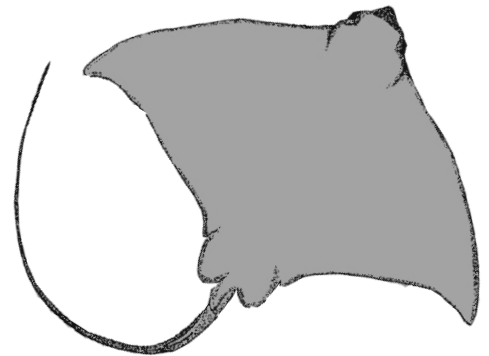




UNIVERSIDADE DO ALGARVE
Faculdade de Ciências e Tecnologia

Assessment of reserve effect in a Marine
Protected Area: the case study of
the Professor Luiz Saldanha
Marine Park (Portugal)



Inês Isabel Gralho Correia de Sousa



Faro, 2011



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Inês Isabel Gralho Correia de Sousa

Thesis developed within the  **LIFE-BIOMARES project** (LIFE06 NAT/ P/000192) biomares

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"For most of history, man has had to fight nature to survive. In this century he is beginning to realize that, in order to survive, he must protect it."

Jacques-Yves Cousteau

I hereby declare that I am the sole author of this thesis
Esta dissertação é da exclusiva responsabilidade da autora

Juêi Isabel Galvão Correia de Sousa

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Abstract

The Professor Luiz Saldanha Marine Park (PLSMP) is located in the central region of Portugal (Arrábida coast), comprising 38 km of coastline. It was established in 1998 and in August 2005 specific management measures were implemented. Three protection levels were established: Total – human activities not allowed; Partial - some fishing allowed with some gears (octopus traps, jigging, handline); Complementary - fishing allowed with vessels under 7m length and licensed to operate within the marine park. To monitor the reserve effect, in terms of abundance, biomass and also community composition, experimental fishing trials with trammel nets on soft bottoms have been conducted since 2007 (depths between 10 – 45m). The individuals caught were identified to species level, measured to the nearest mm and released when alive. The data (species abundance and biomass) were analyzed both with univariate and multivariate methods, allowing the comparison between the three protection levels.

The data analysis showed higher values of Catch per Unit Effort (CPUE) in number and in weight for the Partial and Total protection areas when compared to the Complementary, where fishing with nets is allowed. Also the biodiversity indices (Margalef and Shannon-Wiener) showed higher values in these two areas. The multivariate analysis (ANOSIM) supports the previous results, in the sense that the communities from Partial and Total sections were found to be significantly different from the one found in the Complementary area. The SIMPER analysis showed that the bastard sole *Microchirus azevia* and the toadfish *Halobatrachus didactylus* are important contributors for the distinction of these communities. It was noticed that in assessing the reserve effect, the benefits of protection is differed from species to species. The analysis at the species level was important in the detection of trends that are probably related with the implemented protection measures. Namely the species *Chelidonichthys lucerna*, *M. azevia* and *Raja clavata* showed abundance increases from the first analyzed period (Aug. 2007 - Aug. 2009) to the second (Aug. 2009 - Aug. 2010), after the full implementation of the marine park. Besides the increase in abundance, *C. lucerna* and *M. azevia* also registered an increase in the median total length. Overall, the results suggest that the Partial and Total protection areas are important for several soft bottom species. The importance of protection level was confirmed by Gaussian GAM models, for both sandy and muddy bottom. This analysis also revealed water temperature as an important predictor of CPUE in weight.

The results obtained include the first signs of a reserve effect concerning the soft bottoms of the Prof. Luiz Saldanha Marine Park. The protection measures, mainly the restriction on the use of trammel and gill nets, seem to benefit some bottom associated species. To better understand the reserve effect on the biodiversity and abundance of soft bottom communities, further sampling should be considered.

Keywords: Marine Protected Areas, reserve effect, Arrábida, soft bottoms.

Resumo

O Parque Marinho Professor Luiz Saldanha fica situado na região central de Portugal (costa da Arrábida) e inclui 38 km de litoral. Este parque foi estabelecido em 1998 e em Agosto de 2005 foram implementadas medidas de gestão específicas. Três estatutos de protecção foram estabelecidos: Total – interdição total às actividades humanas; Parcial - alguma pesca permitida com determinadas artes de pesca (covos, toneira, linha de mão); Complementar - pesca permitida a barcos até aos 7m e licenciados para operar dentro do parque marinho. A fim de monitorizar o efeito de reserva em termos de abundância, biomassa e composição da comunidade, desde 2007 que se têm realizado campanhas de pesca experimental com rede de tresmalho (profundidade entre 10 – 45m) sobre substratos móveis. Os indivíduos capturados foram identificados até ao nível da espécie, medidos ao mm mais próximo e libertados quando vivos. Os dados (abundância e biomassa por espécie) foram analisados com métodos univariados e multivariados, permitindo a comparação dos três estatutos de protecção.

Foram obtidos valores de Captura por Unidade de Esforço (CPUE) em número e em peso mais elevados nas áreas de protecção Parcial e Total do que na Complementar, onde a pesca com redes é permitida. Também os índices de biodiversidade (Margalef e Shannon-Wiener) revelaram valores mais elevados nestes duas áreas. A análise multivariada (ANOSIM) suporta os resultados referidos, uma vez que se verificaram diferenças significativas entre as comunidades das secções Parcial e Total em comparação com a encontrada na Complementar. A análise SIMPER mostrou que as espécies *Microchirus azevia* e *Halobatrachus didactylus* contribuem de forma importante para a distinção destas comunidades. Os resultados estão de acordo com o facto de que a vantagem derivada das medidas de protecção difere de acordo com a espécie. A análise ao nível das espécies foi útil na detecção de tendências que estão provavelmente relacionadas com as medidas de protecção implementadas. Nomeadamente, as espécies *Chelidonichthys lucerna*, *M. azevia* e *Raja clavata*, mostraram aumentos de abundância entre o primeiro (Agosto 2007 - Agosto 2009) e o segundo (2009 de agosto - 2010 de agosto) período analisado. Além do aumento em abundância, as espécies *C. lucerna* e *M. azevia* também registaram um aumento no comprimento total médio. De um modo geral, os resultados sugerem que as áreas de protecção Parcial e Total são importantes para várias espécies de substratos móveis. A importância do nível de protecção foi confirmada nos modelos GAM de distribuição gaussiana obtidos para os substratos arenoso e lodoso. Esta análise também revelou a temperatura da água como um factor importante na previsão do peso da captura.

Os resultados obtidos parecem incluir os primeiros sinais do efeito de reserva nos substratos móveis do Parque Marinho Professor Luiz Saldanha. As medidas de protecção, principalmente a restrição do uso de redes de tresmalho e emalhar, parecem beneficiar as espécies que vivem associadas ao fundo. Para analisar devidamente o efeito de reserva na biodiversidade e abundância das comunidades de substratos móveis, é aconselhada a continuação da amostragem.

Palavras-chave: Áreas Marinhas Protegidas, efeito de reserva, Arrábida, substratos móveis.

Table of Contents

Abstract.....	iii
Resumo	iv
1. Introduction	1
1.1. Study area	2
2. Material and Methods.....	6
2.1. Sampling method.....	6
2.2. Data treatment	9
2.2.1. Quantitative analysis.....	10
2.2.2. Diversity analysis	11
2.2.3. Spatial and temporal analysis.....	11
2.2.4. Multivariate analysis	13
2.2.5. Model fitting	14
3. Results	17
3.1. Sample representativity	17
3.2. Temperature analysis	18
3.3. Biological parameters	18
3.4. Analysis of catch data.....	22
3.4.1. Species trends	27
3.5. Multivariate analysis	33
3.6. Model fitting	37
4. Discussion.....	46
4.1. Analysis of catch data.....	46
4.2. Model fitting	51
4.3. Final considerations.....	53
5. References.....	55
ANNEXES	

List of Figures

Figure 1. Location of the Prof. Luiz Saldanha Marine Park (PLSMP) on the west coast of Portugal.	3
Figure 2. The Prof. Luiz Saldanha Marine Park (PLSMP) and its three different protection levels. The five different sections that compose the experimental trammel nets sampling area are shown (A, B, C, D and E). Each section undertook a different evolution during the implementation period (January 2006 – August 2009; See Annex I).....	4
Figure 3. The Prof. Luiz Saldanha Marine Park (PLSMP) map with respective protection area delimitations and the location of the experimental trammel net sets.	8
Figure 4. Map of the sampling area in the Prof. Luiz Saldanha Marine Park. All the sampling points (middle point of each 500m long net set) are shown (red dots).	9
Figure 5. Species accumulation curve in relation to the cumulative number of samples (trammel net sets).	17
Figure 6. Boxplot of temperature (measurements during spring and autumn sampling campaigns) by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).....	18
Figure 7. Boxplot of the Margalef and Shannon-Wiener indeces by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).	22
Figure 8. Boxplots of the CPUE in weight (Kg.1000m^{-1}) (A), CPUE in number (number.1000m^{-1}) (B) and catch value ($\text{€}.\text{1000m}^{-1}$) (C) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).	24
Figure 9. Boxplots of the specimens total length (cm) (A), weight (g) (B) and estimated value (€) (C) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).	25
Figure 10. Boxplot of the CPUE in weight (Kg.1000m^{-1}) by sector and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).....	26
Figure 11. Boxplots of the specimens total length (cm) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010). Data for four bony fish species: <i>Chelidonichthys lucerna</i> (A), <i>Microchirus azevia</i> (B), <i>Solea senegalensis</i> (C) and <i>Solea solea</i> (D).....	28

Figure 12. Boxplots of the CPUE in number (number.1000m ⁻¹) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010). Data for four bony fish species: <i>Chelidonichthys lucerna</i> (A), <i>Microchirus azevia</i> (B), <i>Solea senegalensis</i> (C) and <i>Solea solea</i> (D).	30
Figure 13. Boxplots of the CPUE in number (number.1000m ⁻¹) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010). Data for four elasmobranch taxa: <i>Torpedo torpedo</i> (A), <i>Myliobatis aquila</i> (B), <i>Raja clavata</i> (C) and family Rajidae (D).....	31
Figure 14. NMDS ordination of samples based on Bray-Curtis similarity (4th root data transformation). Samples are labeled according to protection level.	34
Figure 15. Contribution of analyzed variables (when applied as the only predictor) in explaining the variance of CPUE in weight. Model fitting: Gaussian GAM, identity link function.....	37
Figure 16. Estimated smoothing curves for water temperature (A) and depth (B) in the sandy bottom model. The solid line is the smoother and the dotted lines are 95% point-wise confidence bands.	42
Figure 17. Estimated smoothing curve for water temperature in the muddy bottom model. The solid line is the smoother and the dotted lines are 95% point-wise confidence bands.....	42
Figure 18. Sandy bottom model - Model validation through graphical analysis of the residuals. A - Q-Q plot; B - Residuals <i>versus</i> linear predictor; C - Histogram of the residuals; D - Response against fitted values.....	44
Figure 19. Sandy bottom model - Residuals obtained by the fitted GAM model plotted versus their spatial coordinates. Black dots are negative residuals, and grey dots are positive residuals. Size of dots is proportional to value.....	44
Figure 20. Muddy bottom model - Model validation through graphical analysis of the residuals. A - Q-Q plot; B - Residuals <i>versus</i> linear predictor; C - Histogram of the residuals; D - Response against fitted values.....	45
Figure 21. Muddy bottom model - Residuals obtained by the fitted GAM model plotted versus their spatial coordinates. Black dots are negative residuals, and grey dots are positive residuals. Size of dots is proportional to value.....	45

List of Tables

Table I. Regulations implemented (Ministers Council Resolution No. 141/2005, 23rd August 2005) in the Prof. Luiz Saldanha Marine Park regarding commercial fishing.	5
Table II. Specifications of the trammel nets used during the scientific surveys.	6
Table III. Characteristics of the sites sampled during the experimental trammel nets surveys. ...	8
Table IV. List of variables considered for model fitting and their characteristics.	16
Table V. Commercial fish and invertebrate species caught in the trammel net surveys (FO: frequency of occurrence; IRI: index of relative importance; C.S.: conservation status). Species ordered by IRI.	19
Table VI. CPUE and frequency of occurrence (FO) of the invertebrates with no commercial value.	21
Table VII. Results of the Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) applied to the Margalef and Shannon-Wiener indices for each protection level and in each period.	22
Table VIII. Results of the Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) applied to compare values according to protection level and period - CPUE (ind.1000m ⁻¹ and Kg.1000m ⁻¹), catch value (€); values per individual: total length (TL), mean weight and mean value.	26
Table IX. Results of the Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) applied to CPUE in weight (Kg.1000m ⁻¹) obtained for each sector (Complementary; Partial West, Total, Partial East) and in each period.	27
Table X. Results of Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) to compare the median total length (TL) of four bony fish species according to protection level and period.	29
Table XI. Results of Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) applied to eight fish species, comparing the CPUE in number (ind./1000m) per protection level and period.	32
Table XII. Results of one-way ANOSIM ($\alpha=0.01$; 4 th root data transformation; Bray-Curtis similarity) according to protection level; all samples included (Global R=0.252).	33

Table XIII. Results of one-way ANOSIM ($\alpha=0.01$; 4 th root data transformation; Bray-Curtis similarity) according to protection level; analysis considering the sandy and muddy bottom samples separately (Global R 'sandy bottom' = 0.343; Global R 'muddy bottom' = 0.368).....	34
Table XIV. SIMPER results for the protection level comparisons (4 th root data transformation; Bray-Curtis similarity); all samples included. Species with Contribution% ≥ 3.5 are shown.....	36
Table XV. SIMPER results for substrate/depth comparisons: sandy (10-18m depth) and muddy bottoms (35-40m depth) (4 th root data transformation; Bray-Curtis similarity). Species with Contribution% ≥ 3.5 are shown.	36
Table XVI. Forward stepwise procedure applied in the GAM model fitting for both substrate groups: sandy and muddy bottoms.	39
Table XVII. Parameters estimated for the GAM fitted with the sandy bottom samples.	39
Table XVIII. Parameters estimated for the GAM fitted with the muddy bottom samples.	40
Table XIX. Null deviance, residual deviance, explained deviance, AIC and degrees of freedom obtained for each model: sandy and muddy bottom.	41

List of Annexes

Annex I. Illustration of the Prof. Luiz Saldanha Marine Park (PLSMP) implementation period applied to commercial fishing	i
Annex II. Details of the experimental trammel nets sampling campaigns.	ii
Annex III. Field operations undertaken during the experimental trammel nets campaigns.	iii
Annex IV. List of all the variables used during data exploration.	iv
Annex V. Details of the additional campaigns with trammel nets used in model fitting.	v
Annex VI. Data exploration undertaken previously to model fitting.....	vi
Annex VII. R code used for model fitting.....	xi
Annex VIII. Data exploration of the variable 'Temperature'. Results of the Mann Whitney Rank Sum tests for temperature per period and season.....	xii
Annex IX. Contribution of each <i>taxon</i> to the total number of individuals caught in the Prof. Luiz Saldanha Marine Park (PLSMP) area and according to protection level.....	xiv
Annex X. Some specimens caught during the experimental trammel nets campaigns.	xv
Annex XI. Results of the Dunn pairwise comparisons for the Margalef and Shannon-Wiener diversity indices.....	xvi
Annex XII. Results of the Dunn pairwise comparisons for the variables CPUE in number, CPUE in weight, Catch Value, Total length, Weight per individual and Value per individual.	xvii
Annex XIII. Results of the Dunn pairwise comparisons for CPUE in weight according to sector and period.....	xix
Annex XIV. Exploratory data analysis of the CPUE in weight.....	xx
Annex XV. CPUE in number and in weight per species and per sector.	xxiv
Annex XVI. Results of the Dunn pairwise comparisons for the total length of four bony fish species.	xxvii

Annex XVII. Results of the Dunn pairwise comparisons for the CPUE in number of eight fish taxa..... xxviii

Annex XVIII. Graphical analysis for comparison of the CPUE in weight of eight fish species in the Partial and Total protection areas *versus* the Complementary area..... xxx

Annex IX. Results of the SIMPER analysis for the sandy and muddy bottom samples and according to the protection level..... xxxi

Annex XX. NMDS ordination of samples according to substrate..... xxxiii

1. Introduction

The marine environment provides diverse and valuable resources, while at the same time enabling essential environmental functions and processes to take place. For centuries, oceans were regarded as providers of limitless and openly accessible resources and exploitation occurred with little regard for sustainability. Many marine ecosystems are nowadays heavily impacted by human activities. Fisheries relying on high trophic level species have been reported worldwide as undergoing striking declines due to exploitation (Pauly *et al.*, 1998; Pauly and Palomares, 2005). Moreover, 80 percent of the world fish stocks for which assessment information is available are currently overexploited or fully exploited (FAO, 2009). Several policies that led to mismanagement over the years are beyond this fisheries global crisis (Pauly *et al.*, 2002). For instance, the single-species stock assessment has failed in the management of cod given that it grossly underestimated the severity of the population decline and the increasing impacts of fishing during the decline (Walters and Maguire, 1996). Resulting changes in ecological structure coupled with global climate changes and other impacts lead to increasingly less ability of the marine ecosystems to support demand, even as demand continues to increase (Agardy, 2000).

Marine protected areas (MPAs) are increasingly being chosen from the variety of options available to managers, largely because conventional measures have repeatedly failed (Agardy, 1994, Walters and Maguire, 1996). Classical management, based on capture rates and fishing effort relies on large quantities of information and its application to multi-species fisheries is limited (Roberts and Polunin, 1991). Increasingly, marine reserves are being suggested as an appropriate tool to use side by side with classical practices (Pauly *et al.*, 2002; Russ, 2002). Creating a reserve and decreasing the effort are two different strategies that should be engaged to deal with the large uncertainty associated with fisheries management (Clark, 1996; Pauly *et al.*, 2002). Enclosing areas from exploitation diminishes our dependence on precise and real-time information, due to the protection of part of the population from overharvesting (Botsford *et al.*, 1997; Pauly *et al.*, 2002).

Besides the consumptive values of living resources, non-consumptive values are also generated by marine protected areas (Carter, 2003). In addition to consumptive uses, which include commercial and recreational fishing among other harvesting activities, non-extractive uses of the resources are instigated, such as recreational diving, research activities and the protection of nursery grounds (Greenville, 2007).

Few studies have focused on the economic costs and benefits of MPAs. Nevertheless, the majority conclude that under the appropriate conditions, these areas bring benefits that justify their implementation (Alder *et al.*, 2002). Some authors defend that it is not wise to assume that local effects due to marine reserves have consequences on population dynamics on a wide scale and stock predictions based on this should be avoided (Willis *et al.*, 2003b). Nevertheless, it is acknowledged that the local protection of resources has the potential to improve species

resilience and several studies have already shown evidences that these measures can bring benefits to fisheries through the migration of adults, juveniles and larvae (Gell and Roberts, 2003).

Marine protected areas are nowadays one of the most promising solutions to meet conservation and fisheries management in coastal areas, and are being implemented worldwide, not only in areas known as biodiversity 'hotspots', like coral reefs (Schmidt, 1997; Allison *et al.*, 1998), but also in temperate areas, particularly in coastal zones that are vulnerable to human pressure, which is the case of many protected areas in the Mediterranean (Limousin, 1995; Nogueira and Romero, 1995).

In Portugal, the use of marine protected areas as tools to conservation and management is still considered an innovative approach, as only a few marine parks have been implemented, most of them in the Azores (Santos *et al.*, 1995). In mainland Portugal, the Prof. Luiz Saldanha Marine Park (PLSMP) was one of the first marine protected areas. Its main objective is the conservation of coastal biodiversity, although it is also intend to be a tool for fisheries management (Gonçalves *et al.*, 2003).

Scientific research that took place in this coastal region revealed that is an area with particularly high biodiversity. Henriques *et al.* (1999) obtained results on the local fish assemblages that revealed a level of biodiversity that is remarkably high when compared to the values reported for similar latitudes in the north-eastern Atlantic and the Mediterranean. Moreover this area is known to provide representative habitats for a high proportion of the total shallow-water fish and invertebrate fauna of the Portuguese mainland shores. These facts emphasize the extreme importance of conservation measures in this region (Henriques *et al.*, 1999; Gonçalves *et al.*, 2003).

The aim of the present work was to assess the effects of the Prof. Luiz Saldanha Marine Park management measures on the marine community. For this, a qualitative and quantitative assessment of the fauna occurring on soft bottoms under different protection levels was undertaken through trammel net experimental fishing. Given the recent implementation of this marine park, it was even more fundamental to obtain scientific information concerning the changes occurring in the marine community.

1.1. Study area

Located in western Portugal, the Arrábida coast is recognized for its ecological importance and high marine biodiversity (Henriques *et al.*, 1999; Gonçalves *et al.*, 2003). Protected from the dominant northern winds, the coastline is characterized by high rocky cliffs alternated by sheltered bays (Ribeiro, 2004). In most of the area under 15 - 20 m deep, the rocky bottoms are replaced by soft bottoms.

The coastal section from Portinho da Arrábida to the Sesimbra bay is characterized by a narrow rocky band that extends to a maximum of 20 m deep. The rocky substrate is delimited by sandy bottoms that can go up to 100 m deep in the adjacent area of the marine park. Protected bays with intertidal boulders as well as sand banks are also found in this region. From the Sesimbra bay to west, besides the shallow rocky bottom and sandy areas, patches of subsurface rock can also be found (Gonçalves *et al.*, 2003).

This diversity of habitats gives place to more than 1000 species of marine fauna and flora already described for the region (Saldanha, 1974; Calado and Gaspar, 1995; Henriques *et al.*, 1999; Almada *et al.*, 2000; Gonçalves *et al.*, 2003).

It is worth pointing out that this coast is located near the large metropolitan area of Lisbon, which makes it highly susceptible to intense pressures from leisure and economic activities. Some of these human activities such as fisheries and tourism, have high local importance, both socially and economically (Gonçalves *et al.*, 2003).

The need to couple the area usage with conservation and management concerns led to the conception of legal regulation, with the establishment of the Professor Luiz Saldanha Marine Park (PLSMP; also known as 'Arrábida Marine Park') in 1998. Its implementation aims to protect coastal ecosystems and also promote the sustainability of fisheries resources (Gonçalves *et al.*, 2003; Reis *et al.*, 2004). This marine protected area is included in the Arrábida Natural Park and comprises an area with 52 km², which stretches over 38 km of coast and reaches depths up to 100 meters (Figure 1).

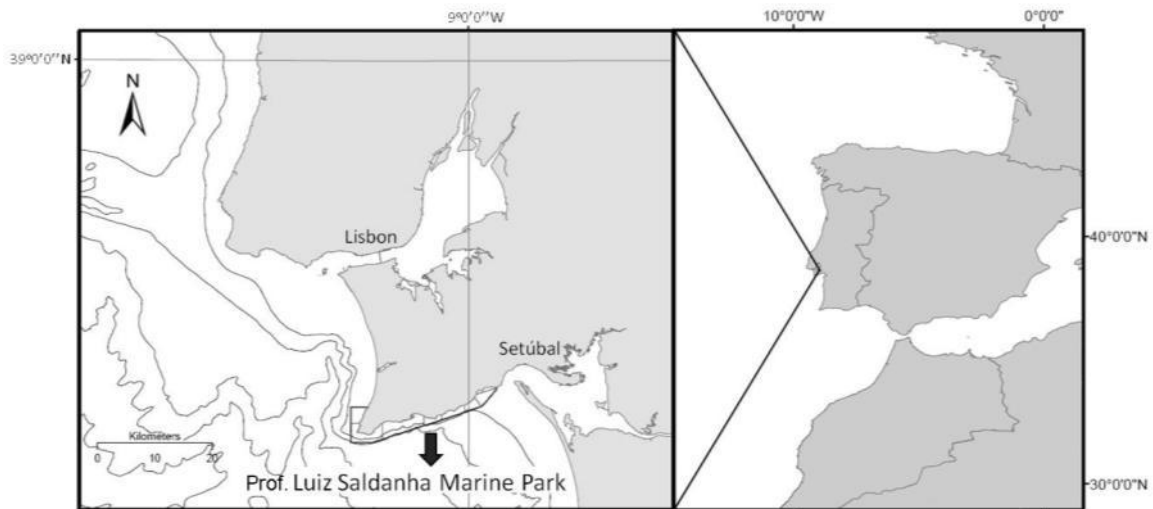


Figure 1. Location of the Prof. Luiz Saldanha Marine Park (PLSMP) on the west coast of Portugal.

It was only in August 2005 that the usage of the PLSMP area was regulated. The official legislation of the Ministers Council Resolution No. 141/2005, 23rd August 2005, divided the region in three different protection areas – Complementary, Partial and Total (Figure 2) – which differ in the level of restrictions imposed. The main restrictions of each area are: Total – human

activities not allowed; Partial – some fishing allowed with some gears (octopus traps, jigging, handline); Complementary – fishing allowed but restricted to vessels under 7m length and licensed to operate within the marine park (Resolução do Conselho de Ministros, 2005). The complete descriptions of each area and its restrictions concerning commercial fishing are given in Table I. In relation to recreational fishing, angling is only permitted in the Complementary area and spearfishing is prohibited in all the marine park area. The establishment of this regulation attempts to harmonize, on the one hand, the region's biodiversity and ecological importance, and on the other, the important socio-economical activities that take place there.

The restrictions related to commercial fishing were implemented gradually during the period between 2006 to 2009: after the establishment of the Complementary protection level in all the marine park area in January 2006, two areas with Partial protection were implemented in August 2006, and in August 2007 four more were created. In August 2008, one Partial protection area was upgraded to Total protection. The last implementation step occurred in August 2009, with enlargement of the previous Total protection area. A detailed illustration of each implementation step is shown in the Annex I.

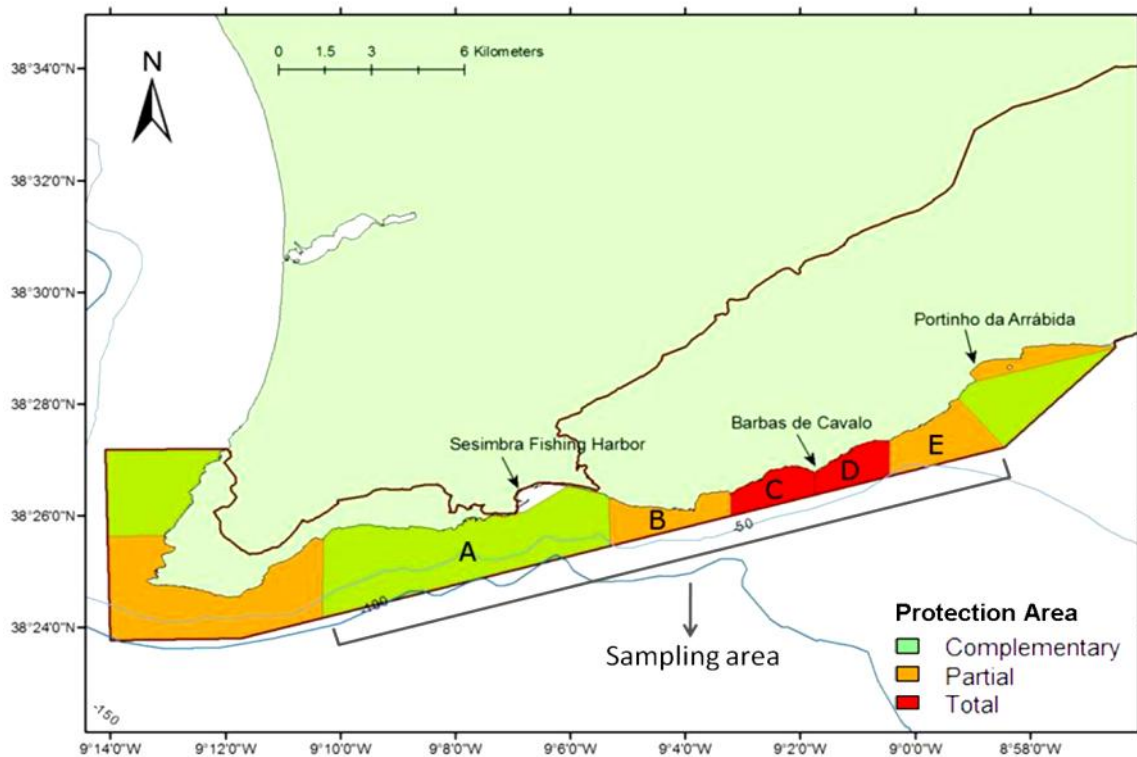


Figure 2. The Prof. Luiz Saldanha Marine Park (PLSMP) and its three different protection levels. The five different sections that compose the experimental trammel nets sampling area are shown (A, B, C, D and E). Each section undertook a different evolution during the implementation period (January 2006 – August 2009; See Annex I).

Table I. Regulations implemented (Ministers Council Resolution No. 141/2005, 23rd August 2005) in the Prof. Luiz Saldanha Marine Park regarding commercial fishing.

Area	Fishing Gear	Management Regulations
All PLSMP Area	All	Fishing allowed only to boats under 7m length and licensed to operate within the marine park
	Purse seine	Not allowed
	Trawling	Not allowed
Complementary Protection Area	Handline and Jigging	Allowed
	Octopus Traps	Allowed (minimum distance from shore line: 200 m)
	Longline	Allowed
	Trammel and Gill nets	Allowed (minimum distance from shore line: 1/4 nm)
Partial Protection Area	Handline and Jigging	Allowed (minimum distance from shore line: 200 m)
	Octopus Traps	Allowed (minimum distance from shore line: 200 m)
	Longline	Not allowed
	Trammel and Gill nets	Not allowed
Total Protection Area	All	Human activities not allowed Boats are only allowed to navigate at more than 1/4 nm from shore line

2. Material and Methods

2.1. Sampling method

The data for this study was obtained during the course of the LIFE-BIOMARES Project (LIFE06 NAT/ P/000192). This project was funded by the European Commission Program LIFE-Nature, with co-financing from SECIL Company (Companhia Geral de Cal e Cimento S.A.).

Since 2007, CCMAR (Centre of Marine Sciences, Algarve) researchers involved in Task D5 (fisheries indicators monitoring) of the LIFE-BIOMARES project have been carrying out experimental fishing surveys on a seasonal basis in the PLSMP area. The sampling has been taking place in the three different PLSMP protection levels, on both sandy and muddy bottoms.

The experimental fishing gear used consisted of a trammel net similar to the type used by the local fishermen (Sesimbra), and for this purpose a local fisherman was contracted to make the trammel nets. The experimental net was made of monofilament and consisted of an inner mesh panel with 100mm stretched mesh and two outer panels with 600mm stretched mesh. The inner net monofilament mesh is of 0.30mm in diameter while that of the outer net is 0.50mm. The net was constructed to have 50 inner and 3 outer meshes in height, with a total height of 1.60m.

Table II. Specifications of the trammel nets used during the scientific surveys.

Twine type	Inner	Monofilament
	Outer	Monofilament
Twine Diameter (mm)	Inner	0.30
	Outer	0.50
Mesh Size (mm)	Inner	100
	Outer	600
Nº Meshes Depth	Inner	50
	Outer	3
Net Height (m)		1.6
Net Length (m)		50
Float diameter (cm) (upper rope)		5
Lead weight (g) (lower rope)		30
Distance between floats (m)		6
Distance between leads (m)		2

Each net had a total of 50m in length and each set consisted of 10 nets. At each location, monitoring was carried out with one set, consisting of a total of 500m of trammel net. Normal fishing practices were followed, leaving the Sesimbra fishing harbour before dawn on board of a typical local fishing boat prepared to operate with trammel nets (fibre glass boat with pilot house; overall length: 6.98m). The nets were set around noon and hauling took place early in the morning just after sunrise. The soak time varied between 20 to 24 hours. This standardized fishing procedure enables Catch per Unit Effort (CPUE) – to be defined by a unit effort of 500m of trammel net, and a soak time of approximately 24 hours. The position of each set was tracked with a handheld Garmin 60CSx GPS, and the depth recorded with the fishing boat's Garmin 128 echo sounder. Temperature data was recorded in Portinho Bay, where the Biomares project data logger was located. Data corresponds to the water temperature at approximately 2m deep and it was recorded every two hours, so the daily average was used.

In each sampling survey, the crew was composed by two to three researchers and an experienced local fisherman, contracted to carry out the fishing operations. The researchers separated, identified and measured the catches as they came on board. The catch was sorted according to species, and all fish, crustaceans and molluscs were measured (total length, carapace length and mantle length, respectively) to the nearest mm and released afterwards when alive ('catch and release' practice). In case of difficulty in the species identification, the specimens were collected in plastic bags, stored frozen and transported to the University of Algarve (CCMAR), where they were analyzed in the laboratory. The fish identification was based on the following bibliography: Whitehead *et al.* (1986), Fischer *et al.* (1987), and Arias and Drake (1990). The invertebrates were identified using Zariquiey-Álvarez (1968), Falciai and Minervini (1995), and Macedo *et al.* (1999). Biomass of the specimens caught (fishes, cephalopods, crustaceans with commercial value) was estimated using length-weight relations described in the literature (Le Foll *et al.*, 1993; Gonçalves *et al.*, 1997; Morato *et al.*, 2001; Stergiou and Moutopoulos, 2001; Santos *et al.*, 2002; Borges *et al.*, 2003; Filiz and Bilge, 2004; Mendes *et al.*, 2004; Veiga *et al.*, 2009; Froese and Pauly, 2010). The commercial value of each specimen (target species) was estimated by multiplying its estimated weight by the species mean commercial value recorded in Sesimbra market in 2009 (DGPA, 2010).

The experimental fishing trials with trammel nets were carried out on a seasonal basis. The sampling locations were chosen according to the different PLSMP protection levels and two different depths / habitat types were sampled, namely sandy ($\approx 12 - 20$ m deep) and muddy bottoms ($\approx 35 - 45$ m deep). Figure 3 shows the sampling locations and the characteristics of each location are given in Table III.

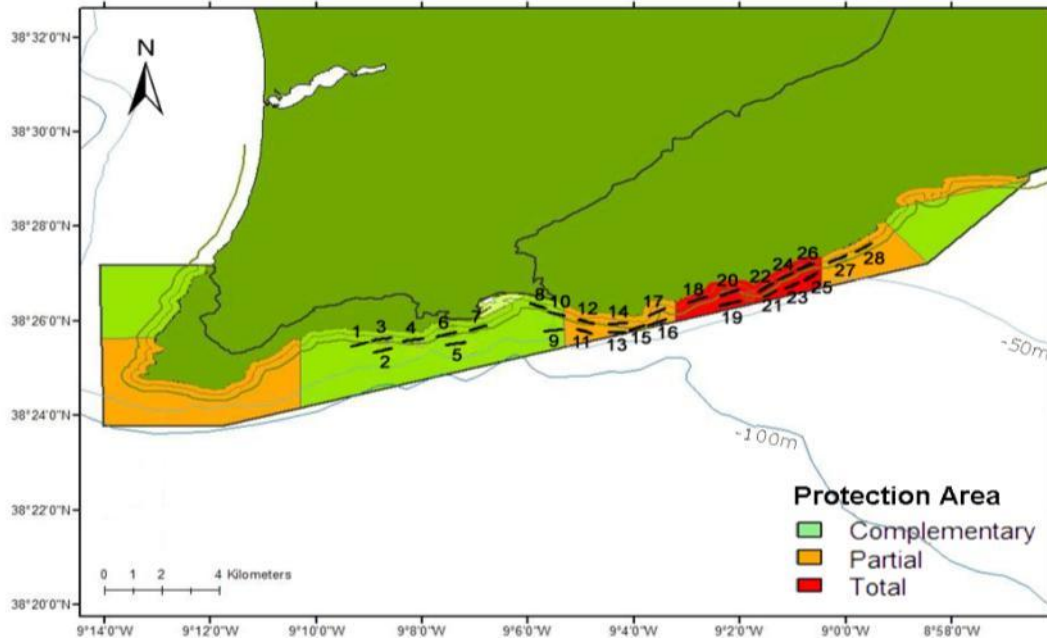


Figure 3. The Prof. Luiz Saldanha Marine Park (PLSMP) map with respective protection area delimitations and the location of the experimental trammel net sets.

Table III. Characteristics of the sites sampled during the experimental trammel nets surveys.

