Assessment of the initial state of two reserves, Micro áreas Ecoturísticas Litorales (MAEL), in Gran Canaria, Canary Islands

micro áreas
ecoturísticas litorales

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1. Abstract

The establishment of '*Micro áreas ecoturísticas litorales*' (MAELs) is a new strategy of marine conservation and management, based on a bottom-up governance strategy. In this study, we assessed the initial state ('state 0') of two MAELs at Gran Canaria Island (Canary Islands): 'El Cabrón' and 'Las Canteras', located in the east and in north-east coast of Gran Canaria Island, respectively. Specifically, we evaluated differences in the abundance and biomass of target fish species between inside (MAELI) and outside (MAELO) these two proposed reserves; five commercially-targeted fish species were selected: the parrotfish, *Sparisoma cretense*, the white sea-bream, *Diplodus sargus cadenati*, the common two-banded sea-bream, *Diplodus vulgaris*, the island grouper, *Mycteroperca fusca*, and salema, *Sarpa salpa*. Fish assemblages were sampled at 7 times within each management category in during summer and autumn of 2013. Univariate tests provided an overall moderate 'reserve effect' for the initial state of both MAELs. *Mycteroperca fusca* and *Diplodus vulgaris* showed greater abundances and biomasses, respectively, within the 'El Cabrón' MAELI compared to the adjacent MAELO. *Sparisoma cretense*, *Diplodus sargus cadenati*, *Diplodus vulgaris* and *Sarpa salpa* showed greater abundances and biomasses within the 'Las Canteras' MAELI compared to the adjacent MAELO. Furthermore, we tested whether taxonomic diversity (through calculation of the Shannon diversity index for the entire fish assemblage) may be a surrogate for the trophic and functional diversity of the fish assemblage to adequately support the capacity of MAMPs to preserve marine biodiversity. Our data suggested a neat link between them.
Keywords: Micro áreas marinas protegidas, MAMPs, functional diversity, taxonomic diversity, trophic diversity, target species and reserve effect.

Resumen

'*Micro áreas ecoturísticas litorales*' (MAELs) es una nueva estrategia de gestión y conservación marina, basada en la estructura de decisión bottom-up. En este estudio, evaluamos el estado inicial ('estado 0') de dos MAELs en Gran Canaria (Islas Canarias). 'El Cabrón' y 'Las Canteras', localizadas en este y noreste de la isla de Gran Canaria, respectivamente. Específicamente, evaluamos diferencias en abundancia y biomasa de especies de peces objetivo-comerciales, dentro (MAELI) y fuera (MAELO) de las dos reservas propuestas; Las cinco especies comerciales estudiadas fueron: *Sparisoma cretense, Diplodus sarguscadenati, Diplodus vulgaris, Mycteroperca fusca y Sarpa salpa.* Las poblaciones de peces fueron muestreadas durante 7 tiempos comprendidos entre verano y otoño de 2013. Tests univariantes mostraron un moderado 'efecto reserva' durante el estado inicial de las dos MAELS. *Mycteroperca fusca* y *Diplodus vulgaris* mostraron mayores abundancias y biomasas, respectivamente, dentro 'El Cabrón' MAELI comparadas con la zona adyacente MAELO. *Sparisoma cretense*, *Diplodus sargus cadenati*, *Diplodus vulgaris* y *Sarpa salpa* mostraron mayores abundancias y biomasas dentro de 'Las Canteras' MAELI comparado con la zona adyacente MAELO. Además, testamos si la diversidad taxonómica (mediante el cálculo del índice de diversidad de Shannon para la población de peces) puede estar relacionada con la diversidad trófica y funcional de la población de peces para evaluar la capacidad de preservar la biodiversidad marina de las MAMPs. Encontramos en nuestros datos una unión entre ellas.

Palabras clave: Micro áreas marinas protegidas, MAMPs, diversidad funcional, diversidad taxonómica, diversidad trófica, especies objetivo y efecto reserva.

2. Introduction

The United Nations (UN) for Food and Agriculture Organization's (FAO) estimate that 75% of the world's fisheries are actually overexploited (Ray Hilborn et al., 2005). In particular, shallow-water fishery resources are being subjected to strong anthropogenic pressures, including overexploitation in the last decades (Lauck et al., 1998; Castilla., 2000). In fact, the main source of erosion of marine ecosystem biodiversity is overfishing (Jackson et al., 2001), but there are others sources of biodiversity loss such as pollution (European agency, 2006), invasion by alien species (Gollasch., 2006) and catastrophes induced by global warming (Harley et al., 2006). A solution to preserve coastal resources consists in the establishment of Marine protected areas (MPAs). Two main objectives have been identified when addressing the purposes of MPAs: ensuring sustainable use of economic resources, and protecting biodiversity – valuable species, habitats and landscapes (Salm *et al.* 2000): In turn, the number of MPA has been increasing in the last decades, to preserve and manage coastal resources and their habitats, and so coastal ecosystems and their biodiversity (Fraschetti et al., 2011).
The efficacy of MPAs has been widely discussed (Harmelin-Vivien et al., 1995; Guidetti et al., 2005; Micheli et al*.,* 2005), what depends on a range of different factors (Barret et al., 2007), as the size of no-take and adjacent buffering areas (Claudet 2008; 2010), the time since protection (Micheli et al., 2004), connectivity with adjacent zones (Vega Fernandez et al., 2008) and, of course, the effective level of enforcement and compliance by local administrations and users (Claudet, 2010).

A new strategy of marine conservation and management promote the establishment of *Micro áreas ecoturísticas litorales* (MAELs), which are based on a bottom-up governance philosophy. In this case, local communities boost the establishment and declaration of protected areas via local administrations, rather than relying on legal authorities with competence in fisheries and conservation management The overall goal of MAELs is to contribute to the conservation of the biological diversity and productivity of the oceans, including ecosystem processes, but promoting sustainable uses such as eco-tourism, traditional fishing, scientific research and so to improve local economy.

Traditionally, management of coastal ecosystems have followed a (top-down approach), where governmental bodies decide on specific regulations. Frequently, MPA governing bodies have not taken full responsibilities in their attempts at management; in turn, managers fail to recognize and encompass stakeholder opinions in their attempts at realizing a successful MPA (Himes, 2007). A different strategy, promotes stakeholder participation, via a bottom-up

strategy, where local communities, users and local-administrations collaborate since the earliest stage of creation of these reserves. It has been widely recognized that public participation and local community involvement is an essential factor contributing to the success of MPAs (Fiske, 1992; Wolfenden, 1994). For example, changes in policies concerning how exploitation of marine resources in the Philippines should be implemented have shifted from a centralized bureaucracy to co-management among local communities, local administration, and the national government (Alcala et al., 2006). Galicia (NW Spain) has pioneered co-management initiatives proposing the creation of a marine reserve, designed and developed by the fishers in partnership with biologists and social scientists, environmentalists and members of the autonomous Government of Galicia (Perez, 2013).

Typically, reserves established via bottom-up governance approaches are of reduced size. The positive effects of small-sized reserves, i.e. with a similar size to the MAELs, have been demonstrated in many cases (Lester et al., 2009; Afonso et al., 2011; Hort et al., 2013), we show the positive the effects of small-sized reserves around the world (Appendix 1). Moreover, a small size do facilitate co-management between stakeholders (e.g. fishers, users, divers, administration), favoring a sustainable management. A goal of any marine reserve is to evaluate the expected benefits, either from an ecological point of view, or also through social and economic metrics. In the literature, there are many different population parameters as bioindicators to assess such expected 'reserve effect'.

