all the aforementioned species were encountered, while in areas A and C only *C. racemosa var. cylindracea* and *S. luridus* were observed.



*Caulerpa racemosa var. cylindracea*

*Percnon gibbesi*

*Siganus luridus*

*Enchelycore anatina*

**Fig 67: Alien species encountered in the study area**

# D. Onboard Sampling

## 1. Diversity

In total, we found 57 species belonging to 31 families with a total biomass of 229608 gr (Table 16).

**Table 16: Species list and common names for the species found during the total sampling period**

| Species | Common Name | Species | Common Name |
|---|---|---|---|
| *Chelidonichthys lucerna* (Linnaeus, 1758) | Tub gurnard | *Symphodus mediterraneus* (Linnaeus, 1758) | Axillary wrasse |
| *Labrus merula* (Linnaeus, 1758) | Brown wrasse | *Serranus hepatus* (Linnaeus, 1758) | Brown comber |
| *Labrus viridis* (Linnaeus, 1758) | Green wrasse | *Serranus cabrilla* (Linnaeus, 1758) | Comber |
| *Loligo vulgaris* (Lamarck, 1798) | Common squid | *Serranus scriba* (Linnaeus, 1758) | Painted comber |
| *Merluccius merluccius* (Linnaeus, 1758) | Hake | *Diplodus sargus* (Linnaeus, 1758) | White seabream |
| *Pagellus erythrinus* (Linnaeus, 1758) | Pandora | *Diplodus annularis* (Linnaeus, 1758) | Annular seabream |
| *Pagrus pagrus* (Linnaeus, 1758) | Red porgy | *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817) | Two-banded seabream |
| *Palinurus elephas* (Fabricius, 1787) | Spiny lobster, Crawfish | *Euthynnus alletteratus* (Rafinesque, 1810) | Little tunny |
| *Phycis phycis* (Linnaeus, 1766) | Forkbeard | *Zeus faber* (Linnaeus, 1758) | John dory |
| *Sciaena umbra* (Linnaeus, 1758) | Brown meagre | *Octopus vulgaris* (Cuvier, 1797) | Common octopus |
| *Scorpaena notata* (Rafinesque, 1810) | Small red scorpionfish | *Sphyraena sphyraena* (Linnaeus, 1758) | European barracuda |
| *Scorpaena scrofa* (Linnaeus, 1758) | Red scorpionfish | *Epinephelus costae* (Steindachner, 1878) | Goldblotch grouper |
| *Scyllarides latus* (Latreille, 1803) | Mediterranean slipper lobster | *Epinephelus marginatus* (Lowe, 1834) | Dusky grouper |
| *Sepia officinalis* (Linnaeus, 1758) | Common cuttlefish, Margade | *Dicentrarchus labrax* (Linnaeus, 1758) | Sea bass |
| *Siganus luridus* (Rüppell, 1829) | Dusky spinefoot | *Sarpa salpa* (Linnaeus, 1758) | Salema |
| *Solea solea* (Linnaeus, 1758) | Common sole | *Scorpaena porcus* (Linnaeus, 1758) | Black scorpionfish |
| *Spicara maena* (Linnaeus, 1758) | Blotched picarel | *Raja asterias* (Delaroche, 1809) | Mediterranean starry ray |
| *Spicara smaris* (Linnaeus, 1758) | Picarel | *Dentex dentex* (Linnaeus, 1758) | Common dentex |
| *Symphodus tinca* (Linnaeus, 1758) | East Atlantic peacock wrasse | *Spondyliosoma cantharus* (Linnaeus, 1758) | Black Sea-bream |
| *Synodus saurus* (Linnaeus, 1758) | Lizard fish | *Labrus mixtus* (Linnaeus, 1758) | Cuckoo wrasse |
| *Trachinus radiatus* (Cuvier, 1829) | Starry weever | *Seriola dumerili* (Risso, 1810) | Greater amberjack |
| *Trigloporus lastoviza* (Bonnaterre, 1788) | Streaked gurnard | *Dasyatis pastinaca* (Linnaeus, 1758) | Common stingray |
| *Uranoscopus scaber* (Linnaeus, 1758) | Stargazer | *Raja miraletus* (Linnaeus, 1758) | Brown ray |
| *Coris julis* (Linnaeus, 1758) | Rainbow wrasse | *Muraena helena* (Linnaeus, 1758) | Mediterranean moray |
| *Sparisoma cretense* (Linnaeus, 1758) | Parrotfish | *Trachinus draco* (Linnaeus, 1758) | Greater weever |
| *Oblada melanura* (Linnaeus, 1758) | Saddled sea bream | *Pagellus bogaraveo*(Brünnich, 1768) | Blackspot seabream |
| *Mullus surmuletus* (Linnaeus, 1758) | Striped red mullet | *Symphodus ocellatus* (Linnaeus, 1758) | - |
| *Mullus barbatus*(Linnaeus, 1758) | Red mullet | | |
| *Boops boops* (Linnaeus, 1758) | Bogue | | |
| *Mugil cephalus* (Linnaeus, 1758) | Flathead (grey) mullet | | |

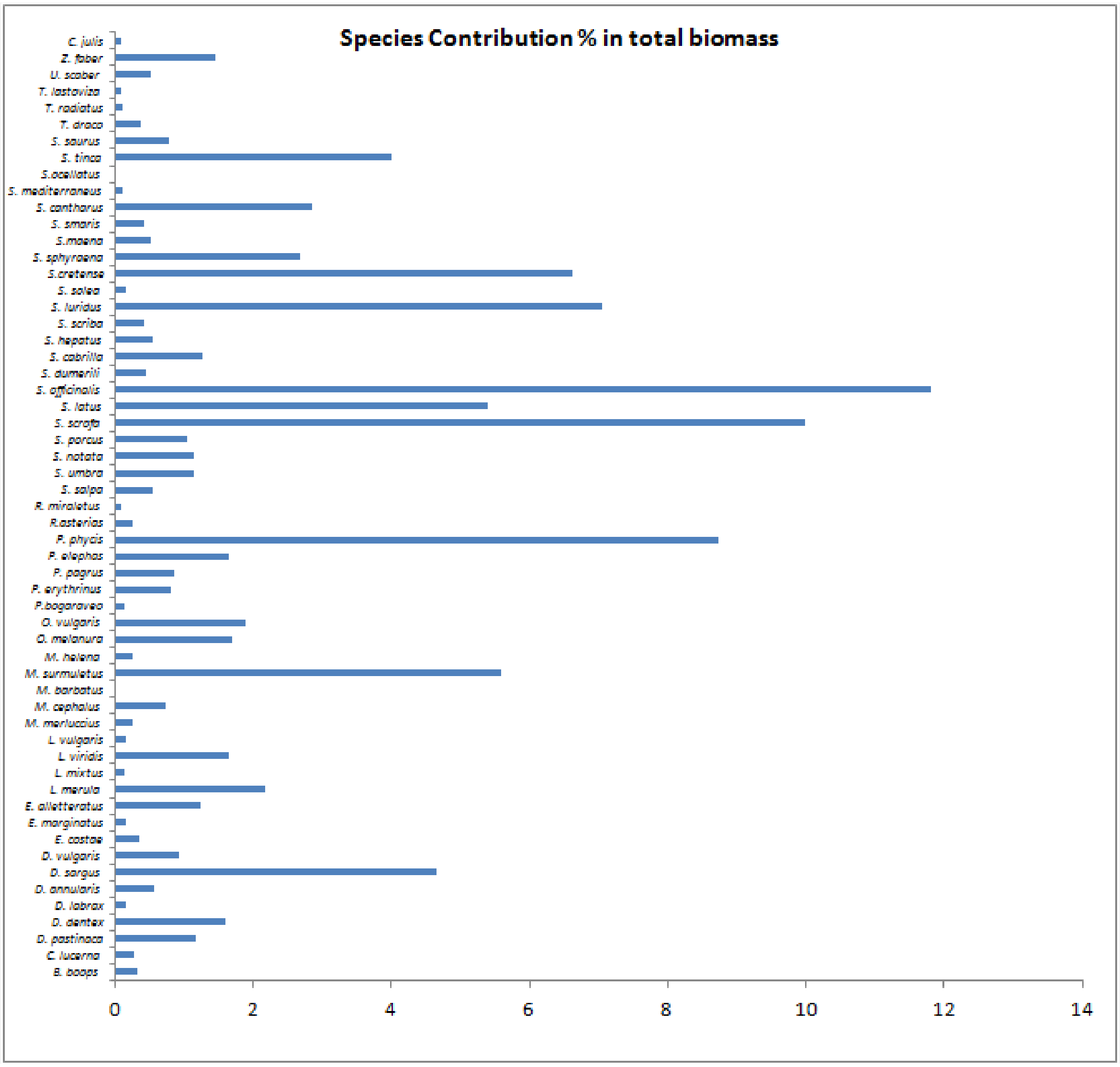



**Fig 68: Species contribution to the overall collected biomass during the sampling period**

Species contribution to the overall fished biomass is presented in Fig 68. In terms of total biomass, the dominant species were found to be *D. sargus*, *M. surmuletus*, *P. phycis*, *S. scrofa*, *S. latus*, *S. officinalis*, *S. luridus*, *S.cretense* and *S. tinca* which concentrated almost 64% of the total biomass (Fig 69).

When species number is considered (Fig 70a), maxima were detected in the fishing site A3 inside the MPA (25 species) whereas minima were found in the fishing site K2 which is located far away from the MPA (4 species). The average species number per sampling site was calculated to 14.61 inside the MPA and to 10.71 for the sampling locations that are found beyond the boundaries of the MPA (Fig 70b). However, Mann - Whitney test results suggested that the former difference in mean species number was not significant ($U = 51.50$; $p>0.05$).


Fig 69: Species with the highest contribution to the overall fished biomass in the study area

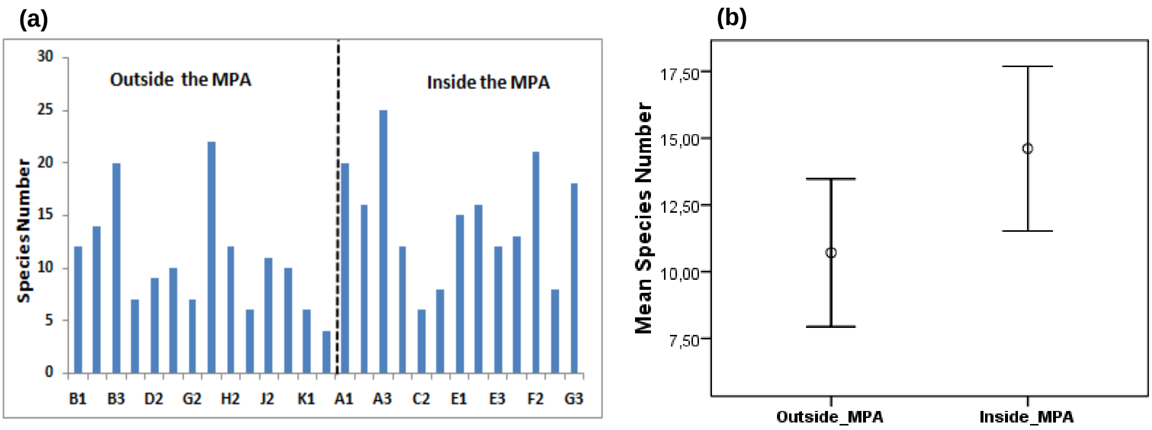



Fig 70. (a) total species number per sampling location, and (b) mean species number inside and outside the MPA (bars represent standard error of mean)

Considering the dominant species, from the 97500 gr of biomass that were caught inside the MPA, 7 species concentrated almost 59% of that amount. In more details, the invasive species *S. luridus* was the most dominant species within the limits of the MPA since it was accounted for the 11.64% of the total biomass therein (155 individuals). *S. cretense* was found to be the second most dominant species in terms of biomass covering 9.07% of the total biomass in the MPA followed by *D. sargus* with 8.89%, *S. scrofa* with 7.70%, *S. latus* with 7.57%, *S. tinca* with 6.88% and *M. surmuletus* with 6.37%, respectively (Fig 71).

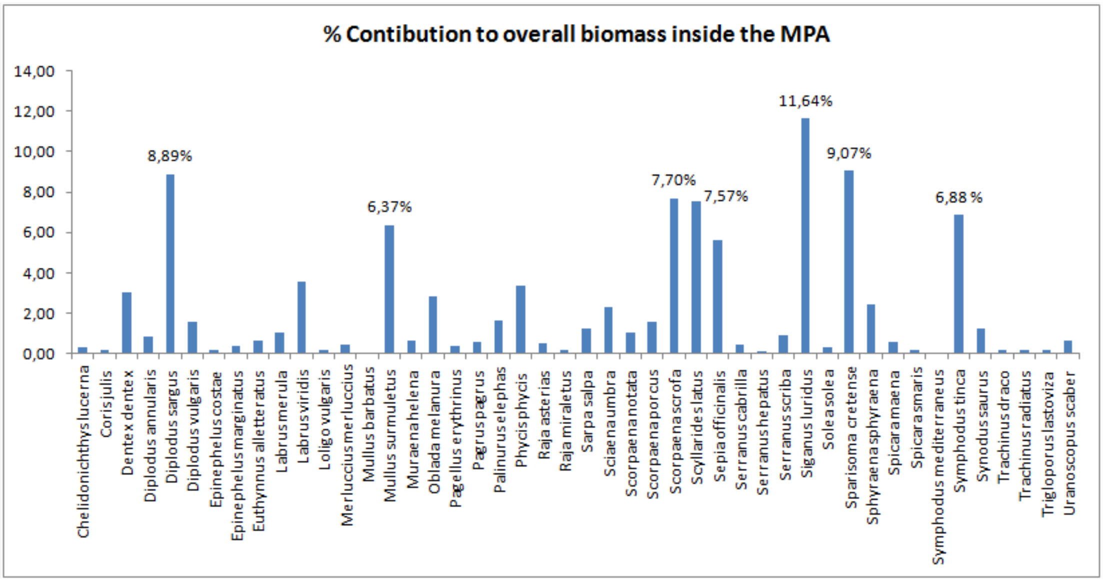



**Fig 71: Species contribution to the biomass that was fished within the borders of the MPA**

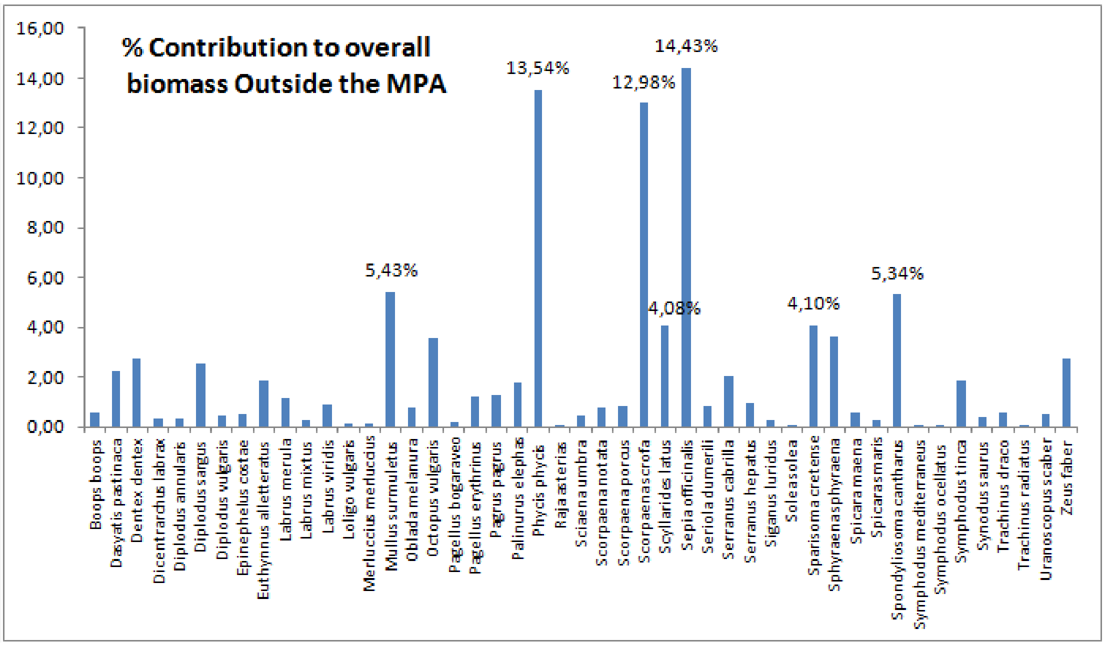



**Fig 72: Species contribution to the biomass that was fished outside the borders of the MPA**

On the other hand, 7 species were also responsible for the 60% of the total collected biomass outside the MPA. In this case, *S. officinalis* was the most dominant species accounting for 14.43% of the biomass that was caught outside the MPA (77 individuals), followed by *P. phycis* with 13.54%, *S. scrofa* with 12,98%, *M. surmuletus* with 5.43%, *S. cantharus* with 5.34%, *S. cretense* with 4.10% and *S. latus* with 4.08%, respectively (Fig 72).

## 2. Species Aggregated Catch per Unit Effort

Results of One-Sample Kolmogorov-Smirnov Test suggested that both catch (biomass) and effort (net x hours) data did not significantly depart from the normal distribution (Z=0.678; p>0.05 and Z=0.730; p>0.05 correspondingly). Implication of Pearson's parametric index revealed a significant linear correlation between the former variables (Pearson Correlation = 0.545; p=0.03; N = 27) and thus denoted that catch is proportional to effort. Linear regression model analysis further indicated that there is a statistically significant relationship between catch and effort (C = 0.249f + 2480.02; $r^2$ = 0.297; $F_{1, 25}$ = 10.55; p = 0.003 - Fig 73). As the intercept is not significantly different from zero ($t_{25}$ = 1.243; p = 0.226), we could assume that the regression pass by the origin and thus $CPUE_{1,2,3}$ are unbiased estimates of the CPUE.

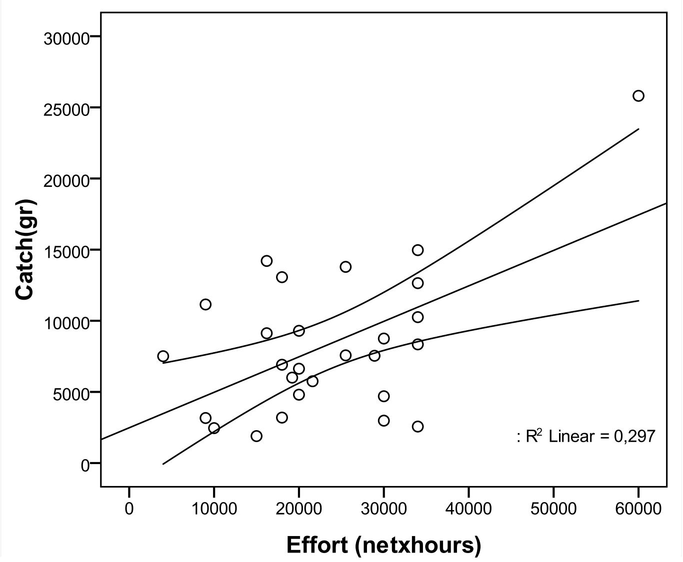



**Fig 73: Relationship between catch (gr) and effort (net x hours) . 95% confidence Intervals are also shown.**

Considering the sampling sites, maxima of CPUE were detected in sampling site C3 which is located inside the MPA whereas minima were recorded in sampling site D1 which is found outside the MPA (Fig 74a ). Pooled CPUE measurements with respect to the sampling sites located inside and outside the MPA as a grouping factor pointed out at the direction of a slightly higher mean CPUE inside the MPA. However, the latter difference of mean CPUE inside and outside the MPA was not statistically significant as it was proved by Mann-Whitney test results (U=82; p>0.05)(Fig 74b ). In this respect we can assume that CPUE is comparable when the different sampling areas are considered (inside *vs* outside the MPA), therefore suggesting a similar fish stock status in the former areas.

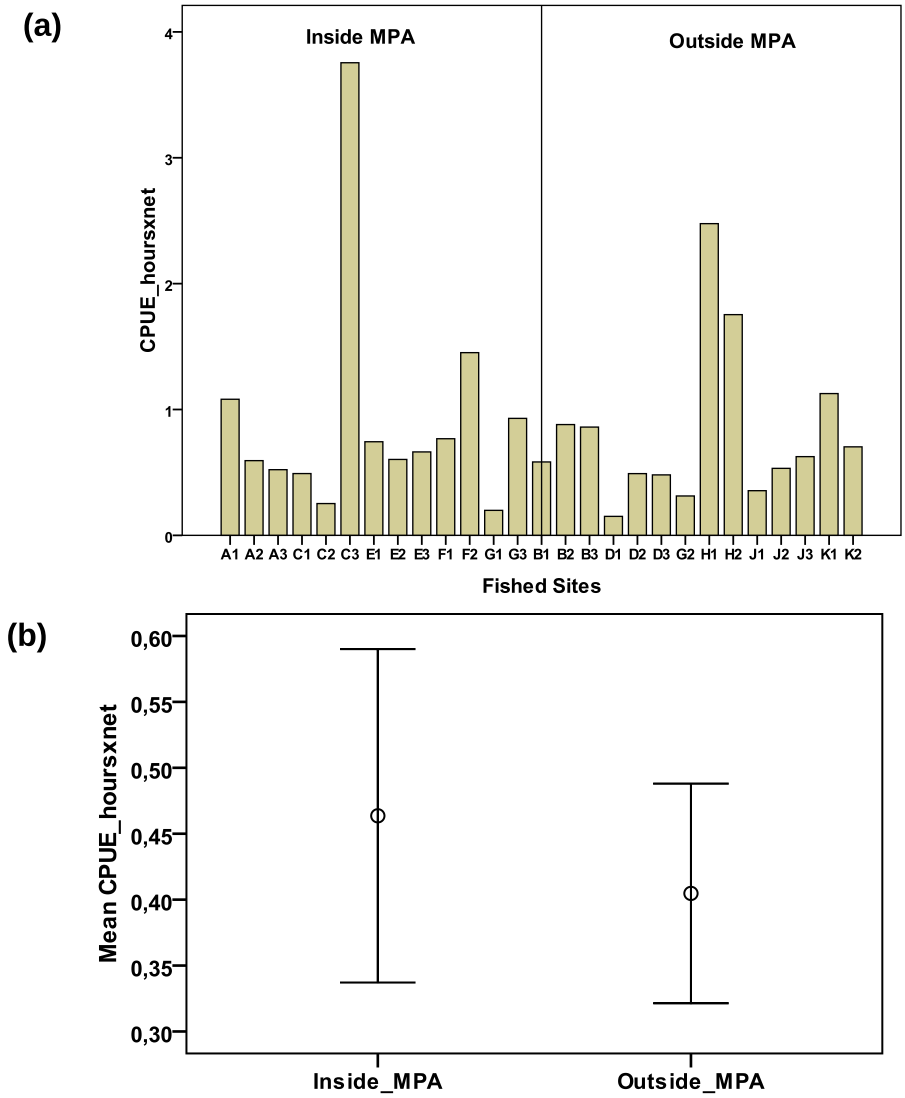



**Fig 74: (a)CPUE$_{(net\ x\ hours)}$ for each fishing set across the study area and (b) Mean CPUE$_{(net\ x\ hours)}$ for the pooled data inside and outside the MPA (bars represent standard error of mean)**

When species aggregated IPUE is considered, maxima were detected at the sampling site C3 [41.41€ x (gr/net x hours) and 165.64€ as total income from fish catch] which is located inside the MPA whereas minima were recorded at sampling site G1 [1.25€ x (gr/net x hours)] and 37,470€ as total income from fish catch] also found inside the MPA (Fig 75a). IPUE mean values did not differ significantly when sampling stations from the different sampling groups (inside *vs* outside MPA) were compared (Mann-Whitney test results, U = 2.3; p>0.05) (Fig 75b). Thus, it can be assumed that the mean fishing profits (weighted by the sampling effort) did not varied significantly and hence fishermen that are fishing inside the MPA are not receiving further financial benefits in comparison to the fishermen that are fishing outside the MPA.

