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Impacts of partial marine protected areas on coastal fish communities exploited by recreational angling

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ABSTRACT

The usefulness of partial marine protected areas (MPA) that implement some form of fisheries-management regulations, but do not ban fishing and the take of fish entirely, has been questioned due its perceived limited conservation benefits. Here, we provide empirical data demonstrating fish conservation benefits of partial MPA when the stocks in question are mainly exploited by recreational angling. We studied a multi-species recreational fishery from the Balearic Islands (Mediterranean Sea) comparing three kinds of spatially close managed areas. The implementation of a partial MPA decreased the fishing pressure attracted, and the protected areas hosted greater abundances and larger-sized fish compared to areas of open access. Possibly the greatest conservation benefit of partial MPA resulted from the reduced fishing effort attracted, likely as a result of aversion of anglers to use areas where some form of management is affecting the recreational experience. In addition, the constraints on artisanal fishing may also have contributed to the conservation benefits we found. Depending on the right social and ecological context, partial MPA may therefore work as expected. Our study is observational and therefore cause-and-effect cannot be conclusively provided. However, our positive data suggest that more empirical data from other recreational fisheries and stocks should be collected before discarding the use of partial MPA in terms of providing a suitable compromise between conservation objectives and securing access to resources.

1. Introduction

It is commonly appreciated that commercial fishing exerts considerable pressures on marine ecosystems and that preventing overexploitation demands sophisticated management systems to control excessive fishing mortality (Worm et al., 2009). Somewhat less appreciated is the fact that in many coastal areas recreational fishing exploitation is intense, which may exert similar or even higher fishing mortality rates relative to commercial fisheries on selected species desired by recreational anglers (Coleman et al., 2004b; Figueira and Coleman, 2010; Lewin et al., 2006). Therefore, managing recreational fishing mortality in marine environments with a view to maintain fish population abundance, biomass, size structure and species diversity is warranted in many areas of the world (Coleman et al., 2004b; Fujitani et al., 2012; Ihde et al., 2011).

Fisheries managers have a wide range of tools available to direct fishing mortality and the size classes of fish taken by recreational anglers. Despite ongoing scientific uncertainty as to their effectiveness and their potential to increase overall fish stocks, one effective means of conserving fish stocks in the face of intensive commercial and recreational fishing mortality may be the implementation of no-take marine reserves (Bohnsack, 2000; Fenberg et al., 2012; Halpern and Warner, 2002; Roberts et al., 2001; Tetreault and Ambrose, 2007). However, such measures often create stakeholders conflict because access to valued ecosystems, localities and stocks are prohibited or heavily curtailed (Coleman et al., 2004a; Cox et al., 2003; Granek et al., 2008; Salz and Loomis, 2005). Therefore, marine recreational fisheries managers may be inclined to implement less strict management alternatives using a mix of various more traditional regulatory measures such as size-based harvest limits, daily or weekly bag limits, annual quotas and partial season closures rather than implementing total effort controls (Cox et al., 2002; Ihde et al., 2011). However, the effectiveness of such tools is questionable if the total fishing effort, hence fishing mortality, is not curtailed (Cox et al., 2003; Lynch, 2006; Fujitani et al., 2012). Also, implementation of total catch-and-release policies may not

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solve the issue of overexploitation if release mortalities and effort remains high (Bartholomew and Bohnsack, 2005; Coggins et al., 2007).

One way of assessing the potential conservation benefits of "mixed-regulation" systems constitutes comparatively studying partial marine protected areas (pMPA), where fishing mortality is partly constrained but some fishing effort and restricted catch retention still allowed (Denny and Babcock, 2004; Guidetti et al., 2010). A range of recent studies have questioned the usefulness of pMPAs suggesting limited or no conservation benefits on exploited fish stocks (Denny and Babcock, 2004; Di Franco et al., 2009; Fujitani et al., 2012; Shears et al., 2006). However, some empirical studies indicated the potential conservation benefits of pMPAs for recreational angling (Bohnsack, 2011). Contrasting the fish community structure and effort attracted to specific pMPA in a recreational angling fishery constitutes an interesting opportunity to understand the potential use of pMPA for managing recreational fisheries (Lynch, 2006; Fujitani et al., 2012).

The Mediterranean Sea offer suitable conditions to investigate the impact of pMPAs on small-bodied coastal fish communities exploited mainly by recreational fisheries (Coll et al., 2010). Three reasons play a role. First, the coastal zones of the Mediterranean Sea are intensively populated and highly developed for tourism. Hence, from a management perspective trade-offs exist between offering protection to marine habitat through full closure to fisheries and maintenance of access to resources to large numbers of small-scale commercial and recreational fisheries (Di Franco et al., 2009; Forcada et al., 2009; Guidetti et al., 2010; Lloret et al., 2008a; Morales-Nin et al., 2005, 2010). Second, the importance of marine recreational angling fisheries is increasingly recognized in the Mediterranean Sea (e.g., Gianguzza et al., 2006; Gordoa, 2009; Lloret et al., 2008b; Morales-Nin et al., 2005), and these fisheries often target different near-shore fish species of small body size relative to small-scale commercial or artisanal coastal fisheries (Stergiou et al., 2006). To help understanding the impact of recreational angling in coastal marine fish communities, there is a need to systematically assess the impact of various management approaches on small-bodied multi-species fish communities in the Mediterranean Sea. Finally and the third reason, in the Mediterranean Sea there exist a variety of spatially restricted coastal areas that range in level of management from full closure to open-access (e.g., Di Franco et al., 2009; Gianguzza et al., 2006; Guidetti et al., 2010). Despite their usually small size (Francour et al., 2001), such areas may offer protection to small-bodies species with highly restrictive spatial distribution offering an ideal situation of complete protection of the individual's home ranges (Botsford et al., 2003).

The objective of the present study was to contrast the coastal fish community along shallow seagrass meadows in spatially close locations in the Balearic Islands (Mediterranean Sea) that differ by the degree of fisheries management actions but are not fully closed to fishing (pMPAs). Some of the species of interest in the present study, such as *Serranus scriba*, have not shown declines in abundance and biomass with increasing coastal fishing pressure outside the Mediterranean (Canary Islands) because they may benefit from competitive release by the removal of large-bodied top predators (e.g., *Epinephelus marginatus*, Tuya et al., 2006). These findings contrast with other reports from the Mediterranean Sea, including the Balearic Islands (Cardona et al., 2007; Morales-Nin et al., 2005), that suggest recreational angling can be substantial on the coastal fish community and may accordingly change abundance, biomass and size structure of the fish community (Lester et al., 2009). If this is the case, we would expect that some level of protection offered to fish through various management tools such as size-based harvest limits, bag limits and temporal closure should be reflected in increased abundance, biomass and size