Many biological studies have focused on one or several target species and, in many circumstances, reported increased abundances and larger sizes inside MPAs (e.g. Barret et al., 2006; Tuya et al., 2006; Brito et al., 1997, 1998, 2001). However, conservation of particular species is questioned, because it depends on species-specific life traits (Villamor et al., 2012). Moreover, understanding species' role in nature is limited; less 1% have been studied (Wilson, 2000), a species can be considered to be functionally redundant when the community contains functionally-analogous species, so that its disappearance from the community entails no measurable loss of functionality (Duarte, 2000).

Relationships between species, their biodiversity and ecosystem function are important for predicting the ecological and economic impact of human interventions (Armsworth et al., 2007). Indices based only on the taxonomic identity provide an incomplete view of biodiversity (Villeger et al., 2010). A recent consensus point out the importance of particular taxa rather than species richness to explain ecosystem processes in aquatic communities (O'Connor et al., 2008). A step further in biodiversity assessment needs to consider the role of each species in ecosystems or species responses to environmental conditions. This can be somehow approached through the estimation of trophic and functional diversity of biotic communities in conjunction with taxonomic diversity studies (Mc Gill et al., 2006). Thereby, taxonomic studies that traditionally have focused on the identity of species may be complemented with trophic and functional diversity approaches to adequately support the capacity of MAELs to preserve marine biodiversity.

In this study, our goal was to assess the initial state ('state 0') of two MAELs at Gran Canaria Island, by comparing several descriptors inside and outside these two proposed reserves. This included the abundances and total biomasses of several target species (univariate responses), as well as estimators of the taxonomic diversity (through Shannon diversity index) and trophic and functional diversity (multivariate responses). We ultimately aimed to unravel whether taxonomic, trophic and functional diversity were correlated within the study systems.

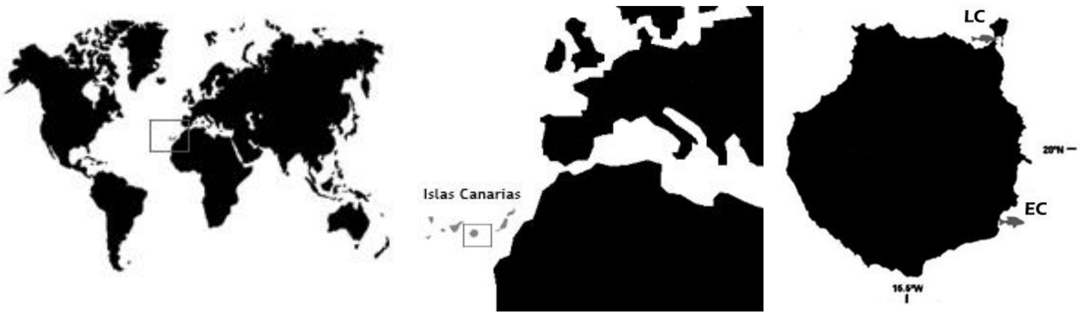
3. Material and methods

3.1 Study area and sampling design

This study focused on two recently proposed *Micro áreas ecoturísticas litorales* (MAELs) at Gran Canaria Island. The first, 'El Cabrón', is located in the east side of Gran Canaria Island. The second, 'Las Canteras', is located in north-east side of the island (Fig 1). Both zones are biogeographically and climatically similar. At both locations, two adjacent areas were studied, one within the proposed MAEL: no take zone (MAELI), where the exploitation of benthic and demersal resources will be prohibited, hereafter so-called 'Cabrón' and 'Canteras', respectively, and two adjacent areas outside these protected areas (MAELO), hereafter so-called 'Risco Verde' and 'Confital', respectively, where fishing activities are allowed. Data collection were undertaken during Summer-Autumn of 2013 (Table 1), at 7 random times. From an environmental point of view, both areas at each location were similar in terms of depth, type of bottom, wave climate and oceanography. At Cabrón and Risco Verde, sampling was performed between 10 and 18 m depth, on rocky bottoms of similar structural complexity, to minimize the possible effect of the habitat (so-called 'habitat effect', *sensu* García-Charton and Pérez-Ruzafa., 1999). At 'Canteras' and 'Confital', sampling took place between 3-5 m depth, on rocky bottoms of similar structural complexity.

Table 1. Sampled localities and times to compare fish assemblages between MAELI and MAELO at Gran Canaria Island.

	Locality (UTM)			
	Cabrón	Risco Verde	Canteras	Confital
Date	27º52'N 15º23'W	27º51'N 15º23'W	28º08'N 15º26'W	28º09'N 15º26W
T1	26/07/2013		8/06/2013	
T2	10/08/2013		22/07/2013	
T3	12/09/2013		30/07/2013	
T4	22/09/2013		7/08/2013	
T5	30/09/2013		12/08/2013	
T6	7/10/2013		2/09/2013	
T7	15/10/2013		12/10/2013	



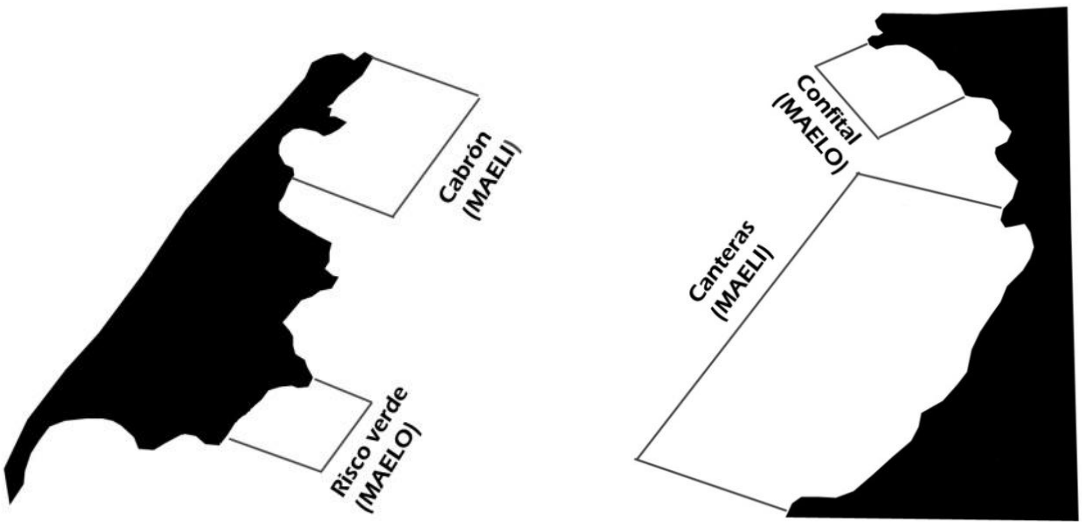


Figure 1. Location of study areas in Gran Canaria Island.

3.2 Selection of fish species, trophic and functional groups

We selected three commercially-targeted fish species for the study: the parrotfish, *Sparisoma cretense*, the white sea-bream, *Diplodus sargus cadenati*, and the common two-banded sea-bream, *Diplodus vulgaris.* Furthermore, the island grouper, *Mycteroperca fusca* was selected at 'El Cabrón' and the Salema, *Sarpa salpa*, at 'Las Canteras'. All are fish species easily identifiable *in situ*, do not show any cryptic behavior that could produce bias for the visual census technique. These species were selected because of their commercial interest, their larger abundances and they capacity to response to conservation measures in the region (Brito et al., 1998, 2001, 2005; Tuya et al., 2006).

Fish populations (all species) were sampled by means of visual census techniques. At each sampling area, 4 replicated 25 m long transects were haphazardly laid during daylight hours. The abundance and size of fishes was recorded on waterproof paper by a SCUBA diver within 2 m of either side of transects, according to standard procedures (Brock, 1982; Lincoln- Smith, 1989; Kingsford and Battershill, 1998). This strip transect size gives optimal precision and accuracy for abundance and size-structure data of rocky-reef fish in the Canarias (Tuya et al., 2004, 2006). Biomass was calculated using available length–weight relationship for the Canarian Archipelago

(www.fishbase.org). All measured biotic variables were standardized to an area of 100 m^2.