(a)

(b)

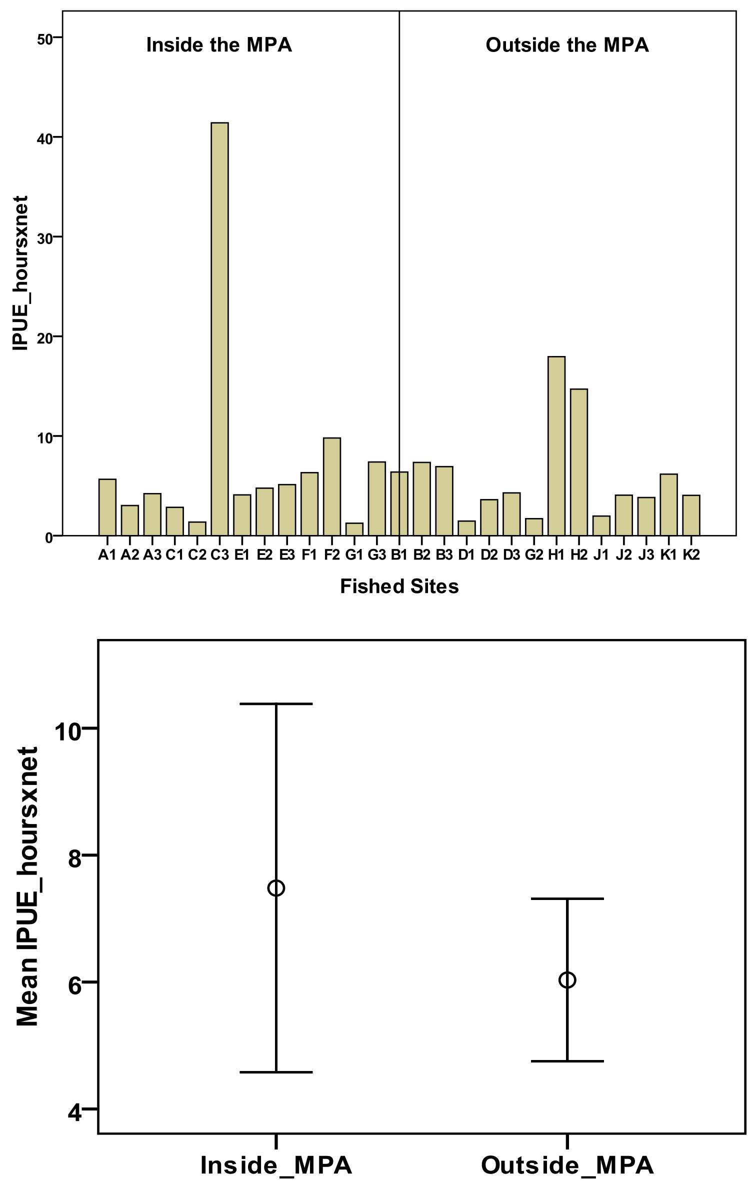



**Fig 75: (a)IPUE$_{(net \times hours)}$ for each fishing set across the study area and (b) Mean IPUE$_{(net \times hours)}$ for the pooled data inside and outside the MPA (bars represent standard error of mean)**

Calculation of $CPUE_1$, $CPUE_2$ and $CPUE_3$ indices produced a pattern of contradictory results with respect to the different groups of the sampling sites (inside *vs* outside the MPA, Fig 76). In this sense, $CPUE_1$ calculation suggested that CPUE was 13.6% higher inside the MPA than outside the MPA, whereas $CPUE_2$ was 34 times bigger in sampling sites that are found outside the MPA. On the contrary, $CPUE_3$ values were comparable when fishing areas from different sampling groups (inside *vs* outside the MPA) were compared since CPUE3 was 0.18% higher outside the MPA.

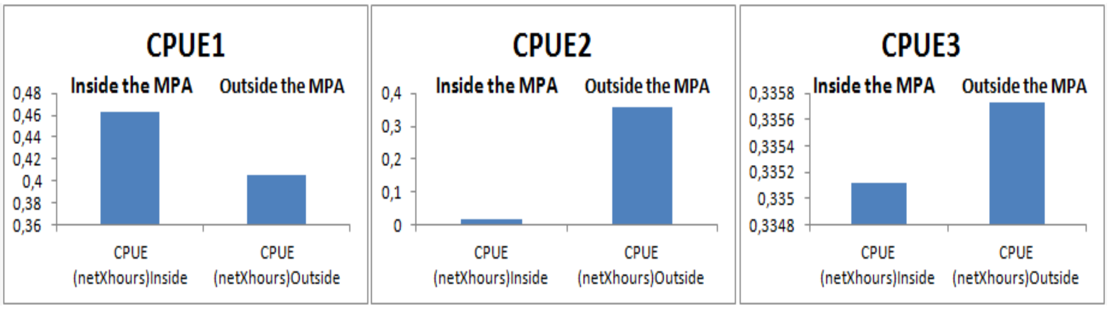
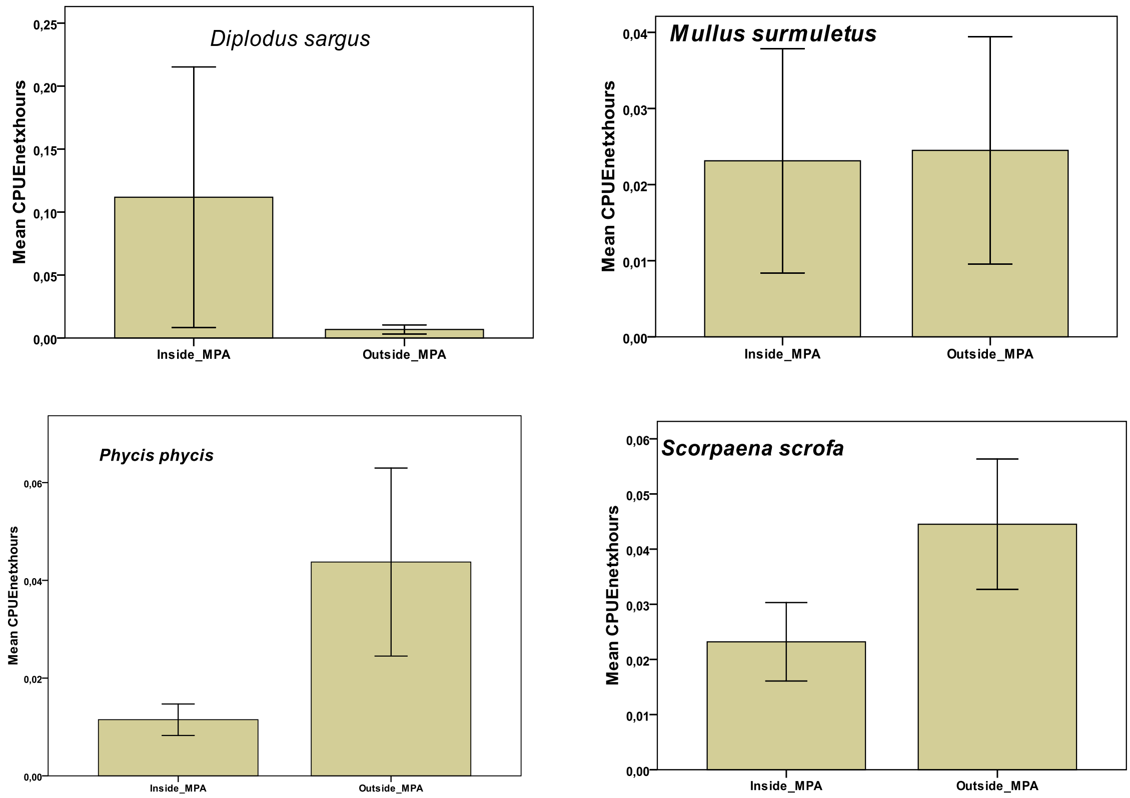



**Fig 76: Aggregated species CPUE calculated with $CPUE_1$, $CPUE_2$ and $CPUE_3$ formulas inside and outside the MPA**

## 3. Species Catch per Unit Effort

CPUE calculation results for each of the dominant species in the study area are presented in Fig 77. Our results suggested that for the case of *D. sargus* mean CPUE across the fishing sets was found to be 37 times bigger inside than outside the MPA. Likewise, mean CPUE for *S. latus* was found to be 1.6 times higher inside the MPA than the respective CPUE outside the MPA. Enhanced mean CPUE values were detected inside the MPA for both the herbivorous species *S. cretense* and *S. luridus* since mean CPUE was 3.4 and 54 times bigger inside the MPA, respectively. On the contrary, mean CPUE for *S. scrofa*, *P. phycis* and *S. officinalis* exhibited higher values in the fished areas that are located outside the limits of the MPA in comparison to the areas that are found within the MPA (3.6, 3.9 and 2.7 times higher, respectively). When *M. surmuletus* was considered mean CPUE was found to be almost identical between the fished areas inside and outside the MPA (0.24 *vs* 0.23, respectively).



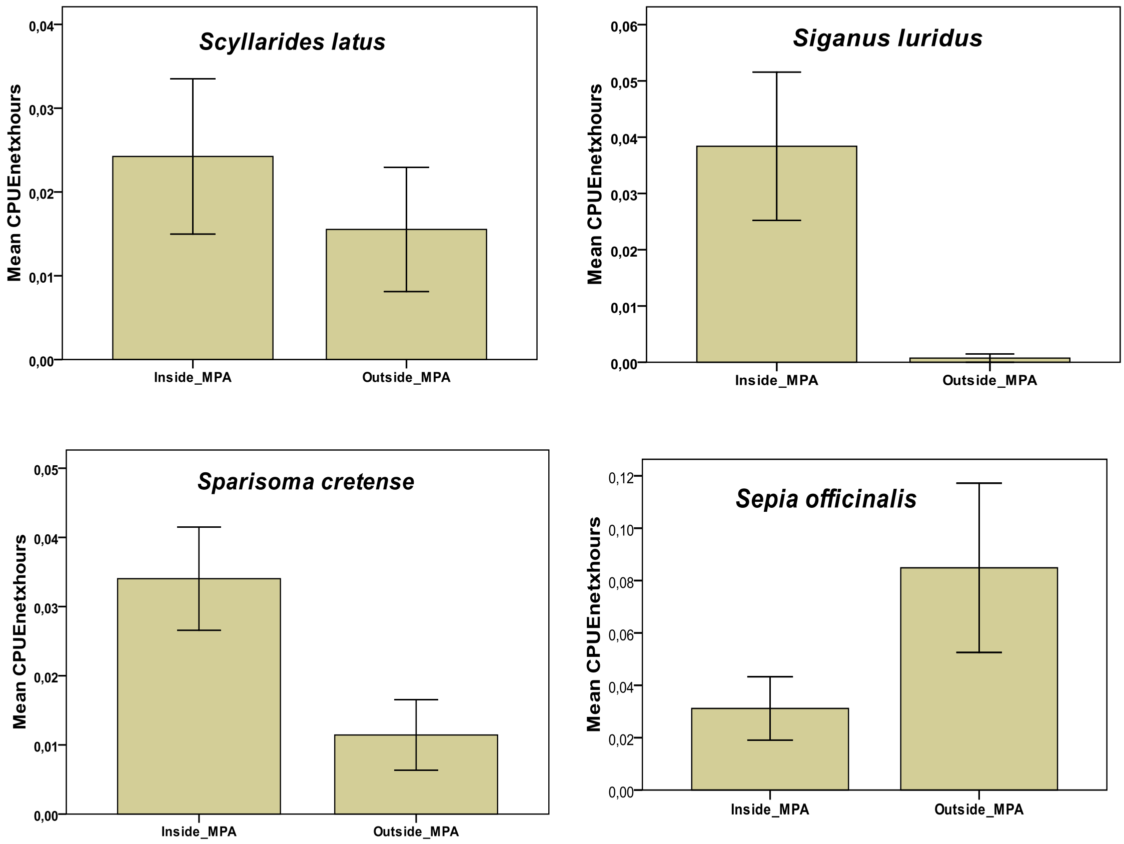
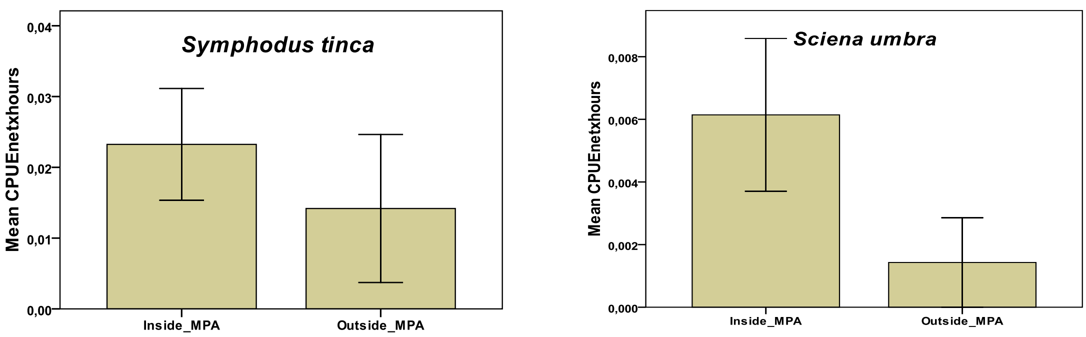



**Fig 77: Mean CPUE and standard error of mean for the dominant species inside and outside MPA (bars represent standard error of mean)**

Further comparisons of mean CPUE between the groups of sampling areas (inside *vs* outside the MPA) for several commercial species are presented in Fig 78. In these cases, *S. tinca*, *S. umbra*, *Epinephelus* spp (*E. marginatus* and *E. costae*) and Labridae (*L. viridis*, *L. merula* and *L. mixtus*), enhanced values of mean CPUE were detected within the limits of the MPA in comparison to the areas that are found outside the MPA (1.6, 6.1, 4.4 and 1.9 times higher inside the MPA correspondingly).



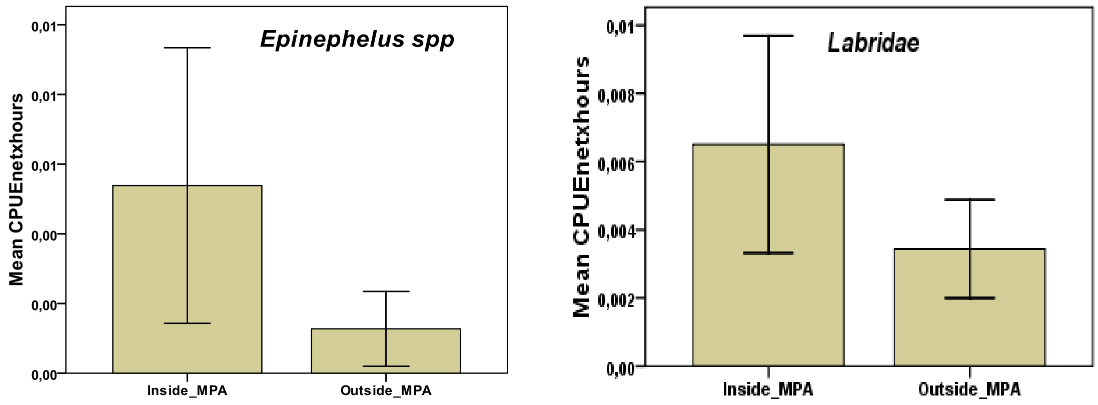



**Fig 78: Mean CPUE and standard error of mean for selected commercial species inside and outside MPA (bars represent standard error of mean)**

However, Mann - Whitney test results revealed that comparisons of the mean CPUE deriving by the sampling locations found inside and outside the MPA achieved statistical significance only for the cases of *Siganus luridus* and *Sparisoma cretense* (Table 17).

**Table 17: Mann - Whitney test results regarding the comparison of the mean CPUE between the areas that are found inside and outside the MPA for several selected species**

| Species | CPUE Inside *vs* Outside the MPA |
|---|---|
| *Diplodus sargus* | **ns** |
| *Mullus surmuletus* | **ns** |
| *Phycis phycis* | **ns** |
| *Scorpaena scrofa* | **ns** |
| *Scyllarides latus* | **ns** |
| *Sepia officinalis* | **ns** |
| *Siganus luridus* | **U = 37.5; p=0.002*** |
| *Sparisoma cretense* | **U = 47; p=0.02*** |
| *Symphodus tinca* | **ns** |
| *Sciena umbra* | **ns** |
| *Epinephelus* spp | **ns** |
| Labridae | **ns** |

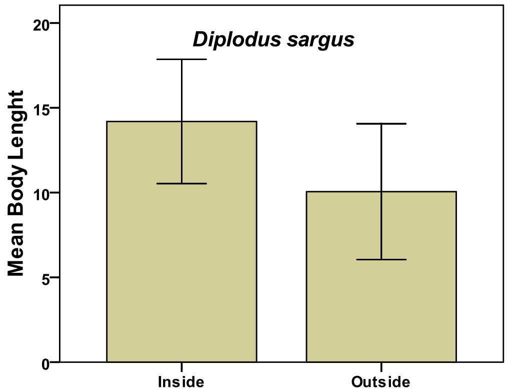
## 4. Species Body Size

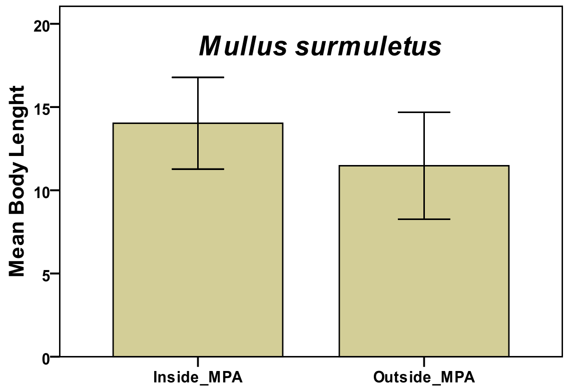
Species total body size presented in Table 18 indicates the minimum and the maximum body length (cm) that was measured in the study area for each of the fished species. The top five largest species included individuals of *Muraena helena* (70cm), *S. sphyraena* (67cm), *D. dentex* (55cm), *D. pastinaca* (55cm) and *E. alletteratus* (48cm). On the contrary, the smallest species corresponded to individuals of *S. officinalis* (7.4cm), *D.annularis* (10cm), *S. porcus* (11.2cm), *S. notata* (12cm) and *S. scrofa* (12cm).

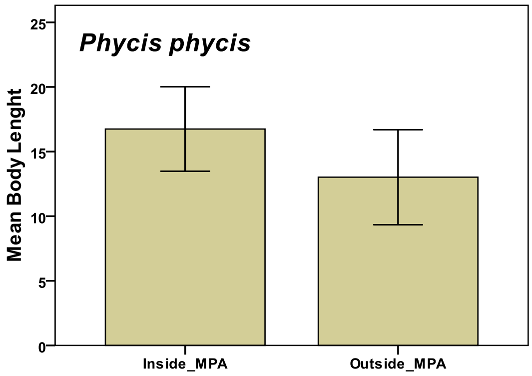
**Table 18: Minimum ($L_{min}$) and maximum ($L_{max}$) values of the measured total body size for each species during the sampling period**

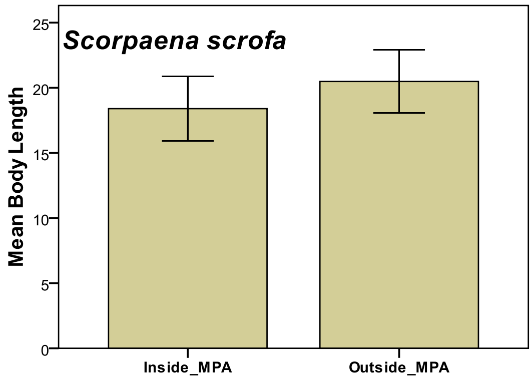
| species | $L_{min}$ | $L_{max}$ | species | $L_{min}$ | $L_{max}$ |
|---|---|---|---|---|---|
| *Chelidonichthys lucerna* | 33 | 33 | *Mullus surmuletus* | 14 | 29 |
| *Epinephelus marginatus* | 29.4 | 29.4 | *Mullus barbatus* | 17.5 | 17.5 |
| *Labrus merula* | 19 | 34 | *Boops boops* | 19.5 | 31 |
| *Labrus viridis* | 17 | 42.5 | *Mugil cephalus* | 33 | 41 |
| *Loligo vulgaris* | 15.5 | 19.5 | *Symphodus mediterraneus* | 13 | 17.5 |
| *Merluccius merluccius* | 25 | 41.5 | *Serranus hepatus* | 16.5 | 20 |
| *Pagellus erythrinus* | 13.5 | 21 | *Serranus cabrilla* | 14 | 22 |
| *Pagrus pagrus* | 13.5 | 26 | *Serranus scriba* | 12.5 | 19 |
| *Palinurus elephas* | 20 | 33 | *Diplodus sargus* | 15 | 38.5 |
| *Phycis phycis* | 19 | 41.5 | *Diplodus annularis* | 10 | 18.5 |
| *Sciaena umbra* | 25.5 | 40 | *Diplodus vulgaris* | 15 | 29 |
| *Scorpaena notata* | 12 | 27 | *Euthynnus alletteratus* | 36 | 48 |
| *Scorpaena scrofa* | 12 | 38 | *Zeus faber* | 20 | 28.5 |
| *Scyllarides latus* | 17 | 30 | *Sphyraena sphyraena* | 49 | 67 |
| *Sepia officinalis* | 7.4 | 20 | *Epinephelus costae* | 24.5 | 32 |
| *Siganus luridus* | 15.5 | 25 | *Octopus vulgaris* | | - |
| *Solea solea* | 20 | 28 | *Dicentrarchus labrax* | 32 | 32 |
| *Spicara maena* | 17 | 22 | *Sarpa salpa* | 13.9 | 29 |
| *Spicara smaris* | 16.5 | 28 | *Scorpaena porcus* | 11.2 | 21 |
| *Symphodus tinca* | 13.6 | 29 | *Raja asterias* | 28 | 46 |
| *Synodus saurus* | 15 | 34 | *Dentex dentex* | 27.5 | 55 |
| *Trachinus radiatus* | 20 | 21 | *Spondyliosoma cantharus* | 18 | 36 |
| *Trigloporus lastoviza* | 17 | 21 | *Labrus mixtus* | 20 | 24 |
| *Uranoscopus scaber* | 18 | 26 | *Seriola dumerili* | 45.5 | 45.5 |
| *Coris julis* | 18 | 21 | *Dasyatis pastinaca* | 55 | 55 |
| *Sparisoma cretense* | 15.5 | 30 | *Raja miraletus* | 29 | 29 |
| *Oblada melanura* | 16.8 | 29.5 | *Muraena helena* | 70 | 70 |
| *Pagellus bogaraveo* | 19 | 23 | *Symphodus ocellatus* | 13.5 | 13.5 |
| *Trachinus draco* | 23 | 38 | | | |

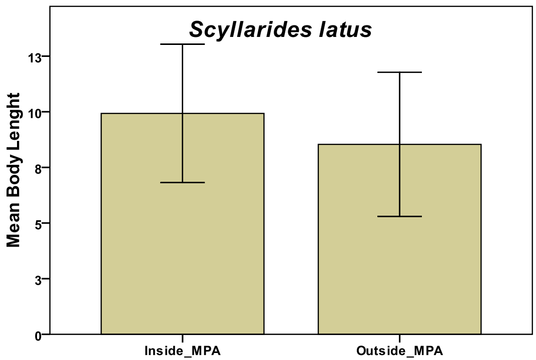
Considering the comparison of the mean body length of the dominant as well as commercially important species that were collected inside and outside the MPA (Fig 79), we found that *D. sargus*, *M. surmuletus*, *P. phycis*, *S. latus*, *S. officinalis*, *S. luridus*, *S. cretense* and *S. umbra* presented higher mean body length in the fishing sets derived by the sampling sites located within the limits of the MPA. In more detail, in the case of *D. sargus* mean body length was 1.25 times bigger inside the MPA, whereas for *M. surmuletus*, *P. phycis*, *S. latus, S. officinalis*, *S. luridus*, *S.cretense*, *S. umbra* was 1.22, 1.49, 1.16, 1.12, 6.94, 1.7 and 4.34 times bigger, respectively, for the individuals fished inside the borders of the MPA. A similar pattern was also detected for *S. tinca* and *Labridae* spp, since mean body length was 1.73 and 1.12 times bigger inside the MPA.