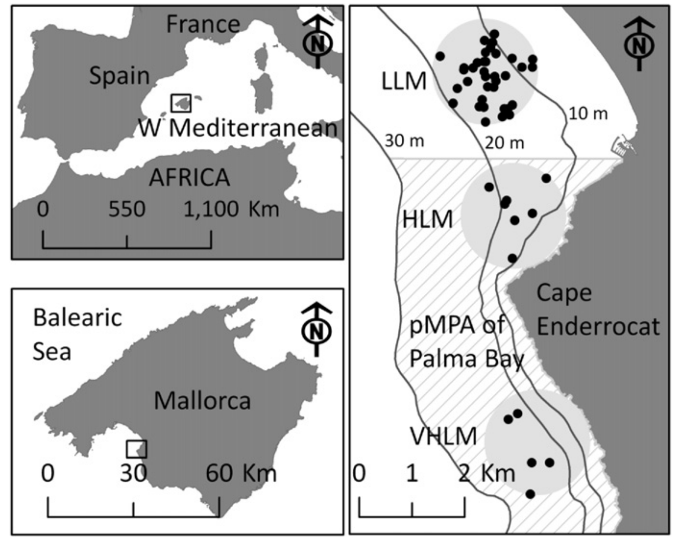

Fig. 1. Map showing the three sampling areas corresponding to the three different levels of management: low level of management (LLM), high level of management (HLM) and very high level of management (VHLM). Sampling areas were buffered by a 1 km radius to estimate recreational fishing effort. The grated area delimits the partial marine protected area (pMPA) of Palma Bay (Mallorca Island, NW Mediterranean). Black circles show the position of the recreational boats identified within each sampling area.

structure relative to ecologically similar areas without any form of management intervention and open to recreational and/or commercial fishing effort. We test this prediction using a comparative assessment approach across various ecologically similar localities. The study was designed to assess fish species using experimental hook-and-line fishing that mimicked local fishing tactics employed by the boat recreational anglers in the Balearic Islands. Such methods mainly target small-bodied coastal fish species along seagrass of *Posidonia oceanica* that are not strongly targeted by small-scale commercial fisheries such as the small serranid, *S. scriba*, the labrid, *Coris julis* or the sparid, *Diplodus annularis* (Cardona et al., 2007), which are the most frequent species captured by local anglers in the study area (Morales-Nin et al., 2005).

2. Materials and methods

2.1. Study site and sampling method

The present study was conducted in 2008 and took place within the MPA of Palma Bay and adjacent areas, southern Majorca Island (Western Mediterranean, N39 28 E2 43, and Fig. 1). This MPA is relatively small (~24 km^2) and extends from the coastline to the 30 m isobath. Fishing activities have been regulated since 1982 albeit not enforced until the late 90's through permanent monitoring by specific MPA-guards. For the purpose of the present study, three experimental "treatments" with different degree of fish stock protection offered by fisheries-management actions were selected in close proximity to each other to control for a potential habitat structure effect unrelated to management regulations.

Experimental areas were selected following three criteria. First, sampling areas presented the same bottom characteristics with seagrass beds dominated by *P. oceanica* seagrass and similar depths (≈10 m). However, it is known that the spatial bottom characteristics at small scales in relation to *P. oceanica* cover are highly variable, which could affect the fish abundance it hosts (Moranta et al., 2006). Thus, prior to sampling a confirmative habitat assessment was carried out to test whether the coverage of *P. oceanica* was similar in the selected treatment areas. To that end, *P. oceanica* cover was

Table 1
Estimated (Markov Chain Monte Carlo (MCMC) mean), lower and upper 95% highest posterior density intervals (HPD) and the *P*-value (Pr(>|*t*|)) of the Generalized Lineal Mixed Models (GLMM) fitted to test differences on *Posidonia oceanica* coverage among experimental areas: low level of management (LLM), high level of management (HLM) and very high level of management (VHLM).

	MCMC mean	HDP 95% lower	HDP 95% upper	Pr(>|*t*|)
Intercept	75.02	35.88	114.89	<0.001
Treatment (HLM)	7.44	−0.99	17.15	0.11
Treatment (VHLM)	−5.02	−14.33	−4.08	0.28

Table 2
Number of boats and anglers (mean and standard deviation) recorded over 70 visual censuses to assess fishing effort at each sampling site: low level of management (LLM), high level of management (HLM) and very high level of management (VHLM). Note the opposite pattern among the fishing effort and the management intervention.

	Boats effort (boats km^2)	Anglers effort (anglers km^2)
LLM	0.52 ± 1.7	0.97 ± 3.0
HLM	0.1 ± 0.45	0.31 ± 1.4
VHLM	0.07 ± 0.5	0.14 ± 1.0

measured using a customized prototype of a non-invasive drop camera system (Model Subcam, Albatros Marine Technologies S.L., Esporles, Spain). The system allowed us to obtain vertical images at the same distance from the sea-bottom covering an area of 0.9 m^2. A total of 5 photos were taken (3–5 m apart) in two different areas per management treatment (n = 10 per experimental area, n = 30 in total). Each photo was quantitatively examined in terms of coverage percentage of *P. oceanica* by two readers using the methodology proposed by Cabanellas-Reboredo et al. (2010). Briefly, *P. oceanica* coverage data were expressed as the Covering Index (CI) using the Braun–Blanquet's scale of the coefficient of abundance-dominance: + (negligible presence), 1 (<5% of surface covered), 2 (5–24% of surface covered), 3 (25–49% of surface covered), 4 (50–75% of surface covered) and 5 (>75% of surface covered). Then, a generalized linear mixed-effect model (GLMM, Zuur et al., 2009) was fitted considering the CI of *P. oceanica* as response variable, experimental treatment (i.e., level of management) as fixed factor, and area and reader were considered as random factors. Results confirmed a non-significant treatment effect on the coverage of *P. oceanica* (Table 1), and we thus assumed all areas to be comparable across the management units in terms of habitat present.

Secondly, the distance between experimental areas was selected following the spatial behavioural patterns of the most common species and sizes sampled. Most of species present and of value to local recreational anglers are hermaphrodites with a limited home range, in most cases lower than 1 km^2 in its adult stages (e.g., *S. scriba*: March et al., 2010, *C. julis*: Palmer et al., 2011, *D. annularis:* March et al., 2011, *Serranus cabrilla*: Alós et al., 2011, *Diplodus vulgaris*: Alós et al., 2012). The distance among areas was determined so as to not allow substantial movement of individuals among areas during the year sampled. Thus, sampling areas were considered far enough apart to allow an unbiased comparison without being influenced by migration, and we therefore considered sampling areas as independent (Westera et al., 2003).

Thirdly, experimental areas were chosen to correspond with varying levels of fisheries management. In the first experimental area (named "low level of management, LLM") management of fisheries was based on the common rules for all open access areas in the Balearic Islands (Fig. 1). In relation to boat-angling these involved: daily bag limits (5 kg of any fish species), gear limits (two rods with maximum of 3 hooks each), and minimum legal size (total length) for some species: *Boops boops* (110 mm), *D. annularis* (120 mm), *Pagellus erythrinus* (150 mm), *Trachurus mediterraneus* (150 mm), *D. vulgaris* (180 mm), *Diplodus sargus* (230 mm) and *Pagrus pagrus* (180 mm). Moreover, in this area recreational fishing tournaments are allowed (see details in Morales-Nin et al., 2010). The two other experimental areas were selected in the buffer area of the pMPA of Palma Bay (Fig. 1). In the first one (named "high level of management, HLM") in addition to the common regulations for the open access mentioned above the following rules were in effect: recreational fishing is banned on 3 work-days a week, there is a minimum hook size (7 mm gape) and all tournaments are banned. Moreover, some species have an additional minimum legal size: *Labrus merula* (310 mm) and *Labrus virids* (350 mm). Finally, the third sampling area (named "very high level of management, VHLM") differed from the HLM because it was located in an area where artisanal fisheries are additionally managed with a temporal closure during part of the year (1/10–30/06).

As indicator of fishing pressure, recreational boats in a buffer of 1 km of radius per each sampling area were censed. A total of 70 visual censuses from boat were carried out in each sampling area. In each visual census, the position, the fishing method, the number of anglers and the date and hour were registered for each boat. The mean of boats and anglers per km^2 showed that, as to be expected, the LLM treatment was visited by a higher number of boats and anglers relative to the other two areas (Table 2). Due to lack of monitoring data, it is unknown whether the two areas with currently lower visitations rates were visited more often prior to installation of the management scheme.