Site number	Site name	Substrate	Section	Final Protection Level	Depth Range (m)
1	Praia do Inferno Dentro	Sand	A	Complementary	12.8 - 14.6
2	Mijona Fora	Mud	A	Complementary	33.8 - 36.6
3	Mijona Dentro	Sand	A	Complementary	11.0 - 13.7
4	Morro Dentro	Sand	A	Complementary	12.0 - 12.8
5	Mula Fora	Mud	A	Complementary	33.8 - 36.6
6	Mula Dentro	Sand	A	Complementary	14.6 - 15.5
7	Farol Dentro	Sand	A	Complementary	14.0 - 14.6
8	Califórnia Dentro	Sand	A	Complementary	11.9 - 12.8
9	Caneiro Fora	Mud	A	Complementary	37.5 - 38.4
10	Caneiro Dentro	Sand	A	Complementary	12.8 - 13.0
11	Pedra Nova Fora	Mud	B	Partial	37.5 - 38.4
12	Pedra Nova Dentro	Sand	B	Partial	14.0 - 14.6
13	Guincho Fora	Mud	B	Partial	37.5 - 41.1
14	Guincho Dentro	Sand	B	Partial	14.6 - 16.5
15	Ares Fora	Mud	B	Partial	37.0 - 37.5
16	Armação Fora	Mud	B	Partial	36.6 - 39.3
17	Armação Dentro	Sand	B	Partial	14.0 - 14.6
18	Cozinhadouro Dentro	Sand	C	Total	13.7 - 14.6
19	Derrocada Fora	Mud	C	Total	35.0 - 36.6
20	Derrocada Dentro	Sand	C	Total	12.8 - 13.7
21	Cabo Fora	Mud	D	Total	41.0 - 43.0

Site number	Site name	Substrate	Section	Final Protection Level	Depth Range (m)
22	Barbas de Cavalo Dentro	Sand	D	Total	13.7 - 15.5
23	Barbas de Cavalo Fora	Mud	D	Total	38.4 - 45.0
24	Batista Dentro	Sand	D	Total	15.0 - 15.5
25	Risco Fora	Mud	D	Total	45.0 - 45.7
26	Risco Dentro	Sand	D	Total	13.7 - 20.0
27	Pinheirinhos Dentro	Sand	E	Partial	14.0 - 14.6
28	Três Irmãs Dentro	Sand	E	Partial	16.5 - 19.2

A total of six sampling campaigns were undertaken during the period from December 2007 to April 2010, resulting in 43 days in the field and a total of 107 fishing trials. In Figure 4, all the sampling points (middle point of each 500m long net set) are shown.

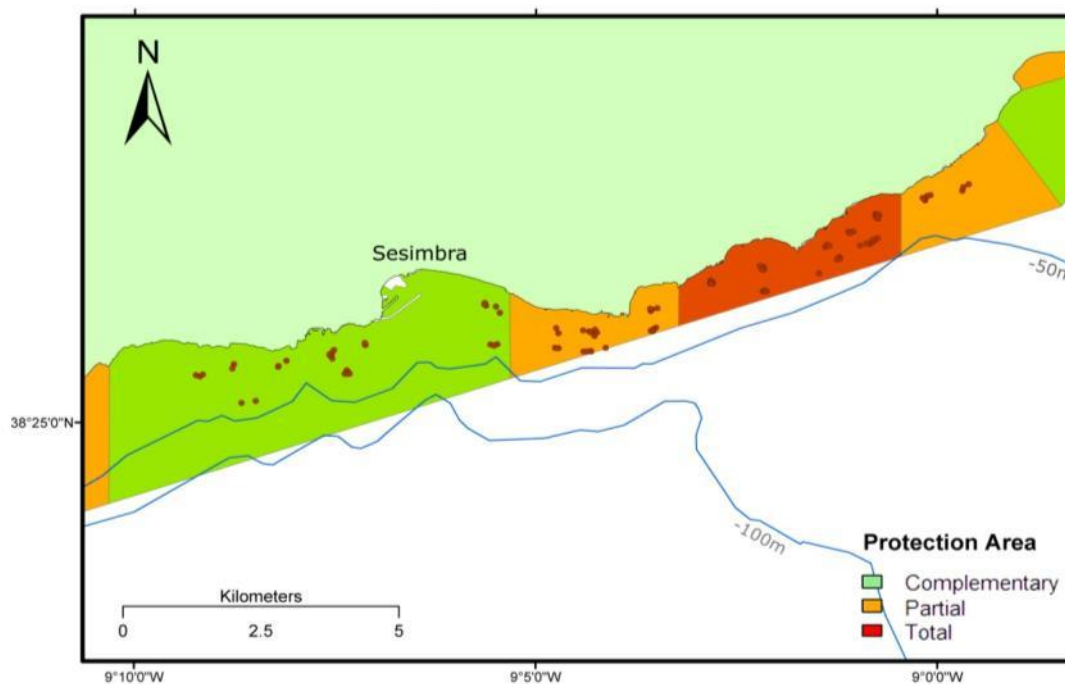


Figure 4. Map of the sampling area in the Prof. Luiz Saldanha Marine Park. All the sampling points (middle point of each 500m long net set) are shown (red dots).

2.2. Data treatment

The data obtained during field sampling was compiled in two EXCEL databases, one with the biological data and another with environmental and geographical information for each sample.

Due to problems arising during some surveys, such as extreme abundances of macroalgae on the net, strong currents or even nets that were manipulated by others (cable found cut off; net found misplaced), several fishing trials were unsuccessful and thus, they were considered outliers and excluded from the data analysis. As a result of this selection, the analyzed sample

was reduced from 107 fishing trials to 98: 27 in the Complementary protection area (18 on sandy bottom, 9 on muddy bottom), 47 in the Partial protection area (32 on sandy bottom, 15 on muddy bottom), and 24 in the Total protection area (14 on sandy bottom, 10 on muddy bottom). Annex II shows the size of each sample according to the several factors and contains detailed information of each campaign. Some photos of the field operations undertaken during the campaigns are given in Annex III.

Concerning the small pelagic species, one important preliminary step was applied to the data. Namely, the species *Boops boops*, *Sardina pilchardus*, *Scomber* spp. and *Trachurus* spp., were caught (often in high abundances due to schooling behaviour) but not considered when quantifying the catch, either in number of individuals, weight or value. These species were only accounted for the list of species for each sample. The exclusion was made due to the natural behaviour of these species, known to show high mobility and low habitat fidelity (Fréon and Misund, 1999), which makes them less meaningful in habitat characterization.

2.2.1. Quantitative analysis

For each species, the following parameters were calculated:

- Absolute (number of individuals) and relative (%N) abundance;
- Absolute (Kg) and relative (%W) weight;
- Catch per unit effort in number (CPUE Nr.): number of individuals caught per unit effort - 1000m 24h (original data - 500m 24h - multiplied by two);
- Catch per unit effort in weight (CPUE Kg): kilograms (Kg) caught per unit effort - 1000m 24h (original data - 500m 24h - multiplied by two);
- Frequency of Occurrence (%FO): expressed in percentage and is calculated by the following formula:

$$\%FO = (C_t / C_i) \times 100 \quad (1)$$

in which C_t is the number of samples with presence of species t and C_i is the total number of samples;

- Categories of frequency of occurrence: the frequency of occurrence expressed in percentage was grouped in categories as follows: occasional species - O: $\%FO < 15$; common species - C: $15 \leq \%FO < 40$; frequent species - F: $40 \leq \%FO < 70$, highly frequent species - HF: $\%FO \geq 70$. These four categories were chosen taking into account a preliminary data exploration to check occurrence, distribution and abundance of the sampled species.
- Index of Relative Importance (IRI): This index was developed by Pinkas *et al.* (1971) and it takes into account the proportion of each species in weight and in abundance, as well as the frequency of occurrence. It is calculated by the following formula:

$$IRI = (\%N + \%W) \times \%FO \quad (2)$$

in which %N, %W and %FO are respectively, the relative abundance, relative weight and frequency of occurrence.

2.2.2. Diversity analysis

The use of diversity indices is a common method for comparing biodiversity between different communities and in the analysis of temporal trends. They are also commonly seen as indicators of ecological welfare (Magurran, 1988).

The Shannon-Wiener and Margalef diversity indices are species richness measures (Magurran, 1988). They were calculated to analyze biodiversity in the present study and for that, the following formulas were used:

- Shannon-Wiener diversity index (H') (Ludwig and Reynolds, 1988):

$$H' = -\sum_i p_i \log(p_i) \quad (3)$$

The parameter p_i is the proportion of individuals of species i . It is based on the proportion of species abundances and it takes into account the evenness and species richness.

- Margalef index (R) (Margalef, 1958 in Ludwig and Reynolds, 1988):

$$R = (S-1) / \log N \quad (4)$$

In this equation, S is the total number of species and N is the total number of individuals. It is a measure of the number of species present within a given number of individuals (Magurran, 1988).

2.2.3. Spatial and temporal analysis

To analyze spacio-temporal trends in the catch data, the samples were grouped in spatial and temporal categories. Preliminary data exploration was undertaken to analyze general trends. Annex IV contains a list of all the variables taken into account for data exploration. Concerning spatial classification, data were grouped according to protection level and according to sector. The protection level corresponds to the degree of restrictions in each area (Complementary, Partial, Total; Table I). In the 'sector' classification, four categories were considered, with the purpose of distinguishing the two sections under Partial protection (sections B and E; Figure 2). Ordered from west to east, the four sectors are: Complementary (section A), Partial West (Partial W; section B), Total (sections C and D), and Partial East (Partial E; section E) (sections: Figure 2). Unlike the protection level, this spatial classification is stable along time. The protection level was implemented gradually and two of the three years sampled were during the implementation period. The sequence of implementation steps is shown in Annex I. Concerning temporal classification, data were grouped per year and then per period. The 'Year' classification considers the number of years elapsed since the beginning of the marine park implementation (23rd August 2005). Three years were analyzed: Year 3 (23rd Aug. 2007 - 23rd Aug. 2008), Year 4 (23rd Aug. 2008 - 23rd Aug. 2009), and Year 5 (23rd Aug. 2009 - 23rd Aug.

2010). It was only in the beginning of Year 5 (23rd August 2009) that the regulation implementation was concluded and the marine park was finally established with its definitive design (See Annex I). In this sense, two different periods were considered: Years 3-4 and Year 5. This classification enables the separation of the implementation period (Years 3-4) from the period when the marine park is already with its final design (Year 5).

Given the non-normal distribution of the obtained data, the statistical approach was to use non-parametric tests to compare the medians of different groups.

The applied non-parametric test was the Kruskal-Wallis ANOVA (Kruskal and Wallis, 1952 *in* Zar, 1996). It calculates the statistic test value through the following formula:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - 3(N+1) \quad (5)$$

in which, N is the total number of observations in all k groups and R_i is the sum of categories with n_i observations in the group i (Zar, 1996). When the Kruskal-Wallis ANOVA revealed significant differences, the Dunn method for pairwise multiple comparisons (Dunn, 1964 *in* Zar, 1996) was applied to distinguish which groups were significantly different.

Whenever only two groups were compared, the Mann-Whitney Rank Sum test was applied (Mann and Whitney, 1947 *in* Zar, 1996). It compares medians and its statistic value is calculated by:

$$U = n_1 + n_2 + \frac{n_1(n_1 + 1)}{2} - R_1 \quad (6)$$

In this expression, n_1 and n_2 are respectively, the number of observations in sample 1 and in sample 2. R_1 is the rank sum of the observations in sample 1.

For the application of these tests, the significance level was considered to be $\alpha=0.05$ (statistical significance: $p<0.05$). The tests were run in the software SigmaStat version 3.5.

For the graphical representation of medians and data dispersion, boxplots are presented. The box contains information on the 25th (Q25) percentile, the 75th percentile (Q75) (the lower and upper limits of the box, respectively), and the median (50th percentile - Q50 - band near the middle of the box) (Tukey, 1977). The limits of the whiskers in the shown boxplots represent the lowest datum still within the interval 1.5 x interquartile range (IQR) of the lower quartile, and the highest datum still within 1.5 x interquartile range of the upper quartile. Observations outside this range are considered outliers and are shown as light dots. Another detail is that the width of the boxes is proportional to the number of observations per class.

2.2.4. Multivariate analysis

Multivariate analysis was performed with the species composition data that were collected in the experimental trammel net campaigns. This analysis method compares samples based on the co-occurrence of species, which enables the estimation of similarity coefficients between each pair of samples. One of the coefficients commonly used in ecology is the Bray-Curtis similarity coefficient (Bray and Curtis, 1957 *in* Clarke and Warwick, 2001), which is described by the following equation:

$$S_{jk} = 100 \frac{\sum_{i=1}^p 2\min(y_{ij}, y_{ik})}{\sum_{i=1}^p (y_{ij} + y_{ik})} \quad (7)$$

where S_{jk} is the similarity coefficient between samples j and k and y_{ij} represents the entry value in the i th row and j th column of the abundance data matrix for species i in the sample j . Similarly, y_{ik} is the count for the species i in the sample k (Clarke and Warwick, 2001).

One-way ANOSIM tests were applied using the Bray-Curtis similarity matrices with transformed data (fourth root) to test for differences between the three protection levels and the two substrates/depths. The statistic value for the ANOSIM tests is calculated through the following formula:

$$R = \frac{(\bar{r}_B - \bar{r}_W)}{\frac{1}{2}[n(n-1)/2]} \quad (8)$$

In this formula, n is the total number of samples, \bar{r}_B represents the average of rank similarities arising from all pairs of replicates between different sites, and \bar{r}_W refers to the average of all rank similarities among replicates within sites. In this sense, when the similarity between replicates is higher, the R value is closer to 1 (Clarke and Warwick, 2001). The significance level taken into account for the ANOSIM tests was $\alpha=0.01$ (statistical significance: $p<0.01$).

The Bray-Curtis similarity coefficients were also used in the NMDS (nonmetric multidimensional scaling) ordination of samples, through the application of the non-metric procedure developed by Kruskal (1964 *in* Clarke and Warwick, 2001). This method generates a non-metric graphical representation that disposes the sample units in space, generally in two dimensions, in a way that the distances between samples correspond to their degree of dissimilarity (Clarke and Warwick, 2001).

SIMPER (similarity percentages) analyses were applied to distinguish which species contribute the most for the differences between groups. This analysis is described by the following equation:

$$\delta_{jk}(i) = 100 \cdot |y_{ij} - y_{ik}| / \sum_{i=1}^p (y_{ij} + y_{ik}) \quad (9)$$

where $\delta_{jk}(i)$ corresponds to the contribution of species i for the dissimilarity between samples j and k (Clarke and Warwick, 2001).

All these four analyses (Bray-Curtis similarity coefficient, ANOSIM, MDS ordination, and SIMPER) were carried out with the software PRIMER (v6.1.5; Primer-E Ltd).

2.2.5. Model fitting

Statistical models are tools for prediction and forecasting based on obtained data (Akaike, 1974). In order to study the relation of the CPUE in weight (unit effort: 500m 24h) with the different explanatory variables, generalized additive models (GAMs) were used.

The option of using CPUE in weight was considered the most appropriate to analyze the catch, as it retains information of both the abundance and fish size. GAMs were the chosen modeling approach applied to the data (Hastie and Tibshirani, 1987, 1990; Guisan and Zimmermann, 2000; Wood and Augustin, 2002). Linear models were applied in a preliminary analysis, but the results were not satisfactory, given that a non-linear pattern was obtained in the residuals, indicating that model structure was possibly inappropriate (Zuur *et al.*, 2007, 2009).

GAMs are a regression technique that can be used with data that violates the principles of normality and homogeneity of variance (Zuur *et al.*, 2007, 2009). These problems can be overcome using the appropriate distribution and model structure. This method is also suitable to deal with non-linear relationships between response and predictor variables (Zuur *et al.*, 2007, 2009).

As semi-parametric extensions of the linear model, GAMs apply non-parametric smoothers to each predictor and additively calculate the component response. This can be expressed by

$$g(E(Y)) = \alpha + s_1(X_{1i}) + s_2(X_{2i}) + s_p(X_{pi}) \quad (10)$$

where g is the link function that relates the linear predictor with the expected value of the response variable Y , X_{pi} is a predictor variable and s_p is a smoothing function (Wood and Augustin, 2002). GAMs offer the possibility of some predictors to be modeled non-parametrically in addition to linear and polynomial terms for other predictors. The probability distribution of the response variable must still be specified, and in this respect, a GAM is parametric (Guisan *et al.*, 2002).

The Gaussian distribution was chosen for the CPUE in weight analysis, given that it is appropriate to use with a continuous variable (Zuur *et al.*, 2009), which is the case of our response variable. Of all the possible explanatory variables (See Annex IV), only a few were chosen for model fitting (Table IV). For instance, all variables concerning management (See Annex IV) describe the spatial categories of the marine park, and only one could be included to avoid collinearity. The protection level is the explanatory variable related to management that was included in this analysis, as both sector and section are spatial categories that do not take

into account the implementation steps. The examined temporal factor was the period, and two periods were considered: Years 3-4 (Aug. 2007 - Aug. 2009: implementation period) and Year 5 (Aug. 2009 - 23rd Aug. 2010: after full implementation of the marine park). Water temperature and depth were the environmental variables taken into account.

Given that collinearity in the predictors is a crucial problem to avoid in GAMs (Zuur *et al.*, 2009), whenever two explanatory variables exhibit high collinearity, one should be excluded from the model. In this sense, an exploratory analysis was applied specifically to detect collinearity between variables (See Annex VI). Outliers both in the response and explanatory variables are also something to prevent, and this aspect was as well analyzed through data exploration (See Annex VI). Given that one of the examined explanatory variables was water temperature, it was important to sample in a wide range of temperature values. For this, data of all four seasons was obtained, and thus, one summer campaign (summer 2008) and one winter campaign (winter 2009) were also included, besides the already mentioned six sampling periods (See Annex II). Details of these two additional campaigns are shown in Annex V. Overall, a total of 111 fishing trials were included for this analysis: 75 in sandy bottom and 36 in muddy bottom (sample size per protection level: sandy bottom - Complementary: 23, Partial: 37, Total: 15; muddy bottom - Complementary: 10, Partial: 17, Total: 9; sample size per period: sandy bottom - Years 3-4: 49, Year 5: 26; muddy bottom - Years 3-4: 28, Year 5: 8). Sampling in only two depth strata (sandy bottom: 12 – 20m deep; muddy bottom: 35 – 45m deep) became a problem for using depth as a predictor in the sense that, because no sampling was undertaken at intermediate depths, the muddy bottom group (lower number of observations) constituted a cluster of outliers (See Annex VI). The only way to overcome this dilemma was to analyze the samples of sandy and muddy bottom separately and obtain two models (transformations of the variable depth were not successful in avoiding the outliers - See Annex VI), one for the prediction of CPUE in each bottom type. In the same sense, it was noted that the Autumn 2009 campaign constituted a group of temperature outliers (See Annex VI). This was due to the fact that during this sampling period, water temperature was between 18-19°C while all the other observations corresponded to temperatures from 13.2 to 16.6°C. This was mainly a problem in the muddy bottom group, for which total sample size was small (n=43). Moreover, only seven observations were obtained in this campaign for this substrate, and thus, the final option was to exclude them from the analysis (muddy bottom final sample size: n=36).

Table IV. List of variables considered for model fitting and their characteristics.

Category	Variable	Type	Unit	Abbreviation	Comments
Ecological	Catch per Unit Effort	Continuous	Kg.500m ⁻¹	CPUE	Response variable
Environmental	Temperature	Continuous	°C	Temp	Water temperature (1)
Environmental	Depth	Continuous	meters	Depth	-
Management	Protection Level	Nominal	-	ProtLevel	-
Temporal	Period	Nominal	-	Period	Before and after the full implementation of the PLSMP

(1) - Water temperature measured at ≈2m deep.

All the model fitting process and related analysis were undertaken using the statistical software R (v2.10.1, R Development Core Team 2009, www.r-project.org; Ihaka and Gentleman, 1996).

The Gaussian GAM model with identity link function was fitted using the *mgcv* package (Wood and Augustin, 2002). The smoothing curves were fitted to the data through the cubic regression splines technique.

The model fitting was undertaken using a forward stepwise selection based on the AIC (Akaike Information Criteria; Akaike, 1973). The R code used for model fitting is shown in Annex VII. Starting with models with only one explanatory variable, the term with the lowest AIC was selected. These initial models were also used to compare the amount of the response variable variance that each variable on its own was able to explain. In the model selection process, the model with the lowest AIC was then refitted with the addition of the remaining variables, one each time. The terms to include were thus selected through this stepwise procedure. In the end, the model with lowest AIC and including only significant variables (t-test: $\Pr(>|t|) < 0.05$; F test: $p < 0.05$) was considered the optimal model.

The final procedure was the model validation, which consisted in two steps: the assessment of normality and homogeneity of the residuals; and the analysis of independence between samples. The validation process was carried out through graphical methods (Zuur *et al.*, 2009).

3. Results

3.1. Sample representativity

To evaluate if the sample size was adequate for the qualitative representation of the composition of the community, a species accumulation curve was obtained (Figure 5). It is possible to observe that the curve reaches a stabilized level after 63 sampling events (72 species). With the 85th and 86th observations, two more species were added to the species count, which suggests that some rare species might have not been sampled. Still, the sample size (total: 98 samples) was considered representative of the community, as the probability of occurrence of new species is considered to be low.

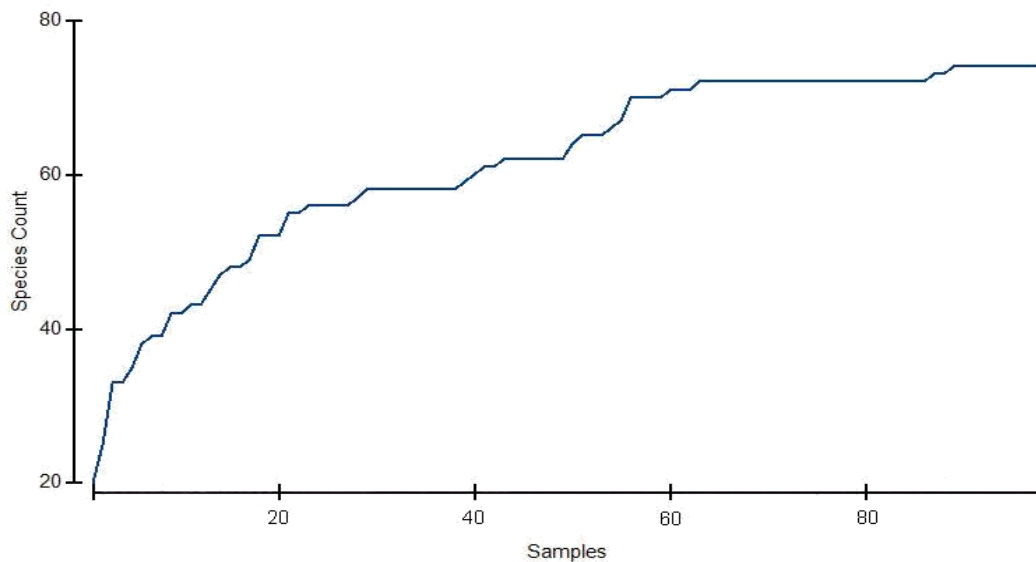


Figure 5. Species accumulation curve in relation to the cumulative number of samples (trammel net sets).

3.2. Temperature analysis

Water temperature variations recorded during sampling campaigns are shown according to period (Years 3-4, Year 5). During the period after the marine park full implementation - Year 5 - the recorded temperatures were higher. The applied Mann-Whitney Rank Sum tests (See Annex VIII) confirms that the observed differences are significant ($p < 0.05$). A scatterplot with all temperature observations during campaigns and a graph with the daily temperatures time series recorded for Arrábida are shown in Annex VIII.

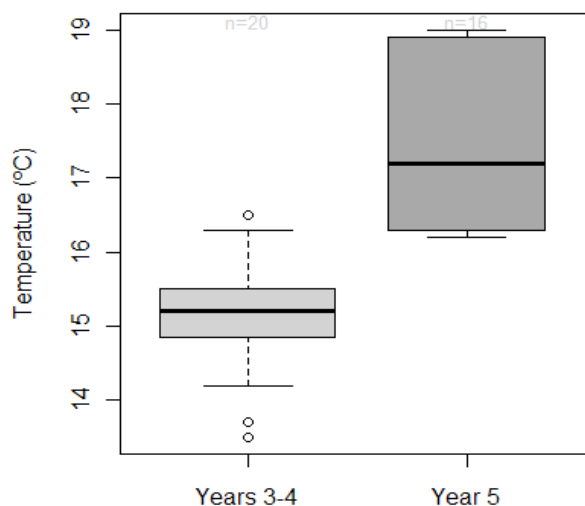


Figure 6. Boxplot of temperature (measurements during spring and autumn sampling campaigns) by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).

3.3. Biological parameters

During the six sampling campaigns, involving 98 fishing trials, a total of 7939 individuals were caught (5918 fishes; 5342 fishes excluding small pelagics; 408 target invertebrates; 1613 non-target invertebrates). The total catch in weight was estimated to be 2054.8 Kg (1721.6 Kg fish; 1653.5 Kg fish excluding small pelagics; 330.2 Kg target invertebrates). In Annex IX, it is possible to see that fishes are the group that account for most of the catch (more than 70% in all the three protection levels). Some photos that illustrate the diversity of fishes caught are shown in Annex X. Soleidae was the most abundant family in the catch, followed by Triglidae. Tables V and VI contain the lists of the sampled species: Table V includes fishes and target invertebrates; and non-target invertebrates are listed in Table VI. A total of 126 species were caught: 76 fish species (64 bony fishes, of which, 6 species of small pelagics; and 12 elasmobranchs), and 50 invertebrate species (16 crustaceans, of which, 3 target species; 3 cephalopods; 13 echinoderms; 7 bivalves; 6 gastropods; 3 cnidarians; 1 polyplacophore; 1 tunicate). Bony fishes make up 87% of the total catch in number and contribute with 62% of total weight. Elasmobranchs, although only contributing to 9% in number, make up 22% of the total weight. It is worth mentioning that among this group, several species have conservation status that gives rise to some concerns: *Raja clavata* and *Raja brachyura* are listed as 'Near

Threatened'; *Mustelus mustelus* is classified as 'Vulnerable'; *Rostroraja alba* and *Raja undulata* are considered 'Endangered' (IUCN, 2010).

The thornback skate *R. clavata* was the most abundant elasmobranch species (115 ind.), while the sole *Microchirus azevia* was the most caught (895 ind.) bony fish (Table V). These are also the top two species concerning the IRI (index of relative importance; Table V). Concerning target invertebrates, the most common was the cuttlefish *Sepia officinalis* (119 ind.), while the sea urchin *Sphaerechinus granularis* (730 ind.) was the non-target invertebrate that was caught most often (Table VI).

Table V. Commercial fish and invertebrate species caught in the trammel net surveys (FO: frequency of occurrence; IRI: index of relative importance; C.S.: conservation status). Species ordered by IRI.

Taxon / Species	n	Weight (Kg)	% N	% W	CPUE Nr.	CPUE Kg	% FO	FO	IRI	C.S.	Obs.
Pisces	5918	1721.6	96.21	83.79	120.78	35.14	100	HF	17999.7		
Actinopterygii	5358	1270.4	87.11	61.83	109.35	25.93	100	HF	14893.3		
<i>Microchirus azevia</i>	895	178.8	14.55	8.70	18.27	3.65	68	F	1589.6	a2	(1), T
<i>Halobatrachus didactylus</i>	494	205.9	8.03	10.02	10.08	4.20	66	F	1197.2		T
<i>Merluccius merluccius</i>	445	157.0	7.23	7.64	9.08	3.20	72	HF	1077.8	a4	(1), T
<i>Solea senegalensis</i>	449	160.7	7.30	7.82	9.16	3.28	70	HF	1064.5	a2	T
<i>Chelidonichthys obscurus</i>	399	48.1	6.49	2.34	8.14	0.98	81	HF	711.5		T
<i>Chelidonichthys lucerna</i>	221	62.6	3.59	3.05	4.51	1.28	62	F	413.2		T
<i>Trigloporus lastoviza</i>	256	43.2	4.16	2.10	5.22	0.88	56	F	351.7		NT
<i>Pagellus acarne</i>	243	22.4	3.95	1.09	4.96	0.46	58	F	293.3	a2	T
<i>Scomber japonicus</i>	339	39.4	5.51	1.92	6.92	0.80	35	C	257.8	a2	T
<i>Bothus podas</i>	309	38.3	5.02	1.87	6.31	0.78	35	C	239.0		T
<i>Balistes capriscus</i>	122	71.5	1.98	3.48	2.49	1.46	37	C	200.8		T
<i>Trisopterus luscus</i>	137	22.2	2.23	1.08	2.80	0.45	38	C	124.9	a2	T
<i>Spondylisoma cantharus</i>	78	20.1	1.27	0.98	1.59	0.41	43	F	96.2	a2	T
<i>Solea solea</i>	112	46.2	1.82	2.25	2.29	0.94	21	C	87.2	a2	T
<i>Mullus surmuletus</i>	59	20.7	0.96	1.01	1.20	0.42	38	C	74.2	a2	T
<i>Scorpaena notata</i>	127	11.4	2.06	0.55	2.59	0.23	27	C	69.5		NT
<i>Boops boops</i>	79	9.8	1.28	0.47	1.61	0.20	29	C	50.3	a2	T
<i>Pegusa lascaris</i>	62	12.8	1.01	0.62	1.27	0.26	19	C	31.7	a2	(1), T
<i>Callionymus lyra</i>	44	3.9	0.72	0.19	0.90	0.08	23	C	21.2		NT
<i>Sardina pilchardus</i>	53	4.8	0.86	0.23	1.08	0.10	17	C	19.0	a1	T
<i>Trachurus trachurus</i>	39	3.5	0.63	0.17	0.80	0.07	22	C	18.0		T
<i>Diplodus vulgaris</i>	24	8.3	0.39	0.40	0.49	0.17	14	O	11.3	a2	T
<i>Scophthalmus rhombus</i>	16	9.8	0.26	0.48	0.33	0.20	15	C	11.3	a2	T
<i>Trachinus draco</i>	25	4.3	0.41	0.21	0.51	0.09	17	C	10.6		T
<i>Pagrus pagrus</i>	22	8.2	0.36	0.40	0.45	0.17	13	O	10.0	a2, b1	T
<i>Arnoglossus imperialis</i>	26	1.1	0.42	0.05	0.53	0.02	20	C	9.7	b4	T
<i>Lepidotrigla dieuzeidei</i>	40	1.8	0.65	0.09	0.82	0.04	12	O	9.1		(1), NT
<i>Dicologlossa cuneata</i>	24	2.6	0.39	0.13	0.49	0.05	15	C	7.9	a2, b4	(1), T
<i>Scomber scombrus</i>	24	7.8	0.39	0.38	0.49	0.16	10	O	7.8	a2	(1), T
<i>Trachurus picturatus</i>	44	3.4	0.72	0.17	0.90	0.07	7	O	6.3		T
<i>Citharus linguatula</i>	19	1.5	0.31	0.07	0.39	0.03	15	C	5.9		(1), T
<i>Mugil cephalus</i>	12	4.5	0.20	0.22	0.24	0.09	9	O	3.8	a2, b4	T
<i>Serranus cabrilla</i>	19	0.8	0.31	0.04	0.39	0.02	10	O	3.6		T
<i>Serranus hepatus</i>	15	1.8	0.24	0.09	0.31	0.04	8	O	2.7		NT
<i>Phycis phycis</i>	7	4.8	0.11	0.23	0.14	0.10	7	O	2.5	a2	T

Assessment of reserve effect in a Marine Protected Area:
The case study of the Professor Luiz Saldanha Marine Park (Portugal)

Taxon / Species	n	Weight (Kg)	% N	% W	CPUE Nr.	CPUE Kg	% FO	FO	IRI	C.S.	Obs.
<i>Chelon labrosus</i>	5	6.0	0.08	0.29	0.10	0.12	4	O	1.5	a2, b4	NT
<i>Conger conger</i>	6	4.0	0.10	0.20	0.12	0.08	5	O	1.5	a2	T
<i>Psetta maxima</i>	5	3.7	0.08	0.18	0.10	0.08	5	O	1.3	a2	(1), T
<i>Scorpaena porcus</i>	6	1.5	0.10	0.07	0.12	0.03	5	O	0.9		T
<i>Arnoglossus thori</i>	7	0.3	0.11	0.01	0.14	0.01	5	O	0.7		T
<i>Chelidonichthys</i> sp.	8	1.4	0.13	0.07	0.16	0.03	3	O	0.6		NT
<i>Dicentrarchus labrax</i>	3	2.2	0.05	0.11	0.06	0.05	3	O	0.5	a2, b4	T
<i>Aspitrigla cuculus</i>	4	0.4	0.07	0.02	0.08	0.01	4	O	0.3		(1), NT
<i>Diplodus sargus</i>	3	0.8	0.05	0.04	0.06	0.02	3	O	0.3	a2	T
<i>Lophius budegassa</i>	3	1.0	0.05	0.05	0.06	0.02	2	O	0.2		(1), T
<i>Micromesistius poutassou</i>	3	0.3	0.05	0.02	0.06	0.01	3	O	0.2		(1), T
<i>Liza saliens</i>	2	1.1	0.03	0.05	0.04	0.02	2	O	0.2	b4	(1), NT
<i>Arnoglossus</i> sp.	3	0.1	0.05	0.01	0.06	0.00	3	O	0.2		T
<i>Microchirus ocellatus</i>	2	0.2	0.03	0.01	0.04	0.00	2	O	0.1		(1), T
<i>Argyrosomus regius</i>	1	1.3	0.02	0.06	0.02	0.03	1	O	0.1		T
<i>Microchirus variegatus</i>	2	0.1	0.03	0.00	0.04	0.00	2	O	0.1		(1), T
<i>Symphodus bailloni</i>	2	0.0	0.03	0.00	0.04	0.00	2	O	0.1	b4	NT
<i>Entelurus aequoreus</i>	2	0.0	0.03	0.00	0.04	0.00	2	O	0.1	a3	NT
<i>Hippocampus hippocampus</i>	2	0.0	0.03	0.00	0.04	0.00	2	O	0.1	a4, b5, c1	NT
<i>Synapturichthys kleinii</i>	1	0.5	0.02	0.02	0.02	0.01	1	O	0.0		(1), T
<i>Pagellus bogaraveo</i>	1	0.4	0.02	0.02	0.02	0.01	1	O	0.0	a2	(1), T
<i>Liza aurata</i>	1	0.4	0.02	0.02	0.02	0.01	1	O	0.0	b4	NT
<i>Synaptura lusitanica</i>	1	0.3	0.02	0.01	0.02	0.01	1	O	0.0		T
<i>Lepidorhombus boscii</i>	1	0.3	0.02	0.01	0.02	0.01	1	O	0.0	a2	(1), T
<i>Zeus faber</i>	1	0.1	0.02	0.00	0.02	0.00	1	O	0.0		T
<i>Arnoglossus laterna</i>	1	0.1	0.02	0.00	0.02	0.00	1	O	0.0		(1), T
<i>Microchirus boscanion</i>	1	0.0	0.02	0.00	0.02	0.00	1	O	0.0		(1), T
<i>Macroramphosus scolopax</i>	1	0.0	0.02	0.00	0.02	0.00	1	O	0.0	b4	NT
<i>Nerophis lumbliciformis</i>	1	0.0	0.02	0.00	0.02	0.00	1	O	0.0	a3	NT
Elasmobranchii	560	451.2	9.10	21.96	11.43	9.21	80	HF	2472.4		
<i>Raja clavata</i>	115	225.7	1.87	10.98	2.35	4.61	44	F	564.0	b3	(1), T
<i>Myliobatis aquila</i>	282	27.8	4.58	1.35	5.76	0.57	29	C	169.6	b5	NT
<i>Torpedo torpedo</i>	54	42.9	0.88	2.09	1.10	0.88	27	C	78.7	b5	(1), T
<i>Mustelus mustelus</i>	30	54.4	0.49	2.65	0.61	1.11	13	O	41.6	b2	(1), T
<i>Rostroraja alba</i>	13	54.8	0.21	2.67	0.27	1.12	8	O	23.5	b1	(1), T
<i>Raja undulata</i>	16	20.3	0.26	0.99	0.33	0.41	16	C	20.4	b1	T
<i>Scyliorhinus canicula</i>	18	9.3	0.29	0.45	0.37	0.19	14	O	10.7	b4	T
<i>Dasyatis pastinaca</i>	19	5.6	0.31	0.27	0.39	0.11	8	O	4.8	b5	(1), T
<i>Pteromylaeus bovinus</i>	6	5.0	0.10	0.24	0.12	0.10	4	O	1.4	b5	(1), T
<i>Raja miraletus</i>	4	1.9	0.07	0.09	0.08	0.04	3	O	0.5	b4	(1), T
<i>Raja brachyura</i>	2	3.1	0.03	0.15	0.04	0.06	1	O	0.2	b3	(1), T
<i>Torpedo</i> cf. <i>mackayana</i>	1	0.6	0.02	0.03	0.02	0.01	1	O	0.0	b5	(1), T
Cephalopoda	166	208.5	2.70	10.15	3.39	4.26	69	HF	891.3		
<i>Sepia officinalis</i>	119	93.0	1.93	4.52	2.43	1.90	56	F	362.5		T
<i>Octopus vulgaris</i>	46	114.9	0.75	5.59	0.94	2.35	28	C	174.7		T
<i>Eledone cirrhosa</i>	1	0.6	0.02	0.03	0.02	0.01	1	O	0.0		(1), T
Crustacea	242	124.7	3.93	6.07	4.94	2.54	36	O	357.2		
<i>Maja squinado</i>	38	109.2	0.62	5.31	0.78	2.23	28	C	163.4	c1	T
<i>Palinurus elephas</i>	28	15.5	0.46	0.75	0.57	0.32	10	O	12.3	c2	T
<i>Melicertus kerathurus</i>	1	0.1	0.02	0.00	0.02	0.00	1	O	0.0		(1), T
Total	6151	2054.8			125.53	41.93					

Assessment of reserve effect in a Marine Protected Area:
The case study of the Professor Luiz Saldanha Marine Park (Portugal)

Table V - Acronyms:

FO: O - occasional: %FO<15	C.S. - Conservation Status	b - IUCN (2010)	c - Bern Convention
C - common: 15≤%FO<40	a - ICN (1993)	b1 - EN: Endangered	c1 - Appendix II - strictly protected fauna species
F - frequent: 40≤%FO<70	a1 - V: Vulnerable	b2 - VU: Vulnerable	c2 - Appendix III - protected fauna species
HF - highly frequent: %FO≥70	a2 - CT: Commercially Threatened	b3 - NT: Near Threatened	(1) - New record for the PLSMP
	a3 - K: Insufficiently Known	b4 - LC: Least Concern	T - Target species
	a4 - I: Undetermined	b5 - DD: Data Deficient	NT - Non-target species

Table VI. CPUE and frequency of occurrence (FO) of the invertebrates with no commercial value.