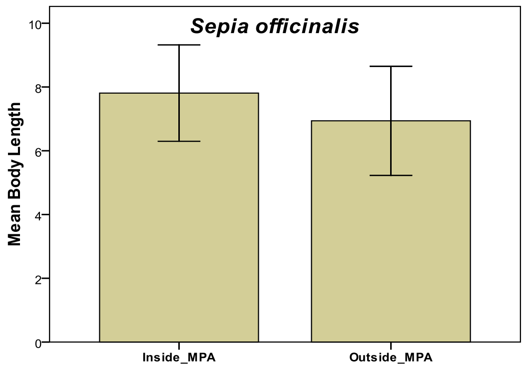

Diplodus sargus
Mean Body Lenght
0
5
10
15
20
Inside
Outside

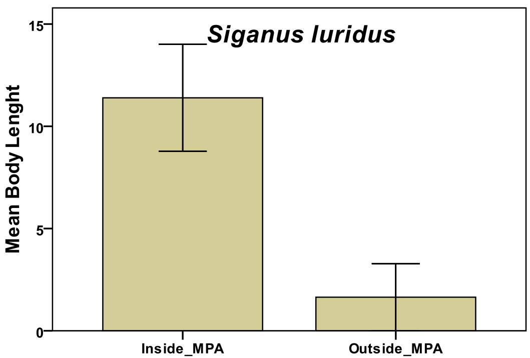

Mullus surmuletus
Mean Body Lenght
0
5
10
15
20
Inside_MPA
Outside_MPA

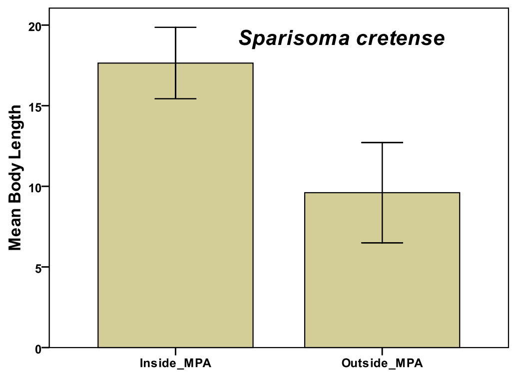

Phycis phycis
Mean Body Lenght
0
5
10
15
20
25
Inside_MPA
Outside_MPA


Scorpaena scrofa
Mean Body Length
0
5
10
15
20
25
Inside_MPA
Outside_MPA


Scyllarides latus
Mean Body Lenght
0
3
5
8
10
13
Inside_MPA
Outside_MPA


Sepia officinalis
Mean Body Length
0
2
4
6
8
10
Inside_MPA
Outside_MPA


Siganus luridus
Mean Body Lenght
0
5
10
15
Inside_MPA
Outside_MPA


Sparisoma cretense
Mean Body Length
0
5
10
15
20
Inside_MPA
Outside_MPA

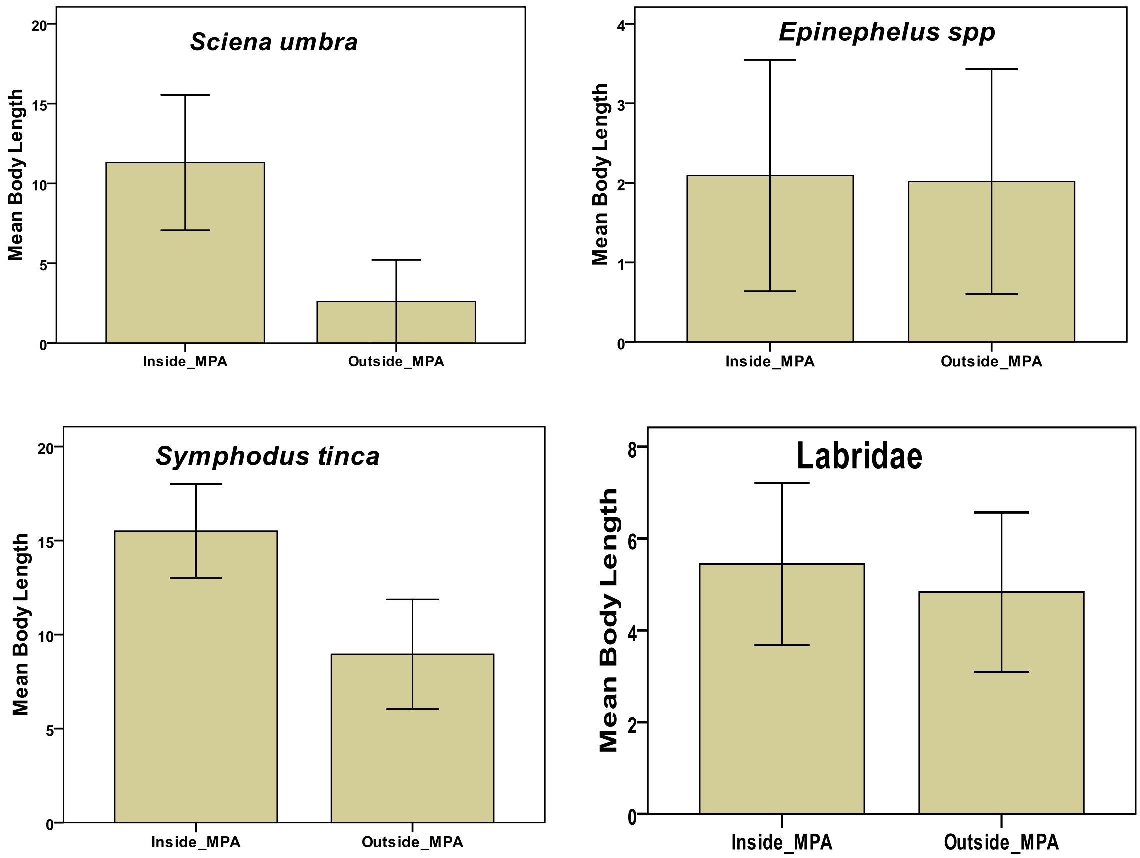



**Fig 79: Mean body length for dominant or commercial species found inside and outside the MPA (bars represent standard error of mean)**

On the contrary, *Epinephelus* spp (*E. marginatus* and *E.costae*) mean body length was comparable when individuals from areas inside and outside the MPA are considered. However, Mann - Whitney test results suggest that all the above differences in the mean body size of the fished species were significant only for the case of *Siganus luridus* (U = 45.5; p<0.05)(Table 19).

**Table 19: Mann - Whitney test results regarding the comparison of the mean body fish length between the areas that are found inside and outside the MPA for several selected species**

| Species | Mean Body length Inside *vs* Outside the MPA |
|---|---|
| *Diplodus sargus* | ns |
| *Mullus surmuletus* | ns |
| *Phycis phycis* | ns |
| *Scorpaena scrofa* | ns |
| *Scyllarides latus* | ns |
| *Sepia officinalis* | ns |
| *Siganus luridus* | U = 45.5; p=0.009* |
| *Sparisoma cretense* | ns |
| *Symphodus tinca* | ns |
| *Sciena umbra* | ns |
| *Epinephelus* spp | ns |
| Labridae | ns |

## 5. Functional Group Analysis

Results suggest that species number fluctuation pattern within each functional group was comparable when pooled fishing sets were taken into account considering the areas inside and outside the MPA (Fig 80). Hence, carnivorous species were the dominant functional group in term of species number for both areas, followed by apex predators, and zooplanktivorous species. In the case of herbivorous species, 3 species were identified inside the MPA whereas 2 species were caught outside the MPA.

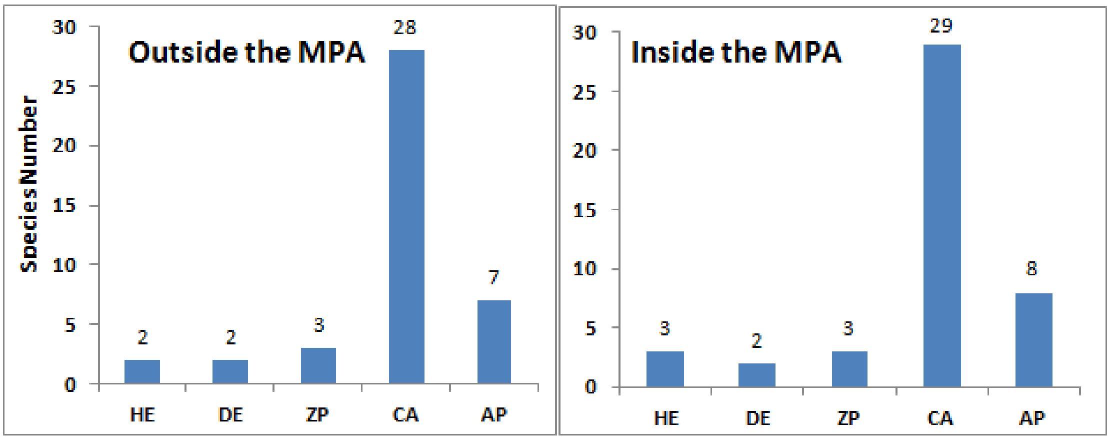



**Fig 80: Species number per functional group for the pooled data concerning the areas inside and outside the MPA**

Calculations of the mean CPUE per functional group revealed that herbivorous, detrivorous and carnivorous species presented 7, 1.66 and 1.33 times higher mean CPUE inside the MPA than outside the MPA respectively (Fig 81). In contrast, in the case of zooplanktivorous species and apex predators mean CPUE was 1.23 and 1.51 times greater in areas located outside the limits of the MPA respectively. However, Mann - Whitney test results suggest that statistically significant differences in the mean CPUE were detected only in the case of herbivorous species ($U=0.001$; $p<0.05$) (Table 20) thus indicating a significantly enhanced mean CPUE inside the MPA for that functional group.

**Table 20: Mann - Whitney test results regarding the comparison of the mean CPUE between the areas that are found inside and outside the MPA for the functional groups considered in the analyses**

| Functional group | Mean CPUE Inside *vs* Outside the MPA |
|---|---|
| *Herbivorous* | **U=0.001;p<0.05*** |
| *Detritivorous* | **ns** |
| *Zooplanktivorous* | **ns** |
| *Carnivorous* | **ns** |
| *Apex Predators* | **ns** |

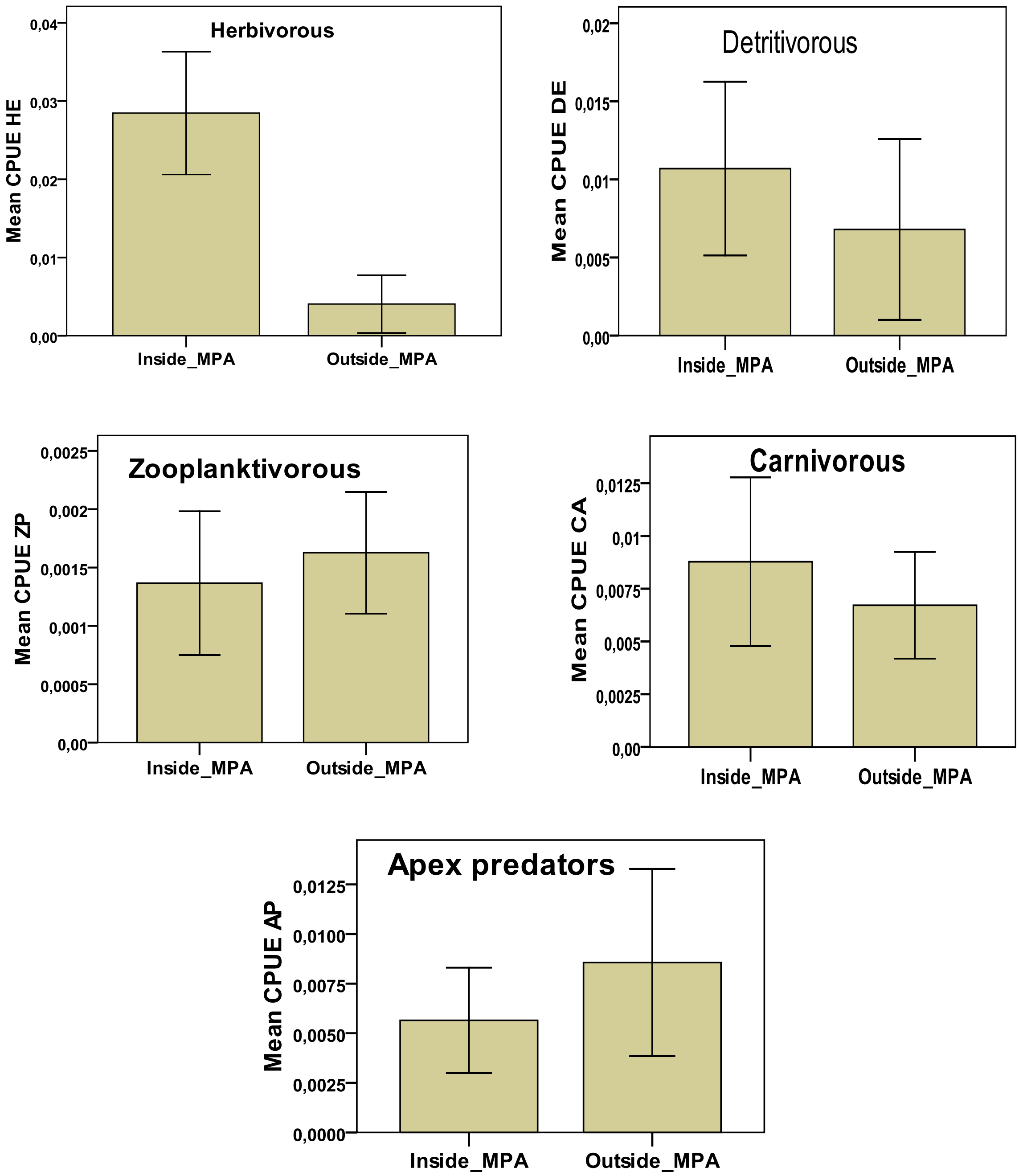



**Fig 81: Mean CPUE calculation for the functional groups with respect to different sampling areas (bars represent standard error of mean)**

## 6. Size of First Sexual Maturation and Minimum Permitted Catch Size

Results of the gathered information about Lm (1st reproduction maturity length), the percentage of the measured population that is lower than Lm, the maximum measured body length, the minimum permitted catch size (MPCS) as well as the percentage of the measured population that falls beneath MPCS for each species are presented in Table 21. Our findings revealed that the body length of 17 species (including all the measured individuals) (29.82% of the total collected species) was smaller than the Lm value for each of these species. Therefore, it is reasonable to conclude that almost 1/3 of the fished species was caught before reaching the size of sexual maturity. Some of these species were *Epinephelus marginatus*, *Zeus faber*, *Merluccius merluccius*, *Pagrus pagrus*, *Trachinus radiatus*, *Euthynnus alletteratus*, *Sphyraena sphyraena*, *Epinephelus costae*, *Dicentrarchus labrax*, *Seriola dumerili* and *Pagellus bogaraveo* which are known to have high commercial value or special ecological importance.

**Table 21: Detailed list including the body length of sexual maturity (Lm in cm), the percentage of the measured population which is smaller than Lm (%<Lm), the maximum body length that was found during the sampling period (Lmax in cm), the minimum permitted catch size (cm) and the percentage of the measured individuals that is smaller than the minimum permitted catch size for each species (% < Min Permitted Size). For the case of the minimum permitted catch size NL (NL) corresponds to limitation deriving by the National Laws and EC (EC) to limitations that European Community legislations are posing.**

| species | Lm | %<Lm | Lmax | Min Permitted Size | %<Min Permitted Size |
|---|---|---|---|---|---|
| ***Chelidonichthys lucerna*** | 33.7 | 100 | 33 | 8(NL) | 0 |
| ***Epinephelus marginatus*** | 58.7 | 100 | 29.4 | 45(EC) | 100 |
| ***Labrus merula*** | 25 | 35.3 | 34 | 8(NL) | 0 |
| ***Labrus viridis*** | 27.5 | 66.6 | 42.5 | 8(NL) | 0 |
| ***Loligo vulgaris*** | - | - | 19.5 | 8(NL) | 0 |
| ***Merluccius merluccius*** | 44 | 100 | 41.5 | 20(EC) | 0 |
| ***Pagellus erythrinus*** | 18.2 | 66.6 | 21 | 15(EC) | 14.8 |
| ***Pagrus pagrus*** | 41 | 100 | 26 | 18(EC) | 88.2 |
| ***Palinurus elephas*** | - | - | 33 | 9(NL) | 0 |
| ***Phycis phycis*** | 35.6 | 94.6 | 41.5 | 8(NL) | 0 |
| ***Sciaena umbra*** | 26.4 | 16.6 | 40 | 8(NL) | 0 |
| ***Scorpaena notata*** | 15.2 | 14.2 | 27 | 8(NL) | 0 |
| ***Scorpaena scrofa*** | 31.6 | 97 | 38 | 8(NL) | 0 |
| ***Scyllarides latus*** | - | - | 30 | 9(NL) | 0 |
| ***Sepia officinalis*** | - | - | 20 | 8(NL) | 2.2 |
| ***Siganus luridus*** | 18.5 | 49.6 | 25 | 8(NL) | 0 |
| ***Solea solea*** | 25.2 | 66.6 | 28 | 20(EC) | 0 |
| ***Spicara maena*** | 11.8 | 0 | 22 | 8(NL) | 0 |
| ***Spicara smaris*** | 16.3 | 0 | 28 | 8(NL) | 0 |
| ***Symphodus tinca*** | 16.8 | 16.6 | 29 | 8(NL) | 0 |
| ***Synodus saurus*** | 23.8 | 7.1 | 34 | 8(NL) | 0 |
| ***Trachinus radiatus*** | 29 | 100 | 21 | 8(NL) | 0 |
| ***Trigloporus lastoviza*** | 21.3 | 100 | 21 | 8(NL) | 0 |
| ***Uranoscopus scaber*** | 23.8 | 87.5 | 26 | 8(NL) | 0 |
| ***Coris julis*** | 16.2 | 0 | 21 | 8(NL) | 0 |
| ***Sparisoma cretense*** | 20.4 | 31.5 | 30 | 8(NL) | 0 |
| ***Oblada melanura*** | 20.6 | 44 | 29.5 | 8(NL) | 0 |
| ***Mullus surmuletus*** | 13 | 0 | 29 | 11(EC) | 0 |
| ***Mullus barbatus*** | 13.6 | 0 | 17.5 | 11(EC) | 0 |
| ***Boops boops*** | 4 | 0 | 31 | 10(NL) | 0 |
| ***Mugil cephalus*** | 28.5 | 0 | 41 | 16(NL) | 0 |
| ***Symphodus mediterraneus*** | 10.6 | 0 | 17.5 | 8(NL) | 0 |
| ***Serranus hepatus*** | 9.7 | 0 | 20 | 8(NL) | 0 |
| ***Serranus cabrilla*** | 15 | 2.4 | 22 | 8(NL) | 0 |

| | | | | | |
|---|---|---|---|---|---|
| ***Serranus scriba*** | 17.9 | 93.3 | 19 | 8(NL) | 0 |
| ***Diplodus sargus*** | 29.5 | 90 | 38.5 | 23(EC) | 68 |
| ***Diplodus annularis*** | 13.7 | 38.4 | 18.5 | 12(EC) | 3.8 |
| ***Diplodus vulgaris*** | 16.5 | 31.5 | 29 | 18(EC) | 47.3 |
| ***Euthynnus alletteratus*** | 59.2 | 100 | 48 | 8(NL) | 0 |
| ***Zeus faber*** | 37.6 | 100 | 28.5 | 8(NL) | 0 |
| ***Sphyraena sphyraena*** | 83.4 | 100 | 67 | 8(NL) | 0 |
| ***Epinephelus costae*** | 45.7 | 100 | 32 | 45(EC) | 100 |
| ***Octopus vulgaris*** | - | - | - | 500gr(NL) | 0 |
| ***Dicentrarchus labrax*** | 41.2 | 100 | 32 | 25(EC) | 0 |
| ***Sarpa salpa*** | 25.3 | 81.8 | 29 | 8(NL) | 0 |
| ***Scorpaena porcus*** | 23.3 | 100 | 21 | 8(NL) | 0 |
| ***Raja asterias*** | 39.1 | 50 | 46 | 8(NL) | 0 |
| ***Dentex dentex*** | 44.8 | 80 | 55 | 8(NL) | 0 |
| ***Spondyliosoma cantharus*** | 26.9 | 52.1 | 36 | 8(NL) | 0 |
| ***Labrus mixtus*** | 24.4 | 100 | 24 | 8(NL) | 0 |
| ***Seriola dumerili*** | 70.2 | 100 | 45.5 | 8(NL) | 0 |
| ***Dasyatis pastinaca*** | 32.6 | 0 | 55 | 8(NL) | 0 |
| ***Raja miraletus*** | 46.5 | 100 | 29 | 8(NL) | 0 |
| ***Muraena helena*** | 76.7 | 100 | 70 | 8(NL) | 0 |
| ***Pagellus bogaraveo*** | 31.2 | 100 | 23 | 33(EC) | 100 |
| ***Trachinus draco*** | 30.6 | 33.3 | 38 | 8(NL) | 0 |
| ***Symphodus ocellatus*** | 7.1 | 0 | 13.5 | 8(NL) | 0 |

Likewise, 46.15% of the collected species (24 species) was found to have 75 to 100% of their individuals with a size lower than Lm (Fig 82). This finding further demonstrates that the majority of fish caught never reached the size of reproductive maturity for almost half of the fished species. In contrast, only the 21.5% of the fished species (11 species) was found to have all their individuals larger than Lm. The most important species in terms of their commercial value belonging to the latter category were *S. smaris*, *S. maena*, *M. surmuletus*, *M. barbatus* and *B. boops*.
Regarding the Minimum Permitted Catch Size (MPCS) according to EU and National regulations, our data revealed that all the measured individuals of *E. marginatus*, *E. costae* and *P. bogaraveo* populations were smaller than MPCS (Fig 83). Moreover, 88.2% of the total measured specimen of *P. pagrus* was smaller than MPCS whereas this percentage was calculated to 68% for *D. sargus*, to 47.3% for *D. vulgaris* and 14.8% for *P. erythrinus*.

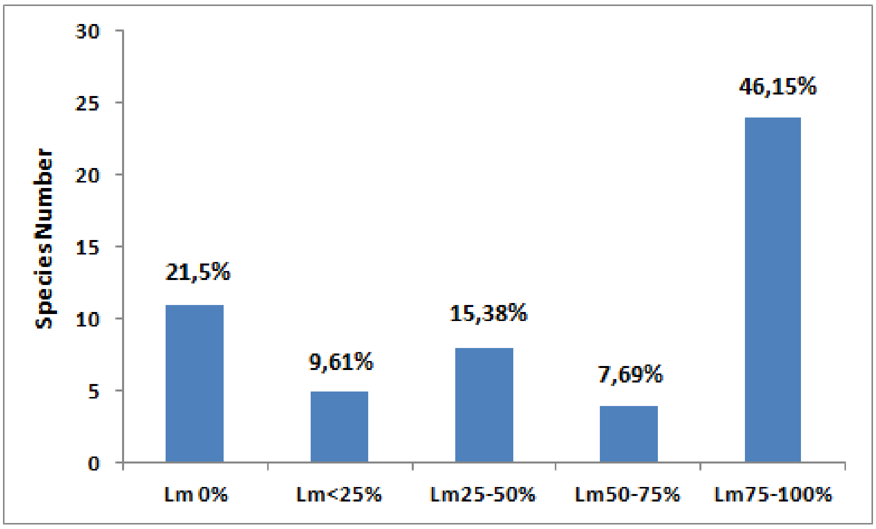



**Fig 82: Percentage of species population for which the measured body size of each specimen is bigger (Lm 0%) or smaller than the size of sexual maturity (see materials and methods for further details)**

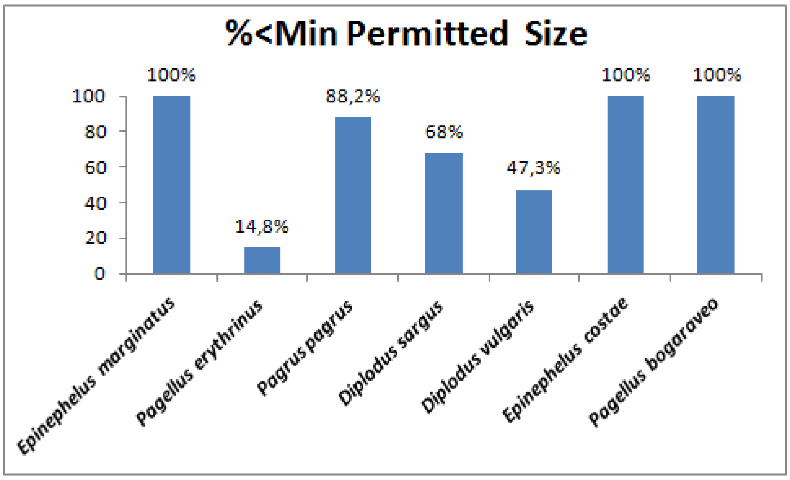



**Fig 83: Percentage of species population for which the measured size of the specimen is smaller than the minimum permitted catch size**

# E. Questionnaires

## 1. Vessel Information

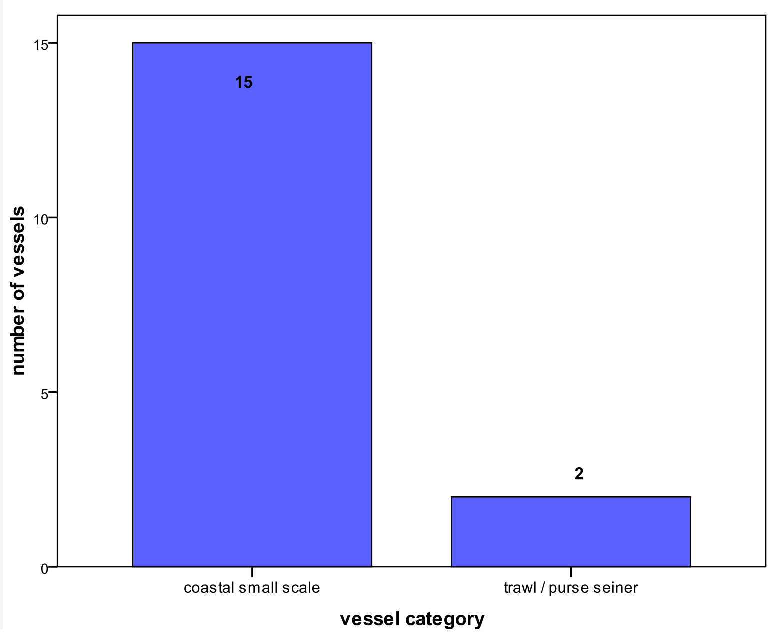



**Fig 84: Vessel category with respect to the fishing type and the distance from the coast that they keep when they fish**

As it is evident from Fig 84. the majority of the vessels included in the analysis (completed questionnaires) are related to small scale coastal fishing activities, while only two vessels were trawlers/purse seiners involved in open sea fisheries.

According to the fishing vessels that took part in the survey, results on vessels' characteristics, such as the total length, capacity in GT and engine horse power, are presented in Fig 85, Fig 86, and Fig 87 respectively.