To assess fish community structure of species targeted by the recreational fishing in each of the three experimental areas (buffers of 1 km of radius in each area), relative abundance and fish size structure was enumerated using controlled experimental angling sessions as per previous research (Alós et al., 2009; Cerdà et al., 2010; Grixti et al., 2007). Angling session units (i.e., samples) consisted of continuous gear-controlled fishing by a single angler for 30 min from an anchored boat made in a random place of each experimental area. Two volunteer anglers with similar levels of experience were selected as experimental samplers. Sampling sessions were standardized, and the same gear was used in all of the sessions. All hooks were baited with similar size pieces of shrimp (*Penaeus vannamei*) covering the whole hook surface as described in Alós et al. (2009). Captured fish were identified and measured for total length (nearest mm). All fish caught during the angling sessions were maintained in two different aerated pounds (i.e., one per angler) until sampling. Due the expected low mortality rates (e.g., Alós et al., 2009; Veiga et al., 2011) all fish were released.

The three experimental areas (LLM, HLM and VHLM) were sampled three times throughout one year (winter, spring and summer). For each season-area, two different sampling days were carried out, realizing four angling sessions per angler in each level of management protection. Thus, the experimental design was overall fully balanced in relation to angling sessions (n = 4), angler (2 categories), day (2 categories), season (3 categories) and level of management (3 categories) with a total of 144 angling sessions and more than 1700 individual fish sampled.

2.2. Data analysis

Two main groups of statistical analyses were carried out for the purposes of the study: (1) multivariate analyses to test for changes in the species-specific patterns of abundance (fish sampled per 30 min) across management intervention, and (2) univariate analyses to test for changes in the fish sizes in the most frequent species sampled (i.e., *C. julis*, *D. annularis* and *S. scriba*, which are the most frequent species caught by the recreational anglers) across management intervention. In all analyses the effect of angler and sampling day was controlled and considered as co-variates.

In the first group of analysis, multivariate analyses were focused on testing the relationship between the fish community composition in terms of species abundance and the fixed effect of interest (i.e., level of management). For this analysis, a response matrix (species-specific abundance) was built using 144 rows representing 144 sampling sessions, and a specific number of columns for species. Species with frequency of occurrence less than 2% were pooled over all angling sessions and were considered occasional or rare and not considered further in the analysis. Additionally, an explanatory variables matrix was built with the management intervention, season, day and angler as dummy variables. In the analysis process, we first described the observed patterns by using Principal Components Analysis (PCA). Then, inferential analyses were completed using Redundancy Analyses (RDA) (Legendre and Gallagher, 2001) to estimate how much variation in the response matrix was attributed to the explanatory variables. We selected RDA instead Canonical Correspondence Analysis because this ordination method is more appropriate when species turnover is not very large (ter Braak and Smilauer, 2002).

The strategy adopted here for model building was model-based for the variables of little direct interest (considered co-variates) and their effects were removed before testing for the effect of the variable our interest (i.e., management intervention). The ratio between the variability (inertia in the multivariate jargon) explained by the model and the residual inertia was used to test the significance of the model using Monte Carlo simulations. When significant differences were detected (i.e., level of management and season), a similarity percentage analysis (SIMPER) was carried out between pairwise factors to evaluate which species contributed to dissimilarity both within and between groups (Clarke and Gorley, 2001). SIMPER was based on breaking down the Bray–Curtis dissimilarity between two samples into contributions for each species (denoted as $\bar{\delta}_i$). $\bar{\delta}_i$/s.d. was used as a useful indicator of how consistently a species contributed to $\bar{\delta}_i$ across all pairs of samples. Thus, large values of $\bar{\delta}_i$/s.d. indicated that this species not only greatly contributed to the dissimilarity between two groups but it also did so consistently in inter-comparisons of all samples in the two groups (Clarke and Gorley, 2001).

In the second group of analysis, generalized linear mixed-effects (GLMM) models were used to test the relationships between the response variable fish size and a number of explanatory variables (Zuur et al., 2009). Management intervention (LLM vs. HLM vs. VHLM), season (winter vs. spring vs. summer) and its interactions were considered as fixed factors, while day and angler were considered random factors.

The effect of a fixed factor was eventually included in the minimum adequate model following a forward step-by-step (by comparing the model with and without the factor trough ANOVA) following the approach proposed by Zuur et al. (2009). Residual distributions were examined for normality by visual inspection of residual histograms, normal QQ plots, and adequate transformation (log-transformed) was applied in the cases where normality assumptions were violated. Homoscedasticity was also examined using box-plots and fitted-residuals. A α value of 0.05 was chosen as the critical level for rejection of the null hypotheses for all analyses. Multivariate analysis was performed using CANOCO 4.5, and the results were visualized with the extension CanoDraw for Windows, and SIMPER was performed using version 6.1.5 of the PRIMER software. GLMMs were fitted using the *lme4* library from the R data analysis software package (http://www.r-project.org/).

3. Results

3.1. Descriptive information

In total, 1711 fishes belonging to 21 different species and 8 families were sampled (Table 3). The most frequent family was the

Table 3
Mean and the standard deviation (s.d.) of the species-specific abundance (fish sampled per 30 min) and fish sizes (total length in mm) calculated for each level of fisheries management: low level of management (LLM), high level of management (HLM) and very high level of management (VHLM).

	LLM					HLM					VHLM				
	n	Abundance		Fish size		*n*	Abundance		Fish size		*n*	Abundance		Fish size	
		mean	s.d.	mean	s.d.		mean	s.d.	mean	s.d.		mean	s.d.	mean	s.d.
Diplodus annularis	284	5.92	5.43	117.44	14.60	255	5.31	4.33	120.45	13.68	107	2.23	2.34	130.54	18.85
Serranus scriba	122	2.54	2.53	129.73	25.29	202	4.21	3.50	140.91	26.27	255	5.31	3.39	150.34	27.27
Coris julis	91	1.90	1.65	145.33	20.70	133	2.77	2.44	150.04	19.93	75	1.56	1.65	141.64	22.62
Boops boops	39	0.81	1.41	192.89	36.54	8	0.17	0.52	140.20	8.29	2	0.04	0.20	119	8.49
Diplodus vulgaris	1	0.02	0.14	192	–	4	0.08	0.28	196.50	53.57	26	0.54	0.92	182.58	30.23
Symphodus tinca	3	0.06	0.24	183.67	40.50	8	0.17	0.52	163.50	30.83	10	0.21	0.58	127	12.76
Trachurus mediterraneus	14	0.29	0.50	190	35.01	0	0	0	–	–	7	0.15	0.71	261.86	17.51
Spondyliosoma cantharus	1	0.02	0.14	145	–	5	0.10	0.37	146.40	17.04	10	0.21	0.77	180.60	47.21
Serranus cabrilla	0	0	0	–	–	0	0.00	0.00	–	–	13	0.27	0.54	131.69	19.20
Chromis chromis	0	0	0	–	–	2	0.04	0.20	129.50	60.10	9	0.19	0.49	90.89	6.25
Labrus merula	0	0	0	–	–	2	0.04	0.29	273	45.53	3	0.06	0.24	273.33	55.77
Diplodus sargus	0	0	0	–	–	0	0	0	–	–	4	0.08	0.45	192	6.78
Oblada melanura	1	0.02	0.14	140	–	1	0.02	0.14	186	–	1	0.02	0.14	195	–
Thalassoma pavo	0	0	0	–	–	0	0	0	–	–	3	0.06	0.24	170.33	5.51
Labrus virids	0	0	0	–	–	0	0	0	–	–	2	0.04	0.20	307	28.28
Pagellus erythrinus	0	0	0	–	–	0	0	0	–	–	2	0.04	0.20	381	57.98
Spicara maena	0	0	0	–	–	0	0	0	–	–	2	0.04	0.20	165.50	86.97
Synodus saurus	0	0	0	–	–	1	0.02	0.14	110	–	0	0	0	–	–
Scorpaena porcus	0	0	0	–	–	1	0.02	0.14	121	–	0	0	0	–	–
Pagrus pagrus	0	0	0	–	–	0	0	0	–	–	1	0.02	0.14	262	–
Symphodus mediterraneaus	1	0.02	0.14	127	–	0	0	0	–	–	0	0	0	–	–

–, no fish caught.