We grouped fish species according to standard trophic groups: omnivorous, micro-invertebrate feeders, planktivorous, macro-invertebrate feeders, macro-invertebrate feeders-piscivorous and herbivorous (Tuya et al., 2004). Ideally, functional groups would be defined pos-hoc using experimental manipulations to define the true functional role of each species (Wright et al., 2006). However, such techniques are not realistically possible for entire fish communities, so we considered traits related to their life style and maximum size (*www.fishbase.org*, Table2.) to create functional groups (Halpern et al., 2008).

We calculated three diversity indices using the classic Shannon H' diversity index from overall abundance data, and the abundance corresponding to the different trophic levels and functional groups, providing a single value for each replicate. These indices estimated the taxonomic, trophic and functional diversity, respectively. The method provides identical sample size among all sites; H' values are comparable and hence can be used to quantify differences in biodiversity between areas and their protection status (Garrabou et al., 2002).

Figure 2. Visual census techniques to assess the abundance and size of fish populations.

3.3 Data analysis

Differences in the abundance and biomass of the target species were determined by applying analysis of variance with permutations (PERMANOVA) that contrasted differences between areas at each study zones (protected versus un-protected area).

The model incorporated the following factors: (1) 'Locality', fixed factor (MAELI versus MAELO), (2) 'Time' (Ti), random factor with seven levels—the seven study dates—and orthogonal to the previous factor. Data were square root transformed prior to analyses, and analyses were based on Euclidean distance (Anderson, 2001). A linear regression model tested whether species diversity, trophic diversity and functional diversity were significantly correlated.

Table 2. Categorization of functional groups according to their mobility and sizes; examples of species considered within each group are provided.

Mobility groups	Size	Species (examples)
Demersal	Small	*Sparisoma cretense*
	Medium	*Mycteroperca fusca*
	Large	*Epinephelus marginatus*
Bentho-pelagic	Small	*Pagellus acarne*
	Medium	*Diplodus cervinus*
	Large	*Seriola sp*
Pelagic	Small	*Chromis limbata*
	Medium	*Trachinotus ovatus*
	Large	*Sphyraena viridiensis*
Benthic	Small	*Bothus podas*
	Medium	
	Large	

4. Results

4.1 Commercially-targeted species

The results of the PERMANOVAs on the abundances and biomasses of the target species: *Diplodus sargus, Diplodus vulgaris, Sparisoma cretense* and *Mycteroperca fusca* in 'Cabrón-Risco Verde'; as well as for *Diplodus sargus*, *Diplodus vulgaris, Sparisoma cretense*, *Sarpa salpa* in 'Canteras-Confital' are shown in tables 3 and 4, respectively.

Diplodus sargus

In the case of 'Cabrón-Risco Verde', the abundance and total biomass were slightly higher in the MAELI (Fig. 3a-b, mean abundance = 6.43 ind 100 m^{-2} ± 2.78, mean biomass = 867.54 g 100 m^{-2} ± 433.95, mean ±SE) than in the MAELO (Fig. 3a-b,mean abundance = 5.87 ind 100 m^{-2} ± 3.07, mean biomass= 418.74 g 100 m^{-2} ± 240.35, mean ± SE). However, significant differences were not detected (Fig. 3a-b; PERMANOVA: 'Locality', p= 0.444 and p= 0.088 for the abundance and total biomass, respectively, Table 3).

On the other hand, at 'Canteras-Confital', the abundance and total biomass were significantly higher in the MAELI (Fig.3c-d, mean abundance = 12.69 ind 100 m^{-2} ± 6.79, mean biomass = 477.38 g 100 m^{-2} ± 271.74, mean ± SE) than in the MAELO (Fig. 3a-b, mean abundance = 1.21 ind 100 m^{-2} ± 0.84, mean biomass = 43.99 g 100 m^{-2} ±35.66, mean ± SE) (Fig. 3c-d; PERMANOVA: 'Locality', P=0.001 and P=0.001, for abundance and total biomass, respectively, Table 4).

Diplodus vulgaris

At 'Cabrón-Risco Verde', we did not observed significant differences in the abundance between the MAELI (Fig. 4a-b, mean abundance = 3.87 ind. 100 m^{-2} ± 2.11, mean biomass = 371.78 g 100 m^{-2} ± 241.43, mean ± SE) and the MAELO (Fig. 4a-b, mean abundance = 2.56 ind 100 m^{-2} ± 1.54, mean biomass = 153.82 g 100 m^{-2} ± 113.63, mean ± SE). However, we found significant differences for the total biomass between the MAELI and MAELO (Fig. 4a-b; PERMANOVA: 'Locality', P=0.039, Table 3).

In 'Canteras-Confital', the abundance and total biomass were significantly greater in the MAELI (Fig.4c-d, mean abundance = 0.74 ind 100 m^{-2} ± 0.57, mean biomass = 94.80 g 100 m^{-2} ± 132.53, mean ± SE) than in the MAELO (Fig.

4c-d, mean abundance = 0.14 ind 100 m^{-2} ± 0.22, mean biomass = 7.09 g 100 m^{-2} ± 10.88, mean ± SE) (Fig. 4c-d; PERMANOVA: 'Locality', p= 0.025 and p= 0.038, for the abundance and total biomass, respectively, Table 4).

Mycteroperca fusca

At 'Canteras-Confital', only one individual was spotted and so no statistical analysis was further carried out. At 'Cabrón-Risco Verde', the abundance and total biomass was larger at the MAELI (Fig. 5a-b, mean abundance = 1.5 ind 100 m^{-2} ± 1.27, mean biomass = 458.62 g 100 m^{-2} ± 520.56, mean ± SE) than in the MAELO (Fig.5a-b, mean abundance = 0.13 ind 100 m^{-2} ± 0.21, mean biomass= 4.96 g 100 m^{-2} ± 10.44, mean ± SE) (Fig.5a-b; PERMANOVA: 'Locality', p= 0.032 and p= 0.027, for the abundance and total biomass, respectively, Table 3).

Sarpa salpa

No individual was spotted at 'Cabrón-Risco Verde', and so no statistical analysis was carried out. At 'Canteras-Confital', larger abundances and total biomasses were recorded in the MAELI (Fig.7a-b, mean abundance = 13.33 ind 100 m^{-2} ± 5.39, mean biomass 458.62 g 100 m^{-2} ± 520.56, mean ± SE) than in the MAELO (Fig. 7a-b, mean abundance = 7.66 ind. 100 m^{-2} ± 10.23, mean biomass = 4.96 g 100 m^{-2} ± 10.44, mean ± SE) (Fig.6a-b; PERMANOVA: 'Locality', p= 0.004 and p= 0.025, for the abundance and total biomass, respectively, Table 4).

Sparisoma cretense

In the case of 'Cabrón-Risco Verde', significant differences were not observed between the MAELI (Fig.6a-b, mean abundance = 5.44 ind 100 m^{-2} ± 1.21, mean biomass = 1598.32 g 100 m^{-2} ± 784.82, mean ± SE) and the MAELO (Fig. 6a-b, mean abundance = 5.14 ind. 100 m^{-2} ± 1.34, mean biomass = 620.61 g 100 m^{-2} ± 250.02, mean ± SE) (Fig. 6a-b; PERMANOVA: 'Locality', p= 0.738 and p= 0.078, for the abundance and total biomass, respectively, Table 3).