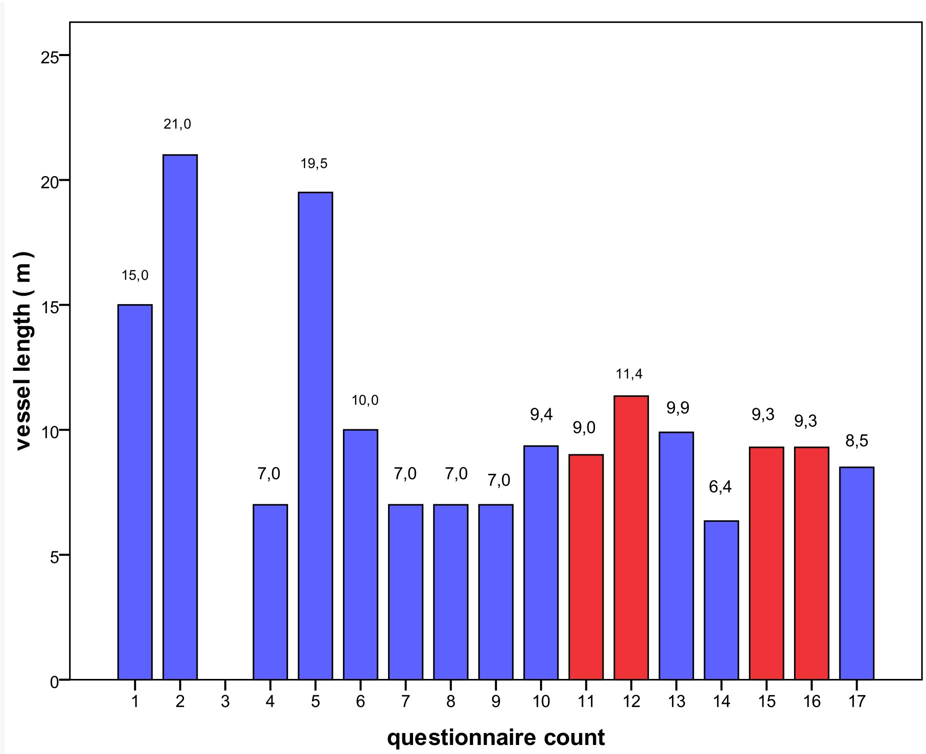



**Fig 85: Total length (in meters) of the fishing vessels per questionnaire. Red bars indicate the cases of the fishing vessels that are active inside the MPA, blue bars indicate the ones that are fishing outside the MPA.**

Vessel size was mainly below 10m, and only 4 vessels had a total length ranging between 10 – 21 m. Mean total length was 9.75 m for vessels operating inside the MPA (red bars), and 10.64 m for those that are active outside the MPA.

Thirteen out of the seventeen vessels completed this question and from those, the majority had a volume capacity below 4 GT. Three vessels had 6, 12.5 and 41 GT capacities.

From the 16 records on this information, it is evident that the majority of the vessels participating in the study had engines with a horsepower ranging from 115HP and below. Only 4 vessels had more powerful engines (135, 180, 260 & 390HP). Apparently, as it is seen in the latter 3 figures, there is no correlation between vessel's lengths, capacity and engine HP, since vessels of the same length have varying capacities and different engines.

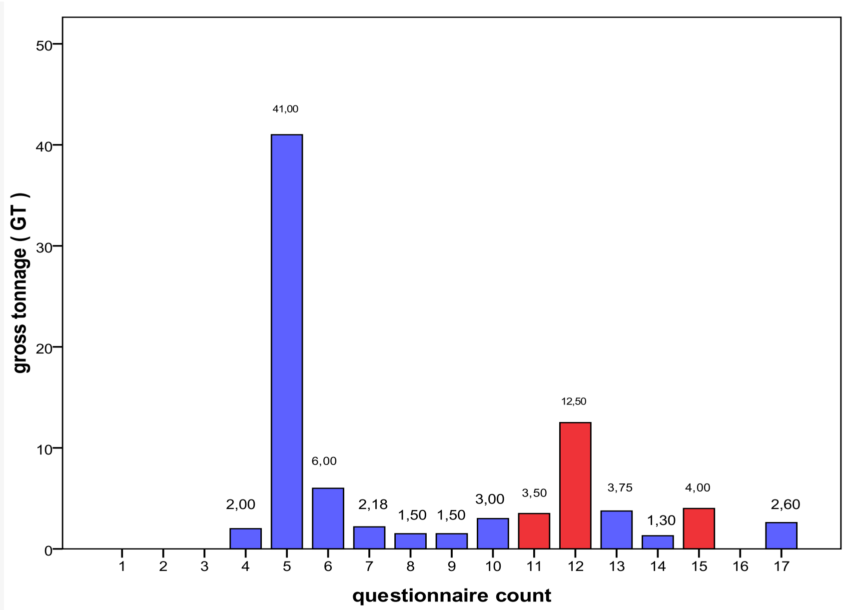



**Fig 86: Vessels capacity as gross tonnage per questionnaire. Red bars indicate the cases of the fishing vessels that active inside the MPA whereas blue bars indicate the ones that are fishing outside the MPA.**

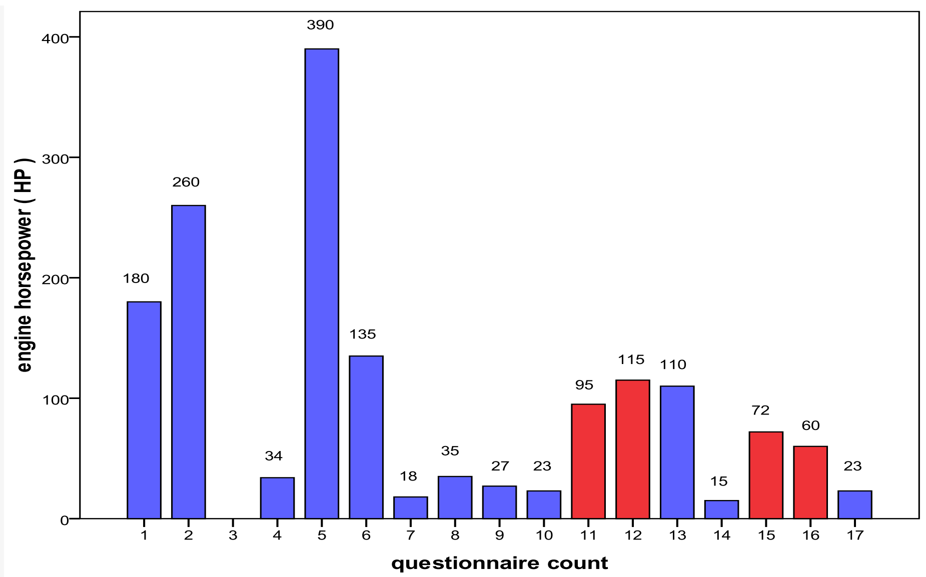



**Fig 87: Engine Horse Power (HP) of the fishing vessels. Red bars indicate the cases of the fishing vessels that active inside the MPA whereas blue bars indicate the ones that are fishing outside the MPA.**

Working expenses mean value per year and corresponding standard error are illustrated in Fig 88. Cost partitioning indicates that expenses are primarily related to payment of salaries (mean = 7800 € per year), fuel (mean = 5125 € per year), and other costs associated with gear replacement and maintenance (Fig 88). Overall, mean total cost of fishing activity is estimated to be approximately 1769 € per year.

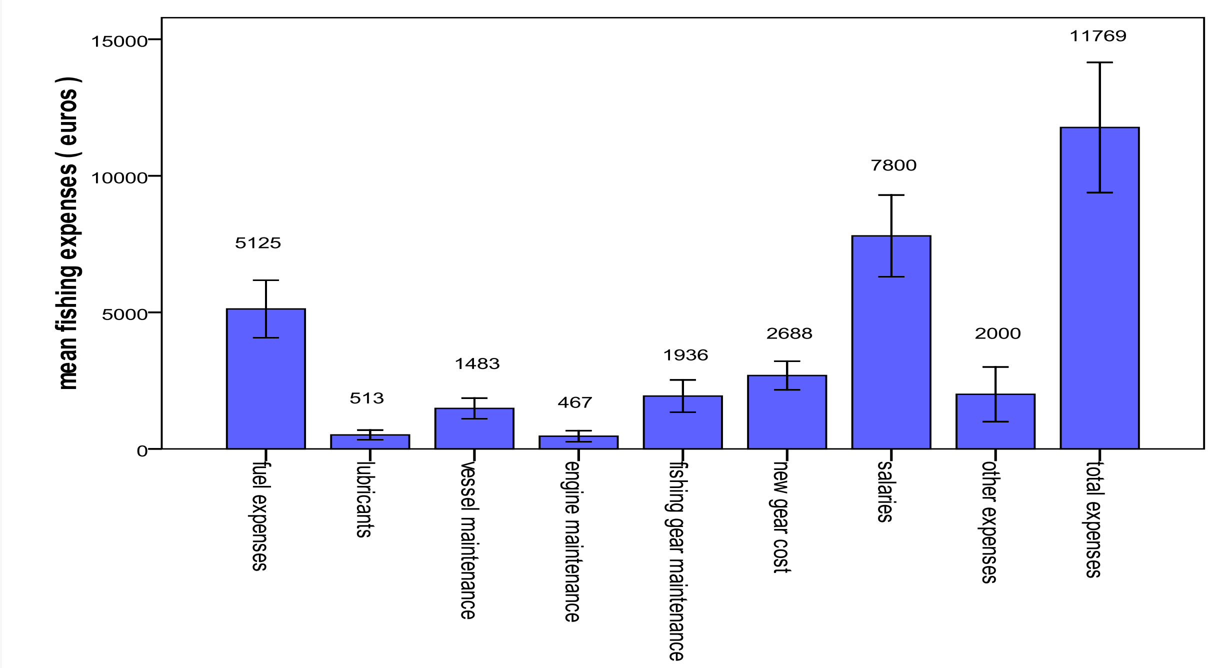



**Fig 88: Cost categories of fisheries that fishermen indicated in the questionnaires and mean values in €/ per year**

## 2. Fishing Gear

Information regarding the main fishing gears used in professional fisheries is illustrated in Fig 89. Data indicate that the majority of the fishing gear (i.e. nets and long lines) correspond to small scale fisheries taking place in close distance from the coast.

According to the results depicted in Fig 90 - Fig 93, local professional fisheries are primarily characterized by the combined use of several fishing gears targeting different species The most common fishing practice during all seasons is the combined use of nets and long lines, followed by the exclusive use of nets. The slight decrease in the use of nets and long lines during the winter season is mainly related to a decrease in fishing effort due to harsh weather conditions.

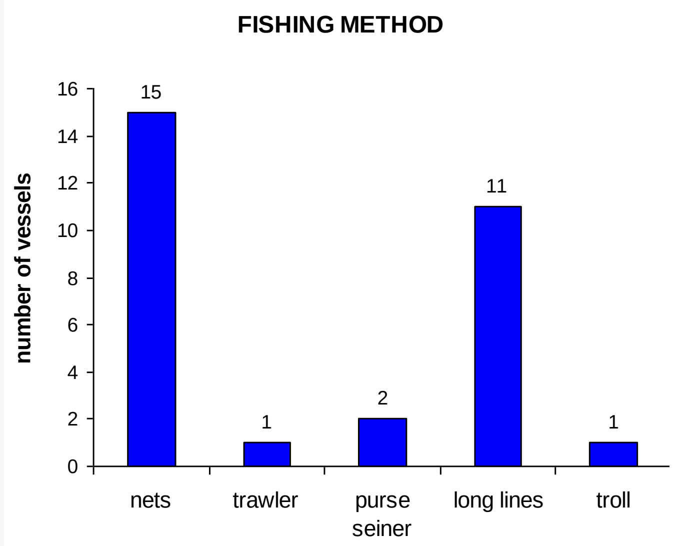



Fig 89: Most frequently employed fishing gears in Zakynthos Island

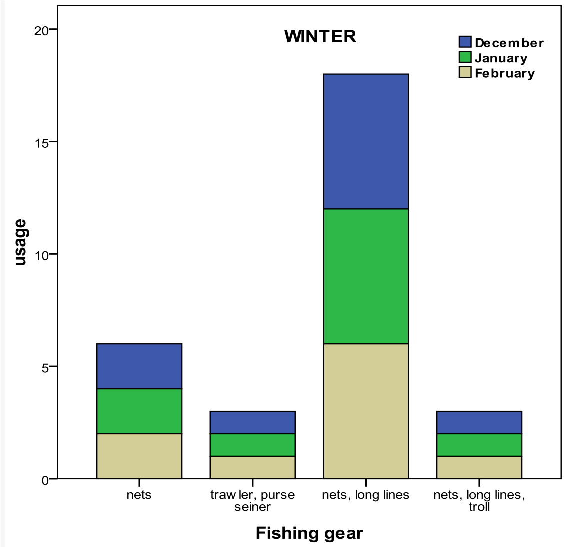



Fig 90: Fishing gear usage by local fishermen during the winter period in Zakynthos Island

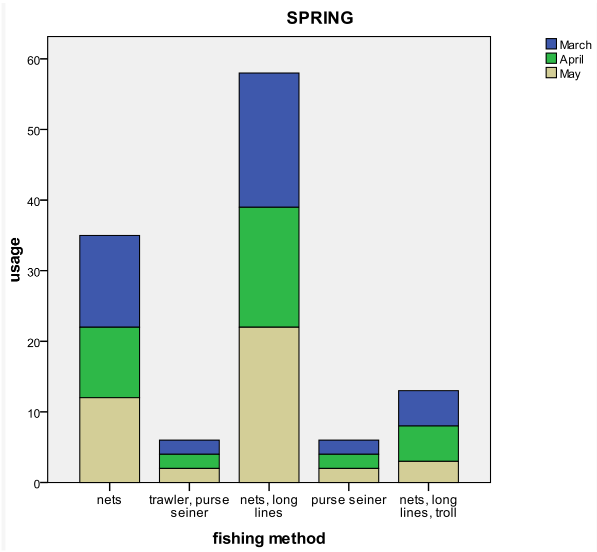



Fig 91: Fishing gear usage by local fishermen during the spring period in Zakynthos Island

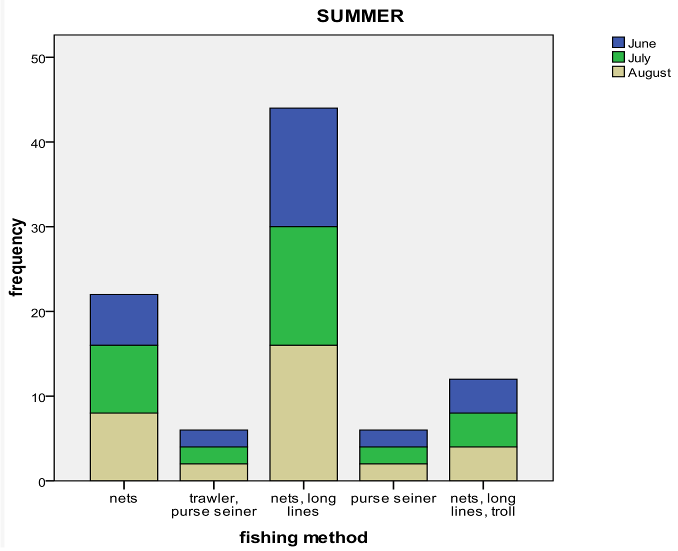



**Fig 92: Fishing gear usage by local fishermen during the summer period in Zakynthos Island**

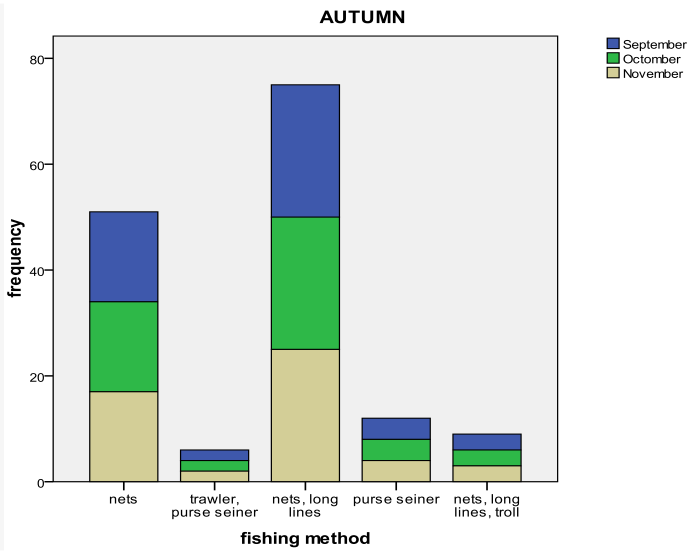



**Fig 93: Fishing gear usage by local fishermen during the autumn period in Zakynthos Island**

## 3. Socio-economic profile of the fishermen

This section regards the socio-economic characteristics of professional fishermen at the island of Zakynthos. Fishermen age ranges between 25-79 years (mean = 54 years, st. dev = 16). The majority of the fishermen, operating both inside and outside the MPA, are highly skilled, having more than 10 years of experience in fisheries practices, with an average of 31 years (Fig 94). Furthermore, 50% of the fishermen that participated in the survey have a family background related to professional fisheries, 75% consider fishing as their primary occupation, while the remaining 25% use fishing as an additional source of income. With regard to seasonal variation in fishing effort, 75% of the fishermen are fishing throughout the year, while 25% of them do not fish during the winter. With respect to the number of people employed onboard per fishing vessel, coastal vessels usually occupy 1-2 people, while higher capacity vessels that are fishing offshore usually occupy 4-7 people.

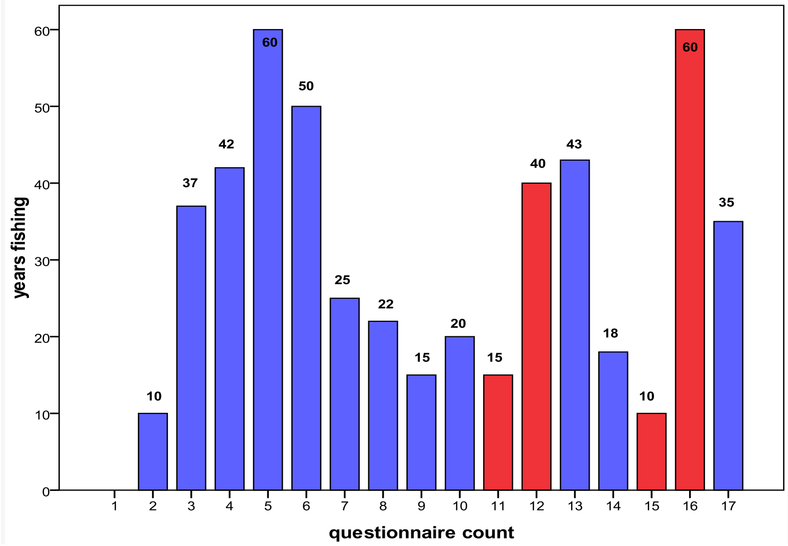



**Fig 94: Fishing experience (in years) of the fishermen that participated in the study. Red bars indicate the cases of fishermen that are active inside the MPA whereas blue bars indicate the ones that are fishing outside the MPA**

In the question regarding if fishing is their exclusive source of income, half of the fishermen that took part in the survey had fishing as the sole source of income. In more details, 8 out of the 16 fishermen that took part in the survey and had other sources of income, declared the other source to be agricultural activities mainly, one person specified the latter as being olive plants and their products, while some of the fishermen had additional income from tourism and restaurant activities (Fig 95).

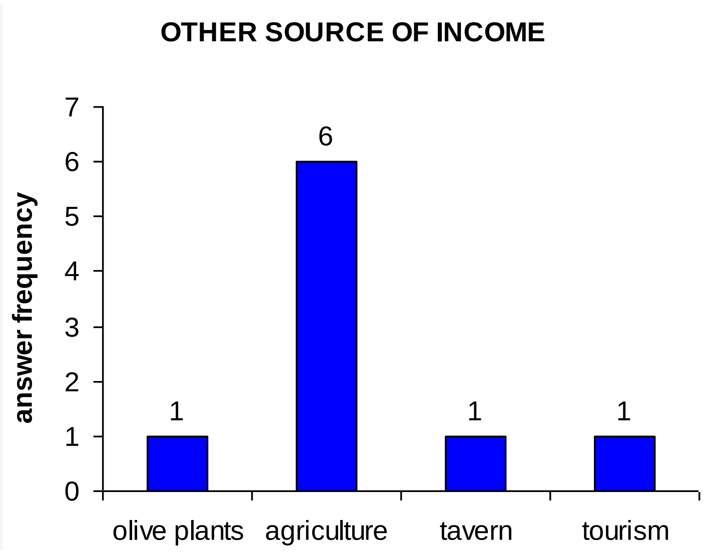



**Fig 95: Frequency distribution of fishermen's answers concerning their alternative sources of income other than fishing**

Finally, on average the annual income from fishing activities was 17000 Euros, while the income of fishermen that had other sources, averaged just less than 12000 Euros per annum.

## 4. Fish Catches and Fishing Grounds

Concerning the reference port of the fishing vessels that participated in the present study, 13 vessels were found to use reference ports located outside the limits MPA while 4 vessels were using the ports that are located within the MPA (Fig 96). The majority of the vessels were using Volimes (6 vessels) and Zakynthos ports (4 vessels).

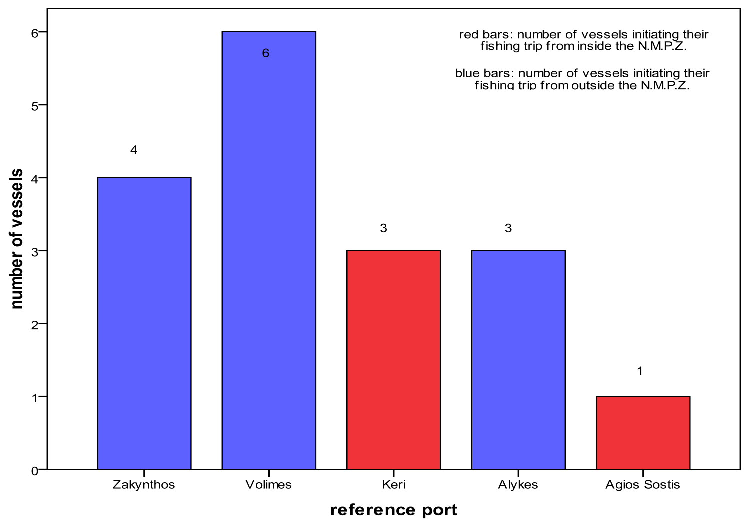



**Fig 96: Reference port for the fishing vessels that participated in questionnaires' surveys. Red bars indicate the number of the fishing vessels that active inside the MPA whereas blue bars indicate the ones that are fishing outside the MPA.**

Fish are made available to the market either through direct retail sale, merchants, or local restaurants (Fig 97). The local restaurant market is stable throughout the year, with the exception of the summer period when there is a twofold increase in demand. Commercial disposition through merchants is also constant throughout the year with the exception of winter where a reduction is noticed, most likely due to either wheather restrictions that can affect the fishing activity or to the reduced demand during this season from the local market. Retail sale of fish caught represents the most preferred form of commercial disposition of fish for all the seasons, with a drop during winter which is mainly due to the latter reasons in combination to the fact that almost 1/4 of the fishermen that participated in the study was inactive during that season.