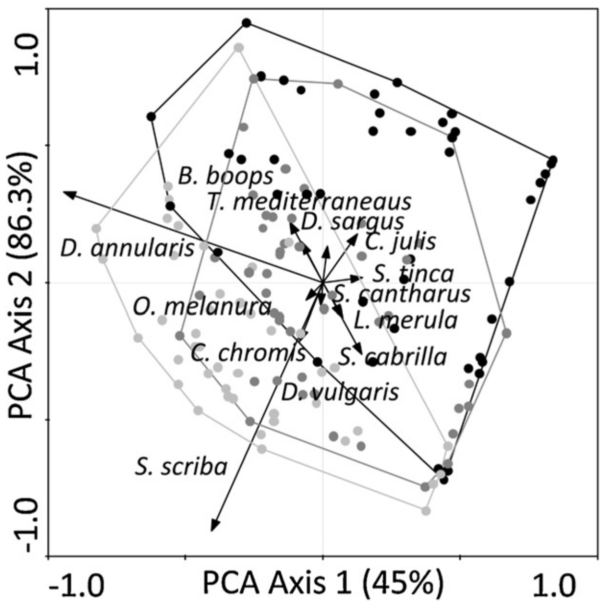

Fig. 2. Bi-plot of the two first axes of the Principal Components Analysis (PCA) performed to assess any patterns of variance between samples (fishing sessions) and species-specific fish abundance. The values in brackets show the cumulative percentage of variance explained by each main component. Samples are grouped according to season and visualized as black circles (winter), dark grey circles (spring) and light grey circles (summer) and each species is projected as a vector.

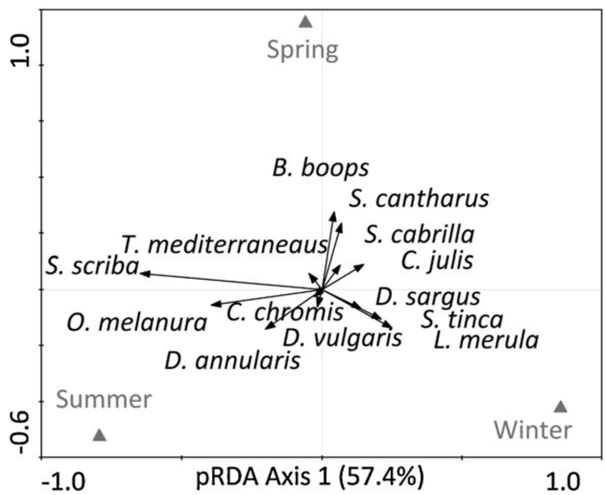

Fig. 3. Bi-plot representing the two first axis of the Partial Redundancy Analysis (pRDA) performed to test the effect of season on species-specific fish abundance. The value in brackets shows the percentage of the variance explained by the first axis (variable tested). Each species is projected by a vector, and the angles between species are proportional to the co-variation between their abundances. The triangles are at the centroid of each category, and species abundance of the seasonal effect for each species can be approximated by projecting the triangles on the species arrow (and its prolongation).

Sparidae (43.9%), followed by the Serranidae (34.6%) and Labridae (19.4%). The other less frequent families encountered were: Carangidae (1.2%), Pomacentridae (0.6%), Centracanthidae (0.1%), Synodontidae (0.1%) and Scorpaenidae (0.1%). At species-specific levels, 89.1% of individuals captured by number were accounted by three species: *D. annularis* (37.8%), *S. scriba* (33.8%) and *C. julis* (17.5%, Table 3). Of all species sampled, 10 species (47.6%) were observed in the LLM area (Table 3). In HLM area, a total of 12 species (57.1%) were observed while the highest percentage (85.7%) of species occurrence in this study was in the VHLM area with a total of 18 species sampled (Table 3).

3.2. Variance in species-specific abundance across areas

Multivariate analysis to test the relationship between the species-specific abundance composition and the explanatory variables included 13 species: *D. annularis, S. scriba, C. julis, B. boops, D. vulgaris, Symphodus tinca, T. mediterraneus, Spondyliosoma cantharus, S. cabrilla, Chromis chromis, L. merula, D. sargus* and *Oblada melanura*. The two first components of the principal component analysis (PCA) explained 86.3% of the total sample variability (Fig. 2). The PCA showed aggregation in function of the explanatory variables suggesting that variance could be explained by the explanatory variable matrix (Fig. 2). This visual interpretation was confirmed by the formal variance partitioning test using the full redundancy analysis (RDA), and the pool of explanatory variables significantly affected the species-specific composition (RDA, after 999 unrestricted permutations, *F*-ratio = 10.72, *P*-value < 0.01). Season explained 57.4% of the total variance within the model, which exerted a highly significant effect on the species-composition (pRDA, after 999 unrestricted permutations, *F*-ratio = 18.3, *P*-value < 0.001 and Fig. 3).

The variable of interest (i.e., management intervention) explained 33.2% of the total variance in species-specific abundance, which was also highly significant (pRDA, after 999 unrestricted permutations, *F*-ratio = 10.5, *P*-value < 0.001 and Fig. 4). The effect of level of management resulted from the fact species-specific abundance and species diversity increased with the level of management intervention with the VHLM area being most species-rich (Fig. 4). The results of SIMPER were in full agreement with those obtained by pRDAs, and *S. scriba* and *D. annularis* were the most important contributors to seasonal and between management-treatments dissimilarity (Table 4). Finally, the effect of potentially confounding variables in the experimental angling was analysed revealing that some modest variability in species-specific abundance was related to the day of sampling (7.8% of the total variance explained, pRDA, after 999 unrestricted permutations, *F*-ratio = 5.21, *P*-value < 0.01), but there was no angler effect (1.6% of

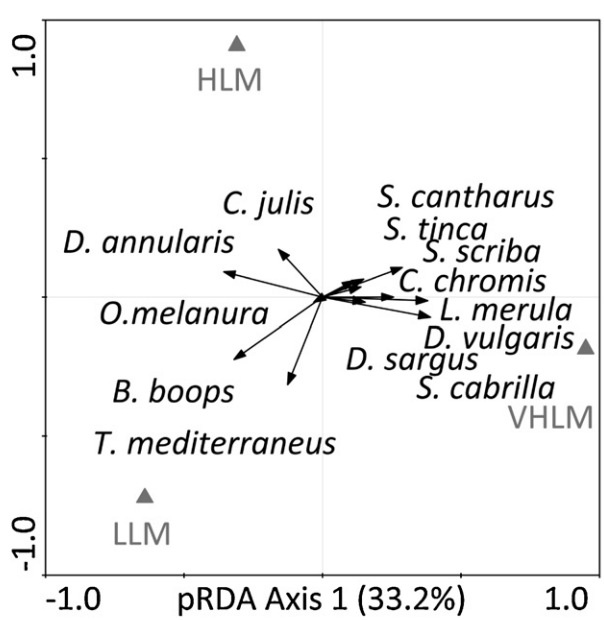

Fig. 4. Bi-plot representing the two first axis of the Partial Redundancy Analysis (pRDA) to test for the effect of management intervention on the species-specific fish abundance. The centroid of each category (low level of management (LLM), high level of management (HLM) and very high level of management (VHLM)) are projected as triangles.