Invertebrates No Commercial Value						
Taxon / Species	n	% N	CPUE Nr.	% FO	FO	Obs.
Echinodermata	1225	75.95	25.00	91	HF	
<i>Sphaerechinus granularis</i>	730	45.26	14.90	55	F	
<i>Astropecten aranciacus</i>	322	19.96	6.57	62	F	
<i>Holothuria forskali</i>	63	3.91	1.29	24	C	
<i>Marthasterias glacialis</i>	40	2.48	0.82	18	C	
<i>Parastichopus regalis</i>	27	1.67	0.55	16	C	
<i>Paracentrotus lividus</i>	14	0.87	0.29	9	O	
<i>Echinus acutus</i>	8	0.50	0.16	5	O	(1)
<i>Asterias rubens</i>	6	0.37	0.12	5	O	
<i>Psammechinus miliaris</i>	6	0.37	0.12	3	O	
<i>Spatangus purpureus</i>	4	0.25	0.08	3	O	(1)
<i>Echinaster sepositus</i>	2	0.12	0.04	2	O	
<i>Ophioderma</i> sp.	2	0.12	0.04	1	O	
<i>Ophiothrix</i> sp.	1	0.06	0.02	1	O	
Crustacea	242	15.00	4.94	29	C	
<i>Polybius henslowii</i>	133	8.25	2.71	7	O	(1)
<i>Pagurus prideaux</i>	11	0.68	0.22	4	O	
<i>Calappa granulata</i>	10	0.62	0.20	8	O	
<i>Pagurus excavatus</i>	6	0.37	0.12	2	O	(1)
<i>Inachus</i> sp.	3	0.19	0.06	2	O	
<i>Pagurus cuanensis</i>	3	0.19	0.06	2	O	
<i>Dardanus calidus</i>	2	0.12	0.04	2	O	
<i>Homola barbata</i>	2	0.12	0.04	1	O	
<i>Atelecyclus undecimdentatus</i>	1	0.06	0.02	1	O	
<i>Dardanus arrosor</i>	1	0.06	0.02	1	O	
<i>Goneplax rhomboides</i>	1	0.06	0.02	1	O	(1)
<i>Macropodia</i> sp.	1	0.06	0.02	1	O	
<i>Pisa</i> sp.	1	0.06	0.02	1	O	
Gastropoda	62	3.84	1.27	26	C	
<i>Cymbium olla</i>	54	3.35	1.10	21	C	
<i>Nassarius reticulatus</i>	3	0.19	0.06	1	O	
<i>Aplysia fasciata</i>	2	0.12	0.04	2	O	
<i>Aplysia depilans</i>	1	0.06	0.02	1	O	
<i>Aplysia</i> sp.	1	0.06	0.02	1	O	
<i>Gibbula cineraria</i>	1	0.06	0.02	1	O	
Bivalvia	23	1.43	0.47	12	O	
<i>Atrina pectinata</i>	10	0.62	0.20	3	O	(1)
<i>Callista chione</i>	3	0.19	0.06	3	O	
<i>Acanthocardia spinosa</i>	3	0.19	0.06	3	O	(1)
<i>Mytilus galloprovincialis</i>	3	0.19	0.06	1	O	
<i>Acanthocardia aculeata</i>	2	0.12	0.04	2	O	
<i>Dosinia exoleta</i>	1	0.06	0.02	1	O	
<i>Pecten maximus</i>	1	0.06	0.02	1	O	
Cnidaria	23	1.43	0.47	7	O	
<i>Calliactis parasitica</i>	20	1.24	0.41	5	O	
<i>Pteroeides griseum</i>	2	0.12	0.04	2	O	
<i>Alicia mirabilis</i>	1	0.06	0.02	1	O	
Polyplacophora	21	1.30	0.43	13	O	
<i>Chaetopleura angulata</i>	21	1.30	0.43	13	O	
Tunicata	17	1.05	0.35	8	O	
<i>Phallusia mammillata</i>	17	1.05	0.35	8	O	
Total	1613		32.92			

FO: O - occasional: %FO<15

F - frequent: 40≤%FO<70

(1) - New record for the PLSMP

C - common: 15≤%FO<40

HF - highly frequent: %FO≥70

3.4. Analysis of catch data

The diversity indices applied to the catch data are plotted in Figure 7 according to period and protection level. The Kruskal-Wallis ANOVA ($\alpha=0.05$; Table VII) and the Dunn test for pairwise comparisons ($\alpha=0.05$; See Annex XI) were the applied statistical analyses. When all campaigns are analyzed together, the differences detected (Kruskal-Wallis ANOVA, $\alpha=0.05$; Table VII), are concerning the Complementary protection level (Dunn pairwise comparisons $\alpha=0.05$; See Annex XI), that shows significantly lower values ($p<0.05$) of both diversity indices (Margalef and Shannon-Wiener). In contrast, Partial and Total protection levels have significantly higher values ($p<0.05$). When analyzing each period, this same pattern is observed for year 5. However, for the previous period, years 3-4, the Total protection level was not found to be significantly higher when compared with the Complementary ($p>0.05$). This suggests that from one period to the other (after the marine park full implementation), an increase in diversity occurred in the Total protection level.

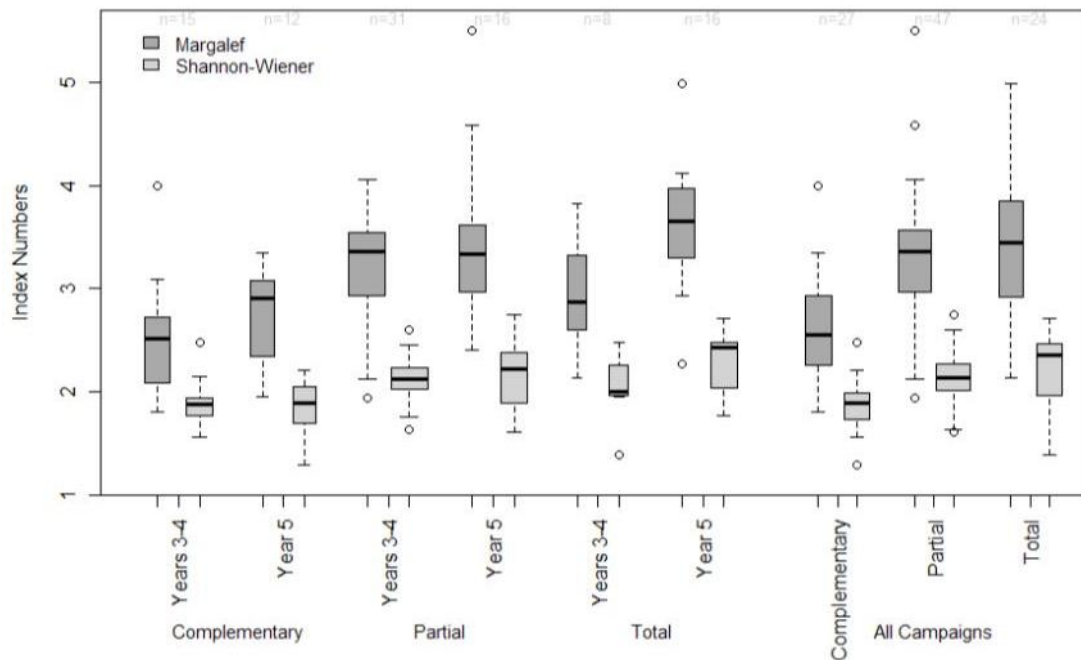


Figure 7. Boxplot of the Margalef and Shannon-Wiener indices by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).

Table VII. Results of the Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) applied to the Margalef and Shannon-Wiener indices calculated for each protection level and in each period.

Diversity Index	Complementary				Partial				Total				H	df	Statistically significant?
	N	Median	Q25	Q75	N	Median	Q25	Q75	N	Median	Q25	Q75			
Margalef															
Years 3-4	15	2.517	1.998	2.728	31	3.359	2.872	3.547	8	2.872	2.606	3.328	14.82	2	Yes ($P<0.001$)
Year 5	12	2.914	2.344	3.082	16	3.342	2.966	3.615	16	3.656	3.299	3.971	13.528	2	Yes ($P=0.001$)
All Campaigns	27	2.552	2.254	2.941	47	3.359	2.924	3.572	24	3.452	2.922	3.853	24.524	2	Yes ($P<0.001$)
Shannon-Wiener															
Years 3-4	15	1.882	1.771	1.95	31	2.12	2.022	2.239	8	2.007	1.968	2.264	12.777	2	Yes ($P=0.002$)
Year 5	12	1.893	1.692	2.055	16	2.22	1.893	2.377	16	2.431	2.039	2.481	12.298	2	Yes ($P=0.002$)
All Campaigns	27	1.892	1.724	1.993	47	2.135	2.004	2.273	24	2.357	1.968	2.466	22.054	2	Yes ($P<0.001$)

When analyzing the CPUE, similar results are observed (Figure 8). Once again, after the detection of significant differences ($p < 0.05$) between the protection levels through the Kruskal-Wallis ANOVAs ($\alpha = 0.05$; Table VIII), the Dunn method was applied ($\alpha = 0.05$; See Annex XII), showing that the Complementary protection level had significantly lower ($p < 0.05$) CPUE values. Concerning CPUE in number, the Partial protection level exhibits the highest values, and it is only in year 5 that the Total protection level becomes significantly higher ($p < 0.05$; Dunn method; See Annex XII) than the Complementary. For CPUE in weight and catch value, the Total protection area was already distinct ($p < 0.05$) from the Complementary in the first period in analysis (years 3-4). In similarity with CPUE in number, the Partial and Total protection levels are not significantly different.

Analyzing individual trends (Figure 9; Table VIII), specifically total length, an increase in the Total protection level is noticeable, which is behind the fact that for year 5, all three protection levels are significantly different ($p < 0.05$; Dunn method; See Annex XII). The observed pattern for the Total protection level in the weight data (Figure 9) also reveals an increase in year 5. Concerning both the individuals weight and value, it is the Total protection level that exhibits higher values in both periods, since it was found to be significantly different ($p < 0.05$; Dunn method; See Annex XII) from both the Complementary and Partial protection levels.

Overall, in relation to catch rates, the Complementary protection level exhibits lower values than both Partial and Total protection levels. These two, when compared with one another, were found to be not significantly different. Concerning individual size, it is the Total protection level that is significantly different from the other two, i.e. the median size of specimens caught in this protection level was found to be significantly higher.

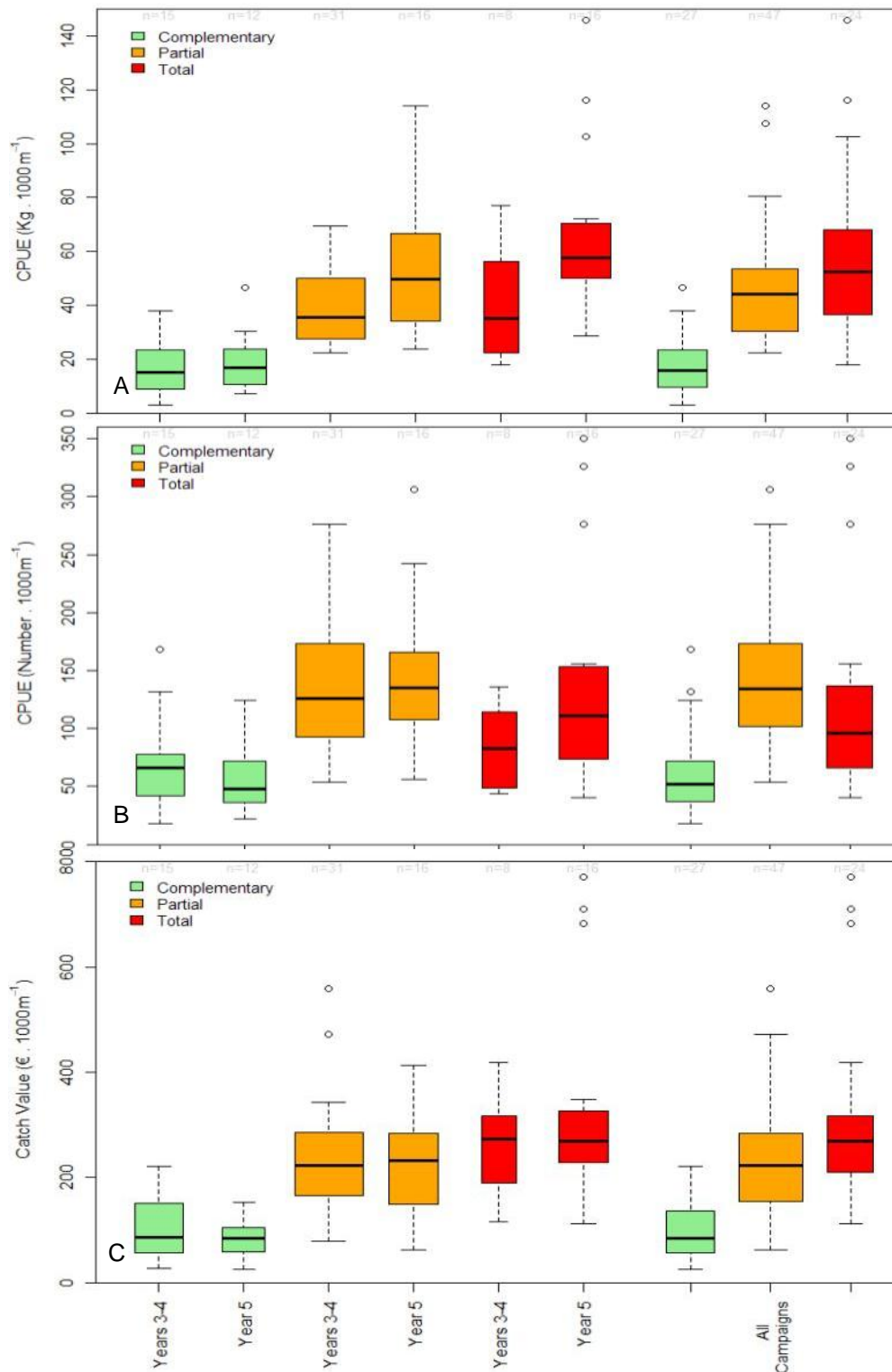


Figure 8. Boxplots of the CPUE in weight (Kg.1000m⁻¹) (A), CPUE in number (number.1000m⁻¹) (B) and catch value (€.1000m⁻¹) (C) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).

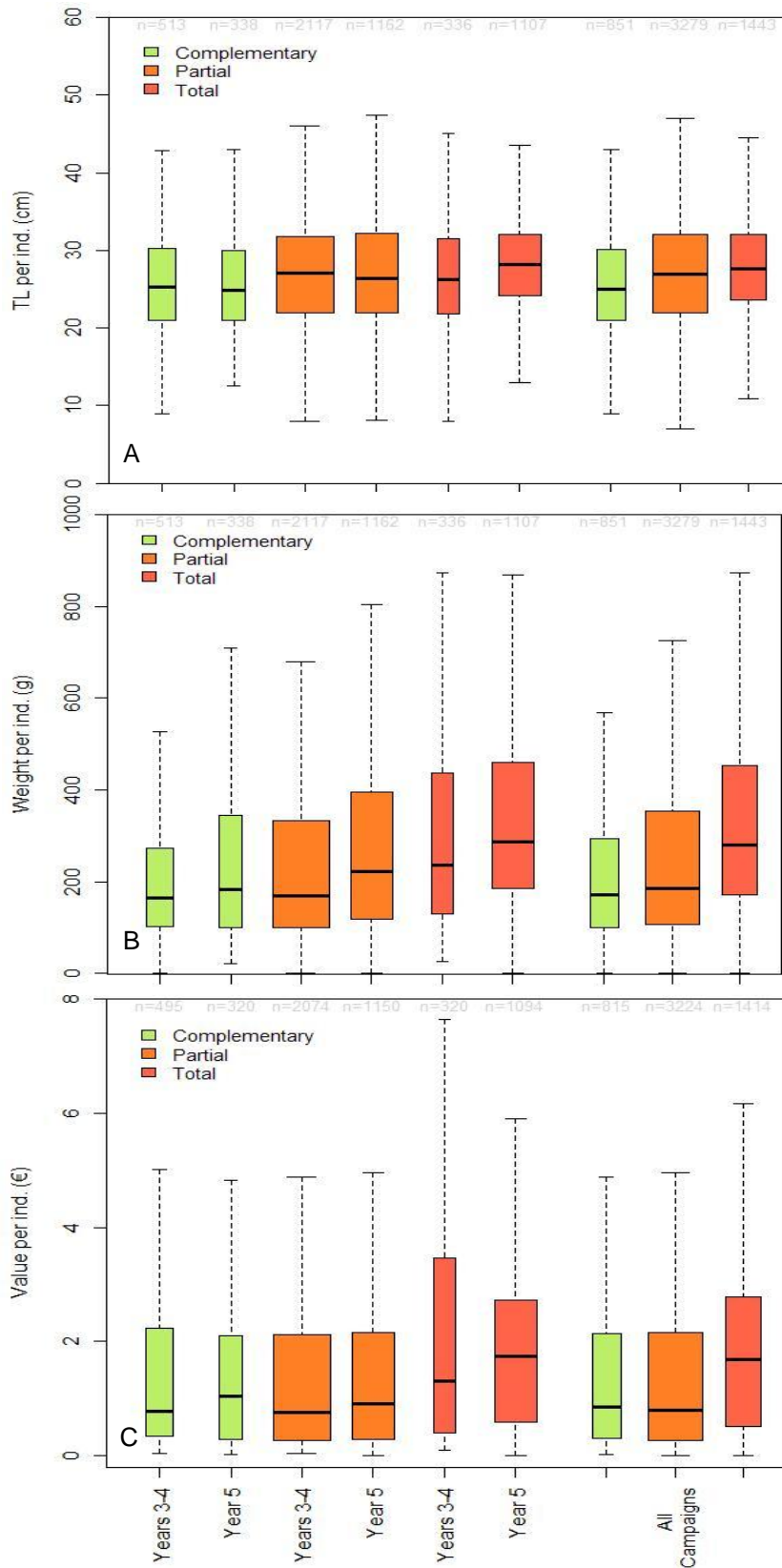


Figure 9. Boxplots of the specimens total length (cm) (A), weight (g) (B) and estimated value (€) (C) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).

Table VIII. Results of the Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) applied to compare values according to protection level and period - CPUE (ind.1000m⁻¹ and Kg.1000m⁻¹), catch value (€); values per individual: total length (TL), mean weight and mean value.

	Complementary				Partial				Total				H	df	Statistically significant?	
	N	Median	Q25	Q75	N	Median	Q25	Q75	N	Median	Q25	Q75				
CPUE (ind.1000m⁻¹)																
Years 3-4	15	66	40	82	31	126	89.5	173.5	8	83	49	114	17.37	2	Yes (P<0.001)	
Year 5	12	48	36	72	16	135	108	166	16	111	74	153	16.655	2	Yes (P<0.001)	
All Campaigns	27	52	36.5	72	47	134	102	173.5	24	96	66	137	31.949	2	Yes (P<0.001)	
CPUE (Kg.1000m⁻¹)																
Years 3-4	15	15.061	8.561	23.957	31	35.356	27.145	50.088	8	35.248	22.409	56.193	21.194	2	Yes (P<0.001)	
Year 5	12	16.785	10.663	23.715	16	49.84	34.095	66.572	16	57.666	50.182	70.494	22.955	2	Yes (P<0.001)	
All Campaigns	27	15.8	9.6	24.0	47	44.1	30.1	54.1	24	52.5	36.7	68.0	44.861	2	Yes (P<0.001)	
Catch Value (€)																
Years 3-4	15	85.639	53.317	151.55	31	223.14	162.66	288.99	8	272.93	190.16	316.88	19.099	2	Yes (P<0.001)	
Year 5	12	83.649	58.192	103.77	16	231.61	148.91	283.82	16	268.51	228.37	325.62	22.011	2	Yes (P<0.001)	
All Campaigns	27	84.989	53.317	135.24	47	223.14	152.9	285.34	24	268.51	208.91	316.88	42.951	2	Yes (P<0.001)	
Total Length per ind. (cm)																
Years 3-4	513	25.3	21	30.2	2117	27.1	21.9	31.8	336	26.3	21.75	31.5	16.411	2	Yes (P<0.001)	
Year 5	338	24.85	21	30	1162	26.4	22	32.2	1107	28.2	24.2	32	49.957	2	Yes (P<0.001)	
All Campaigns	851	25	21	30.1	3279	26.9	22	32	1443	27.7	23.525	32	59.408	2	Yes (P<0.001)	
Weight per ind. (g)																
Years 3-4	513	163.82	101.68	273.55	2117	168.96	100.28	332.07	336	236.32	130.33	435.87	46.768	2	Yes (P<0.001)	
Year 5	338	182.42	99.118	345.15	1162	221.43	119.22	394.66	1107	286.48	184.75	462.58	88.392	2	Yes (P<0.001)	
All Campaigns	851	171.04	100.05	293.92	3279	184.56	106.1	354.63	1443	280.25	171.04	453.18	231.638	2	Yes (P<0.001)	
Value per ind. (€)																
Years 3-4	495	0.782	0.345	2.25	2074	0.762	0.258	2.115	320	1.308	0.405	3.469	33.835	2	Yes (P<0.001)	
Year 5	320	1.052	0.278	2.101	1150	0.91	0.276	2.16	1094	1.74	0.586	2.728	116.182	2	Yes (P<0.001)	
All Campaigns	815	0.863	0.313	2.143	3224	0.802	0.266	2.15	1414	1.688	0.515	2.78	177.9	2	Yes (P<0.001)	

One further analysis was conducted with the CPUE data. The chosen spatial variable for this analysis was the sector, given that this is an accurate spatial indicator. While the protection level evolved with time (See Annex I), the sector classification is stable in time and space. Four categories were considered; from west to east: Complementary (section A), Partial West (Partial W; section B), Total (sections C and D), and Partial East (Partial E; section E) (sections: Figure 2). Figure 10 shows the observed trends according to sector and period (years 3-4, year 5).

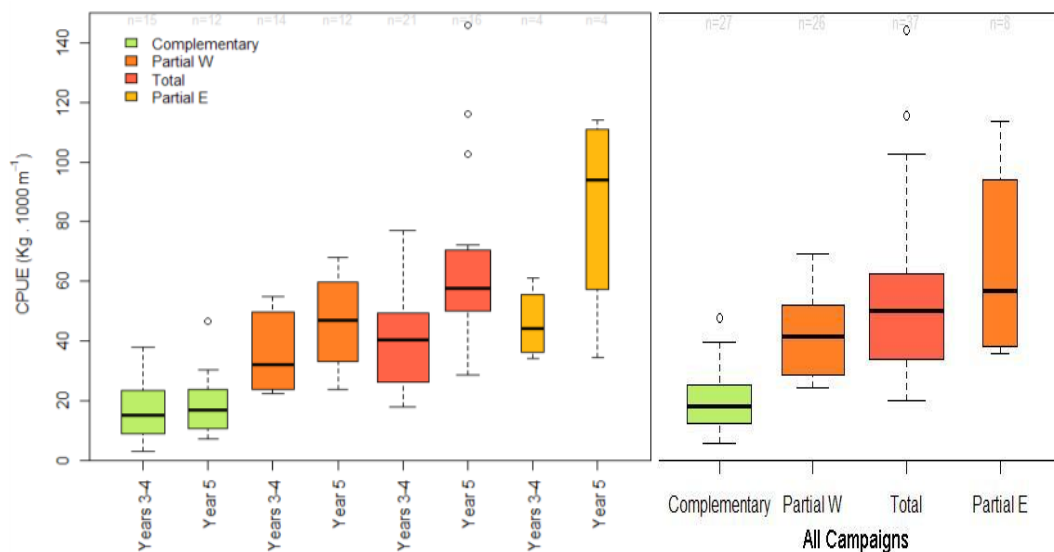


Figure 10. Boxplot of the CPUE in weight (Kg.1000m⁻¹) by sector and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010).

Significant differences were found with the Kruskal-Wallis ANOVAs ($\alpha=0.05$; Table IX), but according to the Dunn pairwise comparisons ($\alpha=0.05$; See Annex XIII) only the Complementary sector had significantly lower ($p<0.05$) CPUE values (Kg.1000m^{-1}), when compared to all the other three sectors. Given the small sample size for the Partial E sector ($n=8$), it is not possible to assess if the CPUE values for this region are significantly higher. However, it is worth mentioning that there might be an increasing gradient of CPUE in weight from west to east, as suggested by Figure 10. Some other explanatory analyses were conducted with CPUE in weight and the graphical outputs are shown in Annex XIV. In these analysis, one detail worth mentioning is that CPUE in weight was significantly higher (Mann-Whitney Rank Sum test; $\alpha=0.05$) in autumn than in spring.

Table IX. Results of the Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) applied to CPUE in weight (Kg.1000m^{-1}) obtained for each sector (Complementary; Partial West, Total, Partial East) and in each period.

CPUE (Kg.1000m^{-1}) Sector:	Complementary				Partial W				Total				Partial E				Statistically		
	N	Median	Q25	Q75	N	Median	Q25	Q75	N	Median	Q25	Q75	N	Median	Q25	Q75	H	df	significant?
Years 3-4	15	15.061	8.6	24	14	32.012	24	50	21	40.262	26	51	4	44.213	36	56	22.203	3	Yes ($P<0.001$)
Year 5	12	16.785	11	24	12	46.796	33	60	16	57.666	50	70	4	94.087	57	111	25.466	3	Yes ($P<0.001$)
All Campaigns	27	15.837	9.6	24	26	39.869	27	51	37	48.906	31	62	8	55.644	36	94	46.053	3	Yes ($P<0.001$)

3.4.1. Species trends

In order to analyze the catch data at the species level, Table X in Annex XV shows the CPUE in number and in weight for each species. Concerning the CPUE in number, *M. azevia* appears again as the most abundant species in the sampled area. Other species seem to be conspicuous, namely *Halobatrachus didactylus*, *Solea senegalensis*, *Merluccius merluccius*, and *Chelidonichthys obscurus*.

The total length per protection level for the following commercially valuable species was analyzed: *Chelidonichthys lucerna*, *Solea solea*, *S. senegalensis* and *M. azevia* (Figure 11). The choice was to include in this analysis species with commercial value (soles have high commercial value) and from the two most representative families of the sampled soft bottom community: Soleidae and Triglidae. For *C. lucerna* and *M. azevia*, the sample obtained from the Total protection level in the year 5 was significantly different ($p<0.05$; Dunn method; See Annex XVI), with a group of specimens significantly larger than the ones found in both the Partial and Total protection levels. For *S. solea*, it was not possible to analyze the difference in year 5, given that this species was only caught in the Total protection area during this period. In the case of *S. senegalensis*, both Partial and Total protection levels are significantly different ($p<0.05$; Dunn method; See Annex XVI) from the Complementary area, this for the first analyzed period. When comparing the Partial with the Total protection area, no significant differences were found ($p>0.05$; Dunn method; See Annex XVI).

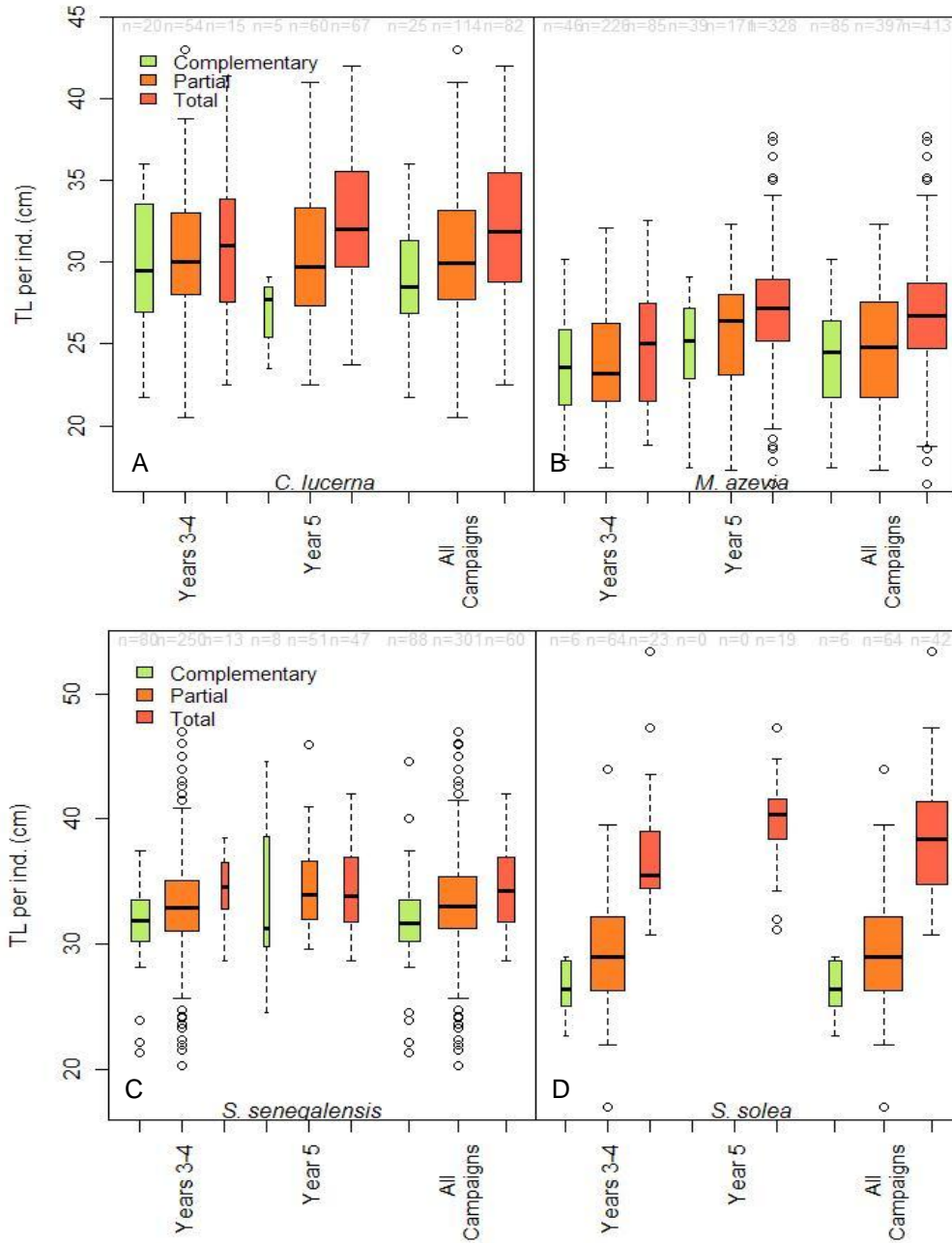


Figure 11. Boxplots of the specimens total length (cm) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010). Data for four bony fish species: *Chelidonichthys lucerna* (A), *Microchirus azevia* (B), *Solea senegalensis* (C) and *Solea solea* (D).

Table X. Results of Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) to compare the median total length (TL) of four bony fish species according to protection level and period.

Total Length (cm)	Complementary				Partial				Total				H	df	Statistically significant?	
	N	Median	Q25	Q75	N	Median	Q25	Q75	N	Median	Q25	Q75				
<i>Chelidonichthys lucerna</i>																
Years 3-4	20	29.5	27.0	33.6	54	30.0	28.0	33.0	15	31.0	27.5	33.9	1.491	2	No (P=0.475)	
Year 5	5	27.7	24.9	28.7	60	29.8	27.4	33.4	67	32.0	29.7	35.6	13.272	2	Yes (P=0.001)	
All Campaigns	25	28.5	26.7	31.8	114	30.0	27.7	33.2	82	31.9	28.8	35.5	14.994	2	Yes (P<0.001)	
<i>Solea solea</i>																
Years 3-4	6	26.4	25.0	28.7	64	29.0	26.3	32.2	23	35.5	34.5	39.0	34.331	2	Yes (P<0.001)	
Year 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NA*	
All Campaigns	6	26.4	25.0	28.7	64	29.0	26.3	32.2	42	38.4	34.8	41.4	56.310	2	Yes (P<0.001)	
<i>Solea senegalensis</i>																
Years 3-4	80	31.9	30.3	33.5	250	32.9	31.0	35.1	13	34.6	32.4	36.7	14.512	2	Yes (P<0.001)	
Year 5	8	31.3	29.9	38.6	51	33.9	32.0	36.7	47	33.8	31.7	36.9	1.1	2	No (P=0.577)	
All Campaigns	88	31.7	30.2	33.6	301	33.0	31.3	35.4	60	34.3	31.8	36.9	21.994	2	Yes (P<0.001)	
<i>Microchirus azevia</i>																
Years 3-4	46	23.6	21.3	25.9	226	23.2	21.5	26.3	85	25.0	21.5	27.6	3.717	2	No (P=0.156)	
Year 5	39	25.2	22.8	27.2	171	26.4	23.1	28.0	328	27.2	25.2	29.0	26.225	2	Yes (P<0.001)	
All Campaigns	85	24.5	21.7	26.4	397	24.8	21.7	27.6	413	26.7	24.7	28.7	70.728	2	Yes (P<0.001)	

* - NA: Statistical Test Not Applied. All individuals were caught in the Total Protection area.

Temporal variations were also analyzed in the CPUE in number of eight fish *taxa*, namely: four bony fish species - *C. lucerna*, *M. azevia*, *S. senegalensis* and *S. solea* (Figure 12); three elasmobranch species - *Torpedo torpedo*, *R. clavata* and *Myliobatis aquila*; and one elasmobranch family - Rajidae (Figure 13) (all commercially valuable species except *M. aquila*).