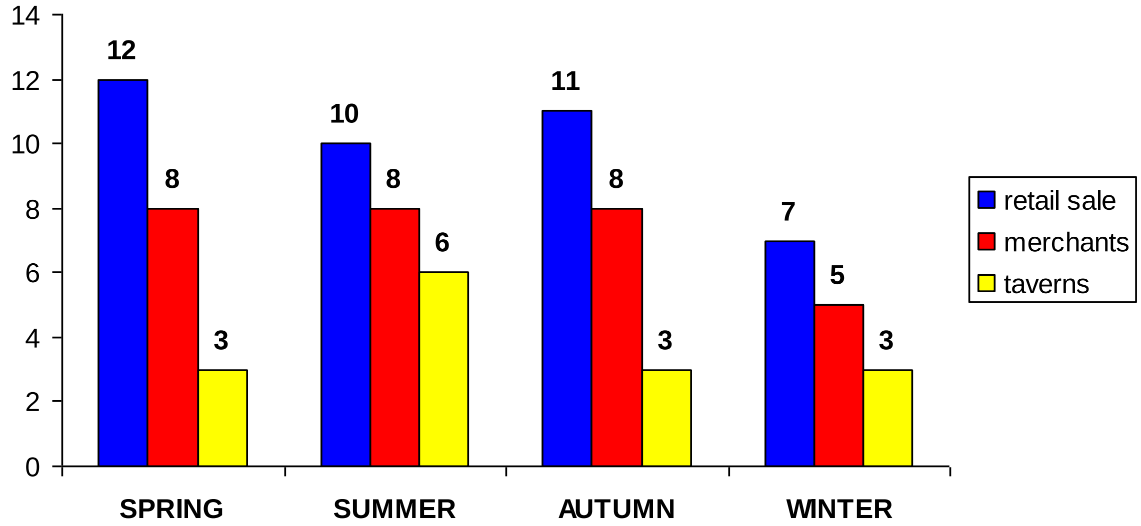



**Fig 97: Fish marketing at different seasons in Zakynthos Island**

The most frequently caught fish species in descending order are:
*M. surmulletus, Serranidae* spp., *S. scrofa, D. dentex,* varius crustaceans*, P. pagrus, M. barbatus, P. erythrinus, D. sargus, B. boops, S. officinalis, S. cretense, S. cantharus,* and Epinephelus spp. (Fig 98). Low catch frequency fish include *P. bogaraveo,* Trachurus spp*., Spicara maena,* Maja *spp., C. julis,* Trachinus spp*., M. helena, C. conger, S. salpa, X. gladius,* and *G. galeos.*

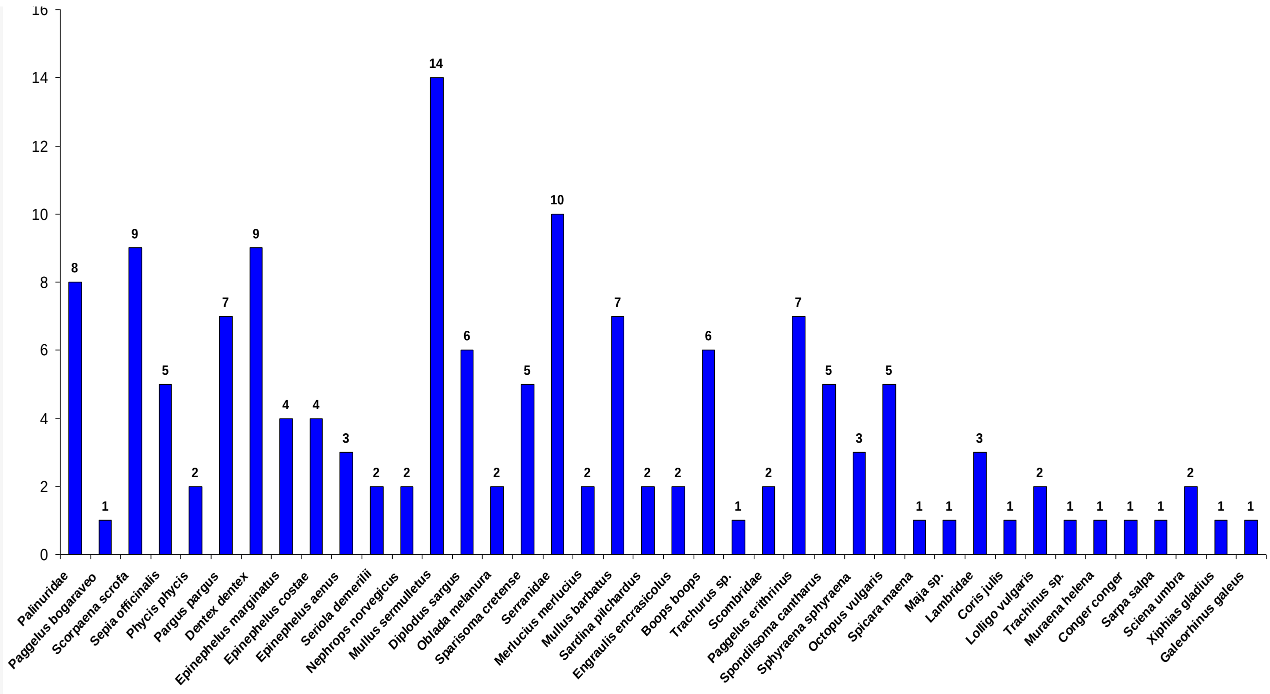



**Fig 98: Most commonly caught species according to fishermen questionnaires**

Commercial price of fish species in descending order are as follows: Epinephelus spp*.*, Sparoid and Palinuroid species *(P. pargus, D. dentex, S. cantharus), M. surmuletus, P. erythrinus, S. umbra,* and *O. melanura* (Fig 99).

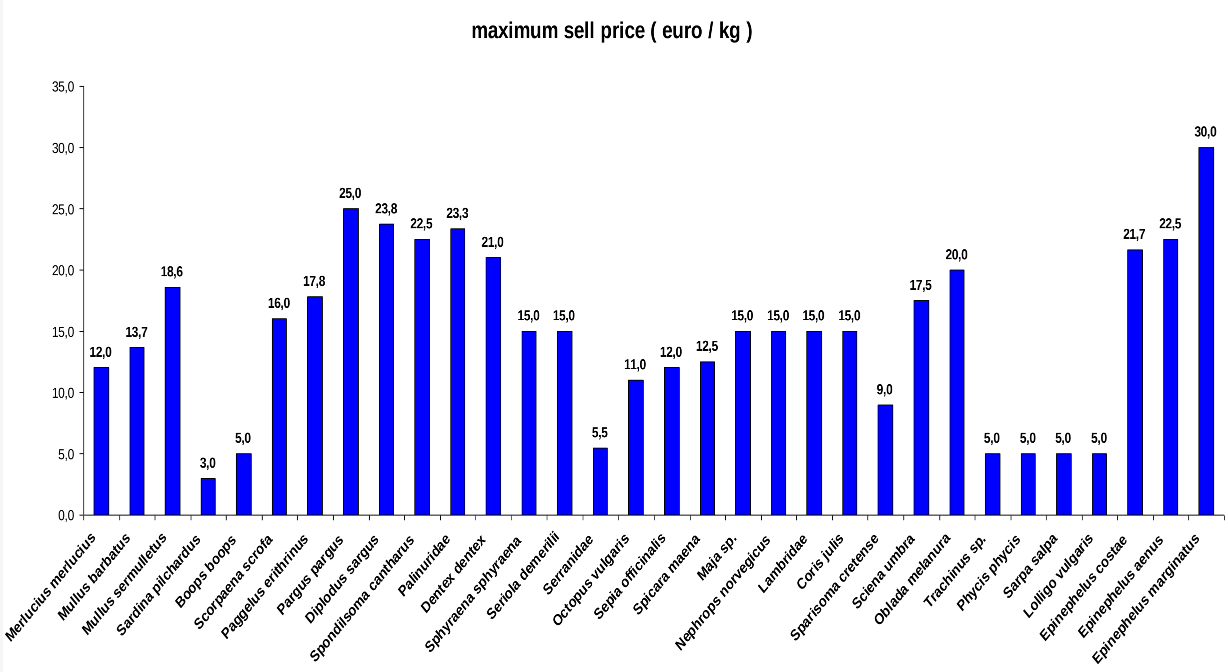



**Fig 99: Maximum value (€/kg) of the commercial price of each species as it was indicated by the local fishermen**

The maximum value was 30 €/kg for *E. marginatus* whereas the minimum value was 3 €/kg for *S. pilchardus*. Regarding the fish and other marine species for which a reduction in catch has been noticed, various crustaceans are in the lead (mainly of the family Palinuridae), followed by *D. dentex*, *E. costae*, *S. maena*, *B. boops*, *M. surmuletus*, *S. scrofa*, and other fish species as depicted in Fig 100.

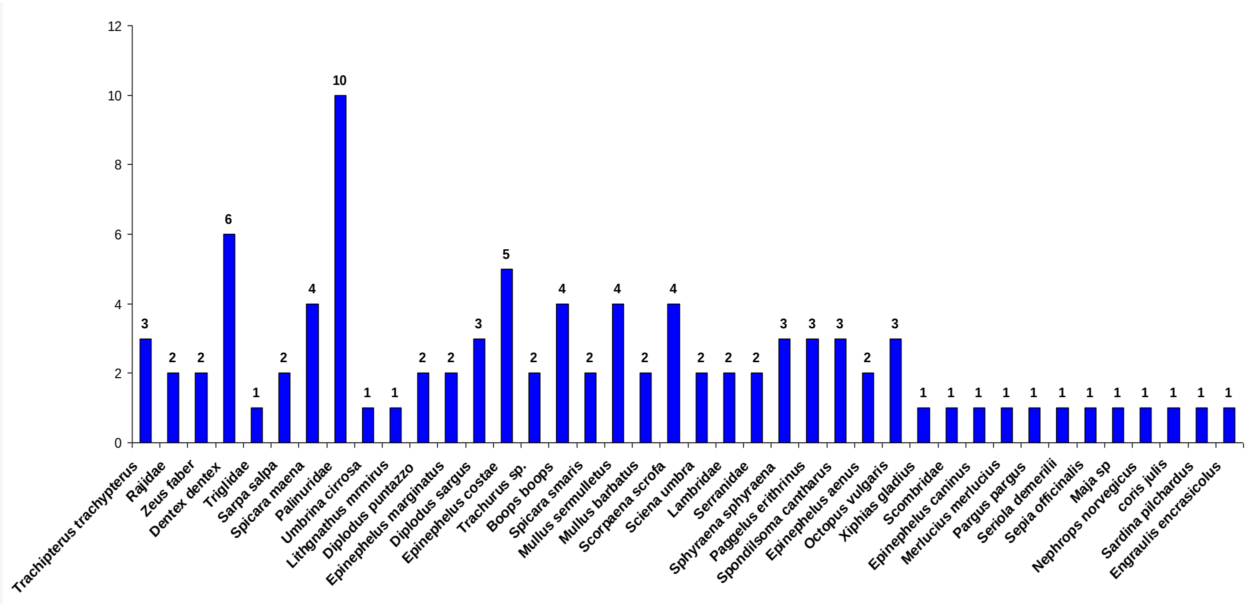



**Fig 100: Fish and other marine species for which a reduction in catch has been during the last years, according to the questionaires**

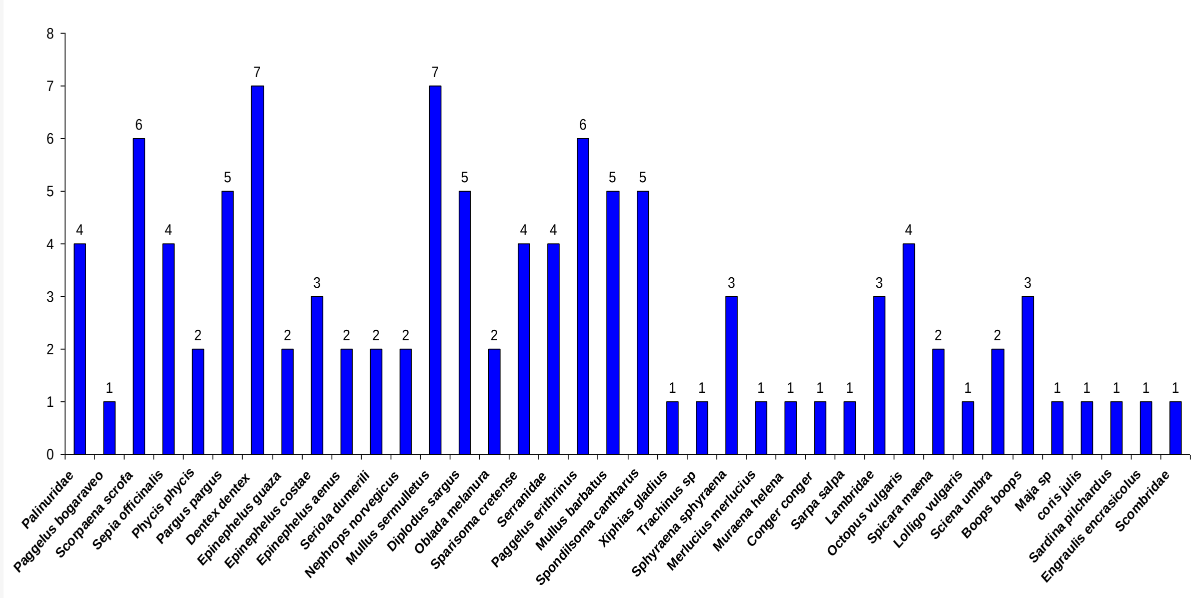



**Fig 101: Fish and other marine species for which a reduction in size has been noticed during the last years, according to the questionaires**

Reduction in the size of fish and other marine species has been noticed for *D. dentex*, *M. surmuletus*, *S. scrofa*, *P. erythrinus*, *P. pagrus*, *D. sargus*, *M. barbatus*, *S. cantharus* (Fig 101).

The areas that fishermen suggested as biodiversity hot spots are shown in Fig 102. In more details, fishermen that participated in the study stated that the north coasts of Zakynthos Island host the highest levels of biodiversity (red color in the map), followed by the south-west and north-east coasts (orange color in the map) and finally by the southernmost coasts where MPA is located (dark green in the map). However, since the majority of the fishermen that participated in questionnaire surveys are known to be active mostly in the northern part of Zakynthos Island, it is therefore reasonable to expect a bias in favor of the areas that they are more familiar with (i.e. Northern coasts).

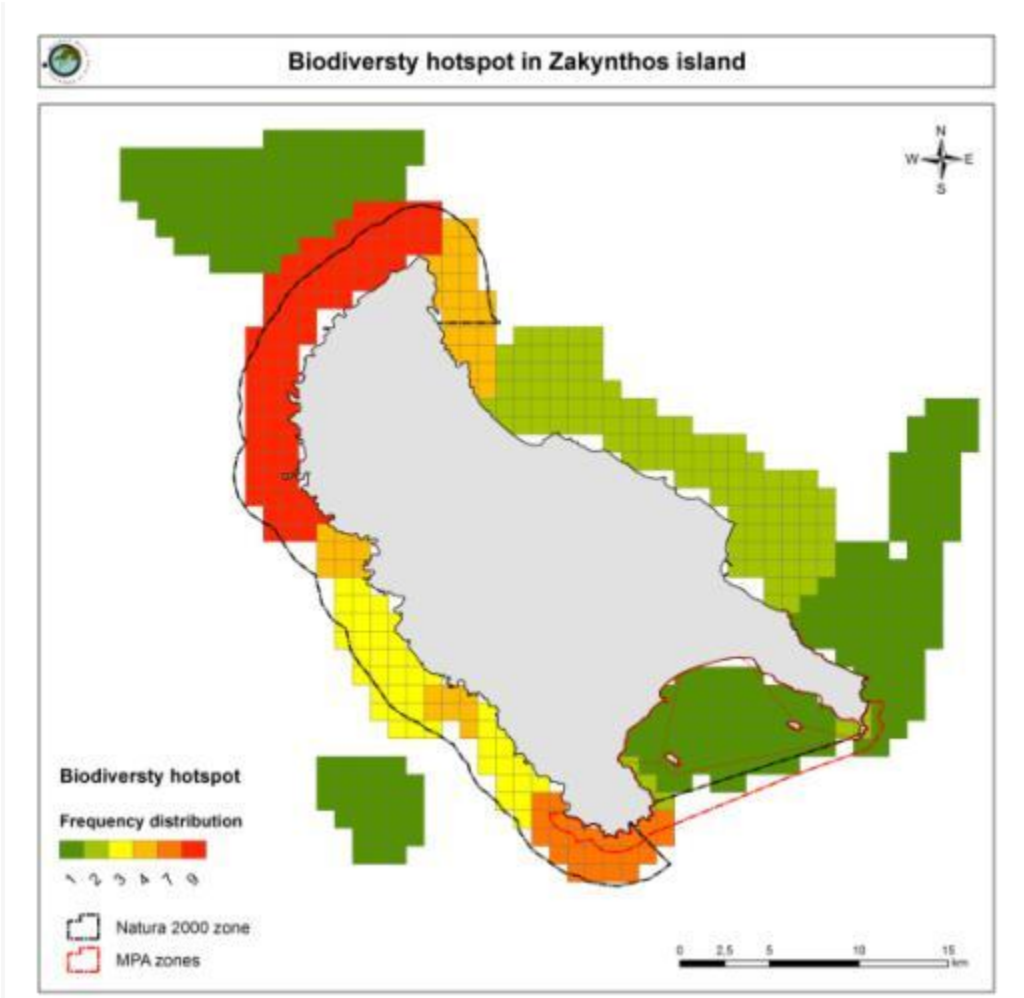



**Fig 102: Biodiversity hotspots in Zakynthos Island as they were indicated from the fishermen that participated in the present study**

With respect to the areas that fishermen consider as the major breeding grounds for the most important commercial species, the MPA of NMPZ was the most frequently selected area (red colour in the map), followed by the central - east coasts (orange colour in the map, Fig 103).

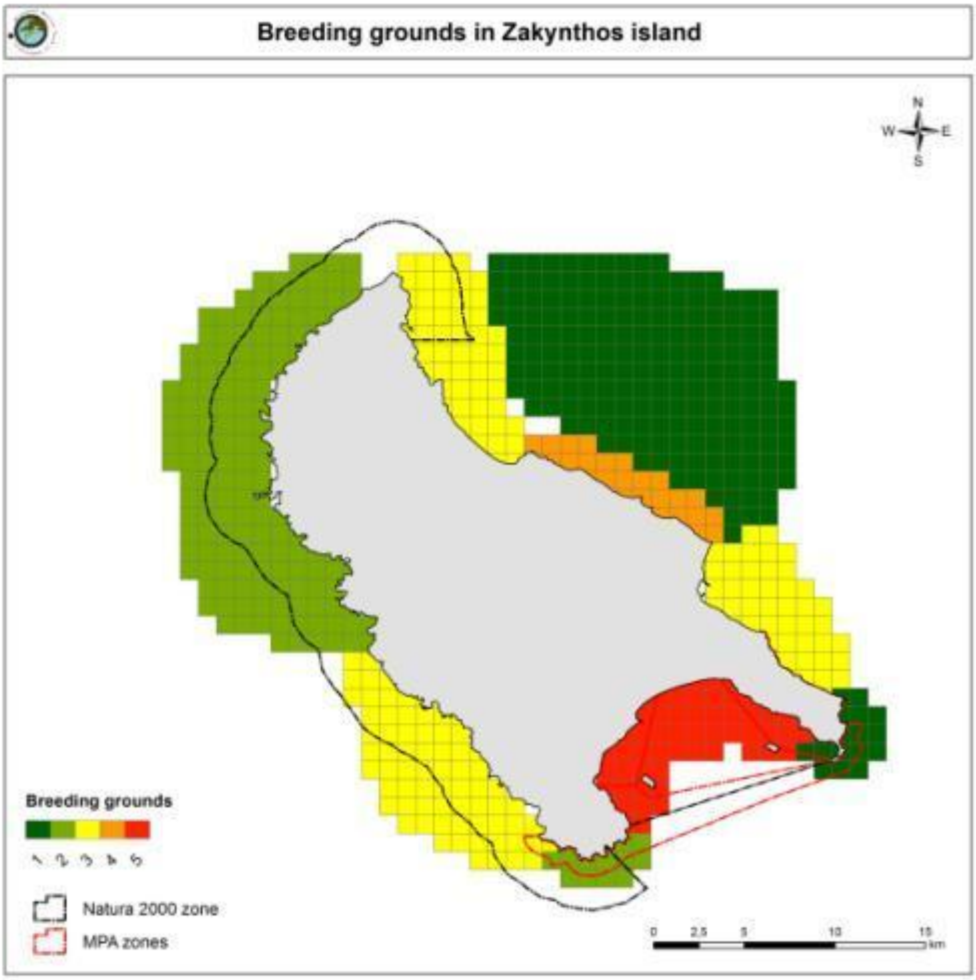



**Fig 103: Most important breeding grounds in Zakynthos Island as they were indicated from the fishermen that participated in the present study**

The major fishing grounds in Zakynthos Island according to the fishermen that participated in questionnaire' surveys are depicted in Fig 104. The northern (red colour in the map) and north - west coasts (orange colour in the map) were found to be the most frequently selected areas thus comprising the most important fishing grounds. The MPA as a fishing ground was found to be preferred from fishermen at a moderate level (yellow colour in the map) alongside with the south - west coasts of Zakynthos Island. Once again, since the majority of the fishermen that participated in questionnaire surveys are originating from the northern part of Zakynthos Island, it is therefore reasonable for them to prefer the northern coasts as their main fishing ground for reasons that are not necessarily related to fishing ground productivity. Hence, the proximity to the harbors, their knowledge of the area and low fuel consumption can also be involved to the observed pattern.

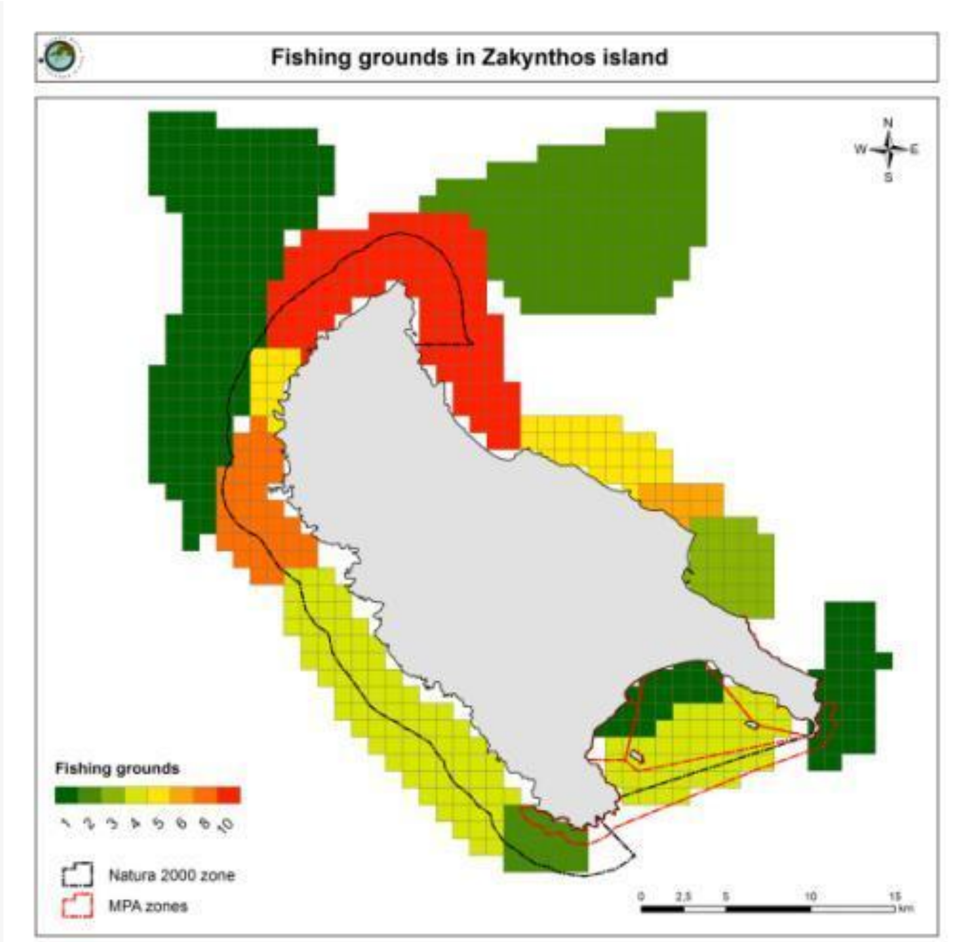



**Fig 104: Preferred fishing grounds from the fishermen that participated in questionnaire' surveys**

The most important selection criterium of a fishing ground is fishing yield followed by easy port access, previous experience of the field and other reasons (Fig 105).

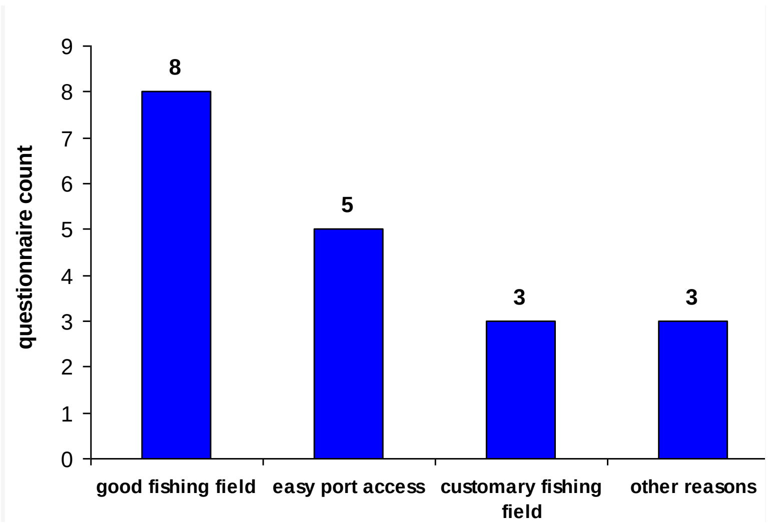



**Fig 105: Reasons for choosing a fishing ground**

As it is evident in Fig 106, fishermen are reluctant to try other fishing fields aiming mostly to an assured catch (small or large) to fields that they have tried before, therefore, putting a lot of pressure in certain fishing fields, something that may account for, at least in part, for the reduction in size of certain fisheries as it was recorded in Fig 101.