Regarding 'Canteras-Confital', the abundance and biomass were greater in the MAELI (Fig. 6 c-d, mean abundance = 6.70 ind 100 m^{-2} ± 2.70, mean biomass 1864.53 g 100 m^{-2} ± 1343.73, mean ± SE) than in the MAELO (Fig. 6c-d, mean abundance = 2.89 ind 100 m^{-2} ± 1.51, mean biomass = 159.08 g 100 m^{-2} ± 95.21, mean ± SE) (Fig.7c-d; PERMANOVA: 'Locality', p= 0.005 and p= 0.046, for the abundance and total biomass, respectively, Table 4).

Table 3. Results of way ANOVAs testing for differences between areas (Cabrón *versus* Risco Verde) and times, for the abundance and total biomass of commercially-targeted fish species. P-values < 0.05 are considered significant.

Cabrón Vs Risco Verde	Abundance				Biomass			
Diplodus sargus cadenati	df	MS	F	P	df	MS	F	P
Locality	1	1.377	0.662	0.444	1	1044.0	4.073	0.088
Time	6	2.457	1.728	0.144	6	475.5	3.337	0.008
LoxTi	6	2.082	1.464	0.218	6	256.3	1.799	0.130
Res	42	1.422			42	142.5		
Total	55				55			
Diplodus vulgaris	df	MS	F	P	df	MS	F	P
Locality	1	1.886	2.688	0.156	1	520.799	7.803	0.039
Time	6	1.954	1.763	0.137	6	202.028	1.988	0.088
LoxTi	6	0.702	0.633	0.711	6	66.742	0.657	0.697
Res	42	1.108			42	101.625		
Total	55				55			
Sparisoma cretense	df	MS	F	P	df	MS	F	P
Locality	1	0.121	0.130	0.738	1	2058.96	4.625	0.078
Time	6	0.362	0.797	0.585	6	649.69	3.980	0.004
LoxTi	6	0.932	2.049	0.077	6	445.11	2.727	0.025
Res	42	0.455			42	163.21		
Total	55				55			
Mycteroperca fusca	df	MS	F	P	df	MS	F	P
Locality	1	5.910	6.022	0.032	1	12269.5	4.011	0.027
Time	6	1.419	4.113	0.004	6	3120.6	2.206	0.052
LoxTi	6	0.981	2.843	0.017	6	3058.8	2.162	0.050
Res	42	0.345			42	1414.6		
Total	55				55			

Table 4. Results of 2-way ANOVAs testing for differences between localities (Canteras-Confital), times, for the abundance and total biomass index of individuals commercially-targeted species. P-values < 0.05 are considered significant.

Las Canteras Vs Confital	Abundance				Biomass			
Diplodus sargus cadenati	df	MS	F	P	df	MS	F	P
Locality	1	77.709	22.650	0.001	1	3068.685	33.378	0.001
Time	6	4.115	3.312	0.009	6	112.901	1.896	0.104
LoxTi	6	3.430	2.761	0.022	6	91.936	1.544	0.184
Res	42	1.242			42	59.520		
Total	55				55			
Diplodus vulgaris	df	MS	F	P	df	MS	F	P
Locality	1	2.448	9.483	0.025	1	208.878	6.504	0.038
Time	6	0.176	0.549	0.780	6	35.177	0.837	0.564
LoxTi	6	0.258	0.805	0.564	6	32.117	0.764	0.642
Res	42	0.321			42	42.021		
Total	55				55			
Sparisoma cretense	df	MS	F	P	df	MS	F	P
Locality	1	14.488	14.479	0.005	1	5.084	5.085	0.046
Time	6	0.890	0.713	0.638	6	2852.681	1.011	0.433
LoxTi	6	1.000	0.801	0.573	6	4444.058	1.575	0.171
Res	42	1.249			42	2820.191		
Total	55				55			
Sarpa salpa	df	MS	F	P	df	MS	F	P
Locality	1	72.470	24.679	0.004	1	24461.08	8.993	0.025
Time	6	3.552	0.766	0.606	6	3523.73	1.171	0.344
LoxTi	6	2.936	0.633	0.707	6	2720.00	0.904	0.510
Res	42	4.636			42	3008.84		
Total	55				55			

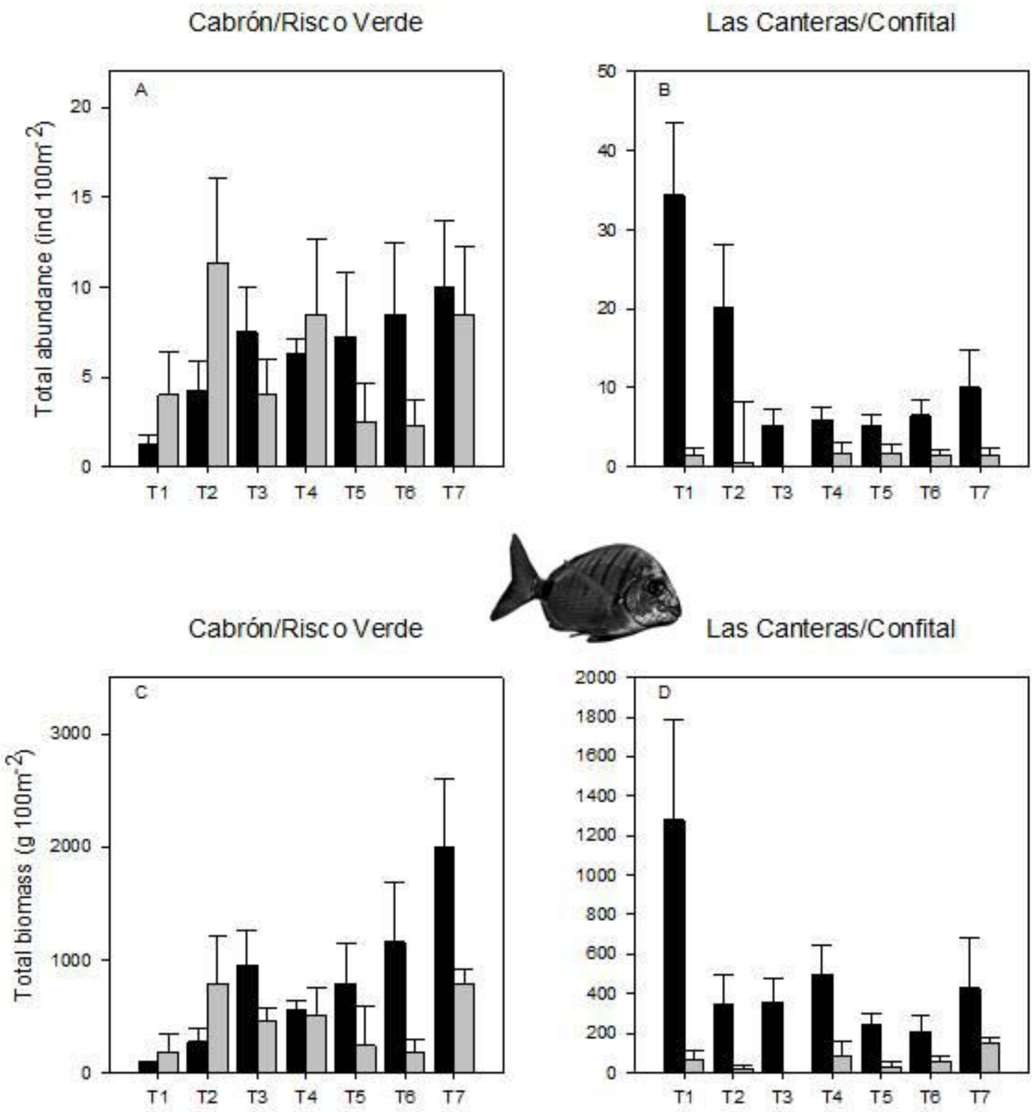


Figure 3. (A, B) Abundance and (C, D) total biomass (± SE) of the white sea-bream, *Diplodus sargus cadenati*, at areas within MAELI (black bars) or MAELO (gray bars) at each sampling time.