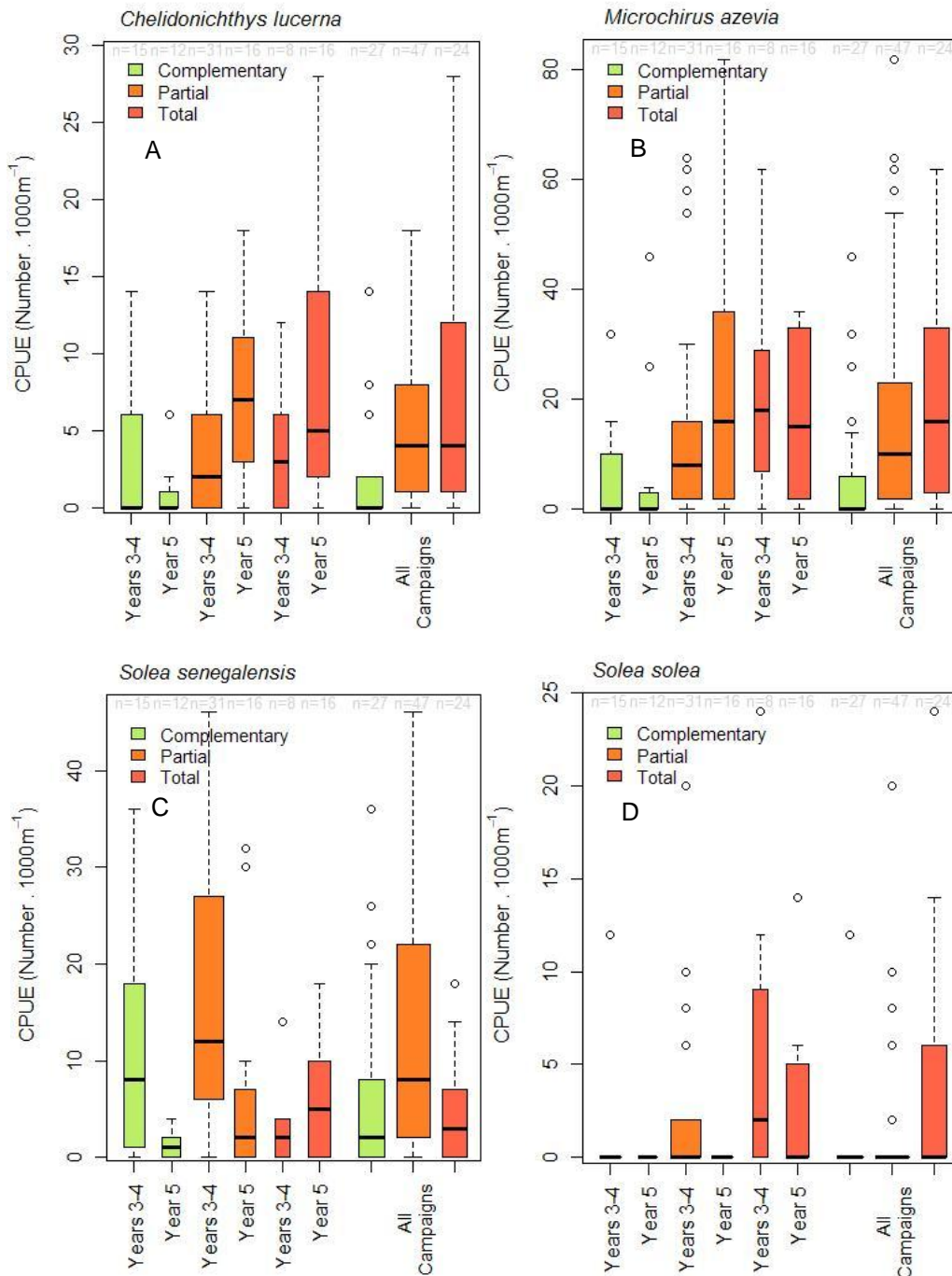


Figure 12. Boxplots of the CPUE in number (number.1000m⁻¹) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010). Data for four bony fish species: *Chelidonichthys lucerna* (A), *Microchirus azevia* (B), *Solea senegalensis* (C) and *Solea solea* (D).

Elasmobranchs are here analyzed given that, although they were less abundant than bony fishes, they are a group known to be particularly sensitive to overfishing (Wetherbee and Cortés, 2004; Coelho and Erzini, 2006, 2008). Rajidae was the most abundant elasmobranch family and comprises several species important for fisheries and which are nowadays listed with

conservation status that gives rise to some concerns: *R. clavata* and *R. brachyura* are classified as 'Near Threatened'; *R. alba* and *R. undulata* are considered 'Endangered' (IUCN, 2010). Thus, family Rajidae is here analyzed in detail, along with the most abundant elasmobranch species, *R. clavata*. The other two analyzed species, *M. aquila* and *T. torpedo*, were chosen as being the most abundant elasmobranchs in the catch after *R. clavata*.

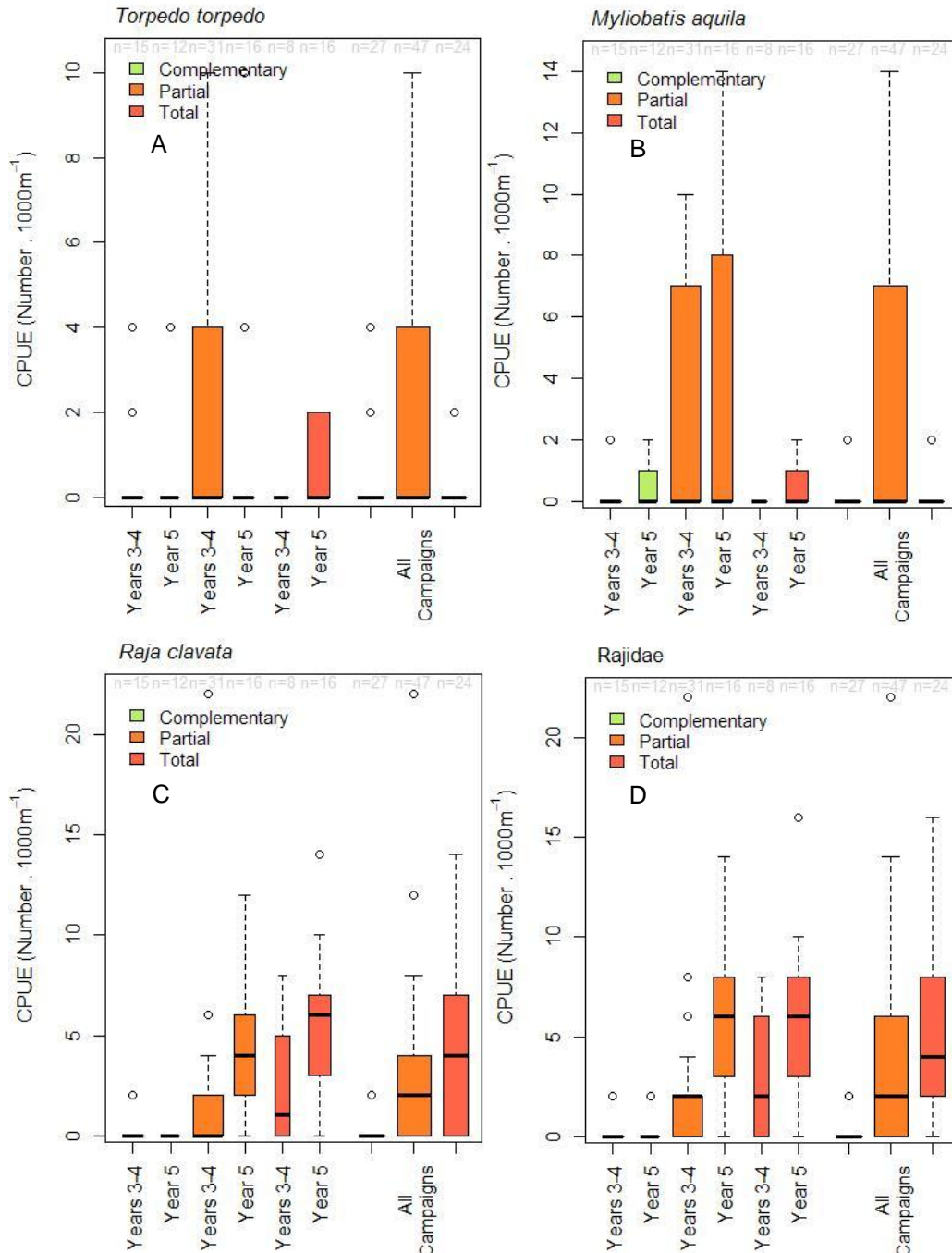


Figure 13. Boxplots of the CPUE in number (number.1000m⁻¹) by protection level and by period (Years 3-4: Aug. 2007 - Aug. 2009; Year 5: Aug. 2009 - Aug. 2010). Data for four elasmobranch taxa: *Torpedo torpedo* (A), *Myliobatis aquila* (B), *Raja clavata* (C) and family Rajidae (D).

Table XI. Results of Kruskal-Wallis One-Way ANOVA on Ranks ($\alpha=0.05$) applied to eight fish species, comparing the CPUE in number (ind./1000m) according to protection level and period.

CPUE (Ind. / 1000m)	Complementary				Partial				Total				H	df	Statistically significant?	
	N	Median	Q25	Q75	N	Median	Q25	Q75	N	Median	Q25	Q75				
Actinopterygii																
<i>Chelidonichthys lucerna</i>																
Years 3-4	15	0.0	0.0	6.0	31	2.0	0.0	6.0	8	3.0	0.0	6.0	1.62	2	No (P=0.445)	
Year 5	12	0.0	0.0	1.0	16	7.0	3.0	11.0	16	5.0	2.0	14.0	14.979	2	Yes (P<0.001)	
All Campaigns	27	0.0	0.0	2.0	47	4.0	0.5	8.0	24	4.0	1.0	12.0	13.456	2	Yes (P=0.001)	
<i>Microchirus azevia</i>																
Years 3-4	15	0.0	0.0	12.0	31	8.0	2.0	16.0	8	18.0	7.0	29.0	5.988	2	No (P=0.050)	
Year 5	12	0.0	0.0	3.0	16	16.0	2.0	36.0	16	15.0	2.0	33.0	6.741	2	Yes (P=0.034)	
All Campaigns	27	0.0	0.0	6.0	47	10.0	2.0	23.5	24	16.0	3.0	33.0	12.835	2	Yes (P=0.002)	
<i>Solea senegalensis</i>																
Years 3-4	15	8.0	0.5	19.0	31	12.0	6.0	27.5	8	2.0	0.0	4.0	7.834	2	Yes (P=0.020)	
Year 5	12	1.0	0.0	2.0	16	2.0	0.0	7.0	16	5.0	0.0	10.0	3.718	2	No (P=0.156)	
All Campaigns	27	2.0	0.0	8.0	47	8.0	2.0	22.0	24	3.0	0.0	7.0	8.016	2	Yes (P=0.018)	
<i>Solea solea</i>																
Years 3-4	15	0.0	0.0	0.0	31	0.0	0.0	2.0	8	2.0	0.0	9.0	7.25	2	Yes (P=0.027)	
Year 5	12	0.0	0.0	0.0	16	0.0	0.0	0.0	16	0.0	0.0	5.0	11.809	2	Yes (P=0.003)	
All Campaigns	27	0.0	0.0	0.0	47	0.0	0.0	0.0	24	0.0	0.0	6.0	12.531	2	Yes (P=0.002)	
Elasmobranchii																
<i>Torpedo torpedo</i>																
Years 3-4	15	0.0	0.0	0.0	31	0.0	0.0	4.0	8	0.0	0.0	0.0	10.168	2	Yes (P=0.006)	
Year 5	12	0.0	0.0	0.0	16	0.0	0.0	0.0	16	0.0	0.0	2.0	1.521	2	No (P=0.467)	
All Campaigns	27	0.0	0.0	0.0	47	0.0	0.0	4.0	24	0.0	0.0	0.0	8.532	2	Yes (P=0.014)	
<i>Myliobatis aquila</i>																
Years 3-4	15	0.0	0.0	0.0	31	0.0	0.0	7.5	8	0.0	0.0	0.0	10.107	2	Yes (P=0.006)	
Year 5	12	0.0	0.0	1.0	16	0.0	0.0	8.0	16	0.0	0.0	1.0	3.123	2	No (P=0.210)	
All Campaigns	27	0.0	0.0	0.0	47	0.0	0.0	7.5	24	0.0	0.0	0.0	11.903	2	Yes (P=0.003)	
<i>Raja clavata</i>																
Years 3-4	15	0.0	0.0	0.0	31	0.0	0.0	2.0	8	1.0	0.0	5.0	6.593	2	Yes (P=0.037)	
Year 5	12	0.0	0.0	0.0	16	4.0	2.0	6.0	16	6.0	3.0	7.0	18.667	2	Yes (P<0.001)	
All Campaigns	27	0.0	0.0	0.0	47	2.0	0.0	4.0	24	4.0	0.0	7.0	27.302	2	Yes (P<0.001)	
Rajidae																
Years 3-4	15	0.0	0.0	0.0	31	2.0	0.0	2.0	8	2.0	0.0	6.0	9.193	2	Yes (P=0.010)	
Year 5	12	0.0	0.0	0.0	16	6.0	3.0	8.0	16	6.0	3.0	8.0	18.648	2	Yes (P<0.001)	
All Campaigns	27	0.0	0.0	0.0	47	2.0	0.0	6.0	24	4.0	2.0	8.0	29.303	2	Yes (P<0.001)	

The tub gurnard, *C. lucerna*, seems to have undergone an increase in CPUE, as in years 3-4, no significant differences ($p>0.05$; Dunn method; See Annex XVII) were found between protection levels, and in the year 5, both Partial and Total areas present significantly higher values ($p<0.05$; Dunn method; See Annex XVII) when compared to the Complementary level. A similar increasing tendency is observed in the *M. azevia* values, but when analyzing the pairwise comparisons for year 5, the applied Dunn method was not able to detect significant differences ($p>0.05$; See Annex XVII). A hypothesis taken into account in this case is that this might be related with the conservative nature of Dunn method (Sawilowsky, 1990). For the soleids *S. senegalensis* and *S. solea*, decreasing trends were detected. The Senegalese sole, *S. senegalensis*, seems to have decreased in both the Partial and Total protection levels. When observing trends with the data of all campaigns (Figure 12), the Partial protection level seems to present higher values, but once again, the Dunn pairwise comparisons did not detect statistically significant ($p>0.05$; See Annex XVII). Concerning *S. solea*, the Total protection area seems to be an important region. Despite the decrease, this is the area with regular presence of

this species. Of all the 129 specimens caught during sampling, 114 (88%) were caught in this area, while of the other 15, 13 were caught in only one campaign, autumn 2007, in the other protection levels.

Observing the elasmobranchs trends (Figure 13), the most striking result is the increase of the thornback ray, *R. clavata*, in both the Partial and Total protection areas. This increase is also reflected in the trend observed for the Rajidae family, where *R. clavata* was the most abundant ray species. The observed pattern is statistically confirmed, as in year 5, *R. clavata* and Rajidae exhibit significantly higher ($p < 0.05$; Dunn method, See Annex XVII) values for both Partial and Total protection levels when compared with the Complementary protection level, which was not detected for years 3-4 ($p > 0.05$). In relation to *T. torpedo* and *M. aquila*, although some significant differences were detected with the Kruskal-Wallis ANOVAs ($p < 0.05$; Table XI), Dunn pairwise comparisons ($\alpha = 0.05$; See Annex XVII) did not allow distinguishing which groups were different. Nevertheless, the trends in Figure 13 suggest that the Partial protection area is important for some elasmobranch species, such as these two, even though *T. torpedo* was also common in the Total protection area and seems to exhibit temporal fluctuations in abundance. Yet another elasmobranch found to be more abundant in the Partial protection level, despite its low catch rates, was the smooth-hound *Mustelus mustelus* (considered 'Vulnerable' in the IUCN Red List of Threatened Species; www.iucnredlist.org; IUCN, 2010). As can be seen in Annex XV, this species exhibits its highest CPUE in the eastern Partial protection area (2.5 ind.1000m⁻¹).

Concerning CPUE in weight, Annex XVIII shows a graphical analysis for the eight most abundant target bony fishes, in which the values in the Partial and Total protection areas are compared with the ones obtained in the Complementary area.

3.5. Multivariate analysis

Concerning the multivariate analysis, the results of the One-Way ANOSIM ($\alpha = 0.01$) applied to compare community composition between the three protection levels are presented in Tables XII and XIII (abundance data; 4th root data transformation; Bray-Curtis similarity). Two analyses were carried out: with all samples together (Table XII) and considering the sandy (10-18m depth) and muddy bottom (35-40m depth) samples separately (Table XIII).

Table XII. Results of one-way ANOSIM ($\alpha = 0.01$; 4th root data transformation; Bray-Curtis similarity) according to protection level; all samples included (Global R=0.252).

All Campaigns	R	Significance
Protection Level - Pairwise Test Groups	Statistic	Level %
Complementary vs Partial	0.34	0.1
Complementary vs Total	0.32	0.1
Partial vs Total	0.10	1.5

Table XIII. Results of one-way ANOSIM ($\alpha=0.01$; 4th root data transformation; Bray-Curtis similarity) according to protection level; analysis considering the sandy and muddy bottom samples separately (Global R 'sandy bottom' = 0.343; Global R 'muddy bottom' = 0.368).

Experimental Trammel Nets Protection Level - Pairwise Test Groups	R Statistic	Significance Level %
Sandy bottom		
Complementary vs Partial	0.47	0.1
Complementary vs Total	0.47	0.1
Partial vs Total	0.11	6.6
Muddy bottom		
Complementary vs Partial	0.37	0.1
Complementary vs Total	0.61	0.1
Partial vs Total	0.24	0.5

According to the ANOSIM analyses (Tables XII and XII), when considering all samples together, differences are considered significant when comparing both Total and Partial protection areas with the Complementary area ($p < 0.01$). The difference between Complementary and the other two protection levels is clear, i.e. its community is significantly different. On the other hand, Total protection area was not found to be significantly different from the Partial ($p > 0.01$). This is similar to the results obtained when analyzing the sandy bottom samples separately. Significant differences were however detected between Partial and Total with the muddy bottom samples ($p < 0.01$). A graphic representation of the similarities between samples from each protection level is shown in the NMDS ordination (Figure 14). As expected from the ANOSIM results, the Complementary samples appear to constitute a distinct group. The obtained graphical representation is considered reliable, given the obtained low stress value (0.23) (Clarke and Warwick, 2001).

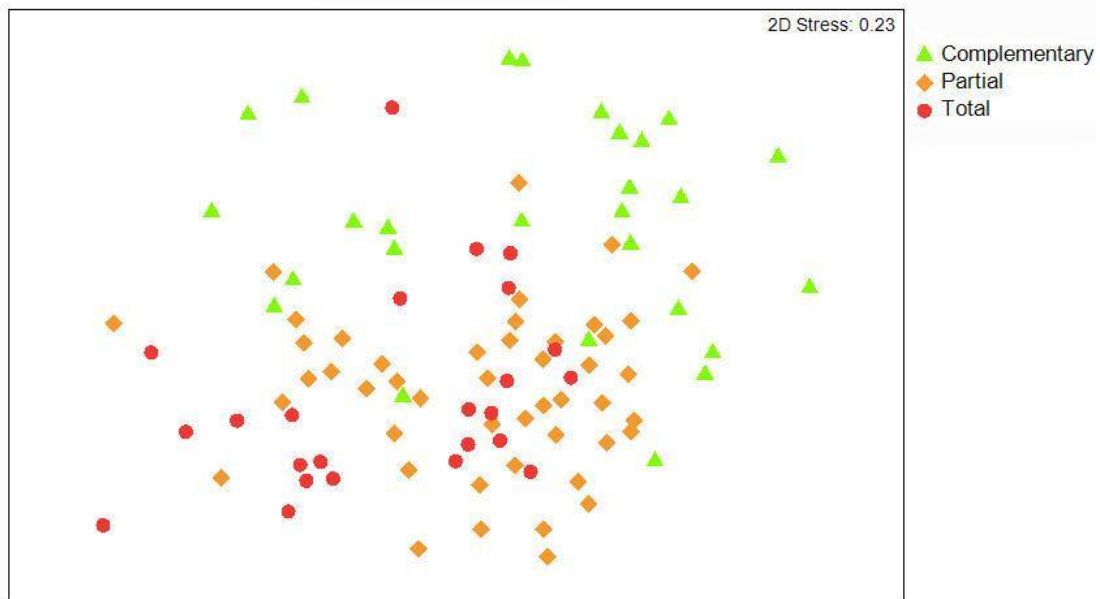


Figure 14. NMDS ordination of samples based on Bray-Curtis similarity (4th root data transformation). Samples are labeled according to protection level.

It was possible to determine the contribution of each species to the average dissimilarity between protection levels by applying the SIMPER analysis (Table XIV). The species *M. azevia*, *H. didactylus* and *Trigloporus lastoviza* appear as the main species contributing to the dissimilarity between Complementary and Partial areas. The Complementary versus Total dissimilarity also has *M. azevia* and *H. didactylus* as determinant species. The bastard sole *M. azevia* and the toadfish *H. didactylus* contributions seem to be important and consistent (Diss/SD>1) in the dissimilarities of the three communities considered (although ANOSIM did not show significance between Partial and Total when both bottom type samples are analyzed together). For *M. azevia*, this is in agreement with the pattern of abundance estimated for this species through CPUE analysis (CPUE ind./1000m: Total > Partial > Complementary; See Annex XV). *H. didactylus* appears to have a similar pattern of abundance.

SIMPER analysis was also applied to the two substrate/depth groups separately (sandy bottom - 10-18m depth; muddy bottom - 35-40m depth), once again to determine the more contributive species for the observed differences between the three protection levels (See Annex XIX). When analyzing the sandy bottom group, again *H. didactylus*, *M. azevia* and *T. lastoviza* are considered major contributors. For the muddy bottom samples, other species, like *S. solea*, *Scorpaena notata*, *C. lucerna*, *Chelidonichthys obscurus* and *R. clavata* gain importance in the distinction of assemblages (more details: See Annex XIX).

Another multivariate analysis was conducted to evaluate substrate/depth effect on the community. Significant differences ($p < 0.01$) were found between samples obtained from sandy (10-18m depth) and muddy bottoms (35-40m depth) (One-Way ANOSIM, $\alpha = 0.01$: abundance data, 4th root data transformation; Bray-Curtis similarity; R statistic=0.522; $p < 0.01$) (NMDS analysis: See Annex XX). The observed dissimilarity is due to distinct species assemblages in each substrate/depth. Muddy bottoms samples are mostly characterized by the bastard sole *M. azevia*, the scorpionfish *Scorpaena notata*, the pouting *Trisopterus luscus*, and the hake *Merluccius merluccius*. The conspicuous presence of *S. notata* (generally considered a rocky bottom species) suggests that patches of subsurface rock might be present along the sampled area at 35-40m depth. Other species, like the Senegalese sole *S. senegalensis* and the toadfish *H. didactylus* showed higher abundances in sandy bottom sets, contributing for the observed dissimilarities (SIMPER analysis; Table XV).

Table XIV. SIMPER results for the protection level comparisons (4th root data transformation; Bray-Curtis similarity); all samples included. Species with Contribution% ≥ 3.5 are shown.

All Campaigns						
Protection Level - Pairwise Comparisons						
Complementary ¹ & Partial ² (Av.Diss = 65.48)						
Species	Av.Abund. ¹	Av.Abund. ²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Microchirus azevia</i>	0.6	1.3	3.46	1.33	5.29	5.29
<i>Halobatrachus didactylus</i>	0.4	1.2	3.29	1.37	5.02	10.32
<i>Trigloporus lastoviza</i>	0.2	1.1	3.23	1.47	4.93	15.25
<i>Solea senegalensis</i>	0.9	1.2	2.85	1.24	4.36	19.61
<i>Chelidonichthys lucerna</i>	0.4	1.0	2.75	1.31	4.2	23.81
<i>Bothus podas</i>	0.6	0.7	2.63	1.06	4.01	27.82
<i>Pagellus acarne</i>	0.7	1.0	2.60	1.25	3.98	31.79
<i>Merluccius merluccius</i>	1.1	1.1	2.47	1.19	3.77	35.56
Complementary ¹ & Total ² (Av.Diss = 69.84)						
Species	Av.Abund. ¹	Av.Abund. ²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Microchirus azevia</i>	0.6	1.5	4.06	1.40	5.81	5.81
<i>Halobatrachus didactylus</i>	0.4	1.3	3.60	1.47	5.15	10.96
<i>Raja clavata</i>	0.0	0.9	3.06	1.42	4.39	15.35
<i>Chelidonichthys lucerna</i>	0.4	1.0	3.00	1.34	4.29	19.64
<i>Merluccius merluccius</i>	1.1	0.9	2.72	1.20	3.89	23.53
<i>Solea senegalensis</i>	0.9	0.8	2.67	1.18	3.82	27.35
<i>Trigloporus lastoviza</i>	0.2	0.8	2.61	1.12	3.74	31.08
Partial ¹ & Total ² (Av.Diss = 58.48)						
Species	Av.Abund. ¹	Av.Abund. ²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Microchirus azevia</i>	1.3	1.5	2.60	1.24	4.45	4.45
<i>Solea senegalensis</i>	1.2	0.8	2.29	1.25	3.92	8.37
<i>Merluccius merluccius</i>	1.1	0.9	2.23	1.20	3.81	12.18
<i>Pagellus acarne</i>	1.0	0.5	2.22	1.25	3.80	15.98
<i>Halobatrachus didactylus</i>	1.2	1.3	2.16	1.10	3.69	19.67
<i>Trigloporus lastoviza</i>	1.1	0.8	2.11	1.17	3.61	23.29

Table XV. SIMPER results for substrate/depth comparisons: sandy (10-18m depth) and muddy bottoms (35-40m depth) (4th root data transformation; Bray-Curtis similarity). Species with Contribution% ≥ 3.5 are shown.

All Campaigns						
Substrate - Pairwise Comparison						
Sandy bottom (10-18m depth) ¹ & Muddy bottom (35-40m depth) ² (Av.Diss = 68.49)						
Species	Av.Abund. ¹	Av.Abund. ²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Microchirus azevia</i>	0.8	1.9	3.77	1.38	5.5	5.50
<i>Solea senegalensis</i>	1.4	0.4	3.37	1.59	4.92	10.41
<i>Scorpaena notata</i>	0.0	1.0	2.95	1.41	4.31	14.73
<i>Halobatrachus didactylus</i>	1.2	0.6	2.94	1.32	4.29	19.02
<i>Trisopterus luscus</i>	0.2	1.0	2.82	1.45	4.12	23.14
<i>Merluccius merluccius</i>	0.8	1.5	2.52	1.27	3.68	26.82

3.6. Model fitting

The GAM (Gaussian distribution; identity link function) approach enabled the analysis of which of the four explanatory variables considered ('Temperature', 'Depth', 'Protection Level' and 'Period') were more important for explaining the observed deviance of the response variable - CPUE in weight. During the data exploration, it was noticed that the variable 'Period' was collinear with 'Temperature', given that in the Years 3-4, the sampled temperatures were between 13.2 and 16.5°C, and in year 5, from 16.2 to 19°C (See Annex VI). This collinearity excluded the use of both variables in the model, as collinearity should be avoided in GAMs (Hastie and Tibshirani, 1990; Zuur *et al.*, 2009). Further analysis revealed that 'Temperature' was a more important predictor than 'Period'. The approach was to fit GAMs with only one explanatory variable and verify how much of the response deviance was explained by each model (Figure 15). In this analysis, 'Temperature' appears to be an important predictor. This result is behind the decision of excluding the factor 'Period' from the model. In Figure 15 is also possible to see that 'Protection Level' seems to be the most important factor for the response deviance (49% of deviance explained in sandy bottom; 34% of deviance explained in sandy bottom). Concerning 'Depth', in both sandy and muddy bottoms, this variable explained about 10% of the total deviance.

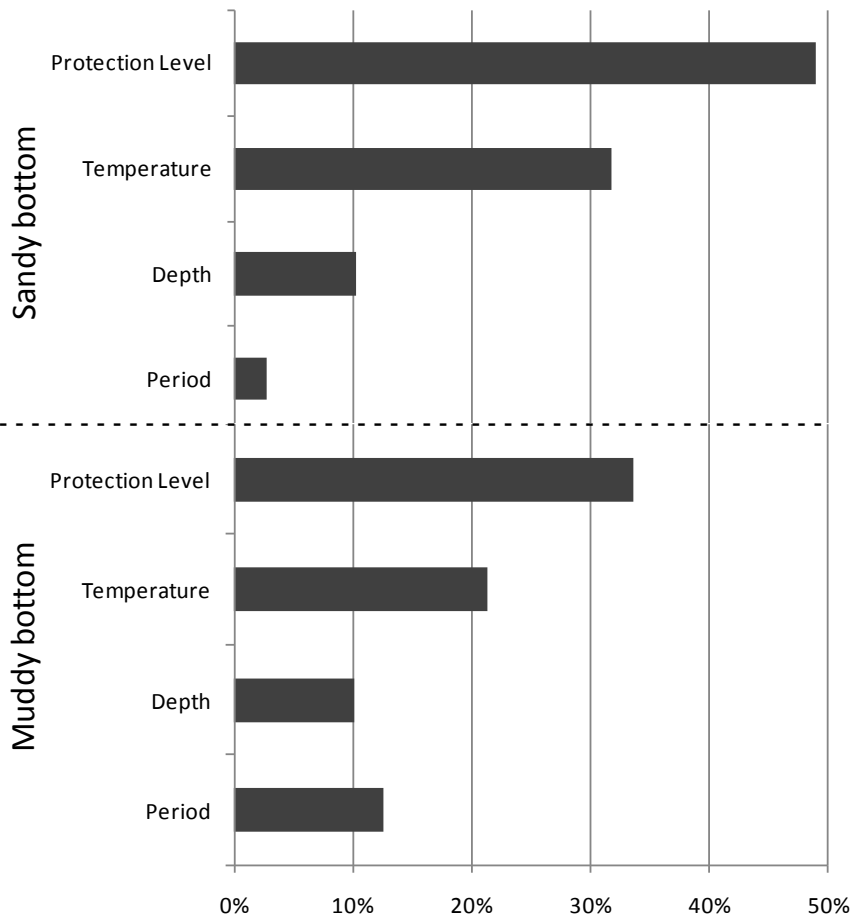


Figure 15. Contribution of each analyzed variable (when applied as the only predictor) in explaining the variance of CPUE in weight. Model fitting: Gaussian GAM, identity link function.

The forward stepwise procedure for model fitting based on AIC was carried out and the results are shown in Table XVI. After the sequential selection steps, the models with lowest AIC, were analyzed through statistical tests: t-tests for the parametric coefficients and F-tests for parametric terms and smooth terms. Tables XVII, XVIII and XIX resume the outputs. Two different models were obtained. For the sandy bottom group (Tables XVI, XVII and XIX), all the three explanatory variables were found significant and included in the final optimal model, namely, 'Protection Level', 'Temperature' and 'Depth' ($p < 0.05$). It is worth mentioning that the variable 'Protection Level' and the smoother for 'Temperature' are both highly significant (Table XVII). Concerning 'Protection Level', the estimated coefficients of both the Partial and Total levels were significantly higher ($p < 0.05$; Table XVII) than for the Complementary level (here considered as the reference level). The environmental factor 'Depth' was the least significant ($p = 0.02$; Table XVII). The estimated coefficients and smoothers of this model are shown in Table XVII. The optimal final model for the sandy bottom group can be expressed as:

$$\text{CPUE} \sim 1 + \text{as.factor}(\text{ProtLevel}) + \text{s}(\text{Temp}) + \text{s}(\text{Depth}).$$

This model has a Gaussian distribution with a dispersion parameter of 38.8 and explains about 63.5% of the variation in the response variable CPUE (Table XIX).

In relation to the muddy bottom group (Tables XVI, XVIII and XIX), the forward selection indicated that the model with all three covariates was the one with lowest AIC (Table XVI). However, when analyzing the significance through the F-test, the smoother for 'Depth' was found to be non-significant ($p > 0.05$; Table XVIII), and thus the chosen final model only includes the smoother for 'Temperature' and the nominal variable 'Protection Level'. It can be expressed as:

$$\text{CPUE} \sim 1 + \text{s}(\text{Temp}) + \text{as.factor}(\text{ProtLevel}).$$

Also with a Gaussian distribution, the dispersion parameter was of 34.7 and the model explains about 55.2% of the observed deviance in CPUE (Table XIX).

In this model, once again, the estimated coefficients of 'Protection Level' for both the Partial and Total levels were significantly higher ($p < 0.05$; Table XVIII) when compared with the Complementary level. The coefficient values and standard errors for the muddy bottom model indicate that the CPUE values expected for the Total level are similar to the ones estimated for the Partial (Partial: 10.039 ± 2.367 ; Total: 11.640 ± 2.773 ; Table XVIII). In the sandy bottom model, although the difference is small, the estimated coefficient and standard error (Table XVII) of the Total level (17.113 ± 2.387) indicate that catch estimates for this area are higher than the ones estimated for the Partial (12.379 ± 1.943). Comparing the estimated intercepts of the two models, the obtained values are similar (Sand: 8.862 ± 1.535 ; Mud: 9.081 ± 1.866 ;

Tables XVII and XVIII), indicating that the values estimated for the response variable are of the same order of magnitude in both bottom types.

Table XVI. Forward stepwise procedure applied in the GAM model fitting for both substrate groups: sandy and muddy bottoms.

Model Selection	
SANDY BOTTOM	
Step 1:	AIC
CPUE ~ s(Temp)	449.9
CPUE ~ s(Depth)	456.0
CPUE ~ as.factor(ProtLevel)	423.1
Step 2:	
CPUE ~ as.factor(ProtLevel) + s(Temp)	420.7
CPUE ~ as.factor(ProtLevel) + s(Depth)	421.1
Step 3:	
CPUE ~ as.factor(ProtLevel) + s(Temp) + s(Depth)	412.2
MUDDY BOTTOM	
Step 1:	AIC
CPUE ~ s(Temp)	252.4
CPUE ~ s(Depth)	255.7
CPUE ~ as.factor(ProtLevel)	246.8
Step 2:	
CPUE ~ s(Temp) + s(Depth)	244.0
CPUE ~ s(Temp) + as.factor(ProtLevel)	236.3
Step 3:	
CPUE ~ s(Temp) + s(Depth) + as.factor(ProtLevel)	235.6
Distribution: Gaussian (link function: identity)	

Table XVII. Parameters estimated for the GAM fitted with the sandy bottom samples.

SANDY BOTTOM				
Optimal Model: CPUE ~ as.factor(ProtLevel) + s(Temp) + s(Depth)				
Parametric coefficients:				
	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	8.862	1.535	5.775	3.92e-07 ***
as.factor(ProtLevel)2	12.379	1.943	6.370	4.34e-08 ***
as.factor(ProtLevel)3	17.113	2.387	7.170	2.19e-09 ***
Parametric terms:				
	df	F	p-value	
ProtLevel	2	29.980	1.76e-09 ***	
Approximate significance of smooth terms:				
	edf	Ref.df	F	p-value
s(Temp)	1.506	1.810	6.186	0.00494 **
s(Depth)	3.529	4.372	2.987	0.02334 *
ProtLevel: Protection Level				
ProtLevel 1: Complementary - reference level (taken to be zero)				
ProtLevel 2: Partial ProtLevel 3: Total				

Table XVIII. Parameters estimated for the GAM fitted with the muddy bottom samples.