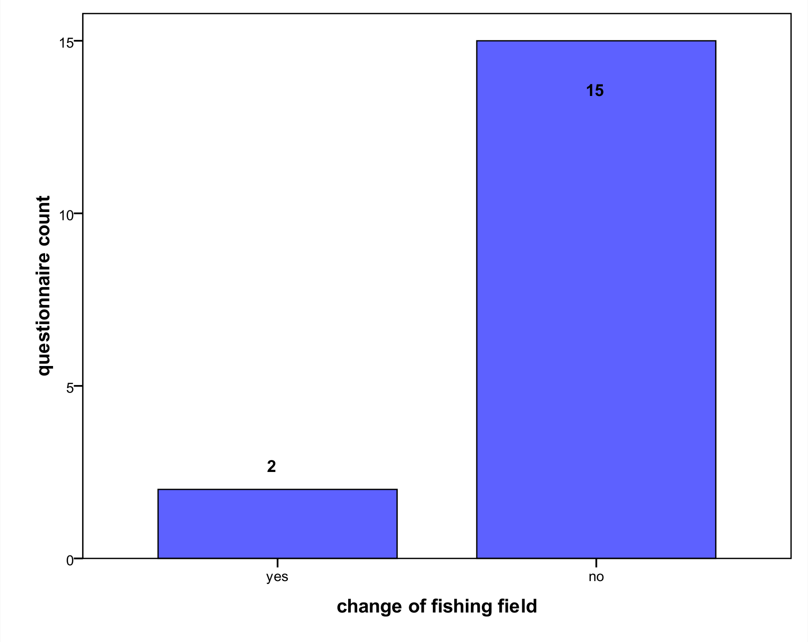



**Fig 106: Willingness of fishermen to fish in a new fishing ground**

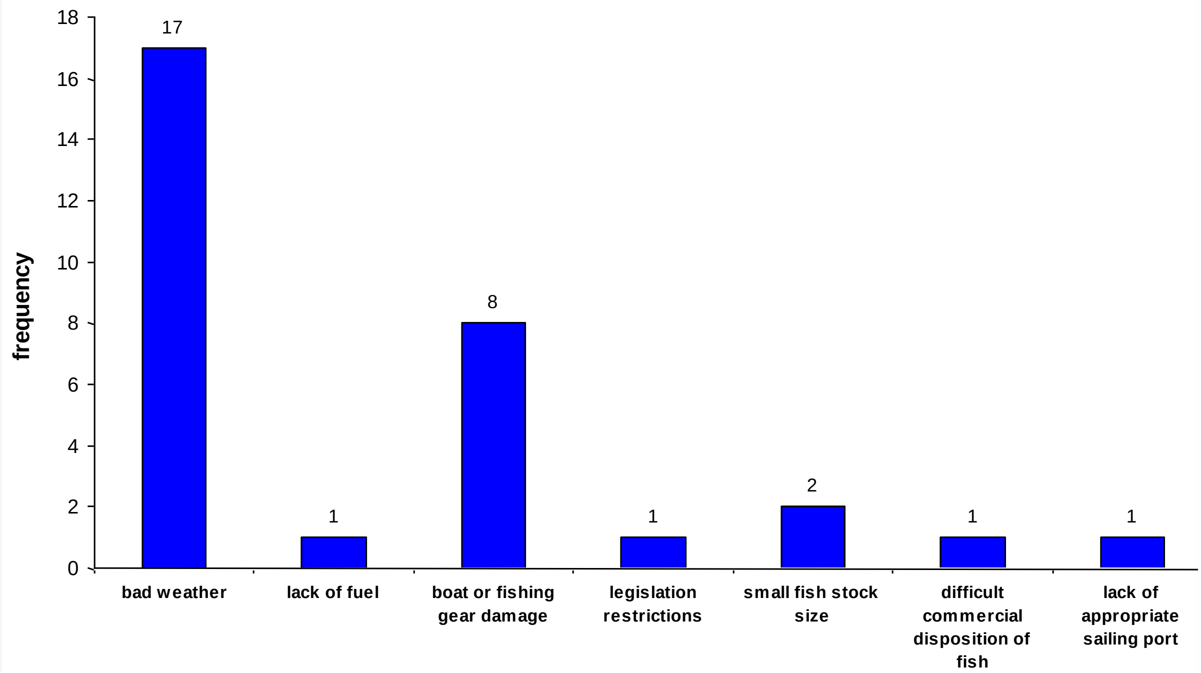



**Fig 107: Frequency of the reasons for not fishing**

The most frequent reason for not fishing is bad weather conditions, followed by boat or gear damage that pin down the vessels. Worth mentioning is the small fish stock size as another reason, while less frequent are reasons such as lack of fuel, legislation restrictions, commercial disposition of catch and lack of appropriate sailing port (Fig 107).

## 5. Problems and Future Perspectives

The main problems that professional fishermen face in Zakynthos Island are damages caused to fishing gear by marine mammals (e.g. monk seals *Monachus monachus* and dolphins), other forms of fishing activities (recreational fishing, including spear fishing), matters related to fish quantities and quality and costs related to both fishing and catch sale (Fig 108).

The most frequent fishing from other localities is practiced from adjacent to Zakynthos areas such as the port of Kyllini, Kefalonia and other Peloponnesian ports, while, interestingly, Italian fishermen practice fishing as well (Fig 109). Moreover, the majority of the fishermen that took part in the survey consider the future of their profession as bad. Despite the fact that the future of fishing as a profession is not considered bright by the majority of fishermen, the majority of them will keep on fishing and half of them will liquidate their vessel and gear or pass it to a relative (Fig 110).

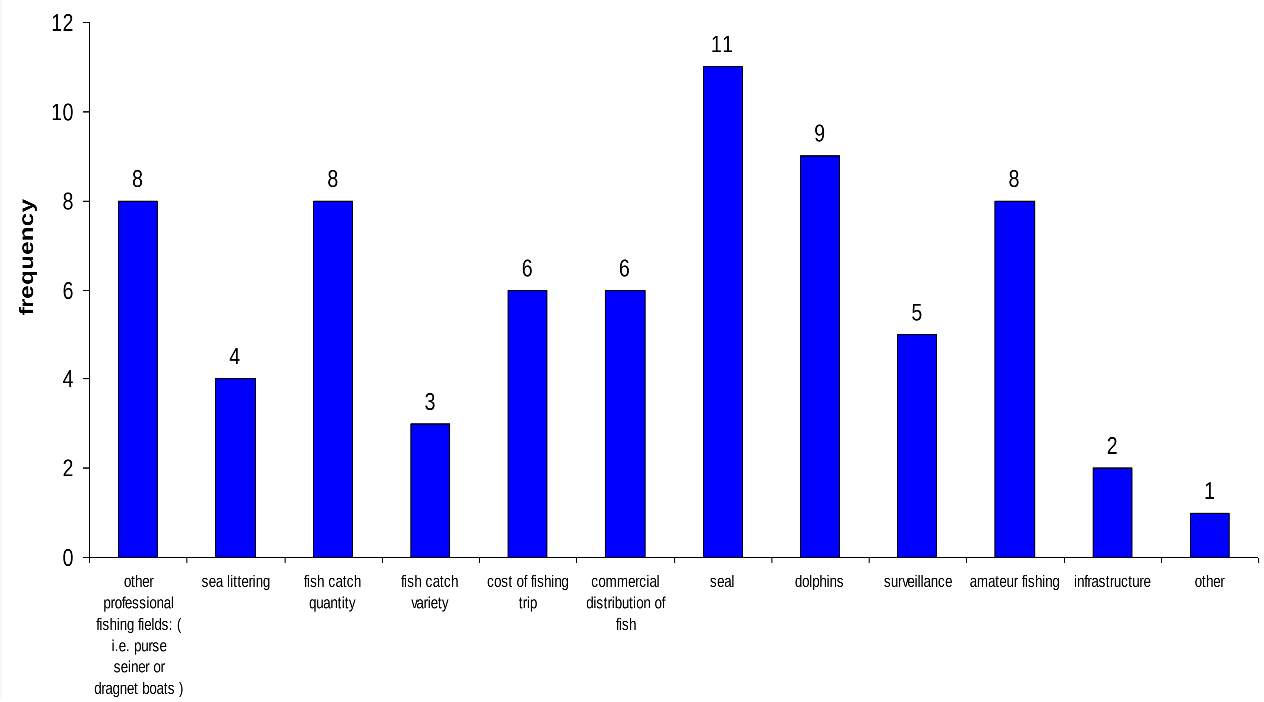



**Fig 108: Main problems that artisanal small scale fishermen are facing in Zakynthos Island**

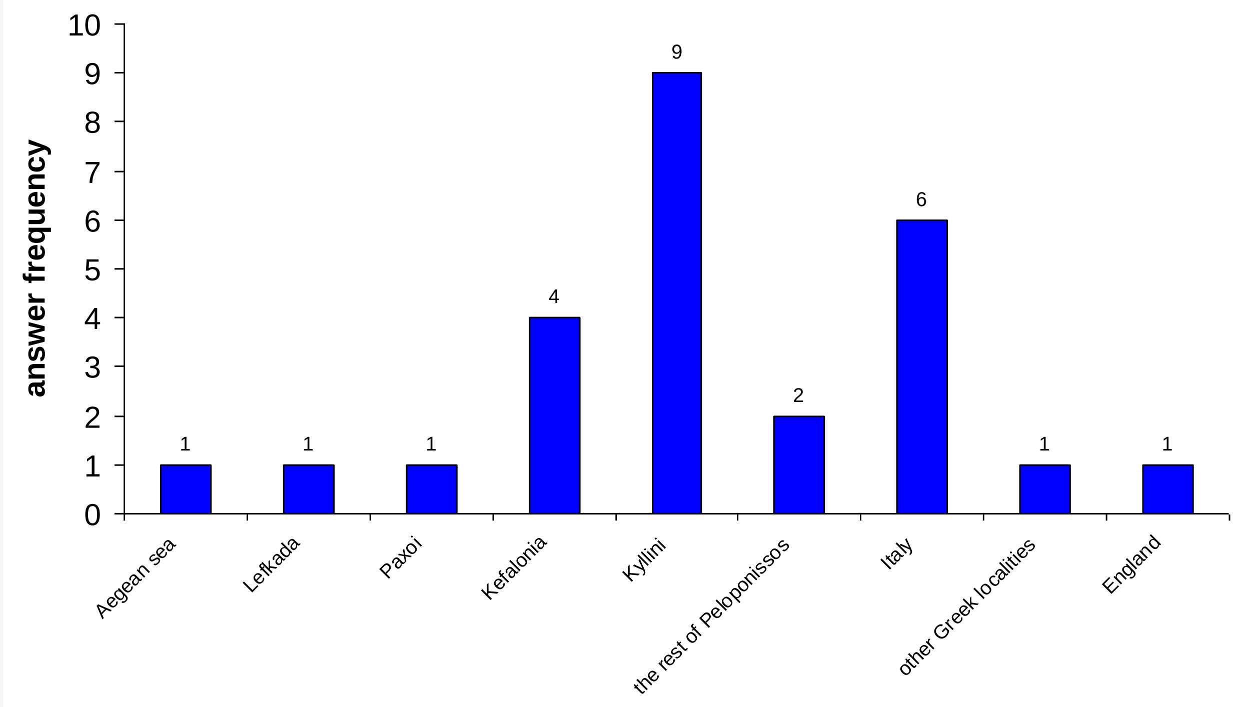



**Fig 109: Frequency of the answers regarding the fishermen that are from other localities and are fishing in Zakynthos Island**

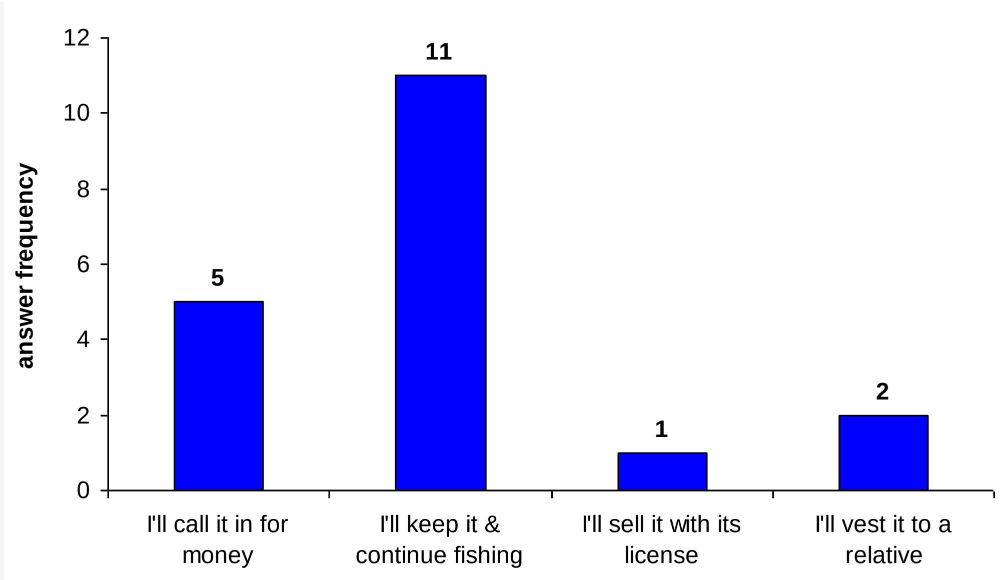



**Fig 110: Frequency of the answers regarding the future plans of the fishermen with respect to their fishing boats**

# F. Database and geodatabase

## 1. Descriptive database

The use of the database provided an interactive repository to store the collected elements of the biodiversity from the UVC activity. The tables of the database were connected with the relation type "**ONE > MANY**" (Fig 111) relating each station (Fig 112) with the tables referring to to the different Class / Phylum that each records belongs to (Fig 113). In total, 11 tables were constructed, from which 10 included the Algae - Plant - Animal (biodiversity) information and 1 that hosted information about environmental parameters such as depth, sea temperature, sea salinity, etc.

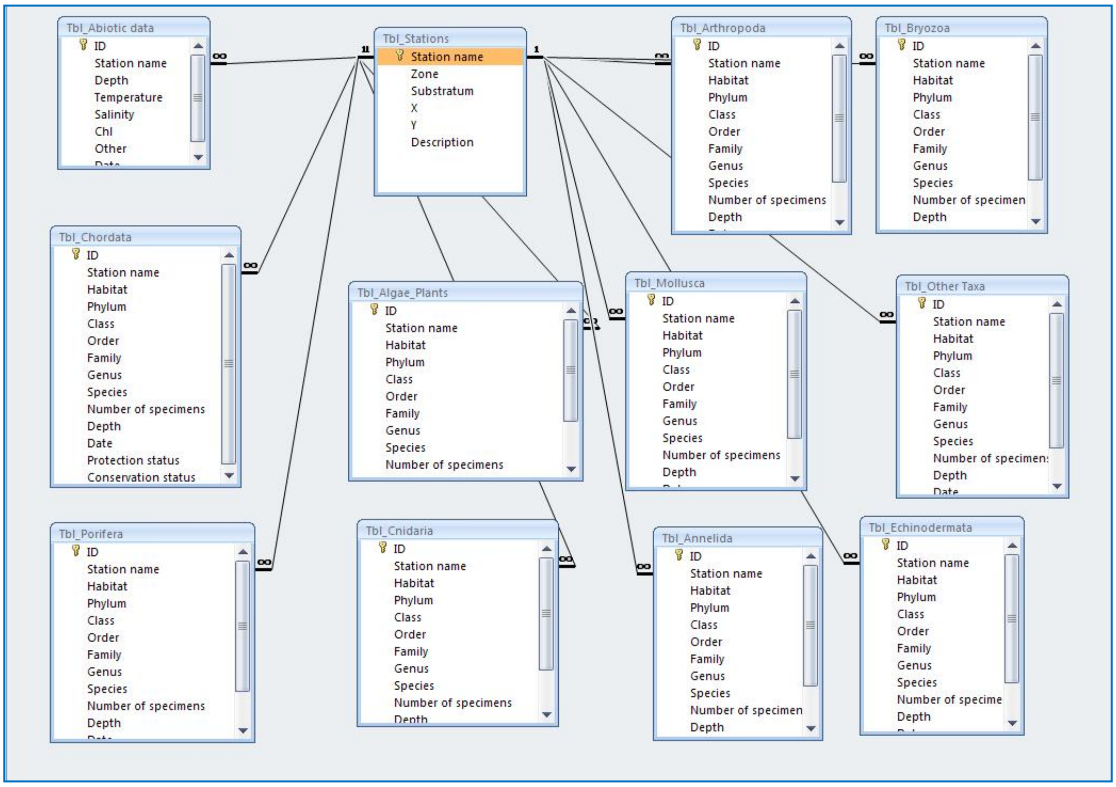



**Fig 111: The one > many relations of the tables. In the center is the "*one*" table (*Tbl_Stations*) and around are the "*many*" tables**

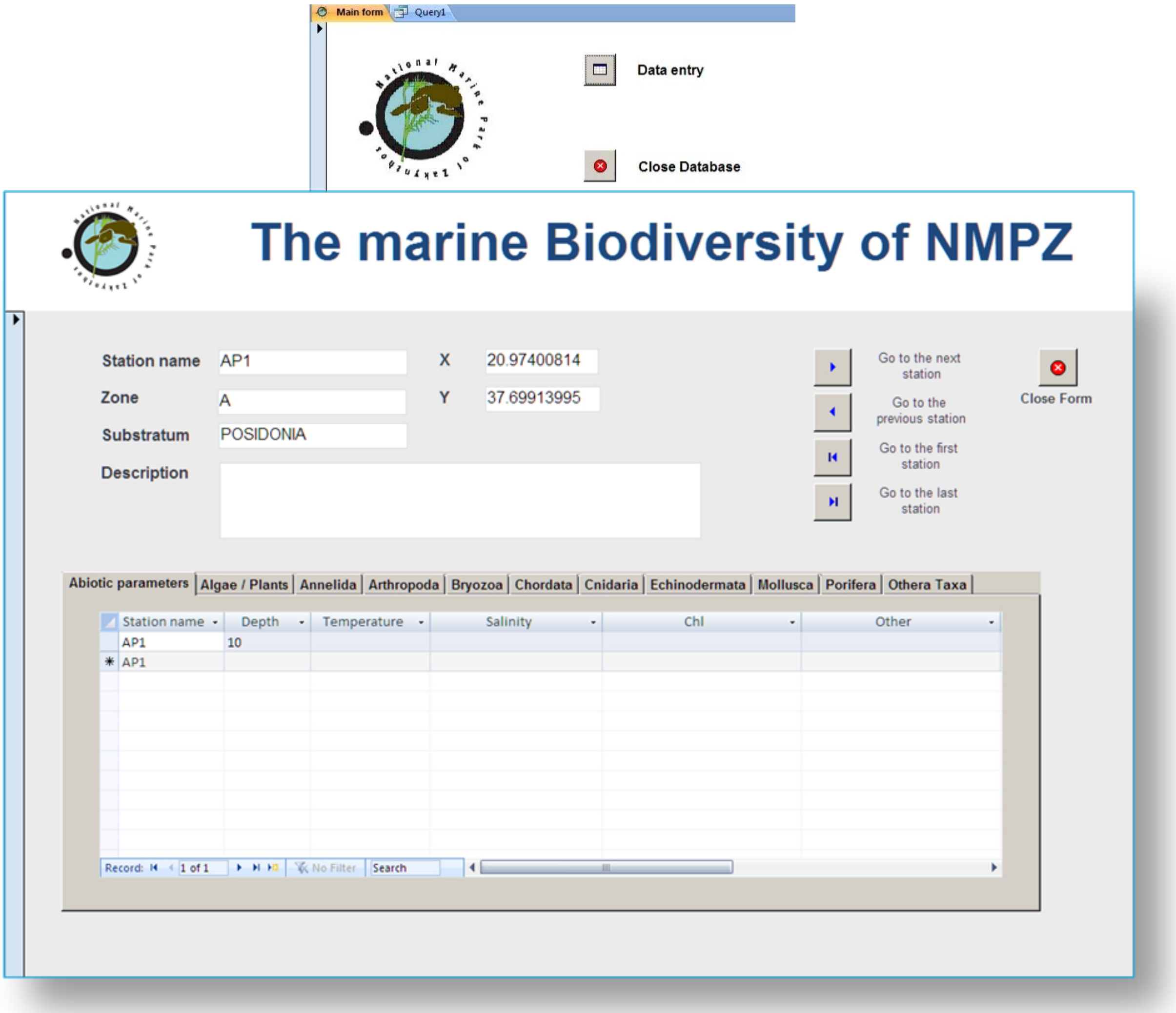



**Fig 112: Main menu of the database, from which the user can enter the data per station**

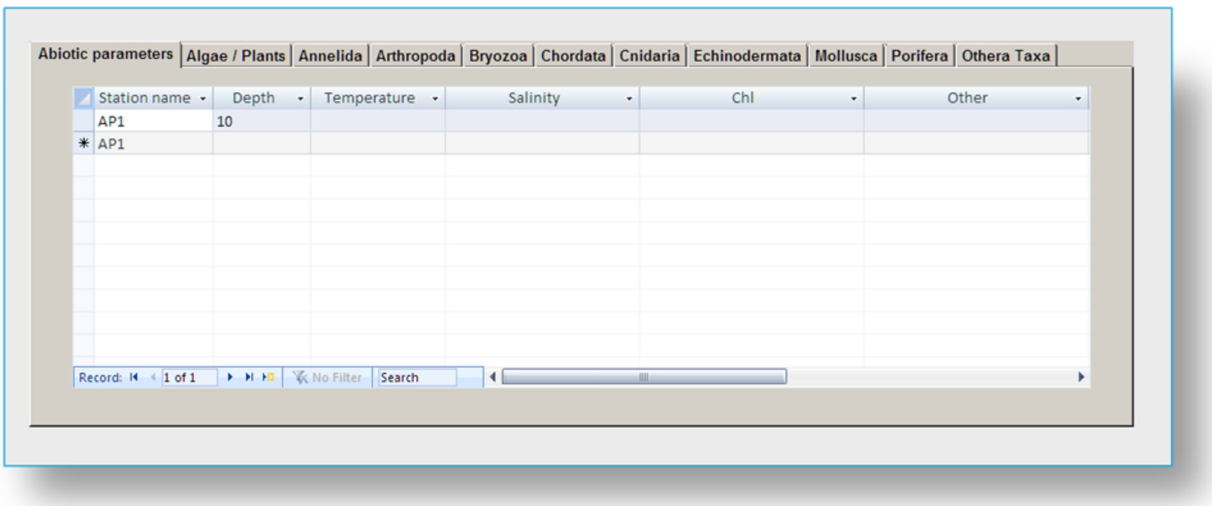



**Fig 113: Tables for biodiversity records for each major taxonomic group**

The project database included 751 records of biodiversity elements (Fig 114).

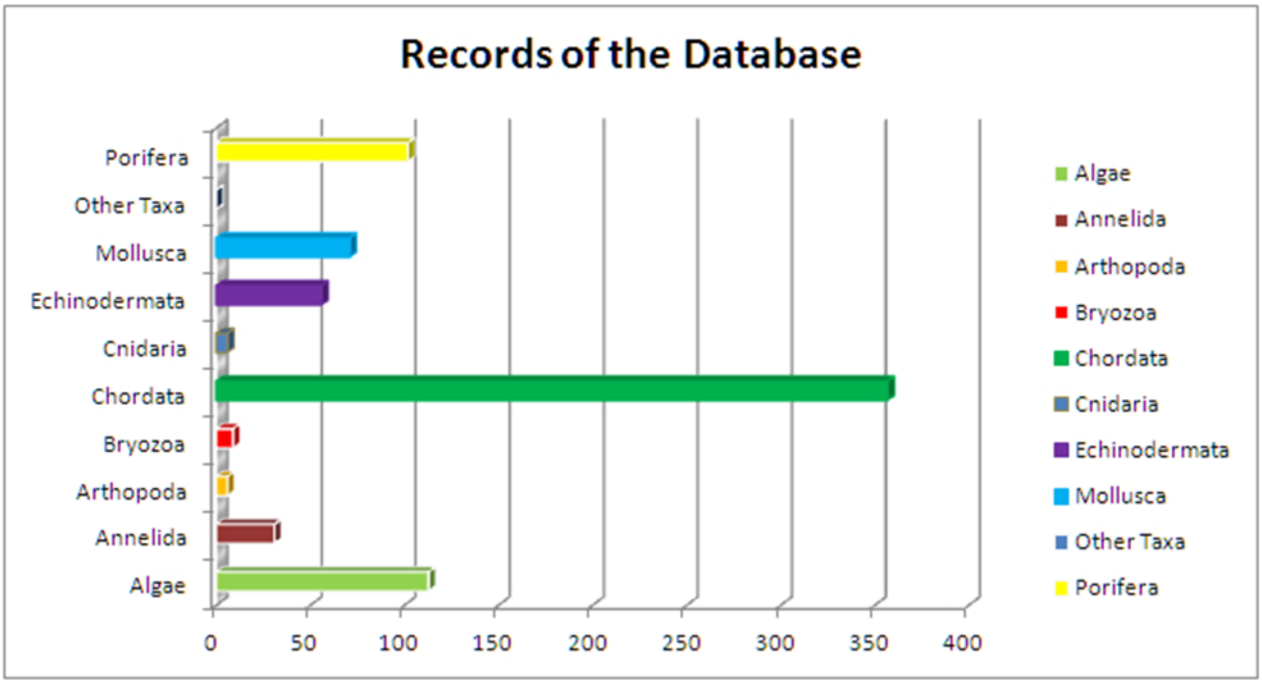



**Fig 114: Records of the biodiversity elements in the database**

Apart from the option to explore the records that have been inserted into the database, the user can run specialized queries (Fig 115) such as the amount of species (as unique records) that have been found so far in the National Marine Park of Zakynthos or its zones (Fig 116).