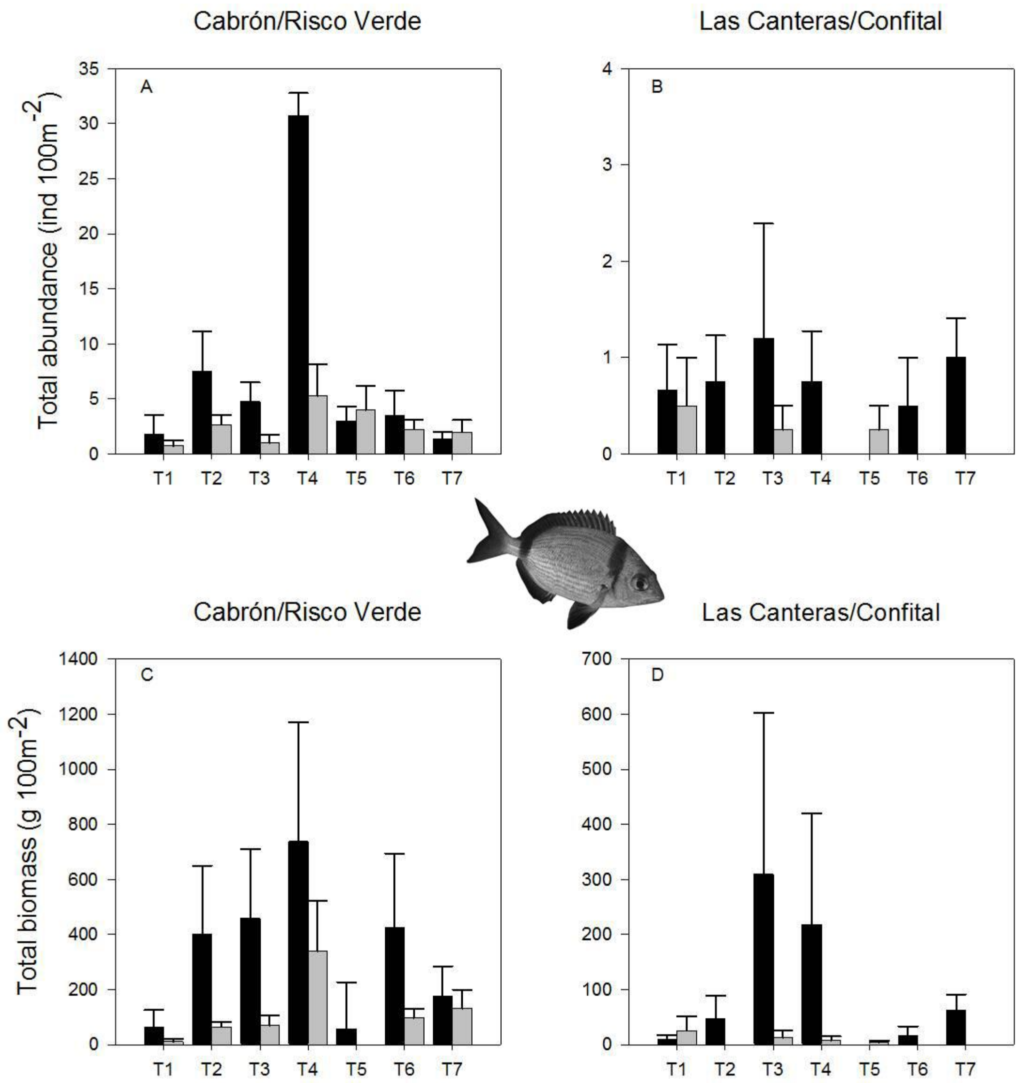


Figure 4. (A, C) Abundance and (B, D) total biomass (± SE) of the *common two-banded sea-bream*, *Diplodus vulgaris*, at areas within MAELI (black bars) or MAELO (gray bars) at each sampling time.

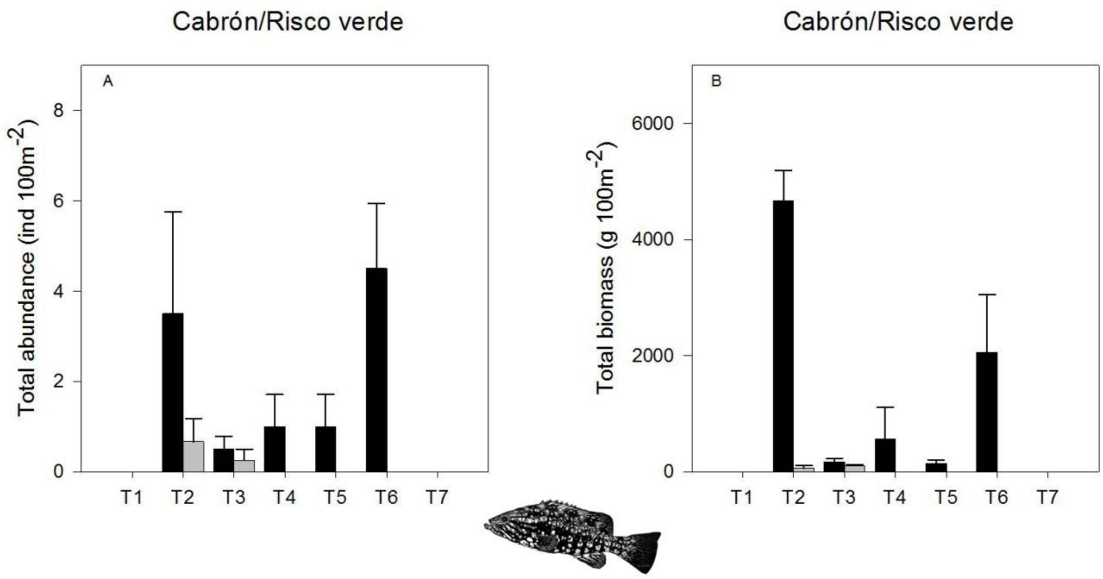


Figure 5. (A) Abundance and (B) total biomass (±SE) of the island grouper, *Mycteroperca fusca,* at areas within MAELI (black bars) or MAELO (gray bars) at each sampling time.

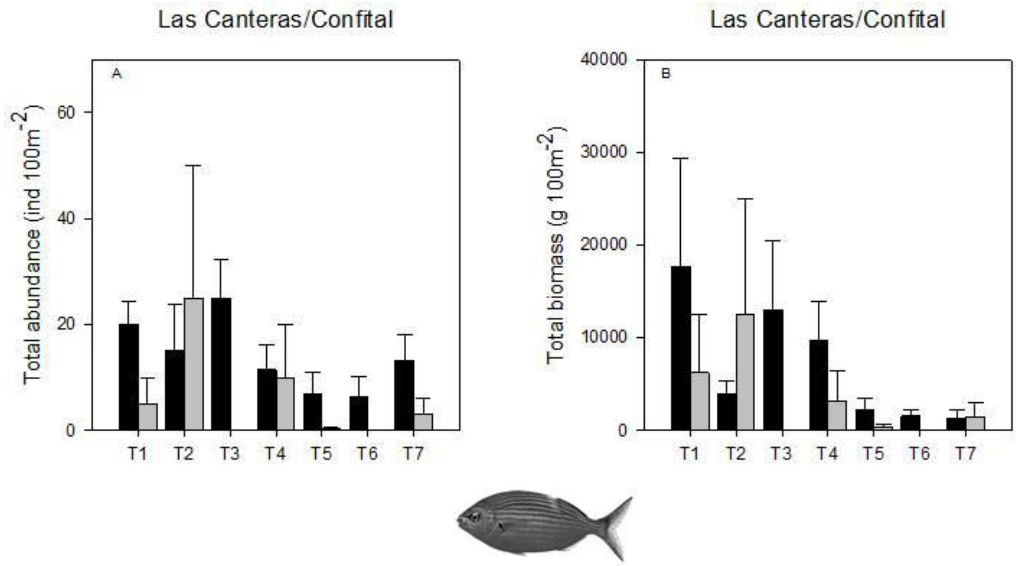


Figure 6. (A) Abundance and (B) total biomass (±SE) of the Salema, *Salpa salpa* at areas within MAELI (black bars) or MAELO (gray bars) at each sampling time.

