

The structure of a nearshore fish assemblage at an oceanic island: insight from small scale fisheries through bottom traps at Gran Canary Island (Canary Islands, eastern Atlantic)

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Abstract – Unsuitable management of fisheries may lead to overexploitation of marine resources. Oceanic islands with narrow continental shelves, in particular, are sensitive to unsustainable levels of fishing intensity. Fish traps are the modality of artisanal professional fishing more important in the coastal waters of the Canary Islands (eastern Atlantic) to capture demersal resources, which are deployed all year-round and allow a release of undersized captures. We aimed at studying the structure of nearshore fish assemblages through deployment of benthic bottom traps carried out at Gran Canary Island. A quantitative description of catches, in terms of abundance, biomass and sizes, of traps deployed from May to October 2009, between *ca.* 20 to 50 m depth, was carried out. We used this information to test whether the structure of nearshore fish assemblages at the island scale varied between three zones located at the NW, NE and E of the island with varying habitat structure. A total of 58 species (22 families) were collected for the overall study from a total of 2568 deployed traps. The species *Sparisoma cretense* (25% of the total biomass), the family Sparidae (16 species, 44%) and *Mullus surmuletus* (4%) accounted for more than 73% of the total catch in terms of biomass. The parrotfish, *S. cretense*, was the fish with the largest catches in terms of number of individuals, followed by *Dentex gibbosus*, *Diplodus vulgaris*, *Stephanolepis hispidus*, *Chromis limbata* and *Mullus surmuletus*. Differences in the structure of the fish assemblage at the island scale were not predicted by differences in the type of bottom. Fishing yields were similar between the NW (0.16 ± 0.02 kg trap⁻¹ day⁻¹) and NE side of the island (0.19 ± 0.01 kg trap⁻¹ day⁻¹), being lower at the E zone (0.15 ± 0.01 kg trap⁻¹ day⁻¹). The most abundant species, the parrotfish *S. cretense*, had a mean size close to its first maturity sizes (SFM₅₀), while both *D. gibbosus* and *D. vulgaris* were below SFM₅₀. In general, the mean size of Sparids was well below SFM₅₀, an indication of overexploitation, while *M. surmuletus* and *S. hispidus* reached a mean size beyond their first maturity sizes.

Keywords: Ichthyofauna / habitat / diversity / coastal fishery / Atlantic Ocean

1 Introduction

In the last century, unsuitable management of fisheries, including artisanal, industrial and recreational, has led to over-exploitation of marine resources in most of the world's coastal areas (Mitcheson et al. 2013; Chiappone et al. 2004; Pauly 2008; FAO 2012), while fishing methods such as trawling are contributing to a continuous degradation of marine habitats worldwide (Messieh et al. 1991; Collie et al. 1997; Watling and Norse 1998; Eno et al. 2013). In many areas of the globe, however, promotion of sustainable fisheries is complex, e.g. not all landings of fisheries are controlled and the use of multiple gear types create an unfavourable regulation, particularly for coastal fisheries (Hernández-García et al. 1998; McClanahan and Mangi 2001). In addition, recreational fishing may be an

uncontrolled source of fishing and contribute to depauperate certain fishery resources. This situation is especially worrying at oceanic islands with reduced continental shelves, where reduced coastal habitats provide finite resources that are easily threatened by unsustainable levels of fishing intensity (Rhodes et al. 2011; SPC 2013; Menezes et al. 2013).

The Canary Islands is an archipelago located between *ca.* 100–450 km off the northwest African coast. Its volcanic origin is manifested in the absence, or very narrow, coastal shelf, particularly in the westernmost islands, what affects topographic and hydrographical features of the coast, and hence the distribution of marine species (Brito 1984, 1991; Falcón et al. 1996; Landaeta et al. 2012). Nearshore ecosystems are characterised by a high biodiversity and fragility, resulting from the reduced representation, in terms of abundance, of most species (Pascual 2004; Tuya et al. 2014). In this archipelago,

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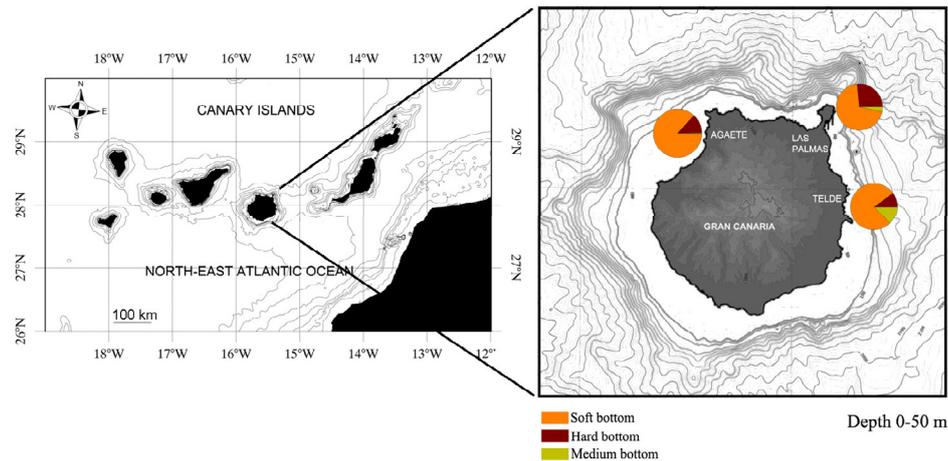


Fig. 1. Map of the three zones at Gran Canaria island: NW – Agaete, NE – Las Palmas, and E – Taliarte; the percentages of each bottom type is included for each zone, hard (i.e. rocky reefs), medium (i.e. cobbles-dominated bottoms) and soft (i.e. sandy bottoms).