Table 4
Results of the SIMPER to analyse dissimilarity between the three seasons sampled and the three level of fisheries management. The species are ordered by decreasing contribution. $\bar{\delta}_i$ corresponds to the average of dissimilarity between groups, $\bar{\delta}_i$ (%) to the contribution of each species to the average dissimilarity, and (s.d.) is the standard deviation.

Winter vs. spring ($\bar{\delta}_i = 56.42$)			Winter vs. summer ($\bar{\delta}_i = 57.72$)			Spring vs. summer ($\bar{\delta}_i = 37.29$)		
Species	$\bar{\delta}_i$ (%)	$\bar{\delta}_i$ (s.d.)	Species	$\bar{\delta}_i$ (%)	$\bar{\delta}_i$ (s.d.)	Species	$\bar{\delta}_i$ (%)	$\bar{\delta}_i$ (s.d.)
Results of SIMPER analyses for factor season								
S. scriba	25.11	1.3	*S. scriba*	30.77	1.44	*D. annularis*	26.1	1.24
D. annularis	23.99	1.23	*D. annularis*	27.37	1.33	*S. scriba*	20.91	1.14
C. julis	16	1.2	*C. julis*	15.75	1.19	*C. julis*	17.69	1.24
B. boops	8.82	0.69	*D. vulgaris*	5.1	0.58	*B. boops*	9.42	0.69
D. vulgaris	4.4	0.54	*S. tinca*	4.1	0.52	*D. vulgaris*	6.12	0.55
S. tinca	4.07	0.54	*B. boops*	3.95	0.48	*T. mediterraneaus*	4.91	0.56

LLM vs. VHLM ($\bar{\delta}_i = 45.08$)			LLM vs. HLM ($\bar{\delta}_i = 55.13$)			HLM vs. VHLM ($\bar{\delta}_i = 49.2$)		
Species	$\bar{\delta}_i$ (%)	$\bar{\delta}_i$ (s.d.)	Species	$\bar{\delta}_i$ (%)	$\bar{\delta}_i$ (s.d.)	Species	$\bar{\delta}_i$ (%)	$\bar{\delta}_i$ (s.d.)
Results of SIMPER analyses for factor area								
D. annularis	27.79	1.07	*D. annularis*	24.36	1.35	*D. annularis*	24.88	1.29
S. scriba	26.22	1.14	*S. scriba*	23.1	1.16	*S. scriba*	23.19	1
C. julis	19.7	0.88	*C. julis*	14.41	1.15	*C. julis*	17.92	1.2
B. boops	11.16	0.74	*B. boops*	8.47	0.72	*D. vulgaris*	7.49	0.68
T. mediterraneaus	4.88	0.59	*D. vulgaris*	6.56	0.65	*S. tinca*	4.52	0.48
S. tinca	3.04	0.41	*T. mediterraneaus*	5.11	0.57	*S. cabrilla*	3.9	0.51

the total variance explained, pRDA, after 999 unrestricted permutations, *F*-ratio = 1.01, *P*-value = 0.408).

3.3. Variance in fish size of *D. annularis*, *S. scriba* and *C. julis* across area

The degree of management in a given area also strongly affected the sizes of the dominant species (Table 3). In terms of *D. annularis*, level of management was significantly related to size of fish encountered by hook and line sampling (ANOVA; $\chi^2 = 43.56$; $P < 0.001$), but this effect was dependent on the interaction with season (ANOVA; $\chi^2 = 14.56$; $P < 0.05$). The significance of the interaction between area and season was caused by stronger effects in winter (Table 3). Overall, the size of *D. annularis* increased with increasing protection levels offered in a given area (Fig. 5). Similar results were obtained in the case of *S. scriba* where the effect of level of management was also highly significant (ANOVA; $\chi^2 = 44.1$; $P < 0.001$). In this case, both the season (ANOVA; $\chi^2 = 0.75$; $P = 0.688$) and the interaction of management × season were not significant (ANOVA; $\chi^2 = 10.1$; $P = 0.123$). Again, significantly larger fish were found in areas offering higher degree of management intervention (Fig. 5). Finally, in the case of *C. julis* the level of management was also positively related to size of fish captured (ANOVA; $\chi^2 = 7.24$; $P < 0.05$), and season (ANOVA; $\chi^2 = 0.41$; $P = 0.816$) while the interaction term (ANOVA; $\chi^2 = 3.96$; $P = 0.682$) was not found statistically significant (Table 3 and Fig. 2).

4. Discussion

Partial MPA (pMPA) have been questioned due its assumed limited conservation benefits to protect exploited fish stocks, particular in relation to intensive commercial exploitation (Denny and Babcock, 2004; Di Franco et al., 2009; Shears et al., 2006). Here, we contrasted the coastal fish community composition and assembly structure predominantly exploited by recreational angling in spatially close locations that differed by degree of fisheries-management tools implemented in each of the area. Contrary to most previous literature reports cited above in the context of intensive commercial or artisanal fisheries, we found a number of conservation benefits in terms of abundance of certain species and size of fish in pMPA for species predominantly targeted by anglers (i.e., *S. scriba*, *C. julis* and *D. annularis*). Possibly the greatest conservation benefit in our study resulted from the reduced fishing effort attracted to pMPA, likely as a result of aversion of anglers to use areas where some form of management is affecting the recreational experience (Beardmore et al., 2011; Fujitani et al., 2012; Shears et al., 2006). We are unsure whether the reduced use of the pMPA found in the present study is long-term or only a short-term effect, with a rebound of effort happening in the future as shown elsewhere by Fujitani et al. (2012). At present state, however, the more intensively managed pMPA attracted much less fishing effort than the open access areas, which likely contributed to the conservation values of such area (Lynch, 2006).

Our data suggest that for the management of recreational angling in coastal areas pMPA might be a suitable tool, which will likely exert its effect through a combination of effort displacement to non-protected areas and altered fishing mortality or selectivity due to size-based harvest tools and other regulations in pMPA. Moreover, as we found the greatest CPUE and species diversity in the area temporally closed to artisanal fishing, it is likely that the constraints on these fisheries also contributed to the conservation effects of pMPA in our study. Because many of the species we included in our study are not core target species of artisanal fisheries, the beneficial conservation effects of pMPA is contingent on the total angling effort in a particular region because excessive fishing effort can negate any potential conservation benefits offered by any protected area that is still accessible to recreational anglers (Cox et al., 2003; Fujitani et al., 2012). Therefore, our results must always be interpreted in light of the lower angling effort the pMPA areas attracted, which might constitute the main pathway by which our pMPA exerted its effect on conservation of the small-bodied coastal fish community (Lynch, 2006; Fujitani et al., 2012).