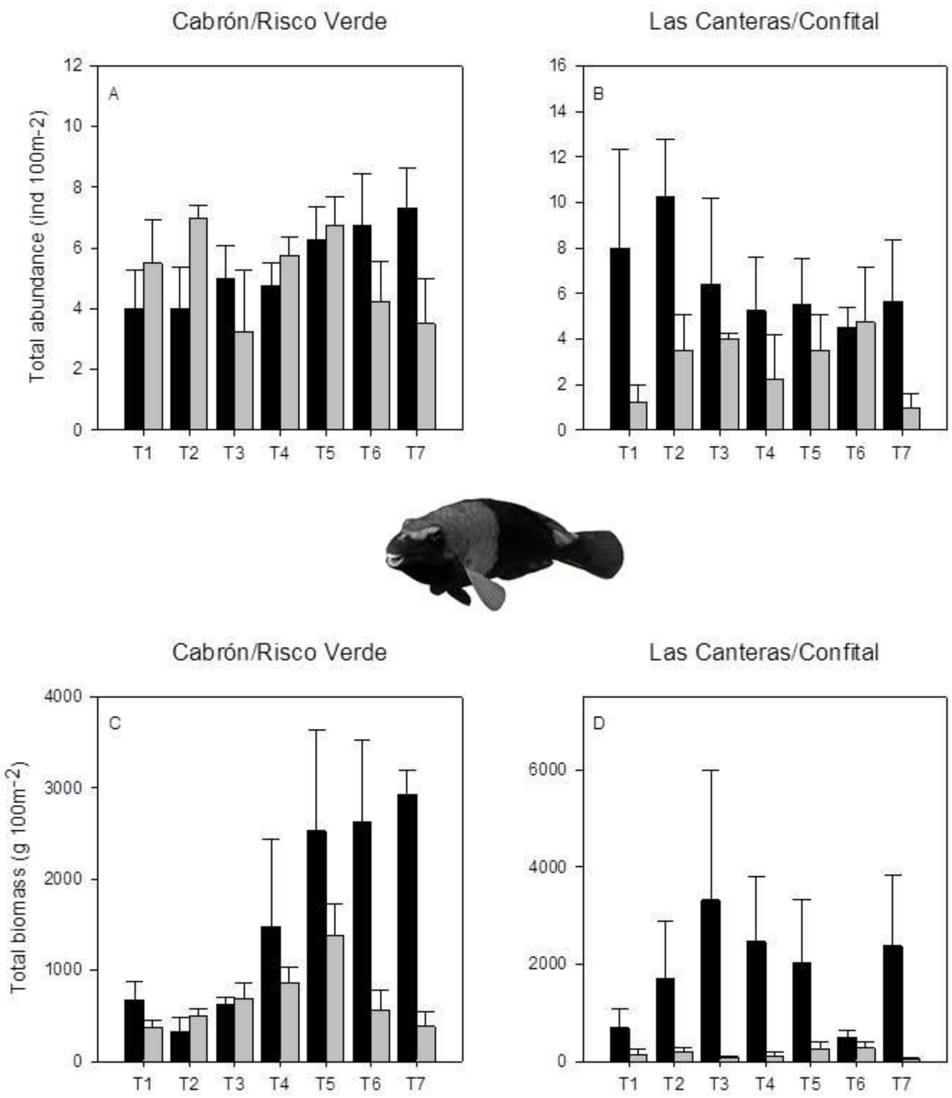


Figure 7. (A, B) Abundance and (C, D) total biomass (± SE) of the parrotfish, *Sparisoma cretense*, at areas within MAELI (black bars) or MAELO (gray bars) at each sampling time.

4.2 Taxonomic, trophic and functional diversity

With regard to taxonomic diversity, no significant differences were detected between protected (MAELI) and non-protected (MAELO) areas at 'Cabrón-Risco Verde' (Table 5, Fig. 8-A). However, taxonomic diversity varied significantly between protected and non-protected area (p= 0.036, Table 4, Fig. 8-A) at 'Canteras'.

Differences in trophic diversity between protected (MAELI) and non-protected (MAELO) areas were not found (Table 4, Fig. 8-B). In turn, analysis of trophic composition did not show significant differences (Appendix 2). In 'Canteras-Confital', we found that functional diversity was significantly greater (Table 5, Fig 8-C) in the MAELI than the MAELO, but the functional composition did not vary (Appendix 2).

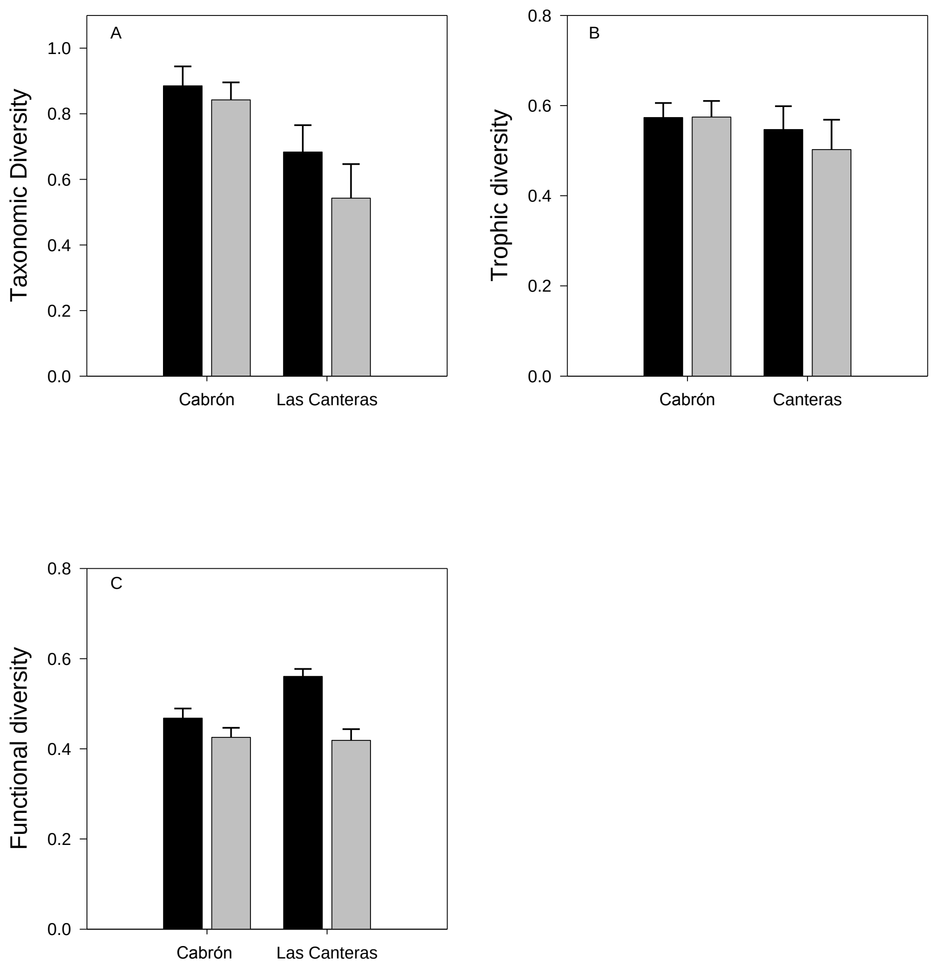


Figure 8. Taxonomic diversity (A), trophic diversity (B), and functional diversity (C) on the two MAMPs studied.