MUDDY BOTTOM				
Model obtained in Step 3:				
CPUE ~ s(Temp) + s(Depth) + as.factor(ProtLevel)				
Parametric coefficients:				
	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	10.307	2.008	5.132	1.59e-05 ***
as.factor(ProtLevel)2	9.201	2.390	3.850	0.000573 ***
as.factor(ProtLevel)3	8.316	3.523	2.360	0.024928 *
Parametric terms:				
	df	F	p-value	
ProtLevel	2	7.476	0.00231 *	
Approximate significance of smooth terms:				
	edf	Ref.df	F	p-value
s(Temp)	1.908	2.276	7.077	0.00216 **
s(Depth)	1.000	1.000	2.142	0.15369
Optimal Model: CPUE ~ s(Temp) + as.factor(ProtLevel)				
Parametric coefficients:				
	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	9.081	1.866	4.867	3.10e-05 ***
as.factor(ProtLevel)2	10.038	2.367	4.240	0.000185 ***
as.factor(ProtLevel)3	11.640	2.773	4.198	0.000208 ***
Parametric terms:				
	df	F	p-value	
ProtLevel	2	11.800	0.000153 ***	
Approximate significance of smooth terms:				
	edf	Ref.df	F	p-value
s(Temp)	1.809	2.166	6.508	0.00359 **
ProtLevel: Protection Level				
ProtLevel 1: Complementary - reference level (taken to be zero)				
ProtLevel 2: Partial ProtLevel 3: Total				

Table XIX. Null deviance, residual deviance, explained deviance, AIC and degrees of freedom obtained for each model: sandy and muddy bottom.

SANDY BOTTOM	
Optimal Model	CPUE ~ as.factor(ProtLevel) + s(Temp) + s(Depth)
Null Deviance	5742.1
Residual Deviance	2094.2
Deviance Explained	63.5%
AIC	412.2
Degrees of freedom	7.04
MUDDY BOTTOM	
Optimal Model	CPUE ~ s(Temp) + as.factor(ProtLevel)
Null Deviance	2411.6
Residual Deviance	1080.8
Deviance Explained	55.2%
AIC	236.3
Degrees of freedom	3.81
Distribution: Gaussian (link function: identity)	

The estimated smoothers of each model are shown in Figures 16 (sandy bottom) and 17 (muddy bottom). Both models include a smoother for 'Temperature' (Figures 16-A and 17) and as expected from previous results (Figure 6; See Annex XIV, Figure 20), an increase in CPUE with temperature is modeled for both bottom types. However, as mentioned before, temperature outliers were excluded from the muddy bottom analysis, and the range of included temperatures was only from 13.2 to 16.6°C, while in the sandy bottom group, temperature ranged from 13.2 to 19°C. The temperature smoother obtained from the sand samples is more informative (wider temperature range) and reliable, given that sample size is larger (sand: n=75; mud: n=36).

Overall, it can be inferred that catch increases are expected to occur when temperature increases. The fact that this trend was also obtained for the muddy bottom supports the reliability of this aspect. In our data set, it seems that the temperature and time effect are coupled together, due to the different temperature intervals corresponding to the two analyzed periods (T° range - Years 3-4: 13.2-16.5°C: Year 5: 16.2-19). The fact that the muddy bottom sample contains mainly observations of the first period (Autumn 2009 campaign excluded; only 8 observations of year 5) is expected to minimize the time effect. Given that under these circumstances, the temperature appears again as significant (p<0.05; Table XVIII), its effect in increasing the catch appears once again to be consistent.

In the sandy bottom model, another smoother was included: Depth. The observed pattern (Figure 16-B) shows that for depths between 14-16m, the lowest values of CPUE are expected. On the other hand, between 16-20m deep the pattern shows a clear increase. Taking also into account previous analyses (See Annex XIV, Figure 18), it appears that there is a higher occurrence of higher catches in muddy than in sandy substrate. However, the difference seems to be small, also given the comparison of both models: the estimated intercept for sand is 8.862

± 1.535 and for mud, 9.081 ± 1.866 . In this sense, it can be inferred that the increasing trend in depths below 20m is expected to be less steep or it can even stabilize. Unfortunately, no significant smoother for depth in the muddy bottom analysis was obtained.

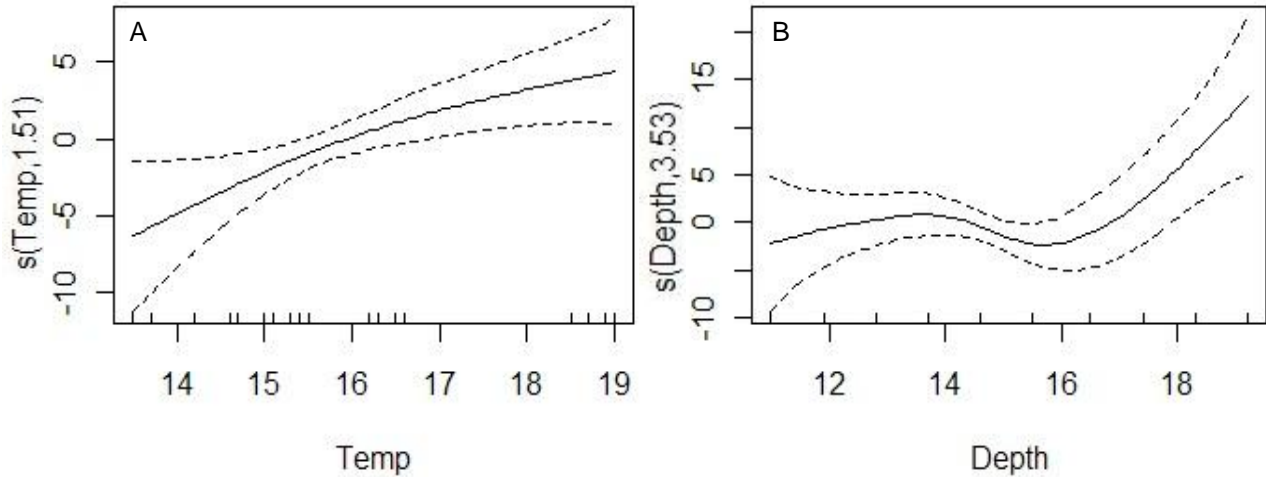


Figure 16. Estimated smoothing curves for water temperature (A) and depth (B) in the sandy bottom model. The solid line is the smoother and the dotted lines are 95% point-wise confidence bands.

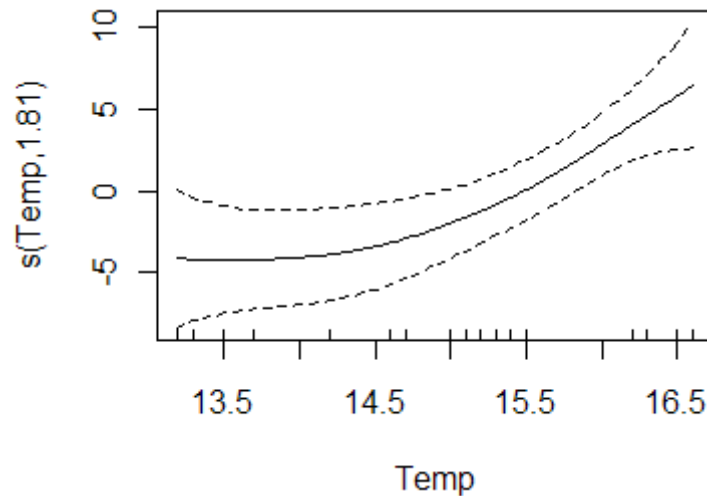


Figure 17. Estimated smoothing curve for water temperature in the muddy bottom model. The solid line is the smoother and the dotted lines are 95% point-wise confidence bands.

As part of the model validation, a graphical diagnosis of the residuals was carried out for both models (sandy bottom model: Figures 18 and 19; muddy bottom model: Figures 20 and 21).

In Figure 18-A, the Q-Q plot indicates both normality and homogeneity in the residuals. The plot in Figure 18-B is also useful to check homogeneity and it reveals a slight increasing pattern, but still, it was not considered a major concern. The histogram is used to confirm normality and although not symmetrically shaped, it is considered satisfactory (Figure 18-C). The graph of response *versus* fitted values (Figure 18-D) shows the expected diagonal pattern, confirming

that the model is equally effective in the predictions of the response variable in all the analyzed range of the predictors. Overall, the four graphs lead us to consider the model as acceptable.

To complete the model validation, there was the need to look at independence. Spatial dependence implies that sites close to each other may have similar values (Zuur *et al.*, 2009). This was verified through a bubble plot with residuals against the spatial coordinates (Figure 19). In this plot, small clusters of negative (black dots) and positive (white dots) values were detected. However, the positive values appear alternated with negative values homogeneously in the extent of the sampling area. Although some concerns are raised by this analysis, the homogeneity suggests a certain level of spatial independence that was considered satisfactory.

The same validation plots were used for the muddy bottom model. The Q-Q plot (Figure 20-A) indicates an acceptable normality pattern for the residuals, but taking a look at Figure 20-C, the histogram shape does not show a normal distribution. In Figure 20-B, the residuals do not show any pattern, which supports that the residuals are homogeneous. Also in the graph of response *versus* fitted values (Figure 20-D), the residuals appear to be homogeneous. Concerning spatial independence, it seems questionable given that negative values seem to be dominant (Figure 21), indicating that the sampled sites may have similar values. Even though similarities in the catch may occur due to environmental conditions shared by different sites independently of spatial proximity, this issue should be examined through further sampling.

In conclusion, the model obtained with the sandy bottom samples is considered acceptable and useful for predictions for this substrate in the PLSMP area. Concerning the obtained model for muddy bottom, it should be regarded with caution given that it raised some spatial dependence concerns and is considered to be preliminary, given the small sample size.

The similarities in the results of both models contribute to confirm the global observed tendencies. In this sense, two points seem to stand out: the expected increase in catch with increase in water temperature and the fact that catches in the Partial and Total protection levels are significantly higher than in the Complementary level.

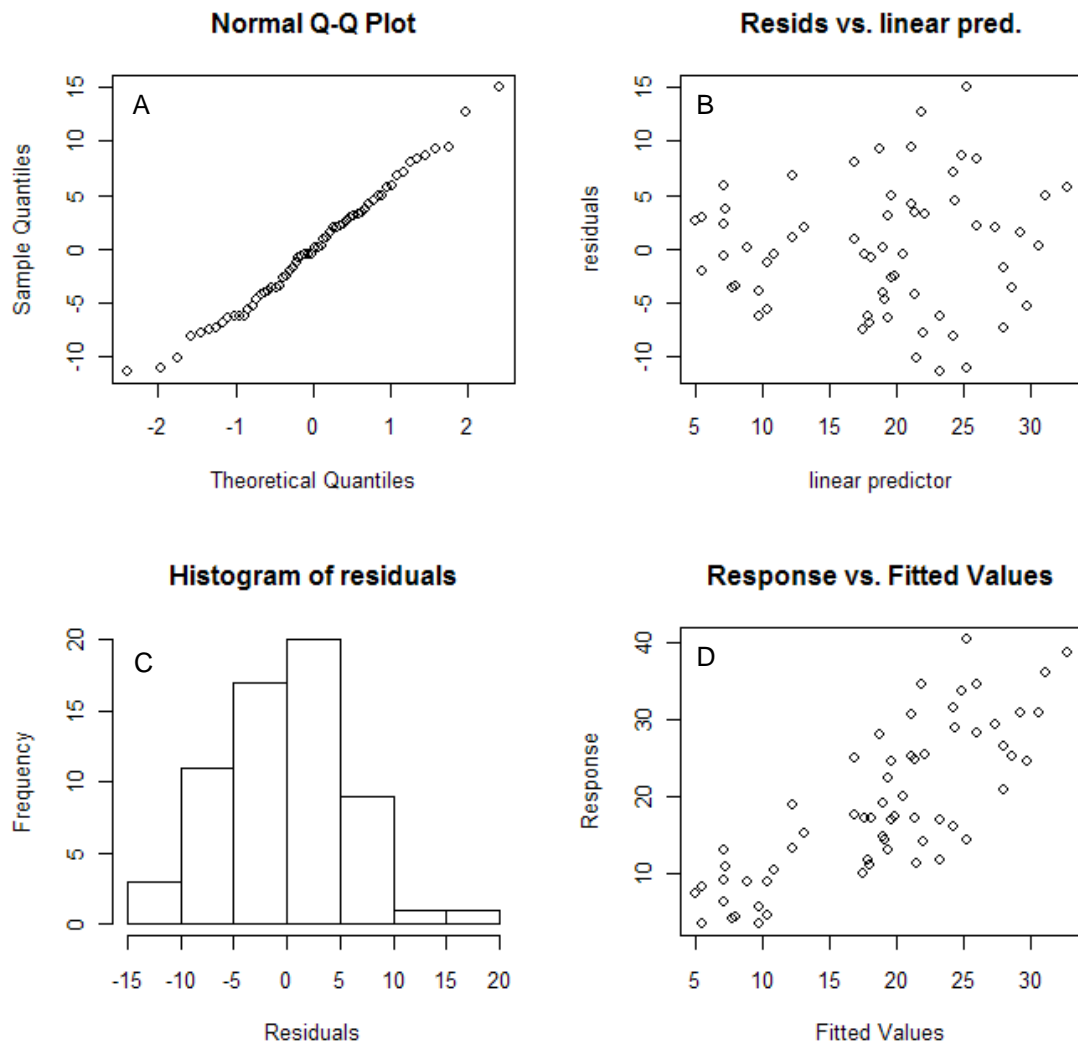


Figure 18. Sandy bottom model - Model validation through graphical analysis of the residuals. A - Q-Q plot; B - Residuals *versus* linear predictor; C - Histogram of the residuals; D - Response against fitted values.

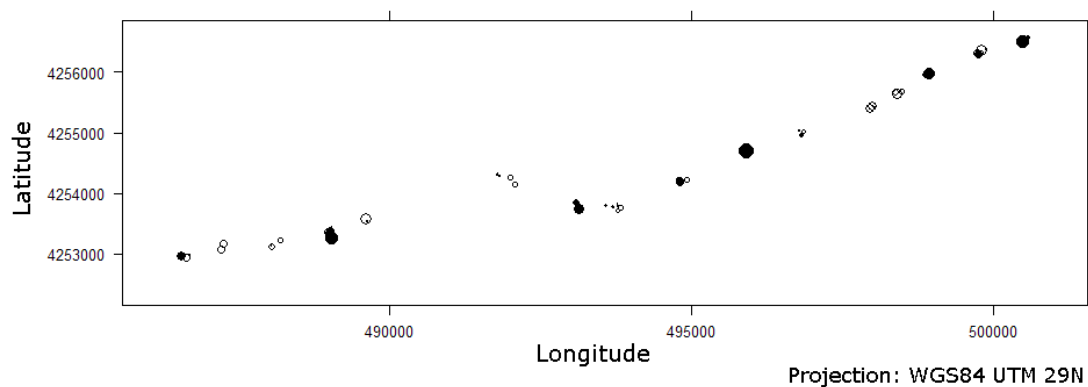


Figure 19. Sandy bottom model - Residuals obtained by the fitted GAM model plotted versus their spatial coordinates. Black dots are negative residuals, and grey dots are positive residuals. Size of dots is proportional to value.

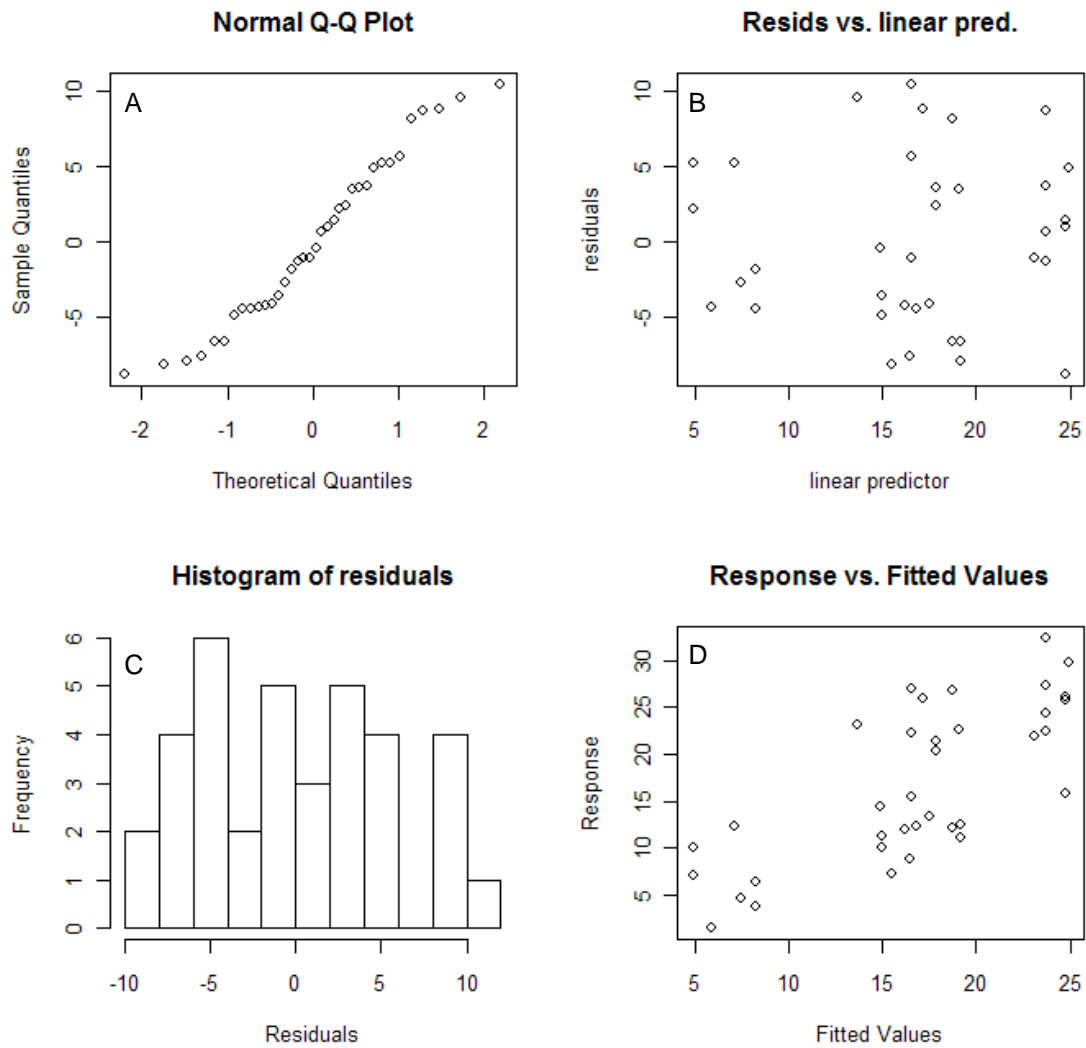


Figure 20. Muddy bottom model - Model validation through graphical analysis of the residuals. A - Q-Q plot; B - Residuals *versus* linear predictor; C - Histogram of the residuals; D - Response against fitted values.

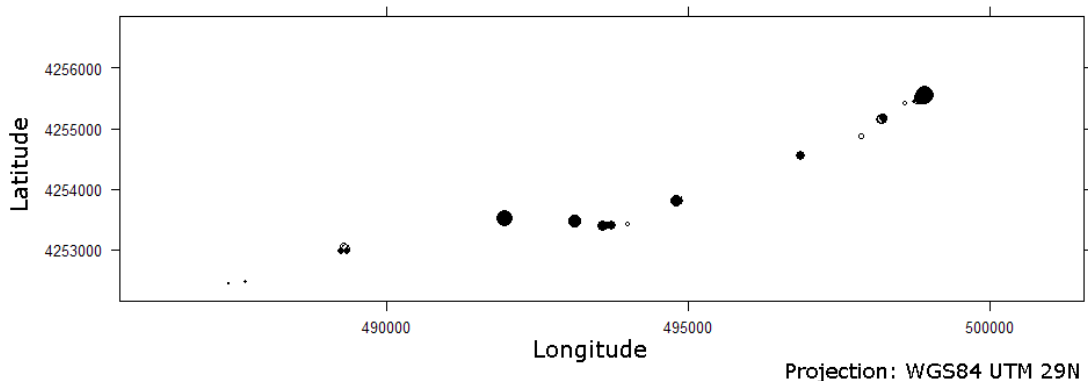


Figure 21. Muddy bottom model - Residuals obtained by the fitted GAM model plotted versus their spatial coordinates. Black dots are negative residuals, and grey dots are positive residuals. Size of dots is proportional to value.

4. Discussion

The assessment of management measures effects is a key aspect when studying marine protected areas. Five years after applying management regulations in the Prof. Luiz Saldanha Marine Park (PLSMP), it was crucial to obtain information concerning the ongoing marine community changes. The fact that it was only recently implemented (August 2005), makes this scientific data even more fundamental, in order to evaluate if the management goals are being accomplished. The present work is an attempt to shed light on this matter, through the assessment of species composition, biodiversity, abundance and biomass. The collected data and the undertaken analyses provide useful information concerning the implementation period and the first year after the full implementation of the marine park.

4.1. Analysis of catch data

The catch rates obtained through trammel net sampling on the soft bottoms of the marine park are here considered as indicators of abundance and biomass, as CPUE can be considered a reliable measure of these quantitative measures when data is collected with standardized methodology (Petrere *et al.*, 2010).

The trammel nets were found to be an adequate method for sampling fish communities in soft bottoms. Not only was the catch mainly composed of fish, but there was also a wide diversity of species and sizes caught. This is related with the unique way of capturing fishes that trammel nets have: the outer panels act together with the inner panel when the fish goes through the net making a 'pocket' that causes tangling. Trammel nets are known for their low species and size selectivity (Erzini *et al.*, 2006a; Stergiou *et al.*, 2006; Gonçalves *et al.*, 2007, 2008; Batista *et al.*, 2009), which in the case of sampling fish assemblages is a useful characteristic.

After the several analyses undertaken with the catch data, some general patterns are evident. One result that stands out is that the Partial and Total protection areas are significantly different from the Complementary in numerous aspects. It was found for instance, that both the Margalef and Shannon-Wiener diversity indices (considered as species richness indices; Magurran, 1988) were higher in these areas. This is in agreement with the observations of Gonçalves *et al.* (2003), who described a higher mean number of fish species in the rocky habitat of this coastal section when compared with the Sesimbra bay area and further west. The present results come to confirm this pattern also for the soft bottoms. It is worth noting that the results reported by Gonçalves *et al.* (2003) are concerning a period previous to the marine park implementation. This reveals that the observed pattern of higher diversity in this region (now correspondent to the Partial and Total protection areas) when compared to the nowadays designated as Complementary area, besides the eventual protection effect, is most likely related to the favourable habitat conditions found in this area.

Concerning the time effect on diversity, it seems that diversity (Margalef and Shannon-Wiener indices) increased in the Total protection area from the first to the second analyzed period. This could be related to the small sample size of the Total protection level during the first analyzed period, which could be inadequate to properly sample biodiversity. However, the hypothesis that the imposed fishing restrictions might also be favouring biodiversity recovery, in similarity with what was reported in other studies (Rius, 2007), should not be ruled out.

Through the ANOSIM test and also in relation to catch rates (in number and in weight), once again, the Partial and Total were significantly different from the Complementary. The results obtained with the total catch data might be related with the spatial abundance pattern of *M. azevia*, *C. lucerna* and *R. clavata* which were found to be significantly more abundant in the Partial and Total protection areas in opposition to the Complementary area. The bastard sole *M. azevia* is one of the main species behind the overall results, as it appears also in the SIMPER analysis as one of the main contributors for the obtained dissimilarities, along with *H. didactylus*. Also as *M. azevia*, *H. didactylus* was more abundant in the Partial and Total protection areas.

Concerning the similarities between the Total and Partial protection areas, both in terms of CPUE (in number and in weight) and also in community structure, several reasons can be causing this similarity, besides the obvious influence of geographical proximity. Another obvious fact is the recent implementation of the Total protection level (first Total section created in August 2008, the second in August 2009). According to Claudet *et al.* (2008), duration of protection affects the populations of commercial fishes and the levels of biodiversity. Moreover, this similarity is not entirely unexpected given that it was already described previously for the marine park (Gonçalves *et al.*, 2003). Another probable factor is that only highly selective fishing methods (octopus traps, jigging, handline) are allowed under the Partial protection statute. Also worth pointing out is that during sampling campaigns, the occurrence of illegal fishing was observed several times both in Partial and Total protection areas. This is probably influencing the similarity between these areas. The rate of illegal fishing is not known, but to properly assess the effect of implemented protection measures, surveillance must be more effective.

This result also suggests that the restriction of fishing with nets is an effective measure that improves the abundance of fish species, which is expected given the characteristic low selectivity of trammel nets (Erzini *et al.*, 2006a; Stergiou *et al.*, 2006; Gonçalves *et al.*, 2007, 2008; Karakulak and Erk, 2008; Batista *et al.*, 2009) and gill nets (Erzini *et al.*, 1997, 2003; Karakulak and Erk, 2008). This is in agreement with the evidences from other protected areas. In a study in a South African MPA, the experimental CPUE for four shorefish species was found to be 5-21 times greater than in nearby exploited areas (Cowley *et al.*, 2002). García-Charton *et al.* (2008) also concluded that the establishment of MPAs in the Mediterranean and Atlantic has proven to be successful for increasing the abundance and proportion of larger individuals in fish populations.

Comparing the Total and Partial protection levels, in some aspects is possible to detect details that distinguish these two areas. Regarding the Partial protection area, one detail worth mentioning is that it might be important for some elasmobranch species. Although it was not possible to confirm this statistically, it seems that species like *T. torpedo*, *M. aquila* or even *M. mustelus* were more abundant in this area (*M. mustelus* was more frequent in the eastern Partial area). This may be more due to environmental conditions, rather than an influence of the protection level itself. However, it is still worth mentioning, given that elasmobranch are particularly sensitive to overfishing (Wetherbee and Cortés, 2004; Coelho and Erzini, 2006, 2008), and their spatial preferences should be known.

In relation to the Total protection area, one result worth mentioning is concerning the size of the caught specimens. The total length values obtained for the Total protection level area showed that the individuals caught in this area were significantly larger. This was evident when analyzing the total catch and it was confirmed at the species level, namely, for the species *C. lucerna* and *M. azevia*. Increases in body size have been reported in other studies. In three temperate rocky reef reserves of New Zealand, protected for between 5 and 20 years, abundance of snapper (*Pagrus auratus*) larger than the minimum legal size was 14 times greater than in fished areas (Willis *et al.*, 2003a). Also in the Mediterranean, in the Medes Islands (García-Rubies and Zabala) and Ses Negres (Rius, 2007) marine reserves, size structure of several rocky reef species was found to be different in the reserve from the one in the unprotected zones.

Also in relation to the Total protection area, yet another important aspect to take into account is that it can be an important area for species with affinities with muddy bottoms. When analyzing only the muddy bottom samples, the ANOSIM revealed that the community in the Total protection area was significantly different from the one in the Partial. Both the soles *S. solea* and *M. azevia* showed affinity with the muddy substrate in the SIMPER analysis. Given that *M. azevia* was a common catch in the Total protection area and that, despite its decreasing trend, *S. solea* was only regularly present in this sector, the hypothesis is risen that this area offers suitable habitat conditions for bottom-feeding species that mainly use muddy substrate (sampled depth: 35-45m depth). Acquiring information on the sediments and bottom fauna in this area is an important step to understanding the reasons behind the distribution of these species. Being commercially valuable species, one thing that could happen is that they could be benefiting from protection. However, the *S. solea* decreasing trend raises concerns about the efficiency of its protection. It is worth mentioning that illegal fishing was detected in this region several times during surveys. The fishing approach was to place the net on the marine park limit and to leave the final portion of the net set inside the Total protection area. This corresponds to fishing in the muddy bottom areas where the *S. solea* occur. The assumption that the Total protection area encloses a habitat with good conditions for bottom feeders and muddy substrate users is yet another reason for protecting it.

The problem of the decrease in *S. solea* abundance could also be related with its life cycle. Several studies on this species have demonstrated that it commonly occurs in estuaries (Cunha, 1994; Veiga *et al.*, 2006; Machado, 2007), which it also uses as an important nursery ground (Cabral, 2000; Cabral *et al.*, 2007). Thus, *S. solea* in Arrábida might be undergoing human pressure (fishing, pollution), especially early in its life cycle, in the nearby Tagus (Lisboa region) or Sado (Setúbal region) estuaries. To efficiently protect this and other species, information on essential habitat is crucial (Lindeman *et al.*, 2000).

When analyzing the effects of management measures, it is possible to conclude that the benefits of protection differ from species to species. Species associated with the bottom habitat and with some level of territorial fidelity are expected to benefit more from protection. The study by García-Rubies and Zabala (1990) in the Medes Islands is one example of this. They reported that *Epinephelus marginatus*, a species with territorial behaviour, was taking advantage from protection, whilst for instance *Mullus surmuletus*, was not showing to be sensitive to the protection measures.

Indeed, the signs of increasing abundance were observed in *C. lucerna*, *R. clavata* and *M. azevia*. As species of the families Triglidae and Rajidae, they are benthic foragers with dependence of the bottom (Olim, 2003; Heithaus, 2004) that makes them more likely to benefit from protection. As expected, species with more sedentary habits and some degree of territorial fidelity are the ones more likely to benefit from protection in marine reserves (e.g., Kramer and Chapman, 1999). Concerning *R. clavata*, Batista *et al.* (2009) described for this same region (Setúbal and Sesimbra) a nearly constant trend in captures throughout the year, which suggests that this species does not undertake seasonal migrations. However, Rousset (1990) referred the Bay of Douarnenez (in the Atlantic coast of France) as a possible nursery and mating area for this species. Once again, the importance of understanding fishes home range and essential habitat is outlined.

Some of the results do indeed seem to be related with the protection measures. Besides the observed general spatial gradient that distinguishes the Partial and Total protection area from the Complementary, the abundance increases in time for the above mentioned species, *C. lucerna*, *R. clavata* and *M. azevia*, corroborates that some species are benefiting from protection in the marine park. The time effect has to be coupled with the spatial analysis to ensure the assessment of a reserve effect. In the case of the present study this is even more important. To assess only spatial trends in the marine park is not a reliable approach, because besides the protection level, it might reflect a gradient from west to east related with the distance to the Sesimbra fishing harbour. Moreover, the study from Gonçalves *et al.* (2003), that preceded the marine park implementation, reveals that the pattern with higher fish diversity in the region that now corresponds to the Total and Partial protection area existed even before the protection measures implementation. This was concerning the rocky inshore community, but it makes the assessment of time effect even more important.

For the temporal increase analysis, attention should be paid to the fact that the water temperature increased from the first to the second analyzed period, and according to our data, temperature seems to be related with increases in abundance. The importance of temperature in fish distribution is widely recognized (Moyle and Cech, 2000; Henriques *et al.*, 2007) and this should be taken into account in the present study. For instance, the fact that 2009 was a year with above average temperatures might be influencing the abundance increase observed for the bastard sole *M. azevia*. This species is known to have its northern limit of distribution in the Portuguese coast (Whitehead *et al.*, 1986; Froese and Pauly, 2010), and in this sense, higher temperatures might be favourable for its occurrence. On the other hand, the other two species with increases in abundance, the thornback ray *R. clavata* and the tub gurnard *C. lucerna*, have wider ranges of distribution (Whitehead *et al.*, 1986; Froese and Pauly, 2010), and the hypothesis considered is that probably, their increases are favoured by the protection measures.

Moreover, temperature may influence catch rates of static gear such as trammel nets that require fish and other organisms to come into contact with the gear. With higher temperatures, fish are more active, thereby increasing contact probabilities with the nets. Thus, higher catch rates may reflect, in part, greater mobility, rather than abundance.

Another result that is probably related with the protection effect is the fact that the median size of specimens has increased in the Total protection area. Significant differences were found between the first and second analyzed periods. Two species that were behind this overall result and showed this same trend were once again *C. lucerna* and *M. azevia*. In the same sense that fishing pressure is known to decrease median size of specimens, increases are expected when the fishery is regulated and restrictive measures are implemented. For instance, Erzini *et al.* (2006b) reported for the black spot sea bream (*Pagellus bogaraveo*) a significant decrease in mean length with the increase of fishing mortality.

Overall, several lines of evidence indicate the importance of the Partial and Total protection areas mainly for the abundance of some species that live associated with the bottom. Given that the similarities between these areas were previously reported (Gonçalves *et al.*, 2003), the fact of the recent implementation of the Total protection area, and that the restriction of fishing with nets was imposed in both areas, similarities between these two levels were expected.

The need to assure that recovery from fishing pressure is effective and the importance of adequately assess the effects of protection outline the importance of efficient law enforcement. Due to the fact that illegal activities seem to be common in the marine park, there is a strong need of more surveillance. Nevertheless, despite the occurrence of illegal fishing and the short time elapsed since its implementation, there are already some indications suggesting that several fish species are benefiting from the reduction of fishing pressure. Overall, given the results obtained, it can be concluded that the present data includes the first signs of positive effects due to the protection measures in the Prof. Luiz Saldanha Marine Park.

4.2. Model fitting

Through the model fitting approach, it was possible to obtain a generalized additive model (GAM) of the CPUE in weight suitable for predictions concerning the sandy bottoms of the marine park. The model obtained for the muddy bottoms should be regarded with some caution, and it should be confirmed in the future through further sampling. Still, it was useful to analyze trends concerning this substrate type, and it was important to notice that in the two models both temperature and the protection level were considered significant predictors of CPUE in weight, which corroborates the importance of these factors.

Others factors were analyzed. Unfortunately, the time effect, here regarded once again as two different periods (before and after full implementation of the marine park), proved to be difficult to analyze. The main reason for this is the fact that the water temperature during sampling in the second period was above average, and therefore the time effect is confounded by the temperature effect. This was a problem already noticed in the previous analyses and thus not entirely unexpected. Annual shifts in the water temperature are common in the studied coastal region. The Portuguese coast is known to be in a biogeographical transitional zone where shifts from cold to warm periods are common (Gonçalves *et al.*, 2003; Henriques *et al.*, 2007). For the model fitting approach, the time factor was not included, as it exhibited collinearity with temperature, which proved to be an important predictor. Similarly, when analyzing temperature, some time effect might be combined. However, temperature consistently proved to be an important factor and its effect in increasing catch is considered significant.

The importance of water temperature as a driving factor in the fish communities of the Arrábida coast was already mentioned in previous studies. Gonçalves *et al.* (2003) pointed out that major changes in weather trends and sea currents have the potential to influence the abundance and diversity of reef-fish communities. The study carried out by Henriques *et al.* (2007) describes the occurrence of pronounced changes in the fish assemblages within the PLSMP related with shifts in the sea surface temperature. This is in agreement with the present results. As mentioned, water temperature seems to be a significant factor influencing the weight of the catch obtained in soft bottoms within the marine park area.

Besides annual oscillations, the seasonal influence is probably included in the overall temperature effect. It was noticed that the catch weight recorded for the autumn season was significantly higher than in the spring. This trend was also reported by Batista *et al.* (2009), whose results for the Arrábida region showed higher captures rates of the local most valuable species in autumn and winter.

Water temperature is therefore considered a good predictor of the catch weight but the extent of its controlling influence is unknown. Coupled with temperature, other forces related with the seasonal behaviour of species are combined. Behaviours related to reproduction, feeding habits and recruitment commonly show seasonal patterns (Moyle and Cech, 2000). Besides, as

already mentioned, temperature may influence catch rates due to the increasing activity of fishes.

In relation to the depth effect, which was only possible to analyze for the sandy bottom group, the detected pattern shows a tendency of increase in CPUE in weight for depths between 16 to 20m. This pattern could either be related with more favourable environmental conditions or with the fishing pressure factor, given that fishing gears like handline, jigging and octopus traps are allowed to operate relatively close to shore (minimum distance to shore line: 200m) in both the Complementary and Partial protection areas. In the Medes Islands marine reserve, García-Rubies and Zabala (1990) noticed that depth affected the size class distribution of rocky fish assemblages. The detected trend outside the reserve was of more abundance of larger sizes in deeper waters and inversely, inside the reserve, large classes were more abundant in shallow waters.

Concerning the management variable - protection level, both models transcribe the pattern of higher catches in the Total and Partial protection levels in relation to the Complementary. This is one further result confirming the distinction of these two areas, as was already noticed in the previous analysis, and also reported by Gonçalves *et al.* (2003). As previously mentioned, here once again, this variable has to be interpreted with caution, as it probably incorporates both the protection effect and the spatial pattern influence. Environmental specificities like coastline shape, substrate and currents might make these two areas more favourable for the occurrence of several species. Also, once again, the hypothesis of a decreasing gradient of human pressure with increasing distance to the Sesimbra harbour should be taken into account.