It is unclear whether the effort reduction we observed was an effect of the implementation of regulations or whether other reasons played a role. It is known from freshwater fisheries that regulations affect the attractiveness of a fishery to anglers (e.g., Beard et al., 2003; Beardmore et al., 2011; Dorow et al., 2010; Johnston et al., 2010, 2011), and Fujitani et al. (2012) showed effort displacements to the implementation of marine protected areas in the in the Gulf of California, Mexico. We thus similarly expect that the regulations present in the pMPA might have contributed to the conservation values of these areas by displacing angling effort to open access areas. Because anglers move to areas with higher catch rates, over time the spatial effort relocation should act to standardize

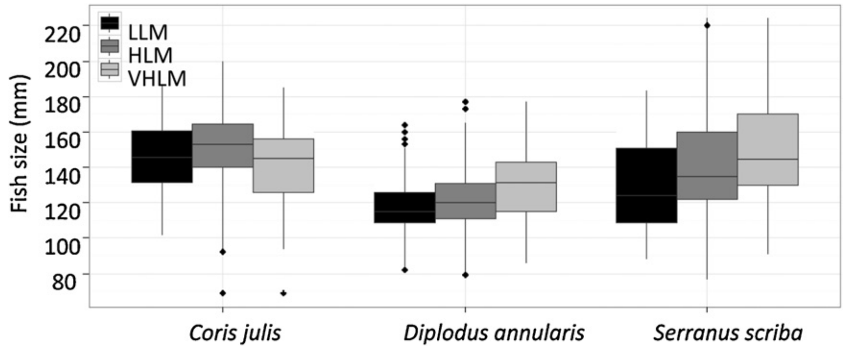

Fig. 5. Box-plot of fish size (total length in mm) for *Coris julis* ($n = 299$), *Diplodus annularis* ($n = 646$) and *Serranus scriba* ($n = 579$) sampled in each sampling area (low level of management (LLM), high level of management (HLM) and very high level of management (VHLM)). Boxes represent the 25th and 75th percentiles, median, and inter-quartile range (IQR), while the whiskers represent the lowest datum within 1.5 IQR of the lower quartile, and the highest datum within 1.5IQR of the upper quartile. Circles represent outlier values.

catch rates among areas if fisher's spatial area choice is exclusively driven by catch rate expectations (Lynch, 2006; Parkinson et al., 2004). However, because we still found among-area variance in catch rates, it is likely that anglers did not move as the ideal free distribution (Matsumura et al., 2010). This is likely because anglers also consider the regulations in place and other non-catch related attributes when deciding for or against certain fisheries (Hunt et al., 2011; Johnston et al., 2010, 2011). This agrees with the fact that a range of factors provide utility to anglers, not just catch rate alone (Johnston et al., 2011). Therefore, it is likely that management intervention displaced fishing effort in our study.

Conservation benefits we found in relation to the management areas were mainly due the high and significant percentage of the variability of the abundances of *D. annularis*, *S. scriba* and *C. julis* across areas. These three most frequent species studied have the peculiarity that are practically only targeted by recreational anglers (Morales-Nin et al., 2005). In fact, these three species were practically absent in the landings of commercial and artisanal fisheries from the local auction as evidenced by the landing list from the Fisheries Department from the Balearic Islands (Alós, personal observation) as well as in the catch composition of the trammel net in the Western Mediterranean (Stergiou et al., 2006). Moreover, due the limited size of these species (e.g., *C. julis*) they are rarely by-catch by the artisanal fishing fleet in the region (Alós, personal observation). This contrasts with the other previous studies on pMPA where the target species investigated were both targeted by recreational and artisanal or small-scale commercial fisheries jointly (Di Franco et al., 2009; Guidetti et al., 2010; Shears et al., 2006).

However, we also detected benefits of pMPA in terms of abundance for other species, which are also targeted by the artisanal fishery (i.e., *B. boops, D. vulgaris, S. tinca, T. mediterraneus, S. cantharus, S. cabrilla, C. chromis, L. merula, D. sargus* and *O. melanura*). Thus, our exploration and finding of greater CPUE and species diversity in the VHLM area that was closed to artisanal fishing for some period of the year also suggested some impact of commercial fishing on the species community examined. Because the only difference to the HLM area was the temporary ban on artisanal fishing, a combination of further angling effort reduction and lack of artisanal target species might have jointly contributed to the results. Although cause-and-effect is difficult to claim form our comparative field study, the close proximity of the study areas and our attempts to standardize the habitat structures across areas provided weight to the idea that the pMPA was related for the observed fish abundance differences.

Not only abundance, but also fish sizes of the three most frequently encountered species were related to the level of management. We found larger fish in the more restrictively managed areas suggesting an impact of fishing in the open access areas. One of the most important benefits of MPAs to marine coastal species is that they allow biomass to increase due to larger fish seeking refuge (Lester et al., 2009). Due to peculiarities of the hook's selectivity, recreational gear in our study areas usually captures larger individuals of *D. annularis*, *S. scriba* and *C. julis* (Cerdà et al., 2010). Thus, fish size should be a good indicator of fishing pressure, and fish should be smaller in areas that are more heavily fished (Lester et al., 2009). Our findings agree with these predictions. In fact, many studies involving small-scale commercial fisheries from the Mediterranean showed that surviving individuals of exploited species are on average larger in no-take MPA than in open access areas (Lester et al., 2009). A demographic truncation effect towards on average smaller and younger fish is a typical result of intensive recreational and commercial fishing (Lewin et al., 2006). We added to this literature by implicating that pMPA may exert similar effects on small-bodied coastal fish predominantly targeted by anglers, but as elaborated above artisanal fishing also played a role.

Comparative field studies where cause-and-effect is impossible to evaluate with certainty because there is no data prior to the implementation of the pMPA, have difficulties to directly link the results to the management. Moreover, studies based in catch rates and other fishery-dependent data as index of abundance can generate biased conclusion due to the selective properties of fishing. For example, if the behaviour has a role in the vulnerability of fish to be harvested, fishery-dependent data can generate an underestimation of the fish abundance due the exploited population is dominated by non-vulnerable individuals (Biro and Dingemanse, 2009). Despite these limitations, our results still allow deriving some tentative management implications to provide useful information for the managers. The somewhat more restrictive, but not fully effort-banned management in pMPA involving regulations on minimum hooks sizes, minimum-size limits and temporal closure of artisanal fishing may be sufficient to protect coastal fishing communities from severe size truncation and strong biomass declines, in particular if regulations also limit or even displace fishing effort to open access areas. The limited capacity of movement of the small-bodied species suggests that a higher numbers of old and large individuals could be maintained inside the pMPA if these areas are larger than the species' home range as was the case in our study (Alós et al., 2011). This could produce a considerable increase in the reproductive potential of the population owing to the high reproduction potential of old and large fish (Birkeland and Dayton, 2005) and maybe also have spill over effects to surrounding areas (Botsford et al., 2009). Hence, for recreational angling targeting small coastal fish, pMPA may offer a needed level protection to avoid local depletion (in terms of abundance), especially protecting large individuals, without constraining fishing effort directly.

This will likely enhance the acceptability of the tools by anglers. Further research considering other pMPA in higher intensity fisheries are recommended to more generally assess the usefulness of this management tool for coastal recreational fisheries that target small-bodied, low mobility fish species for harvest.

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References

Alós, J., Arlinghaus, R., Palmer, M., March, D., Alvarez, I., 2009. The influence of type of natural bait on fish catches and hooking location in a mixed-species marine recreational fishery with implications for management. Fish. Res. 97, 270–277.