Table 5. Results of 2-way ANOVAs testing for differences between areas and times, for the taxonomic, trophic and functional diversity at each location. P-values < 0.05 are considered significant.

	Cabrón Vs Risco Verde				Canteras Vs Confital			
Taxonomic Diversity	df	MS	F	P	df	MS	F	P
Locality	1	0.007	1.138	0.326	1	0.166	9.289	0.026
Time	6	0.009	3.570	0.007	6	0.025	1.761	0.141
LoxTi	6	0.006	2.501	0.041	6	0.018	1.242	0.303
Res.	42	0.003			42	0.014		
Total	55				55			
Trophic Diversity	df	MS	F	P	df	MS	F	P
Locality	1	0.0000	0.002	0.969	1	0.016	1.251	0.305
Time	6	0.0011	0.510	0.797	6	0.011	1.533	0.187
LoxTi	6	0.0023	1.097	0.384	6	0.013	1.863	0.119
Res.	42	0.0021			42	0.007		
Total	55				55			
Functional Diversity	df	MS	F	P	df	MS	F	P
Locality	1	0.015	1.132	0.330	1	0.160	31.57	0.002
Time	6	0.010	1.637	0.165	6	0.014	2.13	0.077
LoxTi	6	0.013	2.116	0.081	6	0.005	0.78	0.594
Res.	42	0.006			42	0.007		
Total	55				55			

4.3 Correlation between taxonomic, trophic and functional diversity

Taxonomic, trophic and functional diversity were positively correlated (Fig. 9).

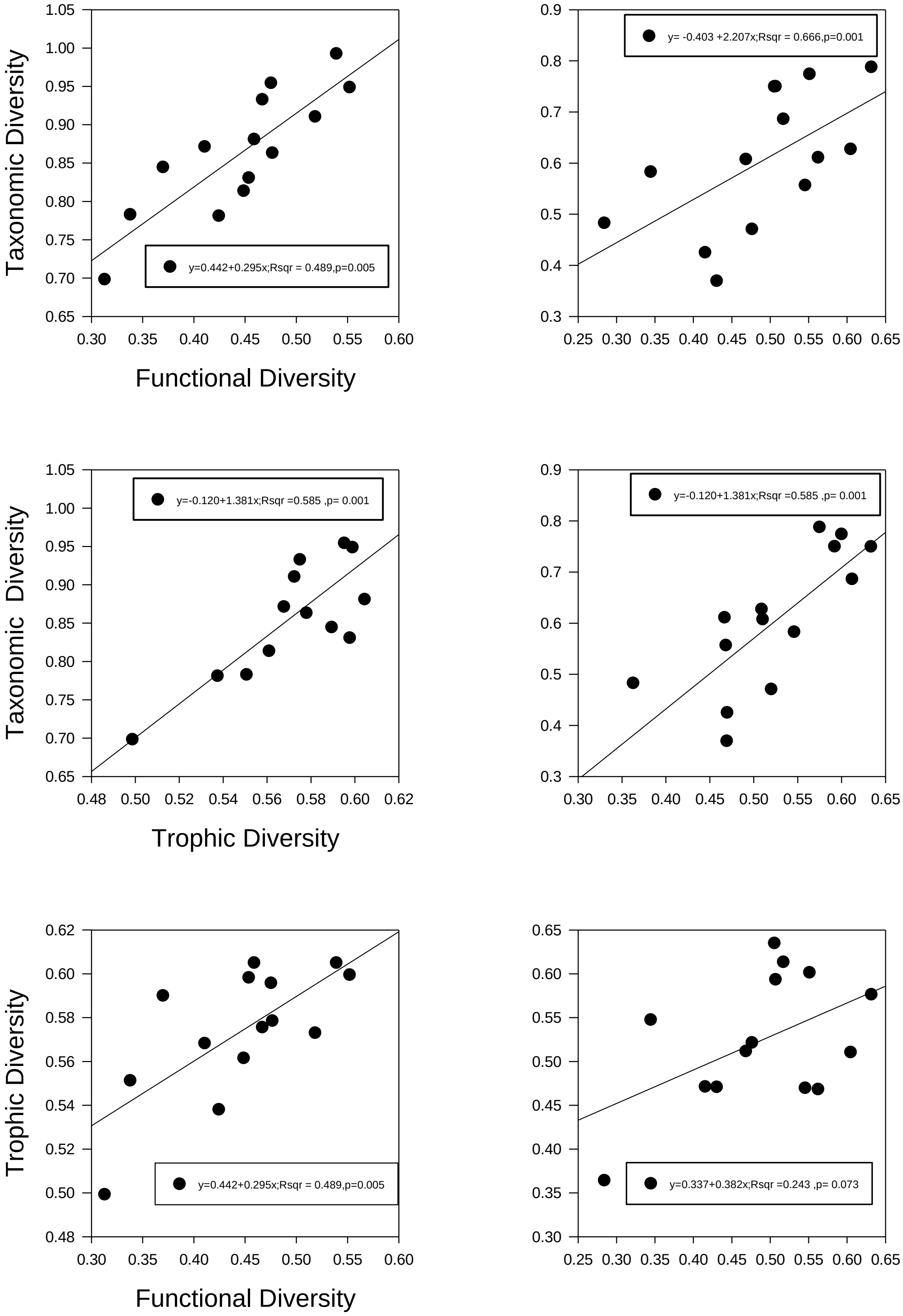


Figure 9. Relationship between taxonomic, trophic and functional diversity. Linear regression models tested the significance of this relation separately for 'El Cabrón' (A, C, D) and 'Las Canteras' (B, D and F).

5. Discussion

5.1 Overall results

Our study aimed to test for differences in the abundances and biomasses of target species between areas that will be soon be implemented as marine protected areas and adjacent, un-protected, areas that may act as controls; this is an attempt to quantify the initial state ('state 0') to get baseline data to assess the so-called 'reserve effect' in the future. Such 'reserve effect' using a range of species have been demonstrated by a range of studies that showed that the abundances and total biomasses of certain species differed between protected and un-protected areas (Barret et al., 2006; Tuya et al., 2006; Brito et al. 1999, 1998, 2001, 2006, among others). To adequately assess the effectiveness of MPAs, before-after control–impact (BACIP) approaches are highly necessary (Edgar and Barret 1997; Edgar et al., 2004). In this sense, our study evaluated the 'reserve effect' immediately before the implementation of the start of the enforcement. Without a doubt, our data will help out to implement a proper BACIP protocols in the future.

Furthermore, we analyzed community-level differences between 'protected' (at 'state 0') and adjacent areas. We used our data to calculate species (taxonomic), trophic and functional diversity, reducing our multivariate data into single diversity values. Some authors have demonstrated that diversity are often higher inside than outside protected areas (Barret et al., 2007; Claudet et al., 2006) and even trophic and functional diversity can response to protection more rapidly than species (taxonomic) diversity (Villamor et al., 2012). Recent syntheses and empirical studies have highlighted that functional traits predict the effects of global changes on ecosystem services better than species diversity *per se* (Cadotte et al., 2011) and many ecosystem processes and services depend more on functional diversity than species diversity (Nystrom., 2006). Importantly, our study has demonstrated that, at the study locations in Gran Canaria Island, there is a clear connection between the 3 ways biodiversity of nearshore fishes was quantified, i.e. at the taxonomic, trophic and functional levels.