The similarities in the results of both models contribute to confirm the global observed tendencies. In this sense, two points seem to stand out: the expected increase in catch with increase in water temperature and the fact that catches in the Partial and Total protection levels are significantly higher than in the Complementary level. More sampling is necessary in both substrate types to confirm patterns of catch in weight, here considered an indicator of abundance, according to temperature and depth. Moreover, to evaluate the relation of fish abundance with the protection measures, it is essential to proceed with surveys in order to ensure that the time effect is properly assessed, given that data from only one year after the full implementation of the marine park is included in this analysis.

4.3. Final considerations

The three years sampling period included in the present study enabled us to obtain useful information on the status of marine communities on soft bottoms within the marine park area. At the present stage, five years after the marine park creation and one year after the full implementation of the management measures, it was important to assess the effect of conservation measures in the abundance of marine species.

Throughout the obtained results, some aspects seem to stand out. It was found that the Partial and Total protection areas constitute a region where biodiversity and fish abundance are higher, in comparison with the Complementary area, where fishing with nets is allowed. In relation to the management plan, the present results highlight that the Partial and Total protection areas are important not only for reef fish assemblages, as reported by previous studies (Henriques *et al.* 1999; Gonçalves *et al.*, 2003) but also for soft bottom communities. In this sense, it was noticed during surveys that for instance fishing pressure might be above what is desirable for a successful biomass increase in the boundary of the Total protection. This coupled with the fact that this region might be important for muddy bottom feeders, leads to the conclusion that some management measures should be applied in this area. Sethi and Hilborn (2008), advert that focusing on the areas surrounding the MPA is of great importance, once that possible benefits might be dissolved due to un-management.

To adequately evaluate the protection effect over time proved to be difficult at this stage, both in the analysis of catch trends and through the model fitting approach. This is related to the short time elapsed since the full implementation of the marine park. Also the fact that during the two analyzed periods water temperatures were different raises difficulties in this assessment. However, increasing trends both in abundance and in size were detected in bottom associated fish species, which is remarkable given the recent full implementation of the marine park. We consider that is safe to relate these results with the decrease of fishing pressure. These findings emphasize the importance of marine reserves for the recovery of soft bottom fish populations.

We can state that the protection effect has to be assessed taking into account not only the species, the described reference status and the time elapsed, but also the environmental and geographical factors. In our results, temperature and the distance to the fishing harbour seem to be important. Other factors like currents, organic matter in sediments and the benthic fauna present are likely to be important. It is also worth mentioning that efficient law enforcement is likely to influence the extent of protection effectiveness.

In relation to the main objectives of the Prof. Luiz Saldanha Marine Park, there is evidence that conservation efforts are already obtaining some positive results. This was also the conclusion of Batista *et al.* (2011), whose results obtained for this same marine park showed ecological improvements concerning habitat recovery and biodiversity conservation. Concerning the marine park role to work as a fisheries management tool, at this stage and concerning the Complementary protection area, is not yet possible to detect increases in catches. Further

monitoring should be carried out over time to evaluate if spillover effect (biomass export from the higher levels of protection) will take place. Whether fish abundance is increasing in the outer boundary areas of the Partial and Total sections is not known. Moreover, the closure of the entire marine park to boats larger than 7 m long can have positive effects in terms of the income of the remaining local small boats. Continuing surveys in the Complementary area should be considered, as well as specific studies in the outer region of the Partial and Total protection areas.

Other future studies might examine the home range (acoustic telemetry techniques) of bottom associated species, to perceive if the marine park design and dimension is effective in their protection. Also more information concerning the essential habitats used by commercially important species should be obtained. Depending on this information, measures of conservation should be considered for nursery grounds and other important areas.

5. References

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ANNEXES

Annex I

Illustration of the Prof. Luiz Saldanha Marine Park (PLSMP) implementation period applied to commercial fishing.

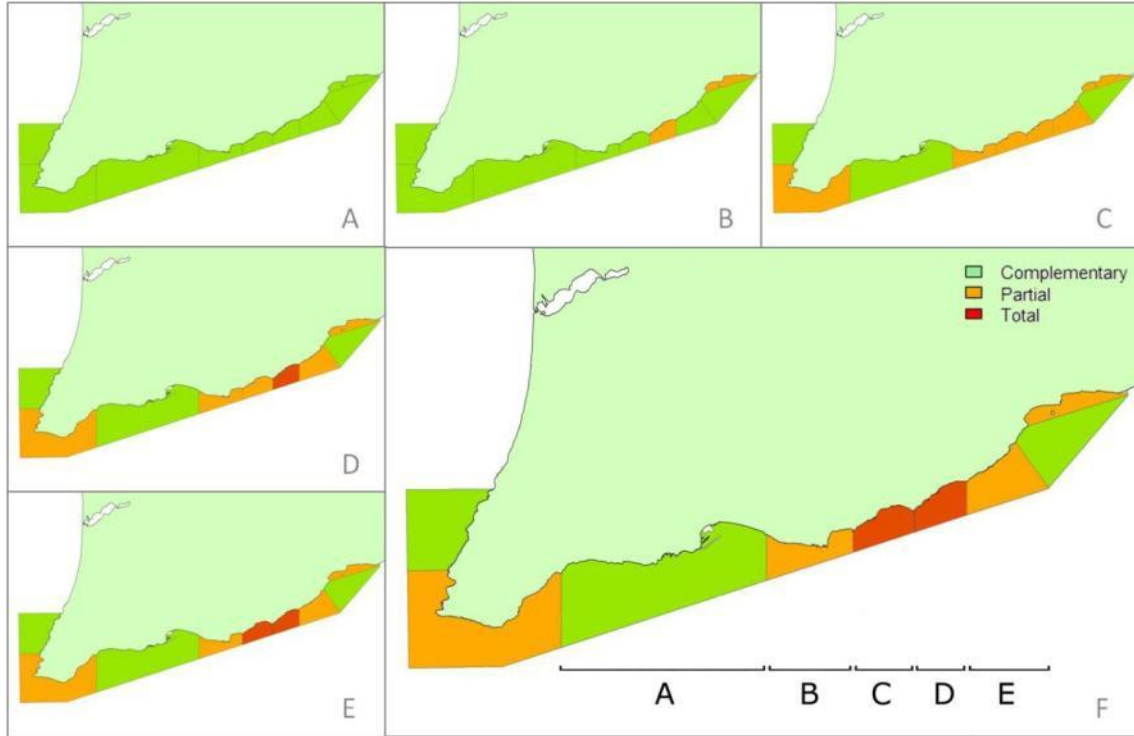


Figure 1. Maps illustrating each step of the Prof. Luiz Saldanha Marine Park (PLSMP) implementation period applied to the commercial fishing regulation. A – 23rd Aug. 05 - 23rd Aug. 06 (year 1): all the PLSMP area under Complementary protection level; this stage only became effective in 1st January 2006; B – 23rd Aug. 06 - 23rd Aug. 07 (year 2): two sections with Partial protection were implemented (section D and Portinho Bay); C – 23rd Aug. 07 - 23rd Aug. 08 (year 3): four more Partial protection areas were created (sections B, C, E and the Cape Espichel region); D – 23rd Aug. 08 - 23rd Aug. 09 (year 4): one total protection area implemented (section D); E and F – 23rd Aug. 2009 (year 5): the final design planned for the LSMP area is achieved, with one last section upgraded to total protection (section C).

Annex II

Details of the experimental trammel nets sampling campaigns.

Table I. List of experimental trammel nets sampling campaigns carried out during this study. Sample sizes according to each factor and details of each sampling campaign are shown.

	Field Work Period	Research team	Sample Size			Total Observations
			PROTECTION LEVEL			
			COMPLEMENTARY	PARTIAL	TOTAL	
Year 3 n=23 23 August 2007 - - 23 August 2008	Autumn 2007 3 - 7 December	Rui Coelho (1)	2	9		11
		Leonel Gonçalves (1)			NA	
		Jorge Assis (1)	Sand - 1	Sand - 6		
	Spring 2008 5 - 9 May	Joaquim Silva (2)	Mud - 1	Mud - 3		12
		Rita Abecasis (1)	3	9		
		Leonel Gonçalves (1)			NA	
Year 4 n=31 23 August 2008 - - 23 August 2009	Autumn 2008 3 - 7 November	Rita Abecasis (1)	4	6	2	12
		David Abecasis	Sand - 3	Sand - 5	Sand - 1	
	Spring 2009 18 - 22 May 25 - 29 May	Joaquim Silva (2)	Mud - 1	Mud - 1	Mud - 1	19
		Inês Sousa (1)	6	7	6	
		Marie Renwart	Sand - 4	Sand - 5	Sand - 3	
Joaquim Silva (2)	Mud - 2	Mud - 2	Mud - 3	5 samples excluded (3)		
Year 5 n=44 23 August 2009 - - 23 August 2010	Autumn 2009 25 October - - 3 November	Inês Sousa (1)	5	8	8	21
		Sarah Laura Simons	Sand - 3	Sand - 5	Sand - 5	
	Spring 2010 5 - 13 April	Joaquim Silva (2)	Mud - 2	Mud - 3	Mud - 3	23
		Inês Sousa (1)	7	8	8	
		Elisabeth Debusschere				
		Bogdan Glogovac	Sand - 5	Sand - 5	Sand - 5	
Joaquim Silva (2)	Mud - 2	Mud - 3	Mud - 3	1 sample excluded (4)		
Total			27	47	24	98 (-9)

Notes: (1) - Biomares research team (3) - Low fishing efficiency: abundance of macroalgae in the net
(2) - Professional fisherman (4) - Low fishing efficiency: net twisted (strong currents and pronounced bottom sloping)

Sample sizes per factor level: Sand - 64 Mud - 34 / Spring - 54 Autumn - 44 Total Sample Size: 98 (107 including outliers)
Sector: Complementary - 27 Partial W - 26 Total - 37 Partial E - 8 / Sections A - 27 B - 26 C - 15 D - 22 E - 8

Annex III

Field operations undertaken during the experimental trammel nets campaigns.

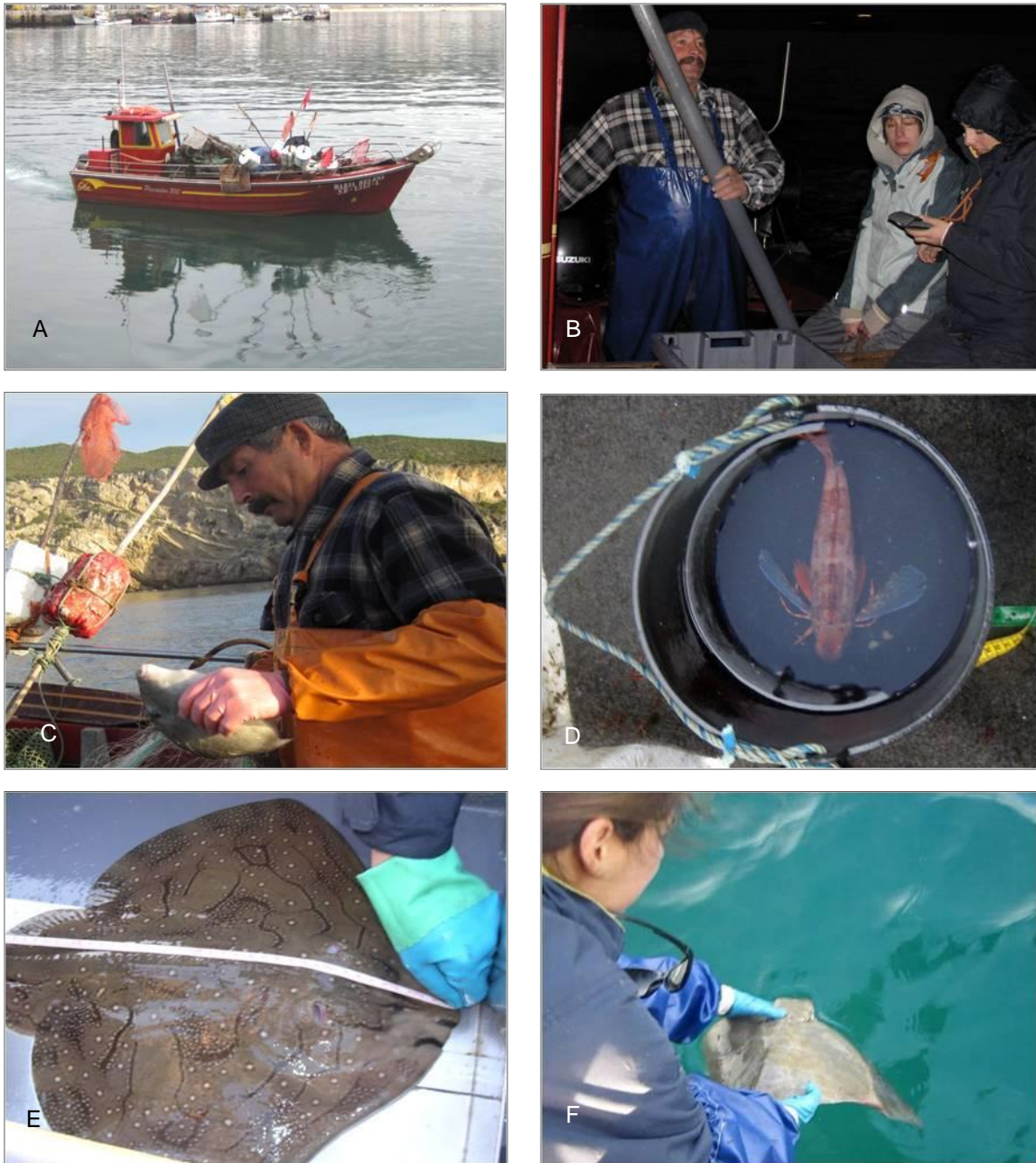


Figure 2. Field operations with the experimental trammel nets: A - commercial fishing vessel used during the fishing trials; B - navigating to the sampling points; C - fisherman untangling a triggerfish *Balistes capriscus*; D - a streaked gurnard *Trigloporus lastoviza* waiting to be measured onboard; E - a ray *Raja undulata* being measured; F - a bull ray *Pteromylaeus bovinus* being released after measured.

Annex IV

List of all the variables used during data exploration.

Table II. Description of all the variables used during the data exploration analysis.

Variable category	Variable	Type	Unit	Abbreviation (1)	Comments
Ecological / Response	CPUE Kg per 1000m of net	Continuous	Kg.1000m ⁻¹ (2)	CPUE	(3)
	CPUE no. individuals per 1000m of net	Continuous	No. ind.1000m ⁻¹	-	(3)
	Value of catch per 1000m of net	Continuous	€.1000m ⁻¹	-	(3)
	Mean Total Length per individual	Continuous	centimeters	-	(3)
	Mean Weight per individual	Continuous	gram	-	(3)
	Mean Value per individual	Continuous	€	-	(3)
Environmental / Explanatory	Depth	Continuous	meters	Depth	12 - 20m: sand; 35 - 45m: mud Sandy or muddy botom
	Substrate	Nominal	-	-	-
	Water Temperature	Continuous	oC	Temp	-
	Season	Nominal	-	-	Spring, Autumn
Geographical / Explanatory	Latitude	Continuous	meters	-	Ref. System: WGS84 UTM (29N)
	Longitude	Continuous	meters	-	-
Management / Explanatory	Protection Level	Nominal	-	ProtLevel	Complementary, Partial, Total
	Sector	Nominal	-	-	Complementary, Partial W, Partial E, Total
	Section	Nominal	-	-	Sections A, B, C, D and E
Temporal / Explanatory	Period	Nominal	-	Period	Before and after the full implementation of the PLSMP (4)

(1) - Abbreviation only used for the variables considered for model fitting.
(2) - Variable shown as Kg.500m⁻¹ in model fitting.
(3) - Pelagic fish species were excluded (*Boops boops*, *Sardinia pilchardus*, *Scomber* spp., *Trachurus* spp.).
(4) - Prof. Luiz Saldanha Marine Park.

Annex V

Details of the additional campaigns with trammel nets used in model fitting.

Table III. Details of the two experimental trammel nets additional campaigns used in model fitting: Summer 2008 and Winter 2009. Sample sizes according to protection level and substrate are shown.

Field Work Period	Research team	Sample Size			Total
		PROTECTION LEVEL			
		COMPLEMENTARY	PARTIAL	TOTAL	
Summer 2008 18 - 22 August	Rita Abecasis (1)	4	8		
	David Abecasis	Sand - 3	Sand - 5	NA	12
	Joaquim Silva (2)	Mud - 1	Mud - 3		
Winter 2009 16 - 20 February	Inês Sousa (1)	4	4	3	
	Marie Renwart	Sand - 2	Sand - 2	Sand - 1	11
	Vasco Ferreira (1)	Mud - 2	Mud - 2	Mud - 2	
	Joaquim Silva (2)	1 sample excluded (3)			
Notes:	(1) - Biomares research team	(3) - Net was manipulated by others			
	(2) - Professional fisherman	(buoy cable was found cut)			
MODEL FITTING >	Total Sample Size: 121 (131 including outliers)				
	Sample sizes per Protection Level: Complementary - 35 Partial - 59 Total - 27				

Annex VI

Data exploration undertaken previously to model fitting.

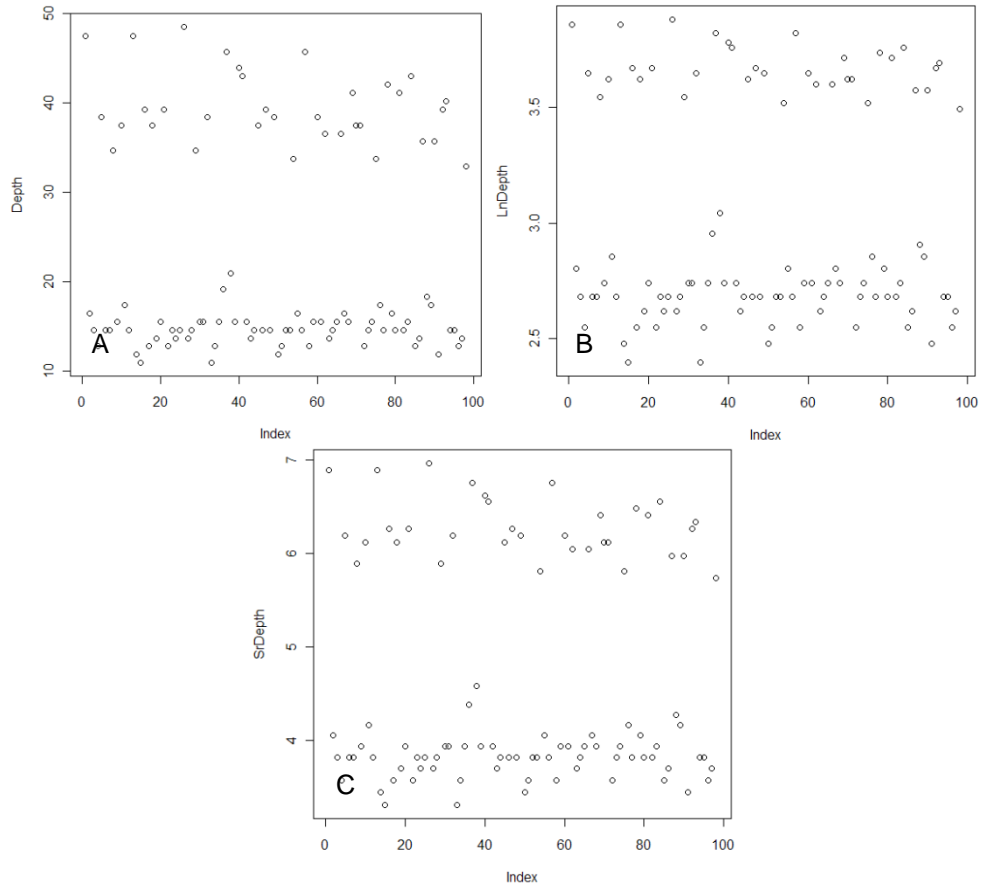


Figure 4. Dotplots of the variable Depth (m) (sandy and muddy bottom samples analyzed together). A - Depth (not transformed); B - Depth: log transformation (natural log); C - Depth: Square root transformation.

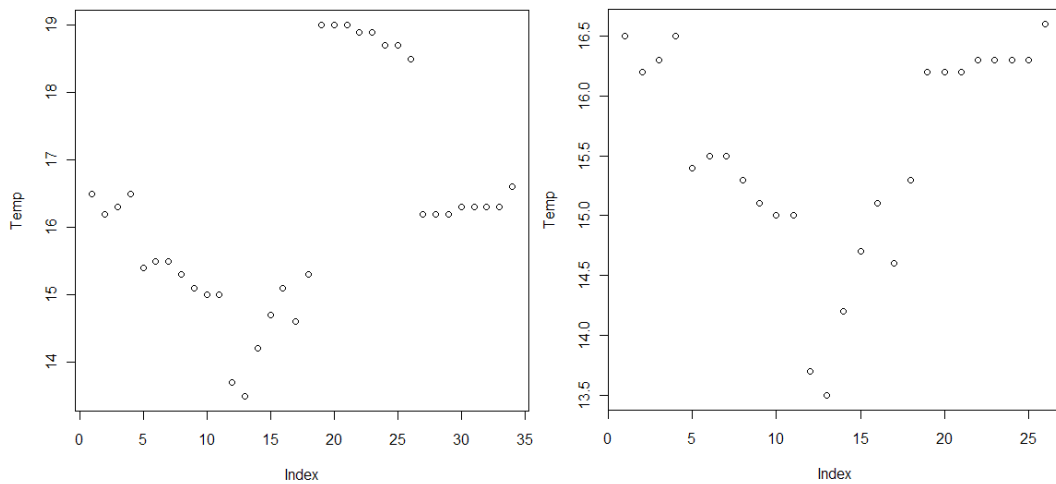


Figure 5. Dotplots of the variable Temperature ($^{\circ}\text{C}$) for the muddy bottom samples. A - Temperature: all samples; B - Temperature: exclusion of the Autumn 2009 campaign.

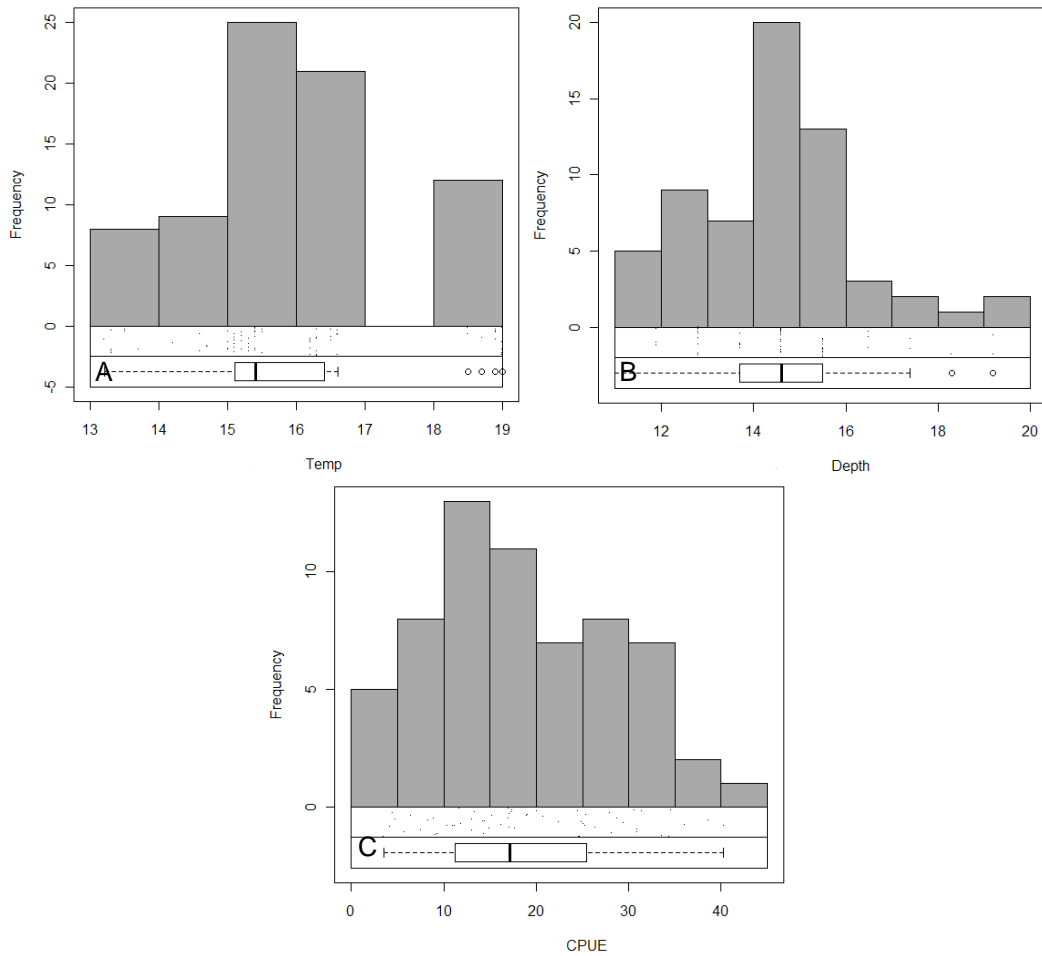


Figure 6. Sandy bottom samples: Histograms (with dotplot and boxplot below) of the continuous variables. A - Temperature (°C); B - Depth (m); C - CPUE (Kg.500m⁻¹).

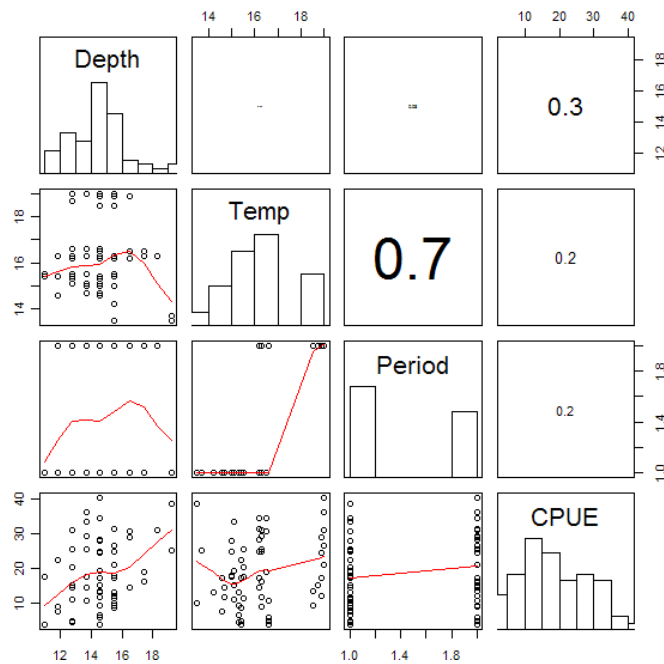


Figure 7. Sandy bottom samples: Pairplot of the Depth (m), Temperature (°C), Period (Years 3-4, Year 5), and CPUE (Kg.500m⁻¹). Lower panels show pair-wise scatterplots with smoothing curve (LOESS); Upper panels show Pearson correlation coefficients (the font of the correlation is proportional to its value).

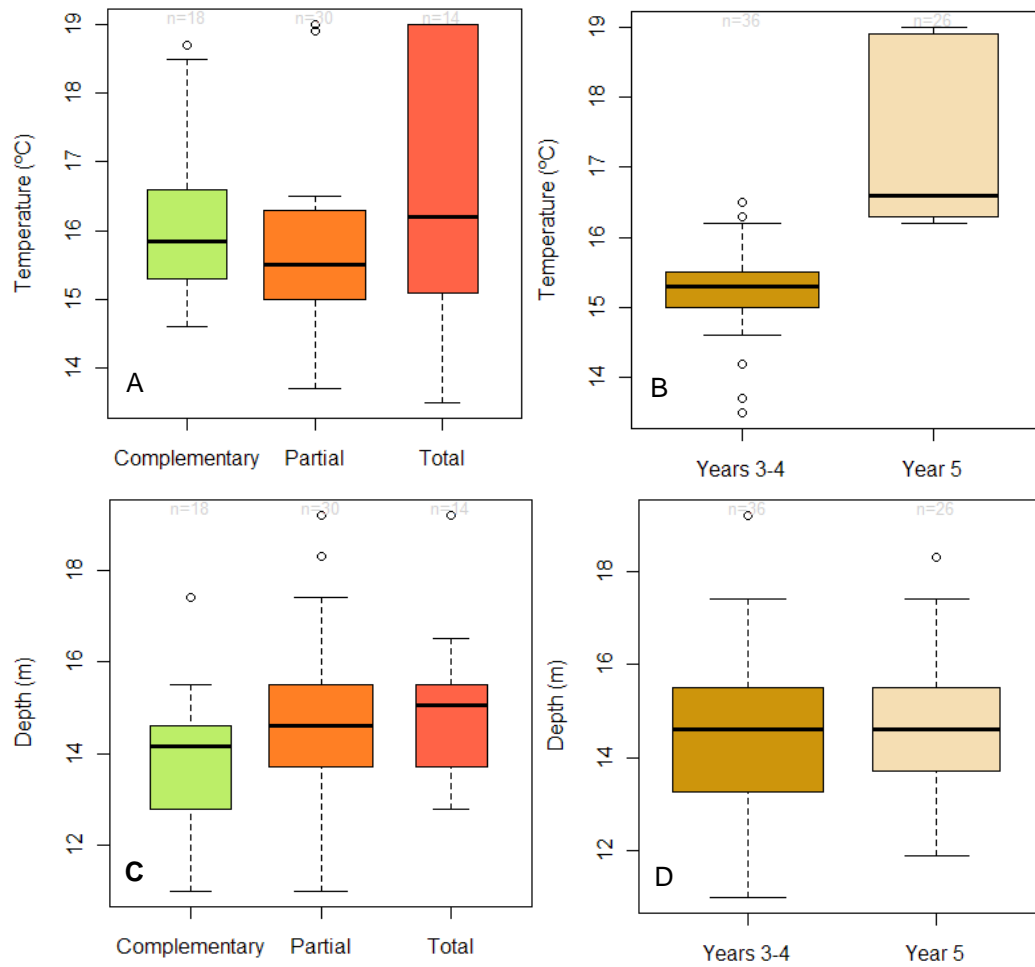


Figure 8. Sandy bottom samples: Boxplots of the continuous variables conditional on the nominal variables. A - Temperature (°C) per protection level; B - Temperature (°C) per period; C - Depth (m) per protection level; D - Depth (m) per period.

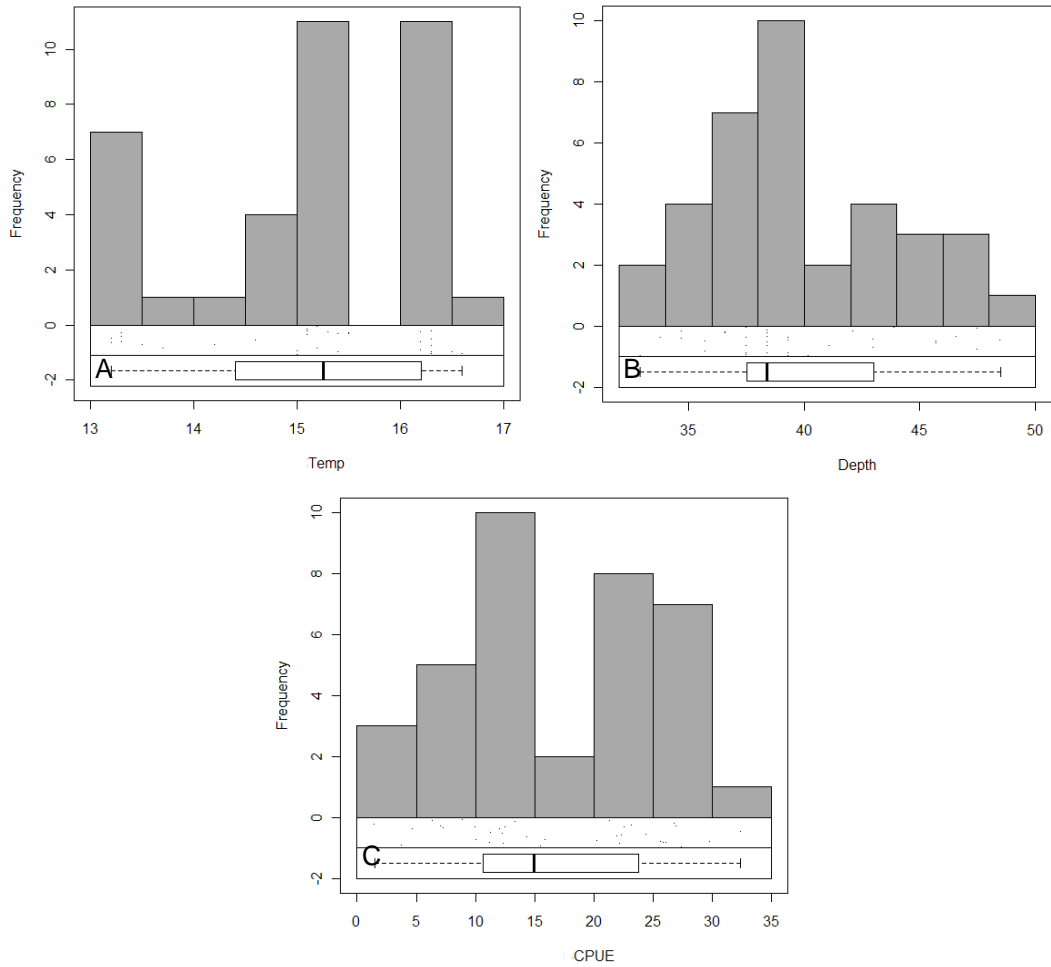


Figure 9. Muddy bottom samples: Histograms (with dotplot and boxplot below) of the continuous variables. A - Temperature (°C); B - Depth (m); C - CPUE (Kg.500m⁻¹).

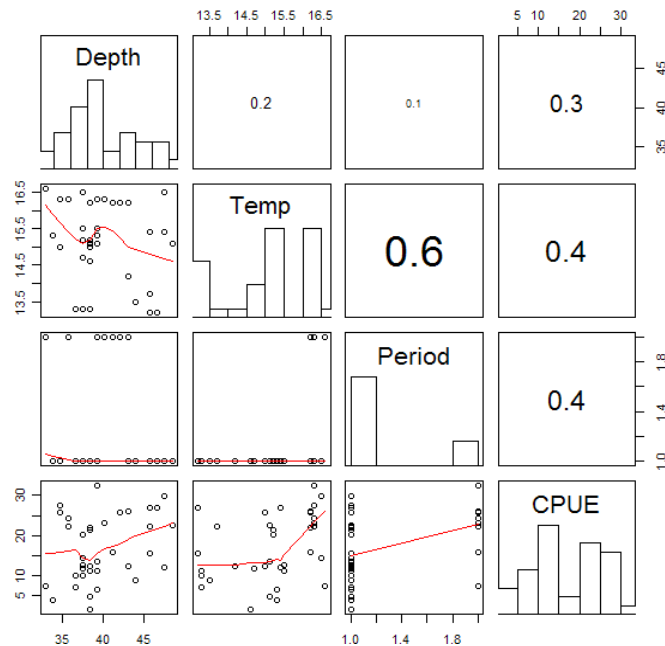


Figure 10. Muddy bottom samples: Pairplot of the Depth (m), Temperature (°C), Period (Years 3-4, Year 5), and CPUE (Kg.500m⁻¹). Lower panels show pair-wise scatterplots with smoothing curve (LOESS); Upper panels show Pearson correlation coefficients (the font of the correlation is proportional to its value).