Alós, J., Cabanellas-Reboredo, M., March, D., 2012. Spatial and temporal patterns in the movement of adult two-banded sea bream *Diplodus vulgaris* (Saint-Hilaire, 1817). Fish. Res. 115–116, 82–88.

Alós, J., March, D., Palmer, M., Grau, A., Morales-Nin, B., 2011. Spatial and temporal patterns in *Serranus cabrilla* habitat use in the NW Mediterranean revealed by acoustic telemetry. Mar. Ecol. Prog. Ser. 427, 173–186.

Bartholomew, A., Bohnsack, J.A., 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Rev. Fish Biol. Fish. 15, 129–154.

Beard, T.D., Cox, S.P., Carpenter, S.R., 2003. Impacts of daily bag limit reductions on angler effort in Wisconsin Walleye Lakes. N. Am. J. Fish. Manage. 23, 1283–1293.

Beardmore, B., Dorow, M., Haider, W., Arlinghaus, R., 2011. The elasticity of fishing effort response and harvest outcomes to altered regulatory policies in eel (*Anguilla anguilla*) recreational angling. Fish. Res. 110, 136–148.

Birkeland, C., Dayton, P.K., 2005. The importance in fishery management of leaving the big ones. Trends Ecol. Evol. 20, 356–358.

Biro, P.A., Dingemanse, N.J., 2009. Sampling bias resulting from animal personality. Trends Ecol. Evol. 24, 66–67.

Bohnsack, J.A., 2000. A comparison of the short-term impact of no-take marine reserves and minimum size limits. Bull. Mar. Sci. 66, 635–650.

Bohnsack, J.A., 2011. Impacts of Florida coastal protected areas on recreational world records for Spotted Seatrout, Red Drum, Black Drum, and Common Snook. Bull. Mar. Sci. 87, 939–970.

Botsford, L.W., Brumbaugh, D.R., Grimes, C., Kellner, J.B., Largier, J., O'Farrell, M.R., Ralston, S., Soulanille, E., Wespestad, V., 2009. Connectivity sustainability, and yield: bridging the gap between conventional fisheries management and marine protected areas. Rev. Fish. Biol. Fish. 19, 69–95.

Botsford, L.W., Micheli, F., Hastings, A., 2003. Principles for the design of marine reserves. Ecol. Appl. 13, S25–S31.

Cabanellas-Reboredo, M., Deudero, S., Alós, J., Hendriks, I., 2010. Initial data on settlement and recruitment of macrobenthic organisms on artificial substrates located over *Posidonia oceanica* meadows. Mar. Biol. Res. 6, 591–599.

Cardona, L., Lopez, D., Sales, M., De Caralt, S., Diez, I., 2007. Effects of recreational fishing on three fish species from the *Posidonia oceanica* meadows off Minorca (Balearic archipelago, western Mediterranean). Sci. Mar. 71, 811–820.

Cerdà, M., Alós, J., Palmer, M., Grau, A.M., Riera, F., 2010. Managing recreational fisheries through gear restrictions: the case of limiting hook size in the recreational fishery from the Balearic Islands (NW Mediterranean). Fish. Res. 101, 146–155.

Clarke, K.R., Gorley, R.N., 2001. Primer v5: User Manual/Tutorial. Plymouth, UK.

Coggins, L.G., Catalano, M.J., Allen, M.S., Pine, W.E., Walters, C.J., 2007. Effects of cryptic mortality and the hidden costs of using length limits in fishery management. Fish Fish. 8, 196–210.

Coleman, F.C., Baker, P.B., Koenig, C.C., 2004a. A review of Gulf of Mexico marine protected areas. Fisheries 29, 10–21.

Coleman, F.C., Figueira, W.F., Ueland, J.S., Crowder, L.B., 2004b. The impact of United States recreational fisheries on marine fish populations. Science 305, 1958–1960.

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais Lasram, F., Aguzzi, J., Ballesteros, E., Bianchi, C.N., Corbera, J., Dailianis, T., Danovaro, R., Estrada, M., Froglia, C., Galil, B.S., Gasol, J.M., Gertwagen, R., Gil, J.o., Guilhaumon, F.o., Kesner-Reyes, K., Kitsos, M.-S., Koukouras, A., Lampadariou, N., Laxamana, E., López de la Cuadra, C.M., Lotze, H.K., Martin, D., Mouillot, D., Oro, D., Raicevich, S.a., Rius-Barile, J., Saiz-Salinas, J.I., San Vicente, C., Somot, S., Templado, J., Turon, X., Vafidis, D., Villanueva, R., Voultsiadou, E., 2010. The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. PLoS ONE 5, e11842.

Cox, S.P., Beard, T.D., Walters, C., 2002. Harvest control in open-access sport fisheries: Hot rod or asleep at the reel? Bull. Mar. Sci. 70, 749–761.

Cox, S.P., Walters, C.J., Post, J.R., 2003. A model-based evaluation of active management of recreational fishing effort. N. Am. J. Fish. Manage. 23, 1294–1302.

Denny, C.M., Babcock, R.C., 2004. Do partial marine reserves protect reef fish assemblages? Biol. Conserv. 116, 119–129.

Di Franco, A., Bussotti, S., Navone, A., Panzalis, P., Guidetti, P., 2009. Evaluating effects of total and partial restrictions to fishing on Mediterranean rocky-reef fish assemblages. Mar. Ecol. Prog. Ser. 387, 275–285.

Dorow, M., Beardmore, B., Haider, W., Arlinghaus, R., 2010. Winners and losers of conservation policies for European eel *Anguilla anguilla*: an economic welfare analysis for differently specialised eel anglers. Fish. Manage. Ecol. 17, 106–125.

Fenberg, P.B., Caselle, J.E., Claudet, J., Clemence, M., Gaines, S.D., Antonio GarcÃa-Charton, J., Gonçalves, E.J., Grorud-Colvert, K., Guidetti, P., Jenkins, S.R., Jones, P.J.S., Lester, S.E., McAllen, R., Moland, E., Planes, S., Sorensen, T.K., 2012. The science of European marine reserves status, efficacy, and future needs. Mar. Pol. 36, 1012–1021.

Figueira, W.F., Coleman, F.C., 2010. Comparing landings of United States recreational fishery sectors. Bull. Mar. Sci. 86, 499–514.

Forcada, A., Valle, C., Bonhomme, P., Criquet, G., Cadiou, G., Lenfant, P., Sanchez-Lizaso, J.L., 2009. Effects of habitat on spillover from marine protected areas to artisanal fisheries. Mar. Ecol. Prog. Ser. 379, 197–211.

Francour, P., Harmelin, J.G., Pollard, D., Sartoretto, S., 2001. A review of marine protected areas in the northwestern Mediterranean region: siting usage, zonation and management. Aquat. Conserv. Mar. Freshw. Ecosyst. 11, 155–188.

Fujitani, M.L., Fenichel, E.P., Torre, J., Gerber, L.R., 2012. Implementation of a marine reserve has a rapid but short-lived effect on recreational angler use. Ecol. Appl. 22, 597–605.

Gianguzza, P., Chiantore, M., Bonaviri, C., Cattaneo-Vietti, R., Vielmini, I., Riggio, S., 2006. The effects of recreational *Paracentrotus lividus* fishing on distribution patterns of sea urchins at Ustica Island MPA (Western Mediterranean, Italy). Fish. Res. 81, 37–44.

Gordoa, A., 2009. Characterization of the infralittoral system along the north-east Spanish coast based on sport shore-based fishing tournament catches. Estuar. Coast. Shelf Sci. 82, 41–49.