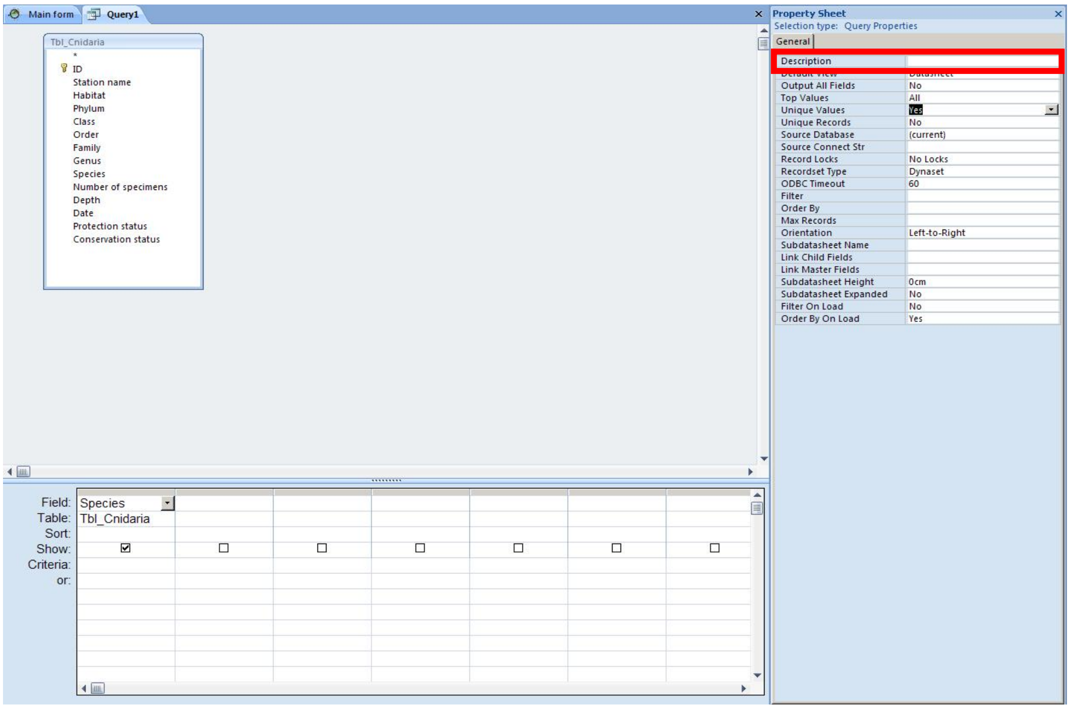



**Fig 115: Designing a query in the database applying the "unique values" filter (in the red box – upper right) will return to the user the amount of unique species of the selected class**

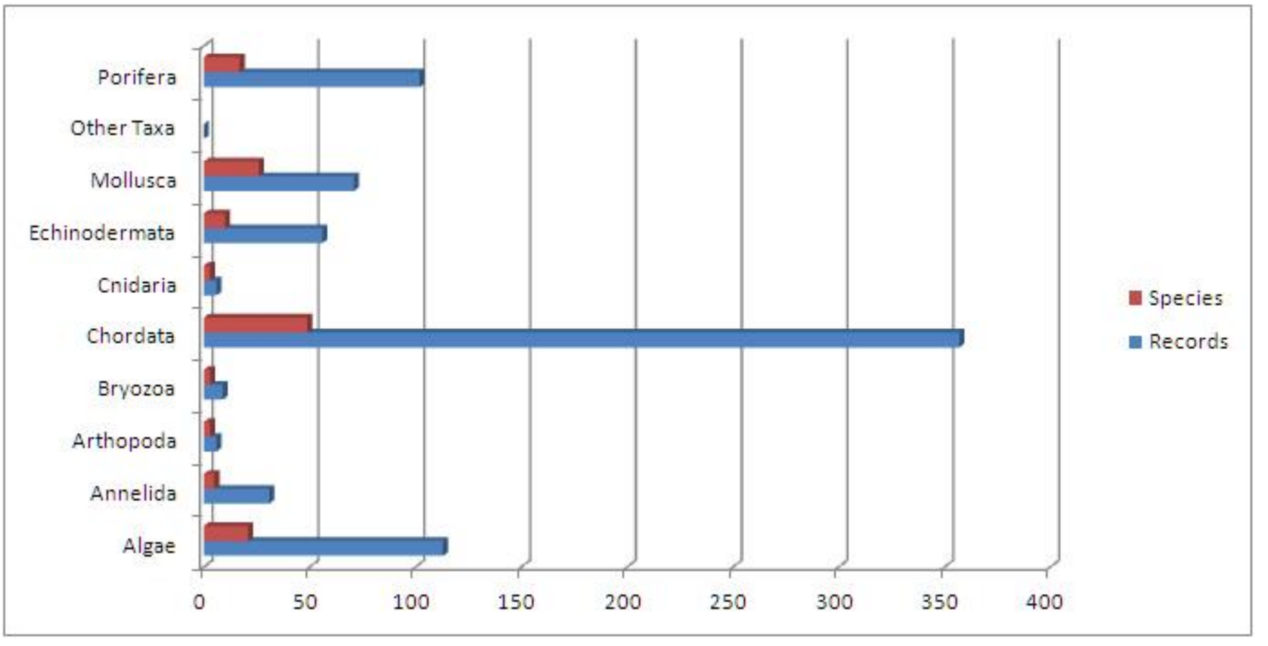



**Fig 116:Number of species vs. records that are stored in the database**

## 2. Geodatabase

The Geodatabase has been designed in order to store all the spatial data, which have been created during the project and have been used in order to design maps. The values of the Geodatabase systems are well known in the GIS community (ESRI, 2013). In our case the value of a Geodatabase is that the users can easily use the geodata for mapping/cartography, can run spatial queries to create more complex data and also acts as a georepository for data storage.

# V. DISCUSSION

## A. Concluding Remarks – Fish fauna UVC

Visual census for the study of fish assemblages was carried out in 19 sampling stations located in the southern and eastern parts Zakynthos Island. A total of 33 fish species was recorded. Rocky habitats displayed higher species richness (30) than *P. oceanica* habitats (24), while the highest number of species was observed in areas A and B.

The most diverse trophic group were the carnivores (57.1% of total species), whereas the rest of the trophic groups displayed relatively low species richness. The allochthonous fangtooth moray *Enchelipore anatine* was sighted in only one station in the present study, namely BR4. It is a tropical Atlantic fish, the presence of which has already been reported in other areas of the Ionian Sea (Guidetti *et al*., 2012) and the Aegean Sea (Kalogirou, 2010).

Fish abundance was higher in rocky than in *P. oceanica* habitats (55.6% versus 44.4% of total fish abundance). In rocky habitats, abundance was greater at stations of area A and presented a declining trend at stations located progressively away from this zone. In *P. oceanica* habitats, area B displayed the highest fish abundance.

Zooplanktivorous fish were the most abundant trophic group in both habitat types (presenting 78.4% of total abundance in rock and 94.4% in *P. oceanica*), followed by carnivores (15% and 6.4%, respectively), herbivores (4.9% and 0.65%, respectively) and apex predators, whose abundance was very low (0.2% and 0.03% respectively).

Biomass was also higher in rocky than in *P. oceanica* habitats (70.6% versus 29.4% of total fish abundance). Areas A and B presented the highest biomass values in rocky habitats, while in *P. oceanica* habitats area B displayed the highest fish biomass.

Carnivores were the trophic group with the highest biomass (34.4%) in rocky habitats, followed by zooplanktivores (32.7%) and herbivores (23.7%), while zooplanktivores had the greatest contribution in biomass recorded at *P.oceanica* habitats (72%). Apex predator biomass was again very low in both habitat types, contributing by only 9% in total biomass of rocky and 9.5% in *P. oceanica* habitats. With regard to herbivorous fish, it is worth mentioning that abundance and biomass of the allochthonous *Siganus luridus* was substantially higher from that of the indigenous *Sparisoma cretense* and *Sarpa salpa*, of which the latter was found in extremely low numbers and only in rocky habitats.

Results of the analyses on community structure, using abundance and biomass data, reveal that differences in community patterns are primarily driven by habitat variation (i.e. habitat type), without, however, ignoring the zoning effect, which seems to play a secondary but still significant role. In rocky habitats, community structure presented some differences in abundance among sampling areas, where areas A and B formulated a significantly distinct group to that of area C. Moreover, when biomass data were considered, a further grouping of sampling stations was detected clearly distinguishing stations of area B from those of area A, although at a high similarity level (approx. 70%). In *P. oceanica* habitats there was no profound pattern of stations grouping, a result that is possibly related to the fact that, with the exception of zooplanktivores, overall abundance and biomass values in this habitat type was relatively low, hence resulting to a homogenized community structure pattern across all stations of the study areas. Therefore, our findings are in line with the notion that environmental factors such as habitat heterogeneity can have more profound effects in fish community status than the ones that are generating from protection (Garcıá-Charton *et al*., 2008)

The SIMPER analyses regarding species contribution to the observed community dissimilarities between the different sampling areas reveal that the observed differences are mainly due to the variations in biomass and abundance of zooplanktivorous species. Abundance of carnivorous fish, mainly of lower commercial interest, play an additional role in the observed dissimilarity between areas A-C and B-C, while higher biomass in area B of *T. pavo, D. sargus* and *C. julis,* also contributes to the dissimilarities between areas B-C. The presence of apex predators in certain stations was also found to be responsible for the observed community differences, however the rare occurrence of these species in certain stations renders the current results arbitrary and does not allow any further meaningful conclusions to be drawn.

Results regarding trophic complexity of species aggregations based on biomass data, reveal that differences in feeding guild complexity patterns are also primarily driven by the habitat effect. However, observed differences in the trophic structure of fish communities were not substantial, as grouping of sampling stations according to habitat type was met to a similarity level of 70%. Still, area effects on trophic complexity are evident, although less prominent, and are mainly attributed to differences in the trophic structure between areas A–B as well as B–C in rocky habitats. In *Posidonia oceanica* habitats, sampling stations did not present any profound pattern of trophic structure with respect to the three sampling areas.

SIMPER analysis suggested that the produced mean dissimilarity in trophic group structure between areas A–B and A–C was mainly attributed to the higher mean biomass in area A of apex predators and zooplanktivores, although the average biomass of all the examined trophic groups was higher in area A than in area C. On the other hand, higher mean biomass of herbivores in area B and apex predators in area C were the main contributors to the observed average dissimilarity between areas B and C. As stated before however, the extremely low frequency of apex predators in all areas (even the most protected one), does not allow any significant conclusions to be drawn and further investigation is needed in order to validate the present results.

Response of fish communities to protection estimated as the natural log response ratio (ln*R*) of density and biomass per set of areas (i.e. A/B, B/C and A/C), indicate that fish communities display an overall positive response to protection. However, the estimation of equivalent ratios per trophic group and for selected species, reveal that different fish respond to protection in a variable way. With regard to trophic groups, the estimated ln*R* indicates that the abundance and biomass of all fish respond positively to protection, except from apex predators which had high abundance and biomass values in areas A and C, and lower in area B. Furthermore, when considering the response of the eight selected species, the ln*R* displays great variability, indicating that other factors, besides zoning effect, may play a more significant role in the structuring of fish assemblages observed in the present study.

The results of the visual census regarding fish assemblages indicate that although there seems to be a pattern of increased abundance and biomass in the more protected areas, the overall low abundance and biomass values, especially regarding *P. oceanica* habitats, as well as apex predators and carnivorous fish, point out that current measures may not provide sufficient protection to produce an evident reserve effect. Recent studies have demonstrated that MPA effectiveness is directly linked to the level of enforcement (Samoilys *et al*., 2007). Partially enforced MPAs fail to achieve sufficient restoration of fish populations, in contrast to adequately enforced no-take marine reserves, which are proved to be effective in the conservation of the fish stocks (Denny & Babcock, 2004; Sala *et al*., 2012). Moreover, the extent of fish spill-over is related to the amount of fishing pressure being exerted at the MPA boundaries (Guidetti, 2007; Harmelin-Vivien *et al*., 2008). Still, additional studies are needed to validate the findings of the present study at a greater temporal scale.

## B. General patterns of biodiversity

The biodiversity survey yielded 134 species of marine biota, belonging to 4 flora and 9 fauna taxonomic groups. Area B presented the highest species richness (90 species in rocky, 55 in *P. oceanica*, and 13 in sandy habitats; total species richness: 103) with stations BR2 and BR1 presenting the highest species richness among all rocky stations (59 and 50, respectively) and BP3 having the highest species richness (41) among all stations with *P. oceanica*. Area C displayed the second highest total species richness (87) and the same species richness with area A for rocky habitats (67). Area A presented the third highest species richness (78), and the second highest species richness for *P. oceanica* (49) and sandy habitats (11).

The aforementioned patterns could be partly attributed to the fact that area B covers a larger surface area, characterized by a more complex substrate profile, and is in close proximity to deeper waters. More specifically, rocky stations of area B displayed a greater geo-morphological variability ranging from flat and highly rugose reefs to large boulders of different shapes and sizes (>3m diameter). Numerous cracks and crevices, particularly in stations BR2, BR3 and BR4, sheltered small cryptic fish species and enclaves of sciaphilic benthic communities (e.g. encrusting red algae, sciaphilic sponges and fragile erected bryozoan species). Well lit rocky reefs of all surveyed areas were dominated by extensive *Cyostoseira* beds. Moreover, the surveyed *P. oceanica* stations of area B were characterized by continuous dense meadows, in contrast to the ones found in areas A and C that appeared to be of thinner density, or even zones of *P. oceanica* matte morte, which were only recorded in area A.

### 1. Protected and exploited species

A total number of 27 species protected by international, EU or national legislation was recorded. Area B presented the highest number of protected species (20), followed by areas C (18) and A (15). In area B, stations BR2 and BR1 presented the highest number of protected species among rocky stations (10 and 9, respectively), while BP3 and BP1 had the highest number (6) among *P. oceanica* stations. In area C, stations CR2 and CR4 presented the highest number of protected species among rocky stations (10 and 8, respectively), while CP1 had the highest number (5) among *P. oceanica* stations. In area A, station AR2 presented the highest number of protected species among rocky stations (8), while AP2 and AP3 had the highest number (6 and 5, respectively) among *P. oceanica* stations.

With regard to the megabenthic species of commercial interest, 16 exploited benthic species were recorded. The greatest number of exploited species was found in areas B and C (12), followed by area A (9).

### 2. Population characteristics of the endangered fan shell *Pinna nobilis*

*Pinna nobilis* is typically found in *P. oceanica* habitats (García-March *et al*., 2002). During the visual census, the largest individuals were found in *P. oceanica* meadows of areas B and C. More specifically, the *P. oceanica* meadows of Area B, characterized by dense seagrass meadows, hosted the most abundant and most developed population in terms of size structure. A total of 27 individuals were recorded in this area, out of which 23 were found in *P. oceanica* and 4 in rocky habitats, with a total length range from 37.56 cm to 87.2 cm. In areas A and C, fan shells were found only in *P. oceanica* habitats and presented lower abundances (i.e. only 4 and 3 *P. nobilis* individuals, respectively). The maximum width and total length values were recorded in area B (30 cm and 87.2 cm) and the minimum in area A (7 cm and 21.03 cm).

### 3. Alien species

Four alien species were recorded in total (i.e. 4 species in station BR4 of area B and 2 species in the remaining stations of areas A, B and C). The highly invasive chlorophyte *Caulerpa racemosa var. cylindracea* was found in both *P. oceanica* and rocky habitats of all areas. In *P. oceanica* habitats, the chlorophyte was found mainly along the margins of the meadow or on 'matte morte', verifying the results of previous studies in the area (Katsanevakis *et al*., 2010).
The rabbitfish, *Siganus luridus,* was found in both rocky and *P. oceanica* habitats of the three areas. It was observed to form common schools of fish along with the parrotfish *S. cretense*, which according to the fish UVC, was the second most abundant herbivorous fish.
The invasive Sally Lightfoot Crab *Percnon gibbesi* (H. Milne-Edwards, 1853) was encountered only in station BR4. Only one individual was observed across the three transects covered, at a depth of 11 m while several individuals were observed in shallower depths alongside the rocky coastline (up to 2 m) (Katsanevakis *et al.,* 2010, 2011b). However it has to be taken into account that this is considered to be a shallow water species while in the framework of the current study all surveyed stations were deeper than 5 m.
One individual of the fangtooth moray, *Enchelycore anatina*, was encountered in a hole of the rocky station BR4, at a depth of 11 m. This species is known to expand from Israel (Bentuvia & Golani, 1984) to the Adriatic Sea (Lipej *et al*., 2011). However, the presence of *Enchelycore anatina* in Zakynthos Island can be considered as the first record in the Eastern Ionian Sea (Greek territorial waters) and the 3rd record from the Greek Seas, after Rhodes (Kalogirou, 2010) and Elafonissos (Golani *et al*., 2002) in south Aegean Sea. This record seems to fill the distributional gap of the species among the aforementioned eastern Mediterranean records and recent sightings from the Adriatic (Lipej *et al*., 2011) and western Ionian seas (Guidetti *et al*., 2012).

## C. Concluding Remarks - OBS

In total, 57 species belonging to 31 families were encountered during the onboard sampling procedure. In terms of total biomass, *D. sargus*, *M. surmuletus*, *P. phycis*, *S. scrofa*, *S. latus*, *S. officinalis*, *S. luridus*, *S.cretense* and *S. tinca* were the dominant species since they concentrated almost 64% of the total biomass. The invasive species *Siganus luridus* was the most dominant species within the limits of the MPA (11.64% of the total biomass) whereas *Sepia officinalis* accounted for 14.43% of the biomass that was caught outside the MPA.
Maxima of CPUE were detected in the front of Gerakas beach which is located inside the MPA whereas minima were recorded in Porto Roma area which is found marginally outside the MPA.
Species Aggregated CPUE was found to be comparable when the different sampling areas are considered (inside *vs* outside the MPA), therefore suggesting a similar fish stock status in the former areas. In this sense, the nourishing marine reserve effect on the fish stocks was not visible. Similar studies in other Mediterranean MPA's have demonstrated increased CPUE values both inside and in the vicinity of the MPA's (Russ *et al*., 2004; Beukers-Stewart *et al*., 2005; Goñi *et al*., 2006).
Several authors have proposed that CPUE can be used as an unbiased estimate of the fish stock status when catch is strictly proportional to fishing effort (Lima *et al*., 2000; Petrere *et al*., 2010 and references therein). Despite the fact that our data met the former criterion, calculation of the different CPUE indices (i.e. $CPUE_1$, $CPUE_2$ and $CPUE_3$) produced contradictory results with respect to the different groups of fishing sets (inside *vs* outside the MPA). CPUE is considered to be one of the most commonly used index in assessing the status of fish stocks, however our results reinforced the claim that CPUE measurements can be notoriously problematic (Maunder *et*

*al*., 2006) and further put forward the question of which CPUE index is the most appropriate or most robust ratio estimator.

With respect to the IPUE, mean fishing profit values of species aggregated data were comparable when fishing sets from different areas are compared (i.e. inside *vs* outside MPA). This finding illustrated that small scale artisanal fishermen who are fishing inside the MPA are not receiving significant financial benefits in comparison to the fishermen that are fishing outside the MPA due to the marine reserve effect. Even though IPUE patterns in MPA's have not been thoroughly investigated, the few existing studies in other Mediterranean MPA's (e.g. Mendes Islands) revealed that artisanal fishing incomes (in the form of IPUE) are receiving a positive effect in the vicinity of the marine reserves which is gradually decreasing with increasing distance from the MPA (Stelzenmüller *et al*., 2009). Thus, our findings are not in line with the former conclusions most likely due to the presence of the partially enforced marine reserve in the MPA of NMPZ. In this respect, the partially enforced marine reserve in the MPA of NMPZ (6 months/year no take zone) is not capable of enhancing the fishing profits of the artisanal fishermen as a result of the reduced CPUE that was detected therein.

Species CPUE was found to be variable for the different species encountered in the analyses. So, we detected cases were CPUE values were higher for several species within the borders of the MPA (e.g. *Diplodus sargus, Scyllarides latus, S. umbra*, *Epinephelus* spp and *Labrus* spp), cases were species CPUE was higher outside the limits of the MPA (e.g. *Scorpaena scrofa*, *Phycis phycis* and *Sepia officinalis)* whereas for certain species CPUE was comparable between the former areas (e.g. *Mullus surmuletus*). However, all the above differences were statistically significant only for the case of the herbivorous species *Sparisoma cretense* and *Siganus luridus* since mean CPUE was 3.4 and 54 times bigger inside the MPA respectively. Therefore, its reasonable to conclude that fishing stocks in the MPA of NMPZ are under an overexploitation status as it was evident from our results for the vast majority of species populations. Moreover, it has been reported in the scientific literature that the lack of obvious marine reserve effects for species diversity, abundance, biomass and body size can be attributed to the fact that MPA's have not been in existence for a sufficiently long time so as to provide to fish populations enough time to recover (Garcıá - Charton *et al*., 2004, 2008 and references therein). Such cases have been reported from Ustica reserve (Sicily, Italy) (Palmeri, 2004) and from ‘CinqueTerre’ MPA (Ligurian Sea, Italy) (Tunesi *et al*., 2006). However, the absence of a clear reserve effect on fish fauna may also be well related to sampling issues or to factors such as habitat variation or depth which can mask the nourishing effect of protection to fish fauna since they are significantly affecting the observed patterns (Garcıá - Charton *et al*., 2008). For the case of the MPA of NMPZ active enforcing of the partial marine reserve started almost 6 years ago, a time period which is rather small with respect to many commercially important species with slow life circles such as *Epinephelus* spp, *Scorpaena scrofa*, *Palinurus elephas*, *Dentex dentex* and *Merluccius merluccius*. However, in order to precisely assess the actual effect of the MPA of NMPZ in the fish stock status further studies should be conducted including broader temporal scales.

With respect to the total body length, the top five largest species included individuals of *Muraena helena* (70cm), *Sphyraena sphyraena* (67cm), *Dentex dentex* (55cm), *Dasyatis pastinaca* (55cm) and *Euthynnus alletteratus* (48cm). *Diplodus sargus*, *Mullus surmuletus*, *Phycis phycis*, *Scyllarides latus*, *Sepia officinalis*, *Siganus luridus*, *Sparisoma cretense* and *Sciena umbra* presented higher mean body length in the fishing sets deriving by the sampling sites that are located within the limits of the MPA. In contrast, *Epinephelus* spp (*E. marginatus* and *E.costae*) mean body length was comparable when specimen from fishing sets deriving by areas inside and outside the MPA are considered. However, all the above differences in the mean body size of the fished species were significant only for the case of *Siganus luridus*. These findings suggested that there was not any profound reserve effect on species population body size. Once again our findings seemed to be in contrast to the ones deriving by other MPA's where the body size of several exploited species (e.g. *E. marginatus*, *E. costae, S. cretense and P. elephas) was* significantly enhanced within the MPA's (e.g. Gonĩ *et al*., 2006; Harmelin-Vivien *et al*., 2007). Following Claudet *et al*., (2008) the older European marine reserves are more effective in increasing the body size of the commercially exploited fish species in comparison to the newly established ones. Therefore, the temporal dimension of protection represents a crusial factor in generating positive marine reserve effects.

Calculations of the mean CPUE per functional group revealed that herbivorous, detritivorous and carnivorous species presented 7, 1.66 and 1.33 times bigger mean CPUE inside the MPA in comparison to the areas that are found outside the MPA respectively. In contrast, for the case of zooplanktivorous species and apex predators mean CPUE was 1.23 and 1.51 times bigger in the areas that are located outside the limits of the MPA respectively. However, statistical significance or the former differences in mean CPUE was only achieved for the case of the herbivorous species, thus indicating a significantly enhanced mean CPUE inside the MPA for that functional group. This can be attributed to the enhanced mean CPUE of *S. luridus* and *S. cretense* within the limits of the MPA (a fact which was also supported by UVC results). In general, the large and long living predators are anticipated to benefit the most from the protection measures since they constitute species which are highly vulnerable to fishing as it was evidenced in several Mediterannean MPA's (e.g Micheli *et al*., 2004; Guidetti *et al*., 2005). However, this was not the case in the MPA of NMPZ especially when apex predators are considered for which CPUE was rather low, thus further indicating an overexploitation status for their populations. On the contrary, the enhanced CPUE of herbivorous species in the MPA may well be attributed to the particularly rich and diverse phytobenthic communities which are known to expand within the MPA (e.g. *Cystoseira* spp,, *Posidonia oceanica*) and are able to provide food and shelter to these species. Recently, Azzurro *et al*., (2007) have shown that *S. luridus* have the capacity to adapt to the local trophic resources [including *C. racemosa* (Bariche, 2006)] whereas the feeding preferences of *S. luridus, S. salpa* and *S. cretense* present a low overlap in resource partitioning among them. In this respect, it is possible for the herbivorous species to co-exist via niche partitioning provided that grazing pressure will not deplete the available resources. However, the particularly enhanced population of *S. luridus* in the MPA of NMPZ, may well lead to the rapid limitation of the preferred algal resource [e.g. *Dictyota* spp and *Cystoseira* spp - Azzurro et al., (2007)] a fact that will likely force the latter species to feed on other algal species since its diet is known to be more dispersed in comparison to *S. salpa* and *S. cretense* (Bariche et al., 2004). Hence, competitive interactions are possible to occur with negative effects on the endemic herbivores of the MPA. Recently, the scarce records of *S. salpa* in Lebanon coasts have been attributed to outcompetition by Siganids (Galil, 2007) whereas Sala et al.,(2011) revealed that the high abundance of the grazing Siganids can result to areas denuded of erect algae in the Eastern Mediterranean with considerable effects on the biodiversity, biomass, and algal growth of the local communities. These findings provide evidence that Siganids effects on the invaded ecosystems can be massive and, therefore, further research is required in order to address: i) the competitive interactions between the *S. luridus*, *S.cretense* and *S. salpa*, ii) the effects of Siganids in the algal status in cases were enhanced siganids populations are met, iii) the effects of siganids grazing on the local biodiversity and finally iv) the functional consequences of algal loss due to Siganids grazing in marine communities.