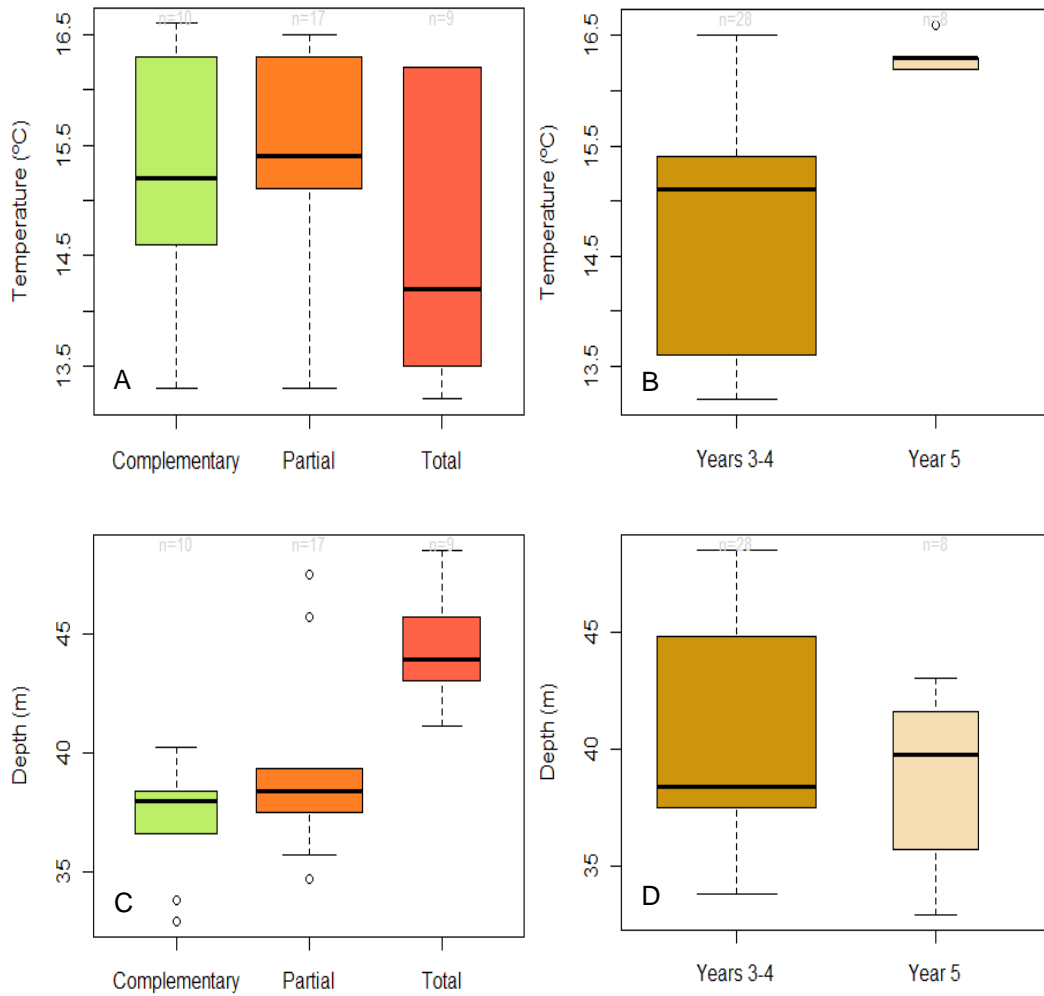


Figure 11. Muddy bottom samples: Boxplots of the continuous variables conditional on the nominal variables. A - Temperature (°C) per protection level; B - Temperature (°C) per period; C - Depth (m) per protection level; D - Depth (m) per period.

Annex VII

R code used for model fitting.

```
##### GAM
DBArrabida<-read.csv2("DB_D5.csv", header=T, sep=";", dec=".")
attach(DBArrabida)
library(mgcv)

###Initial model with all the explanatory variables
##GAM, Gaussian distribution, identity link function

####Choose the variables to include: forward stepwise selection based
####on AIC
##Obtained AIC values: see 'Results - Model Fitting'
a1<-gam(CPUE~s(Temp), family=gaussian)
a2<-gam(CPUE~s(Depth), family=gaussian)
a3<-gam(CPUE~as.factor(Prot_Level), family=gaussian)
AIC(a1,a2,a3)

b1<-gam(CPUE~as.factor(Prot_Level)+s(Temp), family=gaussian)
b2<-gam(CPUE~as.factor(Prot_Level)+s(Depth), family=gaussian)
AIC(b1,b2)

c1<-gam(CPUE~as.factor(Prot_Level)+s(Temp)+s(Depth), family=gaussian)
AIC(c1)

Ms<-gam(CPUE~as.factor(Prot_Level)+s(Temp)+s(Depth), family=gaussian)
AIC(Ms)
summary(Ms)
##choose best model according to the lowest AIC and with all
##parameters significant
plot(Ms, scale=F, page=1)
gam.check(Ms)
```

Annex VIII

Data exploration of the variable 'Temperature'.

Results of the Mann Whitney Rank Sum tests for temperature per period and season.

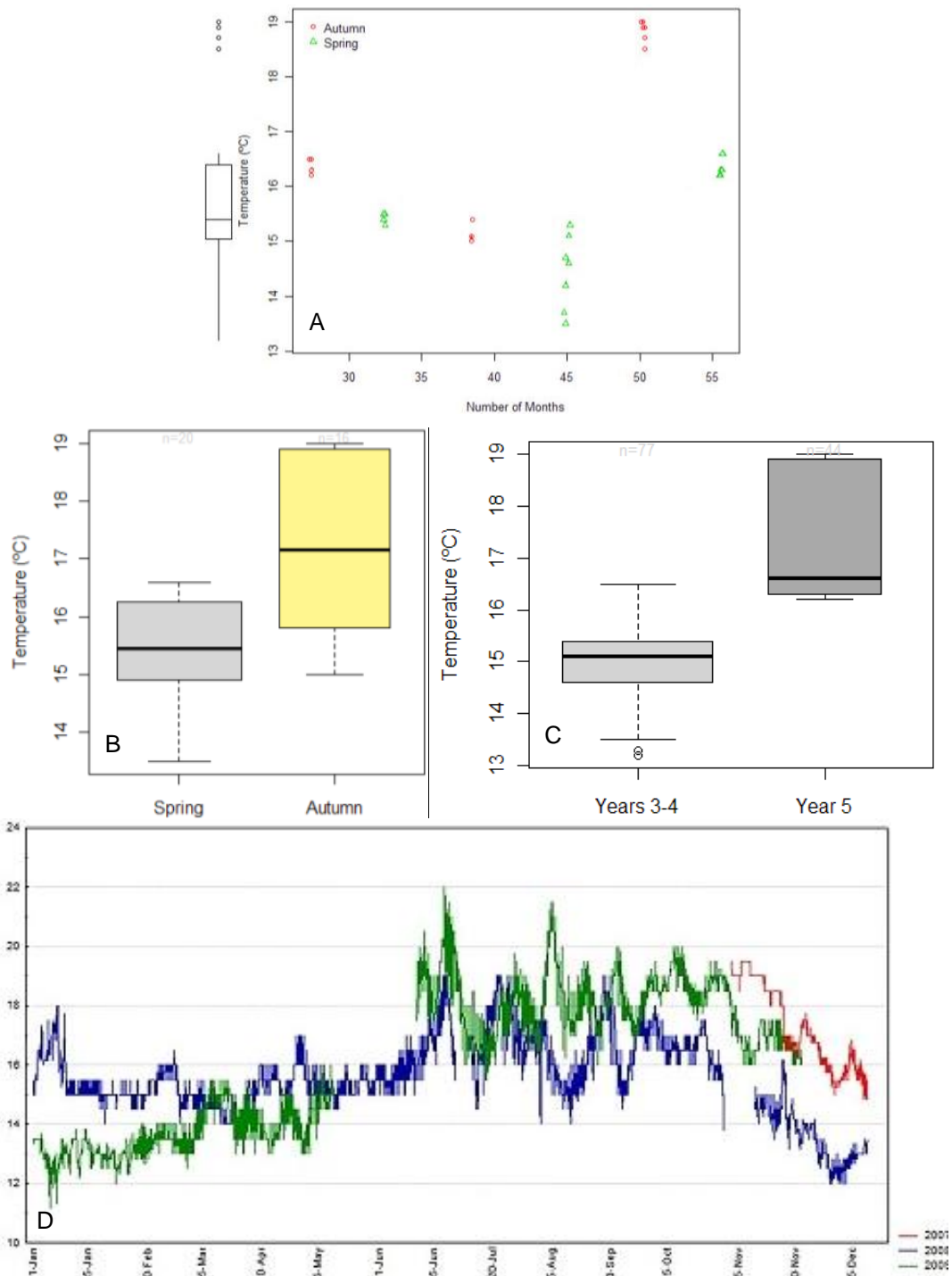


Figure 12. A - Scatterplot (boxplot on the left) of temperature (°C) per number of months (since August 2005) and according to season (spring, autumn). B - Boxplot of temperature (°C) per season (spring, autumn). C - Boxplot of temperature (measurements during winter, spring, summer, autumn sampling campaigns) by period. D - Time series of sea surface temperature in Arrábida; Red - 2007, Blue - 2008, Green - 2009 (Source: Life-BIOMARES project; Rodrigues, 2010; <http://www.ccmr.ualg.pt/biomares>).

Table IV. Results of Mann-Whitney Rank Sum tests ($\alpha=0.05$) applied to compare temperature according to period (Years 3-4, Year 5) and season (spring, autumn).

Temperature (°C)	N	Median	Q25	Q75	U	T	Statistically significant?
Period							
Years 3-4	20	15.2	14.85	15.5	18.0	438.0	Yes (P<0.001)
Year 5	16	17.2	16.3	18.9			
Season							
Spring	20	15.45	14.9	16.25	68.5	387.5	Yes (P=0.004)
Autumn	16	17.15	15.8	18.9			

Annex IX

Contribution of each *taxon* to the total number of individuals caught in the Prof. Luiz Saldanha Marine Park (PLSMP) area and according to protection level.

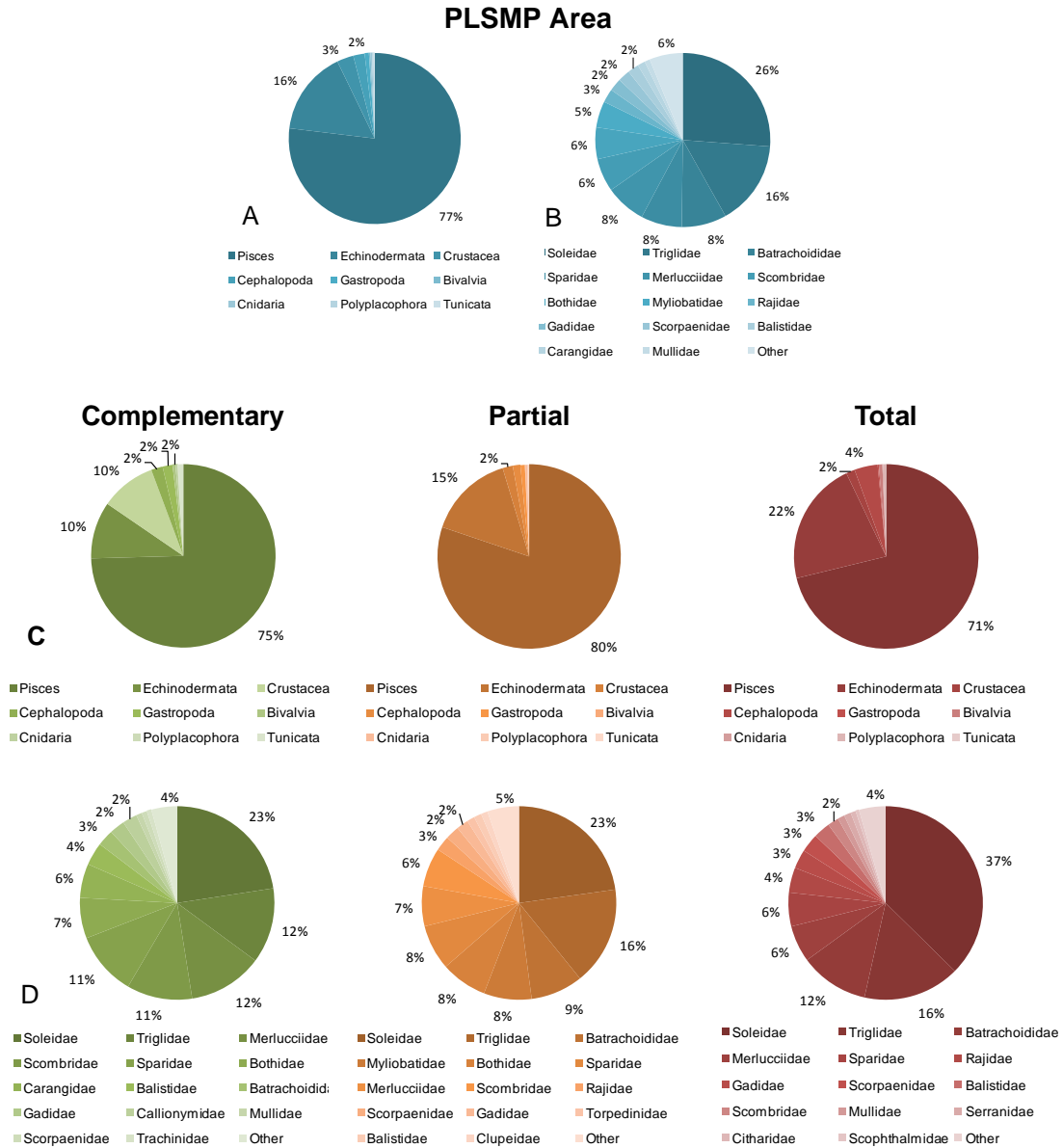


Figure 13. A - Percentage contribution of each *taxon* to the total number of individuals caught in the PLSMP. B - Percentage contribution of each family to the total of fish caught in the PLSMP. C - Percentage contribution of each *taxon* to the total number of individuals caught per protection level. D - Percentage contribution of each family to the total of fish caught per protection level.

Annex X

Some specimens caught during the experimental trammel nets campaigns.



Figure 14. Specimens caught in the Prof. Luiz Saldanha Marine Park during the sampling campaigns with experimental trammel nets: A - *Microchirus ocellatus*; B - *Synapturichthys kleinii* (known distribution up to southern Portugal); C - *Torpedo* cf. *mackayana* (known distribution up to northern Africa); D - *Pteromylaeus bovinus*; E - *Chelidonichthys lucerna*; F - *Mustelus mustelus*.

Annex XI

Results of the Dunn pairwise comparisons for the Margalef and Shannon-Wiener diversity indices.

Table V. Results of Dunn Method pairwise multiple comparisons ($\alpha=0.05$) to applied to compare Margalef and Shannon-Wiener diversity indices according to protection level and period.

	Pairwise Comparisons (Dunn's Method)	Diff. of Ranks	Q	Statistically significant? ($\alpha = 0.05$)
Margalef Years 3-4	Partial vs Complementary	19.020	3.844	Yes
	Total vs Complementary	11.571	1.680	No
	Total vs Partial	7.450	1.194	No
Margalef Years 5	Partial vs Complementary	12.271	2.502	Yes
	Total vs Complementary	17.865	3.642	Yes
	Total vs Partial	5.594	1.232	No
Margalef All Campaigns	Partial vs Complementary	30.227	4.402	Yes
	Total vs Complementary	34.345	4.306	Yes
	Total vs Partial	4.118	0.577	No
Shannon-Wiener Years 3-4	Partial vs Complementary	17.663	3.570	Yes
	Total vs Complementary	13.004	1.888	No
	Total vs Partial	4.659	0.747	No
Shannon-Wiener Years 5	Partial vs Complementary	11.875	2.421	Yes
	Total vs Complementary	17.000	3.466	Yes
	Total vs Partial	5.125	1.128	No
Shannon-Wiener All Campaigns	Partial vs Complementary	27.442	3.997	Yes
	Total vs Complementary	33.900	4.250	Yes
	Total vs Partial	6.459	0.905	No

Annex XII

Results of the Dunn pairwise comparisons for the variables CPUE in number, CPUE in weight, Catch Value, Total length, Weight per individual and Value per individual.

Table VI. Results of Dunn Method pairwise multiple comparisons ($\alpha=0.05$) applied to compare variables according to protection level and period - CPUE in number (ind.1000m⁻¹), CPUE in weight (Kg .1000m⁻¹) and catch value (€).

	Pairwise Comparisons (Dunn's Method)	Diff. of Ranks	Q	Statistically significant? ($\alpha = 0.05$)
CPUE (ind.1000m⁻¹) Years 3-4	Partial vs Complementary	19.716	3.985	Yes
	Total vs Complementary	5.950	0.864	No
	Total vs Partial	13.766	2.207	No
CPUE (ind.1000m⁻¹) Years 5	Partial vs Complementary	19.469	3.969	Yes
	Total vs Complementary	14.906	3.039	Yes
	Total vs Partial	4.563	1.005	No
CPUE (ind.1000m⁻¹) All Campaigns	Partial vs Complementary	38.802	5.651	Yes
	Total vs Complementary	24.810	3.110	Yes
	Total vs Partial	13.992	1.961	No
CPUE (Kg.1000m⁻¹) Years 3-4	Partial vs Complementary	22.430	4.533	Yes
	Total vs Complementary	19.958	2.898	Yes
	Total vs Partial	2.472	0.396	No
CPUE (Kg.1000m⁻¹) Years 5	Partial vs Complementary	18.604	3.793	Yes
	Total vs Complementary	22.417	4.570	Yes
	Total vs Partial	3.813	0.839	No
CPUE (Kg.1000m⁻¹) All Campaigns	Partial vs Complementary	38.846	5.657	Yes
	Total vs Complementary	48.620	6.095	Yes
	Total vs Partial	9.775	1.370	No
Catch Value (€) Years 3-4	Partial vs Complementary	19.755	3.992	Yes
	Total vs Complementary	24.025	3.488	Yes
	Total vs Partial	4.270	0.684	No
Catch Value (€) Year 5	Partial vs Complementary	16.958	3.457	Yes
	Total vs Complementary	22.458	4.578	Yes
	Total vs Partial	5.500	1.211	No
Catch Value (€) All Campaigns	Partial vs Complementary	37.292	5.431	Yes
	Total vs Complementary	48.185	6.041	Yes
	Total vs Partial	10.894	1.527	No

Table VII. Results of Dunn Method pairwise multiple comparisons ($\alpha=0.05$) applied to compare values per individual according to protection level and period - total length (TL; cm), weight (g) and estimated value (€).

	Pairwise Comparisons (Dunn's Method)	Diff. of Ranks	Q	Statistically significant? ($\alpha = 0.05$)
Total Length per ind. (cm) Years 3-4	Partial vs Complementary	170.654	4.050	Yes
	Total vs Complementary	132.064	2.197	No
	Total vs Partial	38.590	0.767	No
Total Length per ind. (cm) Years 5	Partial vs Complementary	164.944	3.546	Yes
	Total vs Complementary	310.133	6.630	Yes
	Total vs Partial	145.189	4.593	Yes
Total Length per ind. (cm) All Campaigns	Partial vs Complementary	333.128	5.382	Yes
	Total vs Complementary	535.944	7.707	Yes
	Total vs Partial	202.816	3.990	Yes
Weight per ind. (g) Years 3-4	Partial vs Complementary	58.845	1.410	No
	Total vs Complementary	231.541	3.870	Yes
	Total vs Partial	290.386	5.796	Yes
Weight per ind. (g) Years 5	Partial vs Complementary	14.243	0.304	No
	Total vs Complementary	329.635	7.006	Yes
	Total vs Partial	315.391	10.088	Yes
Weight per ind. (g) All Campaigns	Partial vs Complementary	215.479	3.481	Yes
	Total vs Complementary	900.049	12.943	Yes
	Total vs Partial	684.570	13.469	Yes
Value per ind. (€) Years 3-4	Partial vs Complementary	58.845	1.410	No
	Total vs Complementary	231.541	3.870	Yes
	Total vs Partial	290.386	5.796	Yes
Value per ind. (€) Year 5	Partial vs Complementary	14.243	0.304	No
	Total vs Complementary	329.635	7.006	Yes
	Total vs Partial	315.391	10.088	Yes
Value per ind. (€) All Campaigns	Partial vs Complementary	55.412	0.898	No
	Total vs Complementary	603.125	8.711	Yes
	Total vs Partial	658.536	13.115	Yes

Annex XIII

Results of the Dunn pairwise comparisons for CPUE in weight according to sector and period.

Table VIII. Results of Dunn Method pairwise multiple comparisons ($\alpha=0.05$) applied to compare CPUE in weight (Kg .1000m⁻¹) according to sector (Complementary, Partial West, Total, Partial East) and period.

CPUE (Kg.1000m ⁻¹)	Pairwise Comparisons (Dunn's Method)			Statistically significant? ($\alpha = 0.05$)
	Sector	Diff. of Ranks	Q	
Years 3-4	Partial E vs Complementary	28.833	3.257	Yes
	Partial E vs Partial W	9.500	1.065	No
	Partial E vs Total	6.500	0.757	No*
	Total vs Complementary	22.333	4.199	Yes
	Total vs Partial W	3.000	0.553	No*
	Partial W vs Complementar	19.333	3.307	Yes
Year 5	Partial E vs Complementary	27.417	3.697	Yes
	Partial E vs Partial W	11.750	1.584	No
	Partial E vs Total	5.000	0.696	No*
	Total vs Complementary	22.417	4.570	Yes
	Total vs Partial W	6.750	1.376	No*
	Partial W vs Complementar	15.667	2.988	Yes
All Campaigns	Partial E vs Complementary	54.162	4.732	Yes
	Partial E vs Partial W	18.702	1.627	No
	Partial E vs Total	9.909	0.894	No*
	Total vs Complementary	44.253	6.149	Yes
	Total vs Partial W	8.793	1.208	No*
	Partial W vs Complementar	35.460	4.539	Yes

* - Statistical Software assumes that there are no significant differences without needing to test.

Annex XIV

Exploratory data analysis of the CPUE in weight.

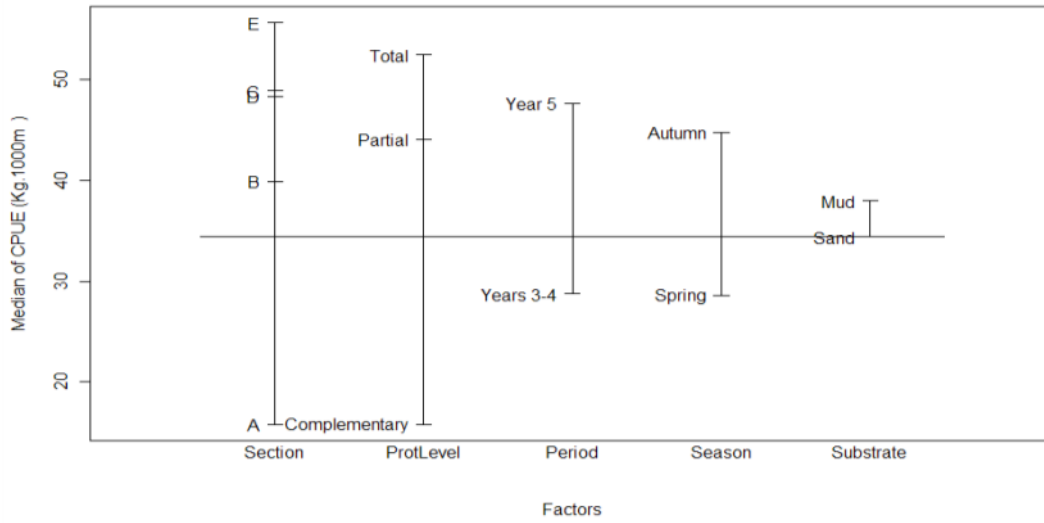


Figure 15. Design plot of the median of CPUE in weight ($\text{Kg} \cdot 1000\text{m}^{-1}$) according to each factor (Section, Protection Level, Period, Season, Substrate) category. The levels of an each factor are shown along the vertical lines, and the horizontal line represents the overall value the median.

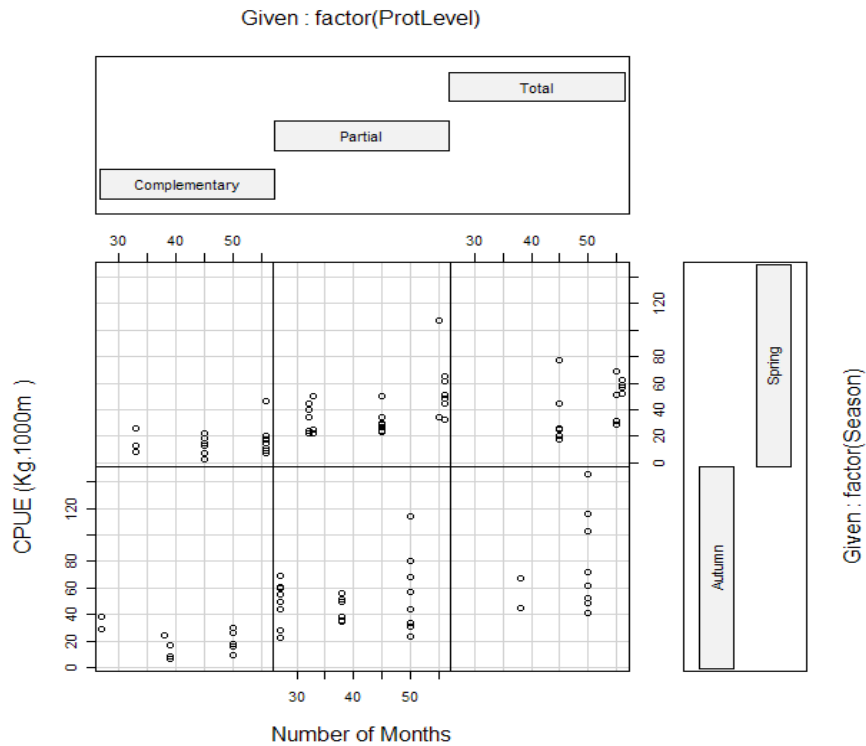


Figure 16. Coplot of CPUE ($\text{Kg} \cdot 1000\text{m}^{-1}$) versus time (number of months since August 2005), conditional on protection level and season.

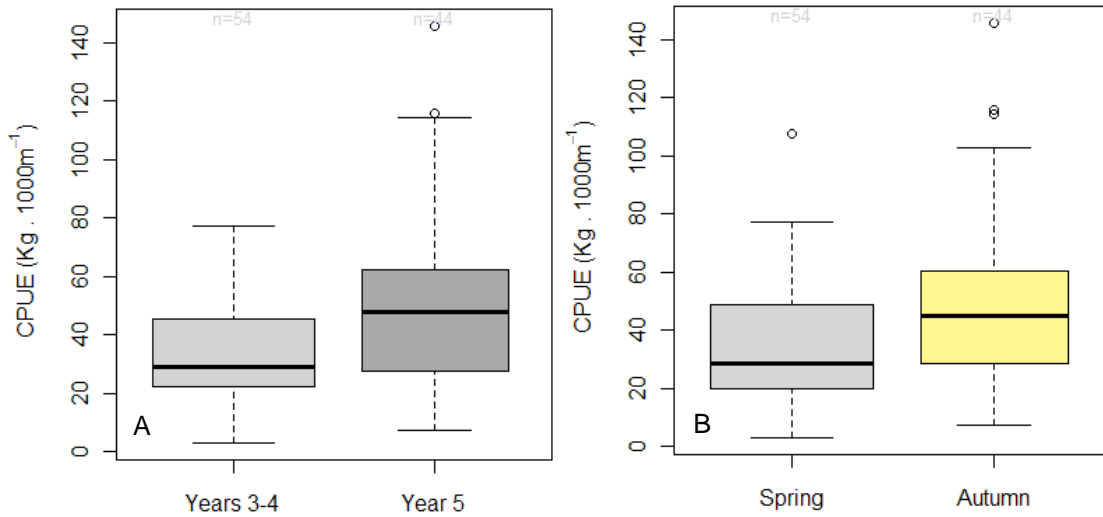


Figure 17. Boxplots of CPUE in weight (Kg.1000m⁻¹) per period (A) and per season (B).

Table IX. Results of Mann-Whitney Rank Sum tests ($\alpha=0.05$) applied to compare the CPUE in weight (Kg.1000m⁻¹) according to period (Years 3-4, Year 5) and season (spring, autumn).

CPUE (Kg.1000m ⁻¹)	N	Median	Q25	Q75	U	T	Statistically significant?
Period							
Years 3-4	54	28.765	22.399	45.188	815.0	2551.0	Yes (P=0.008)
Year 5	44	47.653	27.601	62.293			
Season							
Spring	54	28.64	19.991	48.813	806.0	2560.0	Yes (P=0.006)
Autumn	44	44.784	28.594	60.383			

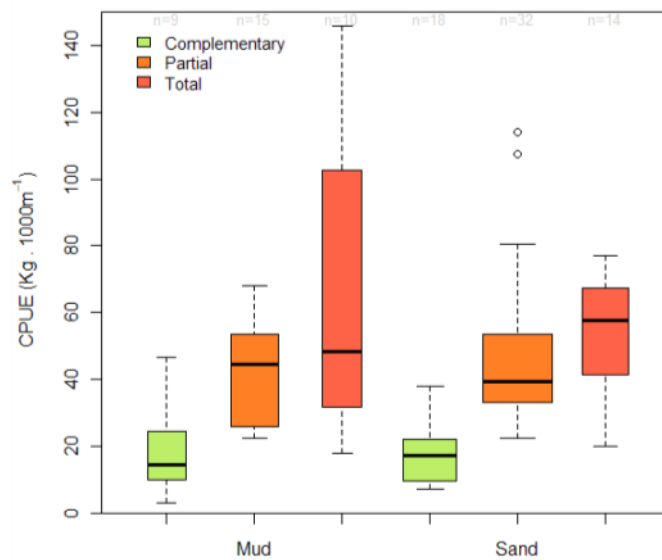


Figure 18. Boxplot of CPUE in weight (Kg.1000m⁻¹) according to protection level and substrate.

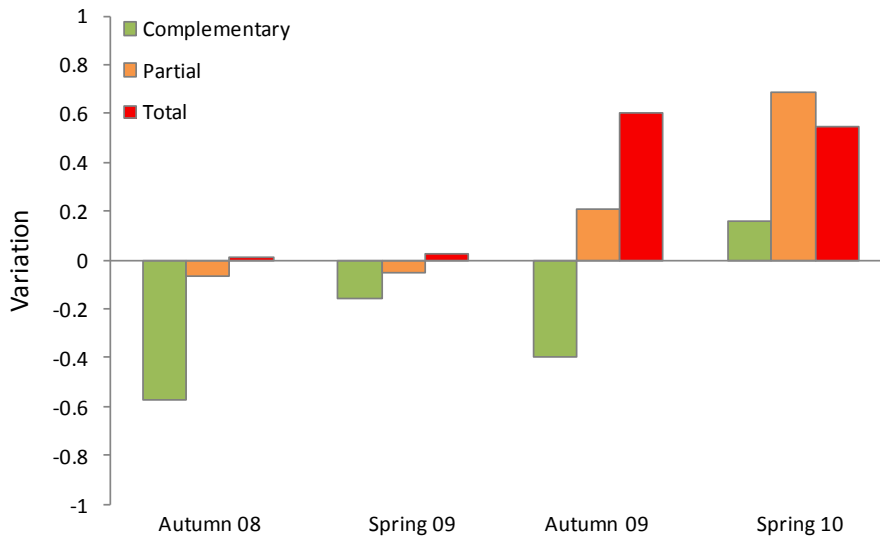


Figure 19. Proportion of variation of CPUE in weight (Kg.1000m⁻¹) in each protection level and for each campaign. Values of the Autumn 2007 campaign were the reference for the following autumn samples. Values of the Spring 2008 campaign were the reference for the following spring samples.

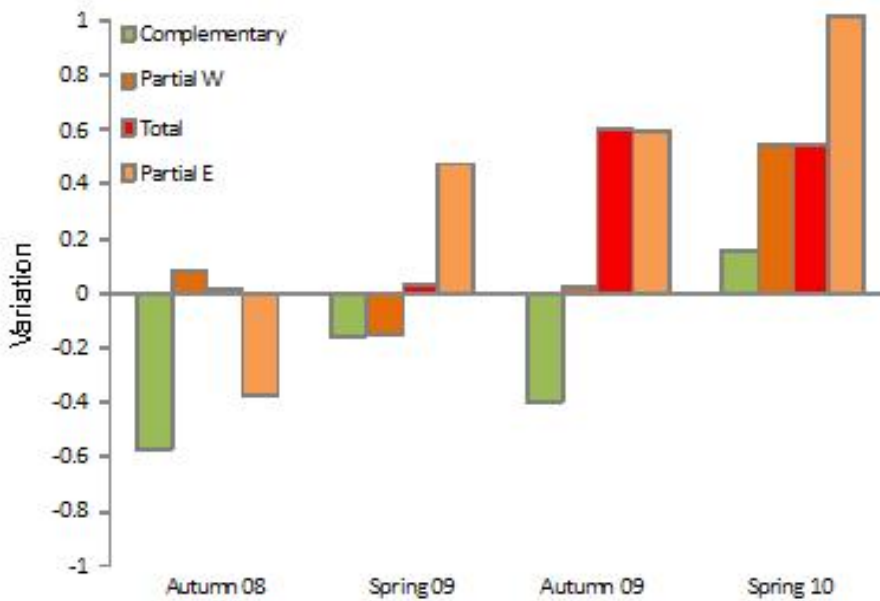


Figure 20. Proportion of variation of CPUE in weight (Kg.1000m⁻¹) in each sector (Complementary, Partial West, Total, Partial East) and for each campaign. Values of the Autumn 2007 campaign were the reference for the following autumn samples. Values of the Spring 2008 campaign were the reference for the following spring samples.

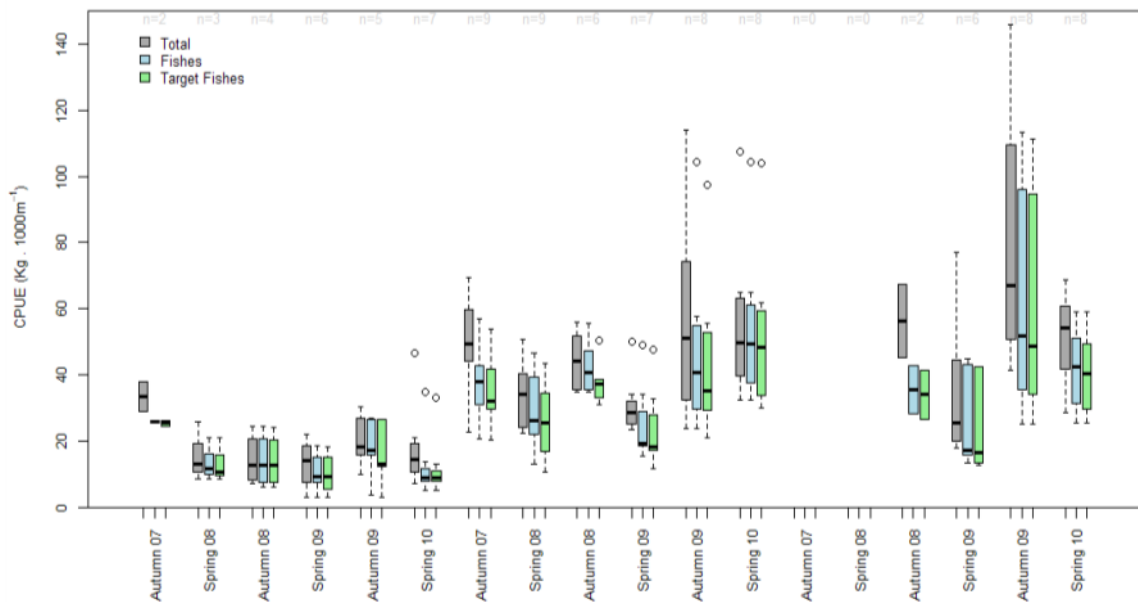


Figure 21. Boxplot of CPUE in weight (Kg.1000m⁻¹) per campaign. Data of total catch (fishes and invertebrates with commercial value), fishes, and target fishes are shown.