Granek, E.F., Madin, E.M.P., Brown, M.A., Figueira, W., Cameron, D.S., Hogan, Z., Kristianson, G., De Villiers, P., Williams, J.E., Post, J., Zahn, S., Arlinghaus, R., 2008. Engaging recreational fishers in management and conservation: global case studies. Conserv. Biol. 22, 1125–1134.

Grixti, D., Conron, S.D., Jones, P.L., 2007. The effect of hook/bait size and angling technique on the hooking location and the catch of recreationally caught black bream *Acanthopagrus butcheri*. Fish. Res. 84, 338–344.

Guidetti, P., Bussotti, S., Pizzolante, F., Ciccolella, A., 2010. Assessing the potential of an artisanal fishing co-management in the marine protected area of Torre Guaceto (southern Adriatic Sea, SE Italy). Fish. Res. 101, 180–187.

Halpern, B.S., Warner, R.R., 2002. Marine reserves have rapid and lasting effects. Ecol. Lett. 5, 361–366.

Hunt, L.M., Arlinghaus, R., Lester, N., Kushneriuk, R., 2011. The effects of regional angling effort angler behavior, and harvesting efficiency on landscape patterns of overfishing. Ecol. Appl. 21, 2555–2575.

Ihde, T.F., Wilberg, M.J., Loewensteiner, D.A., Secor, D.H., Miller, T.J., 2011. The increasing importance of marine recreational fishing in the US: challenges for management. Fish. Res. 108, 268–276.

Johnston, F.D., Arlinghaus, R., Dieckmann, U., 2010. Diversity and complexity of angler behaviour drive socially optimal input and output regulations in a bioeconomic recreational-fisheries model. Can. J. Fish. Aquat. Sci. 67, 1507–1531.

Johnston, F.D., Arlinghaus, R., Stelfox, J., Post, J.R., 2011. Decline in angler use despite increased catch rates anglers response to the implementation of a total catch-and-release regulation. Fish. Res. 110, 189–197.

Legendre, P., Gallagher, E.D., 2001. Ecologically meaningful transformations for ordination of species data. Oecologia 129, 271–280.

Lester, S.E., Halpern, B.S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B.I., Gaines, S.D., Airamé, S., Warner, R.R., 2009. Biological effects within no-take marine reserves: a global synthesis. Mar. Ecol. Prog. Ser. 384, 33–46.

Lewin, W.C., Arlinghaus, R., Mehner, T., 2006. Documented and potential biological impacts of recreational fishing Insights for management and conservation. Rev. Fish. Sci. 14, 305–367.

Lloret, J., Zaragoza, N., Caballero, D., Riera, V., 2008a. Biological and socioeconomic implications of recreational boat fishing for the management of fishery resources in the marine reserve of Cap de Creus (NW Mediterranean). Fish. Res. 91, 252–259.

Lloret, J., Zaragoza, N., Caballero, D., Riera, V., 2008b. Impacts of recreational boating on the marine environment of Cap de Creus (Mediterranean Sea). Ocean Coast. Manage. 51, 749–754.

Lynch, T.P., 2006. Incorporation of recreational fishing effort into design of marine protected areas. Conserv. Biol. 20, 1466–1476.

March, D., Alós, J., Palmer, M., Grau, A., 2011. Short-term residence and movement patterns of the annular seabream *Diplodus annularis* in a temperate marine reserve. Estuar. Coast. Shelf Sci. 92, 581–587.

March, D., Palmer, M., Alós, J., Grau, A., Cardona, F., 2010. Short-term residence, home range size and diel patterns of the painted comber *Serranus scriba* in a temperate marine reserve. Mar. Ecol. Prog. Ser. 400, 195–206.

Matsumura, S., Arlinghaus, R., Dieckmann, U., 2010. Foraging on spatially distributed resources with sub-optimal movement, imperfect information, and travelling costs: departures from the ideal free distribution. Oikos 119, 1469–1483.
Morales-Nin, B., Grau, A.M., Palmer, M., 2010. Managing coastal zone fisheries: a Mediterranean case study. Ocean Coast. Manage. 53, 99–106.
Morales-Nin, B., Moranta, J., Garcia, C., Tugores, M.P., Grau, A.M., Riera, F., Cerda, M., 2005. The recreational fishery off Majorca Island (western Mediterranean): some implications for coastal resource management. ICES J. Mar. Sci. 62, 727–739.
Moranta, J., Palmer, M., Morey, G., Ruiz, A., Morales-Nin, B., 2006. Multi-scale spatial variability in fish assemblages associated with *Posidonia oceanica* meadows in the Western Mediterranean Sea. Estuar. Coast. Shelf Sci. 68, 579–592.
Palmer, M., Balle, S., March, D., Alós, J., Linde, M., 2011. Size estimation of circular home range from fish mark-release-(single)-recapture data: case study of a small labrid targeted by recreational fishing. Mar. Ecol. Prog. Ser. 430, 87–97.
Parkinson, E.A., Post, J.R., Cox, S.P., 2004. Linking the dynamics of harvest effort to recruitment dynamics in a multistock spatially structured fishery. Can. J. Fish. Aquat. Sci. 61, 1658–1670.
Roberts, C.M., Bohnsack, J.A., Gell, F., Hawkins, J.P., Goodridge, R., 2001. Effects of marine reserves on adjacent fisheries. Science 294, 1920–1923.
Salz, R.J., Loomis, D.K., 2005. Recreation specialization and anglers attitudes towards restricted fishing areas. Hum. Dimens. Wildl. 10, 187–199.
Shears, N.T., Grace, R.V., Usmar, N.R., Kerr, V., Babcock, R.C., 2006. Long-term trends in lobster populations in a partially protected vs. no-take marine park. Biol. Conserv. 132, 222–231.
Stergiou, K.I., Moutopoulos, D.K., Soriguer, M.C., Puente, E., Lino, P.G., Zabala, C., Monteiro, P., Errazkin, L.A., Erzini, K., 2006. Trammel net catch species composition, catch rates and metiers in southern European waters: a multivariate approach. Fish. Res. 79, 170–182.
ter Braak, C.J.F., Smilauer, P., 2002. CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (Version 4.5). Microcomputer Power, Ithaca, NY, USA, 500 pp.
Tetreault, I., Ambrose, R.F., 2007. Temperate marine reserves enhance targeted but not untargeted fishes in multiple no-take MPAs. Ecol. Appl. 17, 2251–2267.
Tuya, F., Sanchez-Jerez, P., Haroun, R.J., 2006. Populations of inshore serranids across the Canarian Archipelago relationships with human pressure and implications for conservation. Biol. Conserv. 128, 13–24.
Veiga, P., Goncalves, J.M.S., Erzini, K., 2011. Short-term hooking mortality of three marine fish species (Sparidae) caught by recreational angling in the south Portugal. Fish. Res. 108, 58–64.
Westera, M., Lavery, P., Hyndes, G., 2003. Differences in recreationally targeted fishes between protected and fished areas of a coral reef marine park. J. Exp. Mar. Biol. Ecol. 294, 145–168.
Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S., Jensen, O.P., Lotze, H.K., Mace, P.M., McClanahan, T.R., Minto, C.i.n., Palumbi, S.R., Parma, A.M., Ricard, D., Rosenberg, A.A., Watson, R., Zeller, D., 2009. Rebuilding global fisheries. Science 325, 578–585.
Zuur, A.F., Leno, E.N., Walker, N.J., Saveliev, A.A., Smith, G.M., 2009. Mixed Effects Models and Extensions in Ecology with R. Springer-Verlag New York Inc., New York, USA, 596 pp.