Our finding suggested that almost 1/3 of the fished species was caught before reaching the size of sexual maturity. Some of these species were *Epinephelus marginatus*, *Zeus faber*, *Merluccius merluccius*, *Pagrus pagrus*, *Trachinus radiatus*, *Euthynnus alletteratus*, *Sphyraena sphyraena*, *Epinephelus costae*, *Dicentrarchus labrax*, *Seriola dumerili* and *Pagellus bogaraveo* which are known to have high commercial value or special ecological importance. Likewise, 46.15% of the collected species (24 species) was found to have 75 to 100% of their individuals with a size lower than the size of sexual maturity. This finding further demonstrated that the majority of the fished specimen never reached the size of reproductive maturity for almost half of the fished species. In contrast, only the 21.5% of the fished species (11 species) was found to have all their individuals larger than this threshold. The most important species in terms of their commercial value belonging to this category were *Spicara smaris*, *Spicara maena*, *Mullus surmuletus*, *Mullus barbatus* and *Boops boops*.

Our data revealed that the all the measured individuals of *Epinephelus marginatus*, *Epinephelus costae* and *Pagellus bogaraveo* specimen were smaller than the minimum permitted catch size (MPCS) as it is defined by EU and National regulations. Moreover, 88.2% of the total measured specimen of *Pagrus pagrus* was smaller than MPCS whereas this percentage was calculated to 68% for *Diplodus sargus*, to 47.3% for *Diplodus vulgaris* and to 14.8% for *Pagellus erythrinus*. These findings, alongside with the results of size of sexual maturity, highlight the importance of nets mesh size in the sustainable exploitation of the fish stocks. Nets with a mesh size lower that 28mm mainly captured specimens with a body size below the size of sexual maturity or MPCS and therefore it is strongly suggested to be excluded from the fishing routine in order to maintain fish stocks in sustainable levels.

## D. Concluding Remarks - Questionnaires

Although environmental, ecological and management aspects related to MPA's have been extensively addressed in the scientific literature, less attention have been paid in the comprehension of the attitudes, perceptions, beliefs and preferences of the artisanal fishermen that are practising fishing in the MPA's (Pomeroy *et al*., 2004; Pita *et al*., 2011). As it has been recently proposed, understanding of the former factors is of crucial importance in the adaptive management of commercial fisheries since the performance of fisheries regulations in MPA's can be weakened if fishers' preferences, choices and actions are not considered (Wahle et al., 2003; Dimech *et al*., 2009). For the case of the MPA of NMPZ, field surveys and personal interviews with the local fishermen that are fishing within the limits of the MPA revealed their reluctance in participating in the questionnaire surveys, a fact which was not true for the fishermen that are not fishing in the MPA. In this respect, only 4 fishermen practising fishing in the MPA were willing to participate in the study in contrast to the 13 ones that are fishing mostly in the northern coasts of Zakynthos Island. Similar patterns have also been highlighted by Pita *et al*., (2011) after the review of the relative literature with respect to fishers' perception and attitude. The latter authors have highlighted the powerful effect of fishers' personal interests and concerns in the acceptance of MPA's: the less affected the fishermen are from the MPA the more accepting and supportive they are towards the MPA's. The main reasons for not participating in the study were related to the lack of understanding of the benefits associated with the MPA, the belief that no-take MPA's are not good management tools as well as to their opinion that MPA enforcement is not effective. However, the latter claim was rather controversial since they did not agree in the adoption of more strict enforcement levels such as the transformation of the partially enforced no take zone (Marine Park Zone A) to a permanently enforced one (transition from a 6 months to a 12 months closure). Similar perceptions and attitudes of fishermen towards no-take MPA's have been recorded from UK, Sweedish, Italian and Chilean fishers' thus putting also forward issues related to the understanding of the positive effects that MPA's can have on fisheries, the value of the MPA's as explicitly managed areas as well as the effective enforcement of MPA's regulations (e.g. Himes, 2003; Jones 2008; Gelcich *et al*., 2009; Suuronen *et al*., 2010).

The questionnaire surveys mostly concerned small scale artisanal fisheries, whereas the fishers profile analysis indicated that the mean age of the fishermen was around 53 years old ranging from 25 to 79 years of age. Undoubtedly, the fishermen that took part in the survey have been highly experienced professionals while the vast majority of them are practicing fishing all year-round. Our findings also demonstrated that 75% of the interviewed fishermen had fishing as their primary occupation whereas the remaining 25% had additional sources of incomes deriving mostly by agricultural and tourism activities. However, the fishermen that participated in the surveys were mostly originating from the Northern coasts of Zakynthos Island where tourism activities are not as developed as they are in the area of the MPA (i.e. Laganas Bay). In this respect, the former finding cannot be generalized for the case of the fishermen that are fishing in the MPA. Concerning the average annual income from fishing activities, fishermen seemed to earn around 17000€ per annum, whereas the main fishing cost was calculated to 11769€ per year which was mainly associated to fuel expenses (mean value = 5125€ per year) and crew salaries (mean value = 7800€ per year) respectively. Commercial disposition of fish is taking place via three forms related to direct retail sale, or through merchants or local taverns.

With respect to the most frequently employed fishing gears, nets and long lines is the preferred combination of fishing gears while the exclusive use of nets is following in smaller frequency. Our findings suggested that the target species in Zakynthos Island are among the typical species that small scale fisheries are targeting in coastal areas. The most important fished species is the striped red mullet (*Mullus surmuletus*) followed by *Serranidae* spp., *Scorpaena scrofa, Dentex dentex,* varius crustaceans, *Pagrus pagrus, Mullus barbatus, Pagellus erythrinus, Diplodus sargus, Boops boops, Sepia officinalis, Sparisoma cretense, Spondyliosoma cantharus* and *Epinephelus* spp in descending order. Commercial price of the fish species caught in descending order were as follows: *Epinephelus* spp., Sparoid and Palinuroid species (e.g. *Pagrus pargus, Denetx dentex, Spondyliosoma cantharus), Mullus surmuletus, Paggelus erythrinus, Sciaena umbra* and *Oblada melanura*. In sort, the maximum value was 30€/kg for *E. marginatus* whereas the minimum value was 3 €/kg for *S. pilchardus*.

Regarding the fish and other marine species for which a reduction in catch has been noticed, various crustaceans are in the lead (mainly of the family Palinuridae), followed by *Dentex dentex*, *Epinephelus costae*, *Spicara maena*, *Boops boops*, *Mullus surmuletus* and *Scorpaena scrofa*. Moreover, reduction in the size of fish and other marine species has been noticed for *Dentex dentex*, *Mullus surmuletus*, *Scorpaena scrofa*, *Pagellus erythrinus*, *Pagrus pagrus*, *Diplodus sargus*, *Mullus barbatus* and *Spondyliosoma cantharus*.

With respect to the areas that fishermen considered as the major breeding grounds for the most important commercial species, the MPA of NMPZ seemed to be the most important area followed by the central - east coasts of Zakynthos Island. This finding clearly demonstrates that fishermen recognize the ecological importance of the area which the MPA is located. The MPA as a fishing ground was found to be preferred from fishermen at a moderate level alongside with the south - west coasts of Zakynthos Island. Once again, since the majority of the fishermen that participated in questionnaire surveys are originating from the northern part of Zakynthos Island, it is, therefore, reasonable for them to prefer the northern coasts as their main fishing ground for reasons that are not necessarily related to fishing yields. Hence, apart from the fishing yields, the proximity to the harbors, their knowledge of the area and fuel consumption can also be involved in fishing ground selection, as fishermen stated. Similar findings have also been reported by Abesamis *et al*. (2006) from Apo Island fisheries.

The main problems that professional fishermen face in Zakynthos Island are the interaction between the fishing gear and the marine mammals (damage caused to fishing gear from the monk seal *Monachus monachus* and the dolphins), other forms of fishing activities (recreational fishing including spearfishing), matters related to fish yields and costs related to both fishing and catch sale. Despite the fact that the future of fishing as a profession is not considered bright by the fishermen, the majority of them will keep on fishing whereas some of them are willing to liquidate their vessel and gear or pass it to a relative.

## E. Recreational Fisheries

Recreational fishing is one of the most common human activities in coastal areas and islands worldwide. Several studies have shown that recreational fishing can have a considerable effect in the exploitation of the biological resources (Font & Lloret, 2012), since catches may be comparable or sometimes even exceed those of artisanal fishing fleets (e.g. Coll *et al*., 2004; Lewin *et al*., 2006; Cooke *et al*., 2006; Font *et al*., 2011). At a Mediterranean basin scale, recreational fisheries yields are approximately 10% of the overall fishing yields including all forms of commercial fisheries (small and medium scale fisheries) (Lewin *et al*., 2006). In this respect, recreational fisheries commonly compete artisanal fisheries for biomass export benefits, given that there is an overlap in targeted species and exploited fishing grounds. Therefore, it is reasonable to anticipate conflicts between artisanal and recreational fishing activities (Font & Lloret, 2012), since the latter can have a considerable negative effect on the status of fish stocks, which in return can lead to a reduction of artisanal fishermen incomes.

At Zakynthos Island, recreational fishing (e.g. boat fishing, shore fishing, underwater fishing) has been traditionally considered as one of the main human activities for many decades, while an active recreational fishery union is well established. Since the establishment and operation of the NMPZ-MPA in 2000, all forms of recreational fisheries are strictly prohibited within the limits of the MPA (National Government Gazette 906/D/22 - 12 - 1999), a fact that has been an issue of dispute for local recreational fishermen, and has led to conflicts with the management body of the NMPZ.

The results of the present study demonstrate that fishing stocks in the NMPZ-MPA are under an overexploitation status, as the abundance/biomass of several commercially important or vulnerable species is extremely low (e.g. apex predators and carnivorous species that constitute target species for both artisanal and recreational fishing). Given the level of impact that recreational fishing is proved to have on fish populations, and which can further compromise the sustainability of the already depleted stocks, it is reasonable and extremely important to maintain the present legal status (i.e. total exclusion of recreational fishing from the MPA) and further increase the effectiveness of enforcement. The MPA covers only a small percentage of the total coastal area of Zakynthos Island, and hence there are many other areas that recreational fishermen can fish without undermining the conservation objectives of the MPA. However, additional management measures and an effective monitoring scheme regarding recreational fisheries should be applied in all areas (e.g. Lewin *et al*., 2006; Font & Lloret, 2012), in order to ensure sustainability of the biological resources at Zakynthos Island.

## F. Management Implications

This study contributes to a better understanding of the effects of small scale artisanal fisheries on fish stock status and overall marine biodiversity, both within the limits of the MPA of NMPZ, as well as in the North and Eastern coasts of Zakynthos Island. It also provides insight regarding the effectiveness of management measures, fishers' attitudes, perceptions, preferences and socioeconomic profile. Taking into account the results of the present study, a set of future management actions is being proposed.

The observed overexploitation status of fish stocks in all studied areas, and the lack of a marine reserve effect, indicate that current management measures are not sufficient in maintaining fish stocks at a sustainable level, compromising ecosystem health and fishermen profits. In view of this, and given that the present management scheme is primarily focused on the conservation of the marine turtle *C. carretta*, year-round protection measures, specifically aiming at the conservation of fish stocks, should be adopted and adequately enforced.

The MPA zoning system requires several modifications, including the establishment of year-round no take zones which will exclude all types of anthropogenic activity and will encompass marine features of special importance (e.g. fish reproduction hot-spots). Detailed bionomic surveys are therefore needed in order to determine such areas, as well as define their appropriate spatial and bathymetric extend.

Management of small scale artisanal fisheries within the buffer zones of the MPA of NMPZ should be adopted, through regulation of the maximum number of fishing vessels operating in these areas at any given time, the enforcement of permit fees, and the issuing of a limited number of fishing licenses.

In order to enhance fish biomass, nets with a mesh size smaller than 28 mm should be banned. This will allow a sufficient proportion of fish populations to reach reproductive maturity, and may ultimately have a considerable effect even in areas located outside the MPA, through dispersal processes.

Standard fisheries regulations, such as effective implementation of quotas regarding maximum sustainable yield and minimum fish size, alongside improved surveillance and monitoring of fishing gears and fisheries landings, should be applied in the MPA as well in all areas and ports of Zakynthos. However, in order for such measures to be effective, the adoption of future regulations requires additional studies that specifically aim to address these issues.

Furthermore, given that it requires several years or even decades for the benefits of an effectively managed MPA to become evident, management actions and protection measures should remain consistent throughout time. Moreover, long term monitoring schemes will allow evaluation and improvement of applied regulations through the process of adaptive management.

The active participation and cooperation of the local community and stakeholders in the management decisions is of fundamental importance. However, the co - management of the MPA through the involvement of fishermen and other social groups (e.g. managers, fishermen, local authorities, scientists and maritime police) is far from being achieved and management actions should be gradually focused towards this direction. Nevertheless, fishermen should be involved in the decision-making, safeguarding and governance of the MPA through participative processes.

Educational and awareness raising campaigns, aiming to improve current practices, attitudes and perceptions regarding the marine environment and the potential positive effects of MPAs as management tools may enhance the aforementioned participative processes. Promotion of the positive effects that MPA's can bring about to fish stocks and subsequently to fishing yields and incomes in the long term, could possibly lead fishermen to support and further comply with fishing regulations within the MPA.

With regards to recreational fisheries, given that such activities can further compromise the sustainability of the already reduced fish stocks, it is strongly recommended that all forms of recreational fishing must remain excluded from the MPA of NMPZ.

Continuous monitoring of the MPA is necessary to ensure appropriate evaluation of management measures through time. Future monitoring plans should combine several methodological approaches (similar to those applied in the present study) that will be repeatedly applied at regular time intervals, in order to effectively evaluate the ecological status of species and habitats. The active participation of fishermen in the monitoring process (e.g. keeping up fisheries records and logbooks) would significantly enhance evaluation processes and improve management actions.

Our study also indicated the need for more specialized surveys and monitoring actions in order to address the following issues:

1. Bionomic studies focusing on the spatial extend and ecological evaluation of the different habitats present within the MPA. Such actions should preferably take place during spring, as it is the most appropriate season to study phytobenthic communities.
2. A bionomic survey specifically regarding the ecological status and lower depth limit of the priority habitat *P. oceanica* meadows within the limits of the MPA.
3. In depth study of the well established populations of the allochthonus fish *S. luridus* in the MPA, in order to quantify its effects on local populations of fish and phytobenthic communities.
4. Dedicated surveys in order to monitor the rate of expansion of all allochthonus species, and adopt specific management measures accordingly.

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# VII. ANNEX

## 1. Total Species List

| | |
|---|---|
| **Algae** | *Caulerpa prolifera* (Forsskål) J.V.Lamouroux, 1809 |
| | *Caulerpa racemosa var. cylindracea* (Sonder) Verlaque, Huisman & Boudouresque, 2003 * |
| | *Cladophora* sp. |
| | *Codium bursa* (Olivi) C.Agardh, 1817 |
| | *Dasycladus vermicularis* (Scopoli) Krasser, 1898 |
| | *Halimeda tuna* (J.Ellis & Solander) J.V.Lamouroux, 1816 |
| | *Palmophyllum crassum* (Naccari) Rabenhorst, 1868 |
| | *Flabellia petiolata* (Turra) Nizamuddin, 1987 |
| | *Valonia macrophysa* Kützing, 1843 |
| | *Dictyopteris polypodioides* (A.P.De Candolle) J.V.Lamouroux, 1809 |
| | *Padina pavonica* (Linnaeus) Thivy, 1960 |
| | *Zonaria tournefortii* (J.V.Lamouroux) Montagne, 1846 |
| | *Cystoseira* spp. |
| | *Cystoseira crinita* Duby, 1830 |
| | *Cystoseira spinosa* Sauvageau, 1912 |
| | *Amphiroa rigida* J.V.Lamouroux, 1816 |
| | *Mesophyllum* spp. |
| | *Peyssonnelia* spp. |
| | *Peyssonnelia rubra* (Greville) J.Agardh, 1851 |
| | *Cymodocea nodosa* (Ucria) Ascherson, 1870 |
| | *Posidonia oceanica* (Linnaeus) Delile, 1813 |
| **Annelida** | *Hermodice carunculata* (Pallas, 1766) |
| | *Sabella pavonina* Savigny, 1822 |
| | *Sabella spallanzanii* (Gmelin, 1791) |
| | *Protula tubularia* (Montagu, 1803) |
| | *Eupolymnia nebulosa* (Montagu, 1818) |
| **Bryozoa** | *Adeonella* sp. |
| | *Myriapora truncata* (Pallas, 1766) |
| | *Reteporella* sp. |
| **Chordata** | *Aplidium* sp. |
| | *Apogon imberbis* (Linnaeus, 1758) |
| | *Atherina* sp. |
| | *Boops boops* (Linnaeus, 1758) |
| | *Bothus podas* (Delaroche, 1809) |
| | *Caranx crysos* (Mitchill, 1815) |
| | *Chelidonichthys lucerna* (Linnaeus, 1758) |
| | *Chromis chromis* (Linnaeus, 1758) |
| | *Coris julis* (Linnaeus, 1758) |
| | *Dasyatis pastinaca* (Linnaeus, 1758) |
| | *Dentex dentex* (Linnaeus, 1758) |
| | *Diazona violacea* Savigny, 1816 |

*Dicentrarchus labrax* (Linnaeus, 1758)
*Diplodus annularis* (Linnaeus, 1758)
*Diplodus annularis* (Linnaeus, 1758)
*Diplodus sargus* (Linnaeus, 1758)
*Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817)
*Enchelycore anatina* (Lowe, 1838) *
*Epinephelus costae* (Steindachner, 1878)
*Epinephelus marginatus* (Lowe, 1834)
*Euthynnus alletteratus* (Rafinesque, 1810)
*Gobius auratus* Risso, 1810
*Gobius* sp.
*Gobius vittatus* Vinciguerra, 1883
*Halocynthia papillosa* (Linnaeus, 1767)
*Labrus merula* (Linnaeus, 1758)
*Labrus mixtus* (Linnaeus, 1758)
*Labrus viridis* (Linnaeus, 1758)
*Loligo vulgaris* (Lamarck, 1798)
*Merluccius merluccius* (Linnaeus, 1758)
*Microcosmus* sp.
*Mugil cephalus* (Linnaeus, 1758)
*Mullus barbatus*(Linnaeus, 1758)
*Mullus surmuletus* (Linnaeus, 1758)
*Muraena helena* (Linnaeus, 1758)
*Oblada melanura* (Linnaeus, 1758)
*Pagellus bogaraveo*(Brünnich, 1768)
*Pagellus erythrinus* (Linnaeus, 1758)
*Pagrus pagrus* (Linnaeus, 1758)
*Palinurus elephas* (Fabricius, 1787)
*Parablennius sanguinolentus* (Pallas, 1814)
*Phallusia mammillata* (Cuvier, 1815)
*Phycis phycis* (Linnaeus, 1766)
*Raja asterias* (Delaroche, 1809)
*Raja miraletus* (Linnaeus, 1758)
*Sarpa salpa* (Linnaeus, 1758)
*Sciaena umbra* (Linnaeus, 1758)
*Scorpaena notata* (Rafinesque, 1810)
*Scorpaena porcus* (Linnaeus, 1758)
*Scorpaena scrofa* (Linnaeus, 1758)
*Scyllarides latus* (Latreille, 1803)
*Seriola dumerili* (Risso, 1810)
*Serranus cabrilla* (Linnaeus, 1758)
*Serranus hepatus* (Linnaeus, 1758)
*Serranus scriba* (Linnaeus, 1758)
*Siganus luridus* (Rüppell, 1829) *
*Solea solea* (Linnaeus, 1758)
*Sparisoma cretense* (Linnaeus, 1758)

| | |
|---|---|
| | *Sphyraena sphyraena* (Linnaeus, 1758) |
| | *Spicara maena* (Linnaeus, 1758) |
| | *Spicara smaris* (Linnaeus, 1758) |
| | *Spondyliosoma cantharus* (Linnaeus, 1758) |
| | *Symphodus cinereus* (Bonnaterre, 1788) |
| | *Symphodus mediterraneus* (Linnaeus, 1758) |
| | *Symphodus melanocercus* (Risso, 1810) |
| | *Symphodus ocellatus* (Linnaeus, 1758) |
| | *Symphodus roissali* (Risso, 1810) |
| | *Symphodus rostratus* (Bloch, 1791) |
| | *Symphodus tinca* (Linnaeus, 1758) |
| | *Syngnathus acus* Linnaeus, 1758 |
| | *Synodus saurus* (Linnaeus, 1758) |
| | *Thalassoma pavo* (Linnaeus, 1758) |
| | *Trachinotus ovatus* (Linnaeus, 1758) |
| | *Trachinus draco* (Linnaeus, 1758) |
| | *Trachinus radiatus* (Cuvier, 1829) |
| | *Trigloporus lastoviza* (Bonnaterre, 1788) |
| | *Uranoscopus scaber* (Linnaeus, 1758) |
| | *Xyrichtys novacula* (Linnaeus, 1758) |
| | *Zeus faber* (Linnaeus, 1758) |
| **Cnidaria** | *Cerianthus membranaceus* (Spallanzani, 1784) |
| | *Balanophyllia europaea* (Risso, 1826) |
| | *Madracis pharensis* (Heller, 1868) |
| **Arthropoda** | *Dardanus calidus* (Risso, 1827) |
| | *Lepas anatifera* Linnaeus, 1758 |
| | *Percnon gibbesi* (H. Milne-Edwards, 1853) * |
| **Echinodermata** | *Arbacia lixula* (Linnaeus, 1758) |
| | *Marthasterias glacialis* (Linnaeus, 1758) |
| | *Astropecten aranciacus* (Linnaeus, 1758) |
| | *Echinaster sepositus* (Retzius, 1783) |
| | *Holothuria forskali* Delle Chiaje, 1823 |
| | *Holothuria sanctori* Delle Chiaje, 1823 |
| | *Hacelia attenuata* Gray, 1840 |
| | *Ophidiaster ophidianus* (Lamarck, 1816) |
| | *Paracentrotus lividus* (Lamarck, 1816) |
| | *Sphaerechinus granularis* (Lamarck, 1816) |
| **Mollusca** | *Aplysia depilans* Gmelin, 1791 |
| | *Arca noae* Linnaeus, 1758 |
| | *Euthria cornea* (Linnaeus, 1758) |
| | *Acanthocardia tuberculata* (Linnaeus, 1758) |
| | *Bittium reticulatum* (da Costa, 1778) |
| | *Cerithium vulgatum* Bruguière, 1792 |
| | *Felimare picta* (Schultz in Philippi, 1836) |
| | *Bryopa melitensis* (Broderip, 1834) |
| | *Erosaria spurca* (Linnaeus, 1758) |

| | |
|---|---|
| | *Peltodoris atromaculata* Bergh, 1880 |
| | *Haliotis tuberculata* Linnaeus, 1758 |
| | *Bolinus brandaris* (Linnaeus, 1758) |
| | *Hexaplex trunculus* (Linnaeus, 1758) |
| | *Nassarius mutabilis* (Linnaeus, 1758) |
| | *Octopus vulgaris* Cuvier, 1797 |
| | *Ostrea* sp. |
| | *Pinna nobilis* Linnaeus, 1758 |
| | *Pinna rudis* Linnaeus, 1758 |
| | *Charonia variegata* (Lamarck, 1816) |
| | *Raphitoma* sp. |
| | *Spondylus gaederopus* Linnaeus, 1758 |
| | *Tonna galea* (Linnaeus, 1758) |
| | *Gibbula magus* (Linnaeus, 1758) |
| | *Jujubinus exasperatus* (Pennant, 1777) |
| | *Bolma rugosa* (Linnaeus, 1767) |
| | *Thylacodes arenarius* (Linnaeus, 1758) |
| | *Sepia officinalis* (Linnaeus, 1758) |
| **Porifera** | *Agelas oroides* (Schmidt, 1864) |
| | *Aplysina aerophoba* Nardo, 1833 |
| | *Axinella damicornis* (Esper, 1794) |
| | *Haliclona* sp. |
| | *Chondrilla nucula* Schmidt, 1862 |
| | *Chondrosia reniformis* Nardo, 1847 |
| | *Cliona celata* Grant, 1826 |
| | *Cliona schmidti* (Ridley, 1881) |
| | *Cliona viridis* (Schmidt, 1862) |
| | *Crambe crambe* (Schmidt, 1862) |
| | *Acanthella acuta* Schmidt, 1862 |
| | *Phorbas fictitius* (Bowerbank, 1866) |
| | *Ircinia variabilis* (Schmidt, 1862) |
| | *Sarcotragus foetidus* Schmidt, 1862 |
| | *Petrosia ficiformis* (Poiret, 1789) |
| | *Spirastrella cunctatrix* Schmidt, 1868 |
| | *Fasciospongia cavernosa* (Schmidt, 1862) |

*Asterisk indicates invasive species*

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