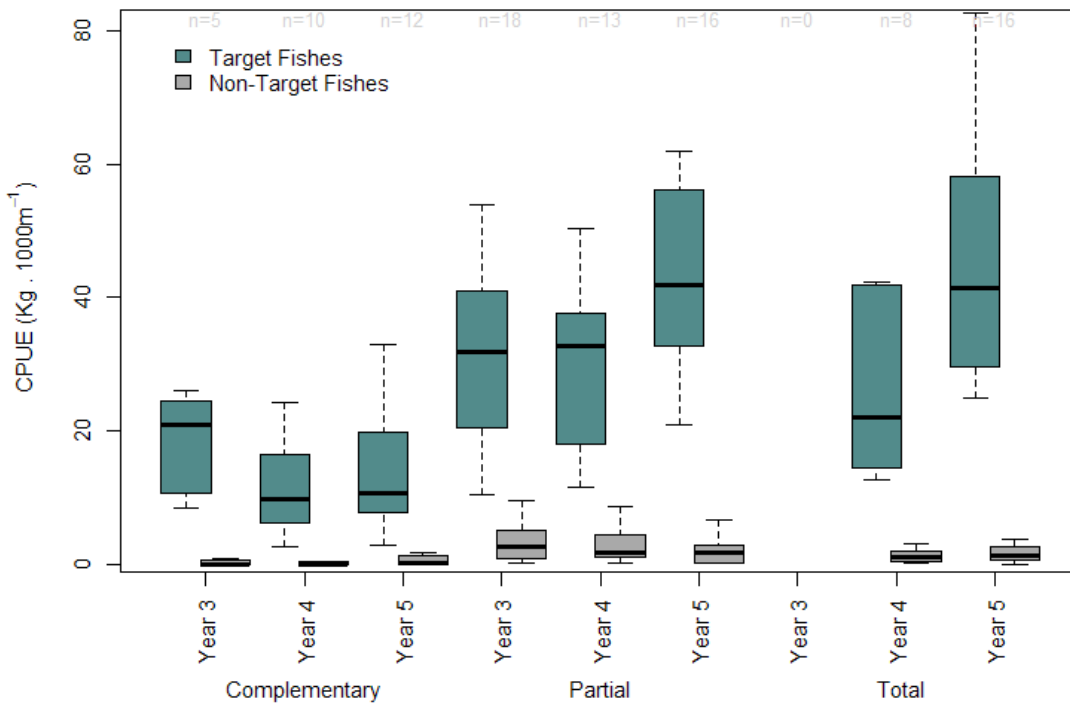


Figure 22. Boxplot of CPUE in weight (Kg.1000m⁻¹) of Target and Non-Target fishes according to protection level and year.

Annex XV

CPUE in number and in weight per species and per sector.

Table X. Species CPUE in number (ind.1000m⁻¹) and weight (Kg.1000m⁻¹) according to sector. Data of all campaigns (spring and autumn). Within each *taxon*, the species are ordered by CPUE in number.

Taxon / Species	Autumn 2007 - - Spring 2010		Sector: order West to East						All PLSMP area	
	Complementary CPUE Nr.	CPUE Kg	Partial W CPUE Nr.	CPUE Kg	Total CPUE Nr.	CPUE Kg	Partial E CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg
Pisces	60.44	14.39	137.69	36.42	119.41	41.39	131.75	55.03	109.02	33.74
Actinopterygii	74.22	13.84	144.69	30.25	111.03	31.25	106.25	28.20	109.43	25.94
<i>Microchirus azevia</i>	6.30	1.04	19.85	3.61	25.84	5.70	18.50	3.07	18.27	3.65
<i>Halobatrachus didactylus</i>	2.07	0.66	5.08	2.22	15.46	6.68	28.50	11.09	10.08	4.20
<i>Solea senegalensis</i>	6.52	2.05	12.15	4.25	9.03	3.44	9.00	3.52	9.16	3.28
<i>Merluccius merluccius</i>	9.41	2.39	11.92	5.10	8.38	3.01	2.00	0.72	9.08	3.20
<i>Chelidonichthys obscurus</i>	6.74	0.76	10.00	1.14	6.54	0.85	14.25	1.79	8.14	0.98
<i>Scomber japonicus</i>	8.22	0.82	15.46	1.93	1.24	0.15	1.00	0.10	6.92	0.80
<i>Bothus podas</i>	4.15	0.45	18.15	2.30	0.92	0.12			6.31	0.78
<i>Trigloporus lastoviza</i>	0.52	0.09	9.77	1.45	5.08	0.96	7.00	1.35	5.22	0.88
<i>Pagellus acarne</i>	4.81	0.43	4.62	0.43	5.08	0.45	6.00	0.68	4.96	0.46
<i>Chelidonichthys lucerna</i>	1.85	0.43	4.85	1.32	6.00	1.79	5.50	1.63	4.51	1.28
<i>Trisopterus luscus</i>	1.78	0.16	4.46	0.53	2.54	0.66	2.00	0.25	2.80	0.45
<i>Scorpaena notata</i>	0.67	0.06	5.08	0.46	2.81	0.25			2.59	0.23
<i>Balistes capriscus</i>	2.89	1.59	2.46	1.47	2.65	1.62	0.50	0.29	2.49	1.46
<i>Solea solea</i>	0.44	0.08	0.38	0.11	5.30	2.32	0.75	0.18	2.29	0.94
<i>Boops boops</i>	2.22	0.25	2.46	0.33	0.81	0.10	0.50	0.05	1.61	0.20
<i>Spondylisoma cantharus</i>	0.52	0.13	1.62	0.46	2.22	0.58	2.25	0.42	1.59	0.41
<i>Pegusa lascaris</i>	3.11	0.70	1.15	0.19	0.22	0.04	0.25	0.04	1.27	0.26
<i>Mullus surmuletus</i>	0.74	0.19	2.00	0.59	0.97	0.41	1.25	0.71	1.20	0.42
<i>Sardina pilchardus</i>	0.52	0.04	2.85	0.26	0.43	0.04	0.25	0.03	1.08	0.10
<i>Callionymus lyra</i>	1.85	0.15	0.69	0.07	0.49	0.04	0.25	0.02	0.90	0.08
<i>Trachurus picturatus</i>	2.59	0.21	0.62	0.04	0.05	0.00			0.90	0.07
<i>Lepidotrigla dieuzeidei</i>	0.22	0.01			2.00	0.09			0.82	0.04
<i>Trachurus trachurus</i>	1.70	0.14	0.54	0.06	0.16	0.02	1.50	0.13	0.80	0.07
<i>Amoglossus imperialis</i>	0.81	0.03	0.92	0.03	0.16	0.01			0.53	0.02
<i>Trachinus draco</i>	0.59	0.07	1.08	0.21	0.16	0.03			0.51	0.09
<i>Dicologlossa cuneata</i>	0.59	0.05	0.62	0.07	0.38	0.04	0.25	0.03	0.49	0.05
<i>Diplodus vulgaris</i>	0.07	0.03	0.92	0.37	0.38	0.12	1.00	0.22	0.49	0.17
<i>Scomber scombrus</i>	0.07	0.01	1.15	0.39	0.38	0.12	0.25	0.07	0.49	0.16
<i>Pagrus pagrus</i>	0.30	0.12	0.15	0.09	0.76	0.26	0.50	0.14	0.45	0.17
<i>Citharus linguatula</i>			0.38	0.04	0.76	0.06			0.39	0.03
<i>Serranus cabrilla</i>			0.54	0.02	0.65	0.03			0.39	0.02
<i>Scophthalmus rhombus</i>	0.30	0.11	0.23	0.17	0.49	0.33			0.33	0.20
<i>Serranus hepatus</i>			0.85	0.05	0.22	0.06			0.31	0.04
<i>Mugil cephalus</i>	0.15	0.06	0.38	0.14	0.22	0.08	0.25	0.10	0.24	0.09
<i>Chelidonichthys sp.</i>					0.43	0.08			0.16	0.03
<i>Amoglossus thori</i>			0.31	0.01	0.16	0.01			0.14	0.01
<i>Phycis phycis</i>	0.07	0.02	0.08	0.09	0.22	0.15	0.25	0.12	0.14	0.10
<i>Conger conger</i>			0.08	0.00	0.16	0.10	0.50	0.51	0.12	0.08
<i>Scorpaena porcus</i>			0.15	0.03	0.22	0.06			0.12	0.03
<i>Chelon labrosus</i>	0.15	0.25			0.05	0.03	0.50	0.50	0.10	0.12
<i>Psetta maxima</i>	0.15	0.11	0.08	0.06	0.05	0.04	0.25	0.16	0.10	0.08
<i>Aspitrigla cuculus</i>	0.15	0.01	0.08	0.01	0.05	0.01			0.08	0.01
<i>Amoglossus sp.</i>	0.15	0.01					0.25	0.01	0.06	0.00
<i>Dicentrarchus labrax</i>	0.07	0.05			0.11	0.08			0.06	0.05
<i>Diplodus sargus</i>	0.15	0.04			0.05	0.01			0.06	0.02
<i>Lophius budegassa</i>			0.23	0.08					0.06	0.02
<i>Micromesistius poutassou</i>	0.15	0.01			0.05	0.01			0.06	0.01
<i>Entelurus aequoreus</i>	0.07	0.00			0.05	0.00			0.04	0.00
<i>Hippocampus hippocampus</i>	0.07	0.00	0.08	0.00					0.04	0.00
<i>Liza saliens</i>					0.05	0.04	0.25	0.08	0.04	0.02

Assessment of reserve effect in a Marine Protected Area:
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Autumn 2007 - - Spring 2010	Sector: order West to East								All PLSMP area	
	Complementary		Partial W		Total		Partial E		CPUE Nr.	CPUE Kg
Taxon / Species	CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg
<i>Microchirus ocellatus</i>			0.15	0.02					0.04	0.00
<i>Microchirus variegatus</i>	0.07	0.00			0.05	0.00			0.04	0.00
<i>Symphodus bailloni</i>	0.07	0.00					0.25	0.00	0.04	0.00
<i>Argyrosomus regius</i>					0.05	0.07			0.02	0.03
<i>Arnoglossus laterna</i>					0.05	0.00			0.02	0.00
<i>Lepidorhombus boscii</i>					0.05	0.01			0.02	0.01
<i>Liza aurata</i>							0.25	0.09	0.02	0.01
<i>Macroramphosus scolopax</i>	0.07	0.00							0.02	0.00
<i>Microchirus boscanion</i>	0.07	0.00							0.02	0.00
<i>Nerophis lumbriciformis</i>					0.05	0.00			0.02	0.00
<i>Pagellus bogaraveo</i>					0.05	0.02			0.02	0.01
<i>Synaptura lusitanica</i>							0.25	0.08	0.02	0.01
<i>Synapturichthys kleinii</i>			0.08	0.04					0.02	0.01
<i>Zeus faber</i>					0.05	0.01			0.02	0.00
Elasmobranchii	1.56	2.02	16.08	9.18	11.57	10.58	29.00	27.21	11.43	9.21
<i>Myliobatis aquila</i>	0.30	0.03	10.62	0.97	5.14	0.53	11.25	1.24	5.76	0.57
<i>Raja clavata</i>	0.07	0.07	2.31	4.25	3.35	7.17	5.50	9.21	2.35	4.61
<i>Torpedo torpedo</i>	0.37	0.27	0.92	0.75	1.19	0.91	3.75	3.14	1.10	0.88
<i>Mustelus mustelus</i>	0.52	0.65	0.31	0.46	0.49	0.66	2.50	6.84	0.61	1.11
<i>Dasyatis pastinaca</i>			0.08	0.01	0.32	0.11	3.00	0.85	0.39	0.11
<i>Scyliorhinus canicula</i>			0.62	0.32	0.43	0.23	0.50	0.24	0.37	0.19
<i>Raja undulata</i>	0.07	0.07	0.38	0.59	0.32	0.38	1.00	1.19	0.33	0.41
<i>Rostroraja alba</i>	0.15	0.90	0.62	1.72	0.05	0.34	0.50	3.50	0.27	1.12
<i>Pteromylaeus bovinus</i>					0.16	0.08	0.75	0.87	0.12	0.10
<i>Raja miraletus</i>	0.07	0.03	0.23	0.11					0.08	0.04
<i>Raja brachyura</i>					0.11	0.17			0.04	0.06
<i>Torpedo cf. mackayana</i>							0.25	0.14	0.02	0.01
Echinodermata	10.15	na	29.08	na	31.03	na	34.00	na	25.00	na
<i>Sphaerechinus granularis</i>	1.33	na	9.77	na	26.16	na	25.25	na	14.90	na
<i>Astropecten aranciatus</i>	5.48	na	13.23	na	2.81	na	6.00	na	6.57	na
<i>Holothuria forskali</i>	1.33	na	2.38	na	0.38	na	1.75	na	1.29	na
<i>Marthasterias glacialis</i>	0.30	na	1.23	na	1.08	na			0.82	na
<i>Parastichopus regalis</i>	0.44	na	1.23	na	0.27	na			0.55	na
<i>Paracentrotus lividus</i>	0.15	na	0.54	na	0.05	na	1.00	na	0.29	na
<i>Echinus acutus</i>	0.44	na	0.15	na					0.16	na
<i>Asterias rubens</i>	0.07	na	0.23	na	0.11	na			0.12	na
<i>Psammechinus miliaris</i>	0.30	na	0.08	na	0.05	na			0.12	na
<i>Spatangus purpureus</i>	0.30	na							0.08	na
<i>Echinaster sepositus</i>			0.15	na					0.04	na
<i>Ophioderma</i> sp.					0.11	na			0.04	na
<i>Ophiothrix</i> sp.			0.08	na					0.02	na
Crustacea	9.93	1.36	4.23	2.98	2.32	2.18	2.50	6.85	4.94	2.54
<i>Polybius henslowii</i>	8.15	na	1.69	na	0.05	na			2.71	na
<i>Maja squinado</i>	0.44	1.35	0.92	2.30	0.65	1.81	2.00	6.85	0.78	2.23
<i>Palinurus elephas</i>			1.08	0.67	0.76	0.36			0.57	0.32
<i>Pagurus prideaux</i>	0.59	na	0.23	na					0.22	na
<i>Calappa granulata</i>	0.07	na	0.08	na	0.32	na	0.50	na	0.20	na
<i>Pagurus excavatus</i>					0.32	na			0.12	na
<i>Inachus</i> sp.	0.07	na	0.15	na					0.06	na
<i>Pagurus cuanensis</i>	0.15	na			0.05	na			0.06	na
<i>Dardanus calidus</i>	0.07	na			0.05	na			0.04	na
<i>Homola barbata</i>	0.15	na							0.04	na
<i>Atelecyclus undecimdentatus</i>	0.07	na							0.02	na
<i>Dardanus arrosor</i>			0.08	na					0.02	na
<i>Goneplax rhomboides</i>	0.00	na			0.05	na			0.02	na
<i>Macropodia</i> sp.	0.07	na							0.02	na
<i>Melicertus kerathurus</i>	0.07	0.00							0.02	0.00
<i>Pisa</i> sp.					0.05	na			0.02	na
Cephalopoda	2.07	1.99	2.08	1.46	5.14	8.12	4.00	3.14	3.39	4.26
<i>Sepia officinalis</i>	1.93	1.47	1.77	1.12	3.03	2.74	3.50	1.97	2.43	1.90
<i>Octopus vulgaris</i>	0.15	0.52	0.31	0.34	2.05	5.34	0.50	1.17	0.94	2.35
<i>Eledone cirrhosa</i>					0.05	0.03			0.02	0.01

Assessment of reserve effect in a Marine Protected Area:
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Autumn 2007 - - Spring 2010	Sector: order West to East								All PLSMP area	
	Complementary		Partial W		Total		Partial E		CPUE Nr.	CPUE Kg
Taxon / Species	CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg	CPUE Nr.	CPUE Kg
Gastropoda	1.78	na	1.46	na	0.22	na	3.75	na	1.27	na
<i>Cymbium olla</i>	1.78	na	1.15	na	0.16	na	3.00	na	1.10	na
<i>Nassarius reticulatus</i>							0.75	na	0.06	na
<i>Aplysia fasciata</i>			0.15	na					0.04	na
<i>Aplysia depilans</i>			0.08	na					0.02	na
<i>Aplysia sp.</i>			0.08	na					0.02	na
<i>Gibbula cineraria</i>					0.05	na			0.02	na
Bivalvia	0.52	na	0.08	na	0.70	na	0.50	na	0.47	na
<i>Atrina pectinata</i>					0.54	na			0.20	na
<i>Acanthocardia spinosa</i>	0.22	na							0.06	na
<i>Callista chione</i>	0.07	na	0.08	na	0.05	na			0.06	na
<i>Mytilus galloprovincialis</i>	0.22	na							0.06	na
<i>Acanthocardia aculeata</i>					0.05	na	0.25	na	0.04	na
<i>Dosinia exoleta</i>							0.25	na	0.02	na
<i>Pecten maximus</i>					0.05	na			0.02	na
Cnidaria	0.37	na	0.77	na	0.43	na	0.00	na	0.47	na
<i>Calliactis parasitica</i>	0.22	na	0.77	na	0.38	na			0.41	na
<i>Pteroeides griseum</i>	0.07	na			0.05	na			0.04	na
<i>Alicia mirabilis</i>	0.07	na							0.02	na
Polyplacophora	0.07	na	0.23	na	0.49	na	2.00	na	0.43	na
<i>Chaetopleura angulata</i>	0.07	na	0.23	na	0.49	na	2.00	na	0.43	na
Tunicata	0.96	na	0.15	na	0.11	na	0.00	na	0.35	na
<i>Phallusia mammillata</i>	0.96	na	0.15	na	0.11	na			0.35	na
Total	101.63	19.20	198.85	43.86	163.03	52.14	182.00	65.40	157.16	41.95

Annex XVI

Results of the Dunn pairwise comparisons for the total length of four bony fish species.

Table XI. Results of Dunn Method pairwise multiple comparisons ($\alpha=0.05$) applied to the mean total length (TL) of four bony fish species per protection level and period.

Total Length (cm)	Pairwise Comparisons (Dunn's Method)	Diff. of Ranks	Q	Statistically significant? ($\alpha = 0.05$)
<i>Chelidonichthys lucerna</i> Year 5	Partial vs Complementary	34.783	1.954	No
	Total vs Complementary	52.582	2.965	Yes
	Total vs Partial	17.799	2.618	Yes
<i>Chelidonichthys lucerna</i> All Campaigns	Partial vs Complementary	23.356	1.654	No
	Total vs Complementary	50.324	3.445	Yes
	Total vs Partial	26.968	2.913	Yes
<i>Solea solea</i> Years 3-4	Partial vs Complementary	18.844	1.635	No
	Total vs Complementary	53.707	4.341	Yes
	Total vs Partial	34.863	5.313	Yes
<i>Solea solea</i> All Campaigns	Partial vs Complementary	19.961	1.440	No
	Total vs Complementary	64.917	4.580	Yes
	Total vs Partial	44.956	6.971	Yes
<i>Solea senegalensis</i> Years 3-4	Partial vs Complementary	42.430	3.331	Yes
	Total vs Complementary	83.914	2.830	Yes
	Total vs Partial	41.484	1.471	No
<i>Solea senegalensis</i> All Campaigns	Partial vs Complementary	60.155	3.825	Yes
	Total vs Complementary	95.352	4.389	Yes
	Total vs Partial	35.197	1.919	No
<i>Microchirus azevia</i> Year 5	Partial vs Complementary	50.800	1.842	No
	Total vs Complementary	107.007	4.064	Yes
	Total vs Partial	56.207	3.833	Yes
<i>Microchirus azevia</i> All Campaigns	Partial vs Complementary	53.860	1.743	No
	Total vs Complementary	186.961	6.072	Yes
	Total vs Partial	133.101	7.325	Yes

Annex XVII

Results of the Dunn pairwise comparisons for the CPUE in number of eight fish taxa.

Table XII. Results of Dunn Method pairwise comparisons ($\alpha=0.05$) applied to four bony fishes, to compare the mean CPUE in number (ind./1000m) per protection level and period.

CPUE (Ind. / 1000m)	Pairwise Comparisons (Dunn's Method)	Diff. of Ranks	Q	Statistically significant? ($\alpha = 0.05$)
Actinopterygii				
<i>Chelidonichthys lucerna</i> Years 5	Partial vs Complementary	17.094	3.485	Yes
	Total vs Complementary	15.906	3.243	Yes
	Total vs Partial	1.188	0.261	No
<i>Chelidonichthys lucerna</i> All Campaigns	Partial vs Complementary	20.916	3.046	Yes
	Total vs Complementary	25.507	3.198	Yes
	Total vs Partial	4.591	0.644	No
<i>Microchirus azevia</i> Years 5	Partial vs Complementary	11.135	2.270	No
	Total vs Complementary	10.979	2.238	No*
	Total vs Partial	0.156	0.034	No*
<i>Microchirus azevia</i> All Campaigns	Partial vs Complementary	19.753	2.877	Yes
	Total vs Complementary	26.120	3.274	Yes
	Total vs Partial	6.367	0.893	No
<i>Solea senegalensis</i> Years 3-4	Partial vs Complementary	6.639	1.342	No
	Total vs Complementary	10.200	1.481	No
	Total vs Partial	16.839	2.699	Yes
<i>Solea senegalensis</i> All Campaigns	Partial vs Complementary	15.404	2.243	No*
	Total vs Complementary	1.280	0.160	No*
	Total vs Partial	16.684	2.339	No
<i>Solea solea</i> Years 3-4	Partial vs Complementary	5.757	1.163	No*
	Total vs Complementary	14.592	2.119	No
	Total vs Partial	8.835	1.416	No*
<i>Solea solea</i> Year 5	Partial vs Complementary	0.000	0.000	No*
	Total vs Complementary	8.250	1.682	No*
	Total vs Partial	8.250	1.817	No
<i>Solea solea</i> All Campaigns	Partial vs Complementary	7.439	1.083	No
	Total vs Complementary	20.065	2.515	Yes
	Total vs Partial	12.626	1.770	No

* - Statistical Software assumes that there are no significant differences without needing to test.

Table XIII. Results of Dunn Method pairwise comparisons ($\alpha=0.05$) applied to four elasmobranch *taxa*, to compare the mean CPUE in number (ind./1000m) per protection level and period.

CPUE (Ind. / 1000m) Elasmobranchii	Pairwise Comparisons (Dunn's Method)	Diff. of Ranks	Q	Statistically significant?
<i>Torpedo torpedo</i> Years 3-4	Partial vs Complementary	10.058	2.033	No*
	Total vs Complementary	3.200	0.465	No*
	Total vs Partial	13.258	2.125	No
<i>Torpedo torpedo</i> All Campaigns	Partial vs Complementary	14.382	2.095	No
	Total vs Complementary	3.368	0.422	No*
	Total vs Partial	11.014	1.544	No*
<i>Myliobatis aquila</i> Years 3-4	Partial vs Complementary	10.067	2.034	No*
	Total vs Complementary	1.433	0.208	No*
	Total vs Partial	11.500	1.843	No
<i>Myliobatis aquila</i> All Campaigns	Partial vs Complementary	16.139	2.350	No
	Total vs Complementary	0.759	0.095	No*
	Total vs Partial	15.379	2.156	No*
<i>Raja clavata</i> Years 3-4	Partial vs Complementary	8.723	1.763	No*
	Total vs Complementary	12.775	1.855	No
	Total vs Partial	4.052	0.650	No*
<i>Raja clavata</i> Year 5	Partial vs Complementary	16.656	3.396	Yes
	Total vs Complementary	19.094	3.892	Yes
	Total vs Partial	2.438	0.537	No
<i>Raja clavata</i> All Campaigns	Partial vs Complementary	23.363	3.403	Yes
	Total vs Complementary	36.745	4.606	Yes
	Total vs Partial	13.382	1.876	No
Rajidae Years 3-4	Partial vs Complementary	12.906	2.608	No*
	Total vs Complementary	14.788	2.147	No
	Total vs Partial	1.881	0.302	No*
Rajidae Year 5	Partial vs Complementary	17.865	3.642	Yes
	Total vs Complementary	18.802	3.833	Yes
	Total vs Partial	0.938	0.206	No
Rajidae All Campaigns	Partial vs Complementary	28.223	4.110	Yes
	Total vs Complementary	38.949	4.883	Yes
	Total vs Partial	10.726	1.504	No

* - Statistical Software assumes that there are no significant differences without needing to test.

Annex XVIII

Graphical analysis for comparison of the CPUE in weight of eight fish species in the Partial and Total protection areas versus the Complementary area.

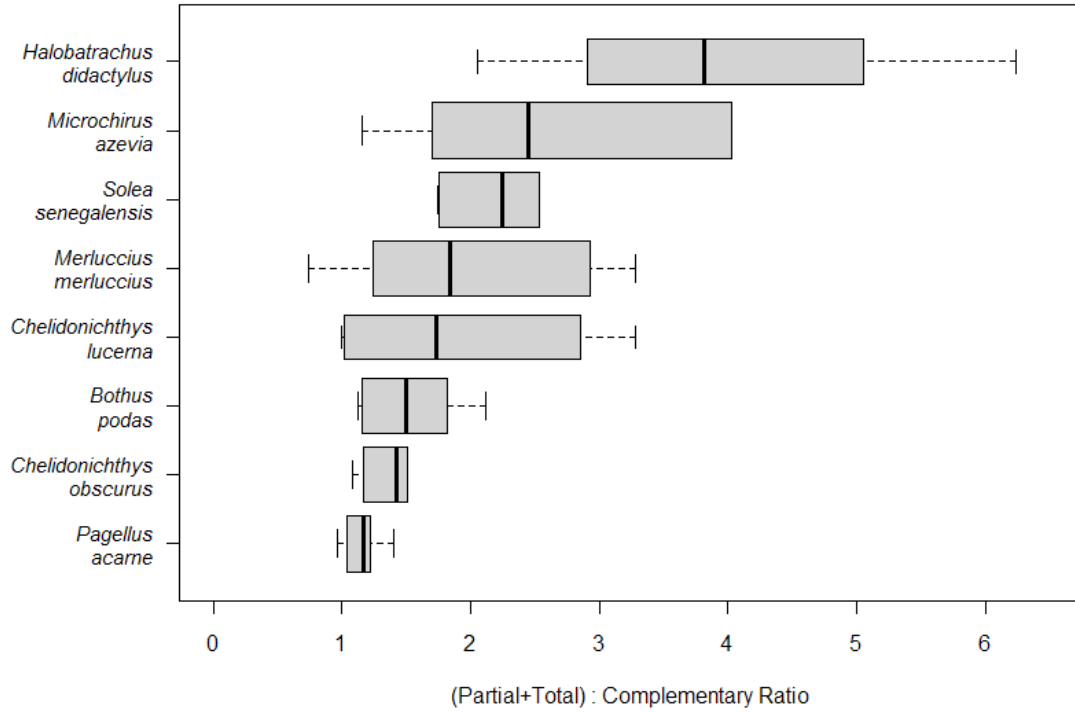


Figure 23. Boxplot of the Ratio of CPUE in weight (Kg.1000m⁻¹): Partial and Total protection areas in relation to the Complementary area. Data for the eight target bony fish species with higher abundance are shown.

Annex IX

Results of the SIMPER analysis for the sandy and muddy bottom samples and according to the protection level.

Table XIV. SIMPER results for protection level comparisons (4th root data transf.; Bray-Curtis similarity); Sandy and muddy bottom samples analyzed separately. Species with Contribution% ≥ 3.5 are shown.

Protection Level - Pairwise Comparisons						
Sandy bottom						
Complementary ¹ & Partial ² (Av.Diss = 62.32)						
Species	Av.Abund.¹	Av.Abund.²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Halobatrachus didactylus</i>	0.5	1.5	3.77	1.55	6.04	6.04
<i>Trigloporus lastoviza</i>	0.0	1.0	3.40	1.70	5.45	11.49
<i>Microchirus azevia</i>	0.2	1.0	3.21	1.33	5.15	16.64
<i>Bothus podas</i>	0.9	1.0	2.92	1.23	4.69	21.34
<i>Myliobatis aquila</i>	0.2	1.0	2.91	1.14	4.66	26.00
<i>Pagellus acarne</i>	0.7	1.1	2.68	1.26	4.31	30.31
<i>Merluccius merluccius</i>	1.0	0.9	2.62	1.22	4.20	34.51
<i>Chelidonichthys lucerna</i>	0.4	0.8	2.51	1.22	4.03	38.53
<i>Pegusa lascaris</i>	0.6	0.4	2.28	1.00	3.67	42.20
<i>Balistes capriscus</i>	0.6	0.6	2.26	1.08	3.63	45.83
Complementary ¹ & Total ² (Av.Diss = 64.32)						
Species	Av.Abund.¹	Av.Abund.²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Trigloporus lastoviza</i>	0.0	1.1	3.81	1.68	5.93	5.93
<i>Halobatrachus didactylus</i>	0.5	1.4	3.75	1.44	5.83	11.75
<i>Microchirus azevia</i>	0.2	1.0	3.54	1.25	5.50	17.26
<i>Chelidonichthys lucerna</i>	0.4	1.1	3.36	1.49	5.22	22.48
<i>Octopus vulgaris</i>	0.1	1.0	3.34	1.84	5.20	27.67
<i>Raja clavata</i>	0.0	0.8	3.00	1.25	4.66	32.33
<i>Merluccius merluccius</i>	1.0	0.5	2.97	1.22	4.61	36.94
<i>Bothus podas</i>	0.9	0.2	2.84	1.19	4.42	41.36
<i>Balistes capriscus</i>	0.6	0.8	2.71	1.18	4.22	45.58
<i>Pagellus acarne</i>	0.7	0.8	2.57	1.15	3.99	49.57
<i>Pegusa lascaris</i>	0.6	0.0	2.41	0.88	3.74	53.31
<i>Sepia officinalis</i>	0.6	0.9	2.37	1.16	3.68	56.99
<i>Spondyliosoma cantharus</i>	0.1	0.7	2.29	1.24	3.57	60.56
Partial ¹ & Total ² (Av.Diss = 52.22)						
Species	Av.Abund.¹	Av.Abund.²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Bothus podas</i>	1.0	0.2	2.70	1.13	5.18	5.18
<i>Myliobatis aquila</i>	1.0	0.2	2.50	1.10	4.79	9.97
<i>Microchirus azevia</i>	1.0	1.0	2.45	1.25	4.70	14.67
<i>Octopus vulgaris</i>	0.3	1.0	2.31	1.52	4.43	19.10
<i>Merluccius merluccius</i>	0.9	0.5	2.14	1.16	4.11	23.20
<i>Pagellus acarne</i>	1.1	0.8	2.11	1.13	4.04	27.24
<i>Balistes capriscus</i>	0.6	0.8	2.04	1.16	3.90	31.14
<i>Raja clavata</i>	0.5	0.8	2.02	1.17	3.87	35.00
<i>Sepia officinalis</i>	0.5	0.9	1.96	1.23	3.75	38.75

Protection Level - Pairwise Comparisons

Muddy bottom						
Complementary ¹ & Partial ² (Av.Diss = 58.91)						
Species	Av.Abund.¹	Av.Abund.²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Scorpaena notata</i>	0.4	1.2	3.27	1.42	5.55	5.55
<i>Chelidonichthys lucerna</i>	0.4	1.2	3.18	1.47	5.39	10.94
<i>Trigloporus lastoviza</i>	0.5	1.2	3.11	1.42	5.27	16.22
<i>Callionymus lyra</i>	1.0	0.2	2.81	1.49	4.76	20.98
<i>Raja clavata</i>	0.1	0.9	2.65	1.45	4.50	25.48
<i>Trisopterus luscus</i>	0.8	1.0	2.42	1.20	4.11	29.59
<i>Pagellus acarne</i>	0.7	0.8	2.38	1.22	4.05	33.63
<i>Microchirus azevia</i>	1.4	1.9	2.25	1.12	3.81	37.45
<i>Chelidonichthys obscurus</i>	1.1	1.0	2.19	1.11	3.72	41.16
<i>Spondylisoma cantharus</i>	0.3	0.8	2.16	1.2	3.66	44.82
<i>Sepia officinalis</i>	0.5	0.9	2.09	1.18	3.56	48.38
Complementary ¹ & Total ² (Av.Diss = 66.07)						
Species	Av.Abund.¹	Av.Abund.²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Solea solea</i>	0.2	1.4	4.03	2.59	6.09	6.09
<i>Halobatrachus didactylus</i>	0.3	1.2	3.29	1.46	4.97	11.07
<i>Scorpaena notata</i>	0.4	1.3	3.18	1.53	4.81	15.88
<i>Raja clavata</i>	0.1	1.1	3.09	1.71	4.68	20.55
<i>Citharus linguatula</i>	0.0	0.9	2.93	2.37	4.44	24.99
<i>Chelidonichthys obscurus</i>	1.1	0.3	2.86	1.43	4.33	29.31
<i>Microchirus azevia</i>	1.4	2.2	2.69	1.19	4.07	33.39
<i>Chelidonichthys lucerna</i>	0.4	0.9	2.52	1.16	3.82	37.20
<i>Trisopterus luscus</i>	0.8	1.3	2.48	1.25	3.75	40.95
<i>Callionymus lyra</i>	1.0	0.4	2.37	1.28	3.59	44.54
Partial ¹ & Total ² (Av.Diss = 50.36)						
Species	Av.Abund.¹	Av.Abund.²	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Solea solea</i>	0.5	1.4	2.77	1.92	5.50	5.50
<i>Trigloporus lastoviza</i>	1.2	0.4	2.70	1.40	5.36	10.87
<i>Halobatrachus didactylus</i>	0.5	1.2	2.62	1.38	5.19	16.06
<i>Chelidonichthys obscurus</i>	1.0	0.3	2.17	1.33	4.32	20.38
<i>Chelidonichthys lucerna</i>	1.2	0.9	2.10	1.17	4.16	24.54
<i>Citharus linguatula</i>	0.2	0.9	2.04	1.65	4.04	28.58
<i>Pagellus acarne</i>	0.8	0.0	2.00	1.27	3.97	32.55
<i>Lepidotrigla dieuzeidei</i>	0.4	0.7	1.92	1.17	3.80	36.35

Annex XX

NMDS ordination of samples according to substrate.

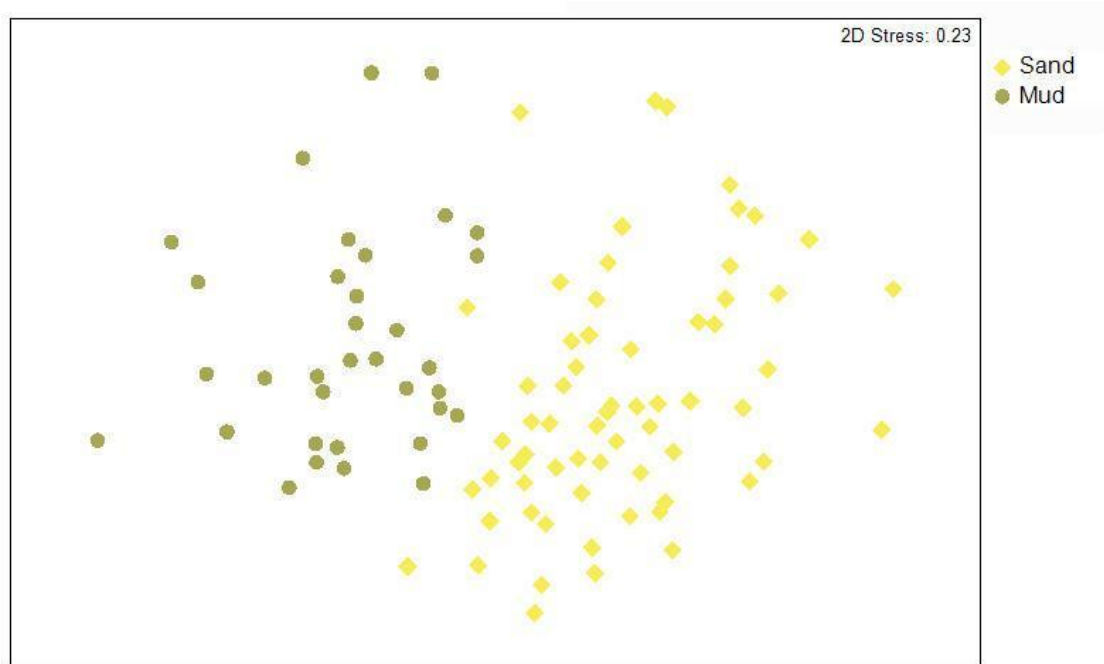


Figure 24. NMDS ordination of samples based on Bray-Curtis similarity (4th root data transformation). Samples are labeled according to substrate/depth: sandy (10-18m depth) and muddy bottom (35-40m).