5.2 Cabrón-Risco Verde

Mycteroperca fusca, a top predator inhabiting shallow rocky reefs of the Macaronesia, was unique among the four studied species in the sense that we found larger abundances and total biomasses inside relative than outside the protected areas (at time 0, of course). In the Canary Islands, Tuya et al. (2006) found the greatest mean abundances and total biomasses of this species at El

Hierro Island (*ca*. mean abundances of 1.5-2 ind 100 m^2), particularly inside the 'Mar de Las Calmas' MPA. We found similar abundance values for this species, even at the state 0 of implementation. This result is indicative of the good status of this fish at this area, as this species is slow-growing, large-sized, with low population turnover rates (Zabala et al., 1997; La Mesa et al., 2002; Bodilies et al., 2003) and is heavily targeted by both professional and recreational fishermen in the Canarias (Bas et al., 1995; Falcon et al., 1996; Tuya et al., 2006). A similar outcome has been described in the Mediterranean Sea, where the effects of protection from fishing near the coast have lead to increments in the abundance and biomass of another Serranid, the dusky grouper, *Epinephelus marginatus* (Zabala et al., 1997; La Mesa et al., 2002).

The sea-bream, *Diplodus vulgaris*, is a species targeted by both recreational and commercial fisheries in the Mediterranean (Coll et al., 2004; Lloret et al., 2004) and the Atlantic (Velga et al., 2010). This fish showed a higher biomass inside than outside the protected area. Small protected areas, such as MAEL can therefore offer an alternative for the sustainable development of this and similar species (Alós et al., 2011).

5.3 Canteras-Confital

The target species: *Sparisoma cretense*, *Diplodus sargus*, *Diplodus vulgaris* and *Sarpa salpa*, showed larger abundances and total biomasses between the future protected area and the neighboring un-protected area. This may be attributed to eased control of fishing activities; by law, fishing is prohibited inside beaches, what is also facilitated by the large number of users that somehow make difficult extraction of resources within the beach. As a result, this area can be a great site to conserve and regenerate fish population. *Sparisoma cretense*, *Diplodus vulgaris* and *Diplodus sargus* are highly prized in both local recreational and commercial fisheries across the Macaronesian region, and especially throughout the Canarian Archipelago (Bortone et al., 1991; Bas et al., 1995). The larger abundances and total biomasses recorded for *Salpa salpa* might be the result of a larger fishing pressure outside the protected area.

5.4 Link between taxonomic, trophic and functional diversity

Estimation of functional diversity is relevant to assess the health state of coastal resources, where there is increasing interest in clarifying the role of natural and human impacts. In this study, we only found higher functional diversity in 'Las Canteras' than in the adjacent un-protected area. If we take into consideration that increments in taxonomic, trophic and functional diversity are expected after the implementation of conservation measures, this data points towards a moderate reserve effect at the time 0.

Our data suggested a link between taxonomic, trophic and functional diversity. According with Clemente et al. (2010), depletion in species diversity constitutes a real loss of functional roles and subsequent cascading effects, so a link between both functional and species diversity is expected. This result does not agree, however, with those reported by Villamor et al. (2012) for five MPAs in the Mediterranean Sea. These authors concluded that, while species diversity shows a weak response to protection within MPAs, trophic and functional diversity better response to protection. Beyond, Villeger et al. (2010) found that taxonomic diversity (here quantified via species evenness) may be useful to work out changes in abundance distribution among species and it could lead to an increase in functional diversity (functional evenness). However, functional diversity (functional evenness), contrary to taxonomic diversity (species evenness), indicates whether the dominance species are functionally similar. In summary, both MAELs have potential to protect natural resources. It would be recommendable to support the protection and assess whether MAELs in the following years accomplished their goals.

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8. Appendix

Appendix 1.The positive effects of small-sized reserves around the world.

	Polunin & Roberts (1993)		Agardy (1993)			Roberts & Hawkins (1997)
Reserve	Saba Marine Park	Ambergris Caye	Reserva Biosfera Sian Ka'an (Quintana Roo)	Parque Marino Isla Saba	Gran Barrera de Arrecifes	Anse Chastanet
Country	Netherlands Antilles	Belize	Méjico	Antillas Neerlandesas	Australia	St. Lucía
Size (ha)	20	20	320000			2.6
Age	4	4	7			2
Indicators: ecologic/fishing						
Total density of fishes	+	+	n.a.	n.a.	n.a.	+
Total biomass of fishes	+	+	n.a.	n.a.	n.a.	+
Density of predators fishes	+	+	n.a.	n.a.	n.a.	+
Biomass of predators fishes	+	+	n.a.	n.a.	n.a.	+
Species diversity	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Species size average	+	+	n.a.	n.a.	n.a.	+
Predators size average	+	+	n.a.	n.a.	n.a.	+
Density of commercial target fishes			n.a.	n.a.	n.a.	
Indicators:socio-economic						
Tourist uses	n.a.	n.a.	+	+	+	n.a.
Divers	n.a.	n.a.	n.a.	+	+	+
Fishing local benefits	+	+	n.a.	n.a.	n.a.	n.a.
Economic local benefits	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Enviroment local benefits	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Russ et al. (2004) Apo Island Filipinas	Parnell et al. (2005) La Jolla Californiam, US	Melita A. Samoilys et al. 2007 Handumon Bohol, Filipinas	Pandanon	Asinan	Bilang-bilangan	Batasan	Harmelin-Viven et al. (2008) Banyuls Francia	Cabo de Palos España	Cabrera	Carry-le-Rouet Francia	Medes España	Tabarca
22.5	216	50	20	66	10.5	21	650	1898	8680	85	418	1400
>18		12	3	7	8	8	>10					
n.a.	-	+	+	+	+	+	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	+	+	+	+	+	+
n.a.	0	+	+	+	+	+	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
+	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	+	+			+	+
n.a.	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Claudet et al. (2008)											
La Restinga	La Graciosa	Cabo de Palos	Tabarca	San Antonio	Columbretes	Medes Islands	Cerbere-Banyuls	Cap Couronne	Carry-le-Rouet	Bouches de Bonifacio	Siis Mal di Ventre
España							Francia				Italia
180	1225	270	120	110	1883	93	65	210	85	1200	529
14	13	13	22	15	18	25	34	14	26	17	15
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
+	+	+	+	+	+	+	+	+	+	+	+
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Appendix 2. Results of two way ANOVAs testing for differences between localities, times, for the species, trophic and functional composition each marine reserve. *Significant difference at *P*<0.05.

	Cabrón Vs Risco Verde				Canteras Vs Confital			
Taxonomic composition	df	MS	F	P	df	MS	F	P
Locality	1	0.976	4.309	0.087	1	1.116	3.981	0.098
Time	6	0.287	2.543	0.032	6	0.275	1.488	0.199
LoxTi	6	0.227	2.006	0.091	6	0.280	1.518	0.195
Res.	42	0.113			42	0.185		
Total	55				55			
Trophic composition	df	MS	F	P	df	MS	F	P
Locality	1	0.004	0.226	0.624	1	0.187	1.295	0.305
Time	6	0.032	1.317	0.281	6	0.045	0.514	0.799
LoxTi	6	0.016	0.658	0.677	6	0.145	1.648	0.168
Res.	42	0.024			42	0.089		
Total	55				55			
Functional composition	df	MS	F	P	df	MS	F	P
Locality	1	0.009	0.048	0.835	1	0.378	1.671	0.246
Time	6	0.147	1.731	0.139	6	0.057	0.573	0.750
LoxTi	6	0.188	2.219	0.062	6	0.226	2.284	0.051
Res.	42	0.084			42	0.099		
Total	55				55			

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