over 100 fish species are exploited by small-scale fisheries using multiple gears, such as seine nets, traps and hand-lines (García-Cabrera 1970; Pascual 1991; Bas et al. 1995; Pajuelo and Lorenzo 1995; Mancera-Rodríguez and Castro 2004, 2015; Martín-Sosa 2012). The structure of the Canarian fishing fleet shows a high social and economic dependency on small-scale fishing (FAO 2011; EU Fisheries in Canary Islands 2013). The assessment and further management of these resources is complicated, because the knowledge of biological parameters is restricted to the main commercial species (González and Lozano 1992; Pajuelo and Lorenzo 1995, 1996, 1999; García-Díaz et al. 1997, 2006; Méndez-Villamil et al. 1997; Pajuelo et al. 2006; González et al. 2012). Importantly, there are no available historical, temporal, series of catches and fishing effort for all gears and ports (Hernández-García et al. 1998), what avoid proper evaluation of fishing trends through decades.

Deployment of fish traps is the modality of artisanal professional fishing more important in the coastal waters of this archipelago, which is practised all year-round (Bas et al. 1995; Melnychuk et al. 2001; Martín-Sosa 2012). This is a passive capture technique, whose advantages in relation to others gears are the simplicity in their design, construction and use in the case experienced fishermen (Hubert et al. 2012). Moreover, this is one of the few gears that can be used when strong winds and swells occur in the coast and there is the possibility of fish selection on board to release part of captures (i.e. undersized individuals). Although there is a high variability between islands and fishing ports, Couce-Montero (2009) estimated through surveys an average number of fish traps per vessel of 180 units. Still, few studies using fish traps as a way to describe fishery resources have been published in the world (Smolowitz 1978; Matsuoka et al. 2005; Erzini et al. 2008; Newman et al. 2011; Langlois et al. 2015). In this study, we initially aimed at improving the knowledge of small scale fisheries through bottom traps at Gran Canary Island (Canary Islands) by providing a quantitative description of catches in terms of fish abundances and biomasses. We analysed the structure of fish sizes of targeted species, as a way to evaluate the status of populations. We finally sought to determine

whether the structure of nearshore fish assemblages at the island scale varied spatially between zones with varying habitat structure.

2 Materials and methods

2.1 Study area

This study focused on Gran Canary Island, which is located at the centre of the Canarian Archipelago, being the third largest island (1532 km²) with 45 km of diameter and a maximum elevation of 1950 m above the sea level (Carracedo et al. 2002). Each island within the Canarian Archipelago consists of an independent large volcanic structure. The shallow subtidal platforms around each island are not continuous except between the islands of Lanzarote and Fuerteventura, and as a result each island has its own independent shallow benthic populations (Sangil et al. 2013). Sediments and rocky reefs mainly compose nearshore bottoms, with a high variability in the distribution and complexity of these habitats, which can be colonized by a range of canopy-forming species (Tuya and Haroun 2006; Tuya et al. 2014). By taken advantage of a published marine cartography for the entire island (GRAFCAN 2008), we grouped the bottom types in three categories: hard (i.e. rocky reefs), medium (i.e. cobbles-dominated bottoms) and soft (i.e. sandy bottoms).

Data were collected at three zones which are located in the vicinity of 3 ports within each area (Fig. 1). In the north-western coast (NW, Agaete), artisanal fishing is performed in an area mainly dominated by soft bottoms (86%) with a wide offshore platform relative to the other two zones. Commercial fishing is performed when sea conditions are adequate, since this stretch of the coast is very exposed to strong trade winds and oceanic swells from the N and NW. In the north-eastern coast (NE, Las Palmas), fishing is also majorly carried out in an area dominated by soft bottoms (70%), but on a much reduced offshore platform. In the eastern coast (E, Taliarte), bottoms are also dominated by soft substrates (77%). This zone has a narrow offshore platform.

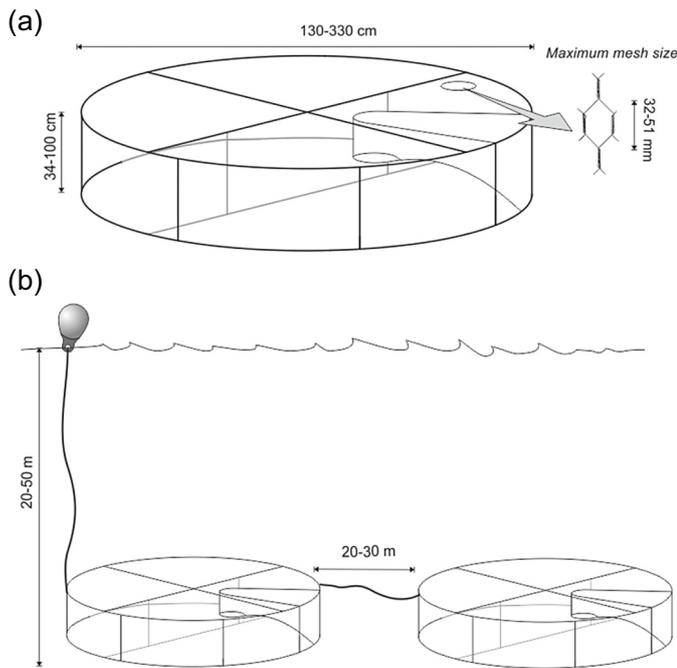


Fig. 2. Fish trap used by the artisanal fishing fleet (a) and long-line method, joining 2 traps together in a gang (b).

2.2 Fishery data collection

Data on catch and effort (number of days and boats) of fish trapping were provided by the local authority of Gran Canary Island (*Cabildo de Gran Canaria*) and was collected by fisheries officials on board. Still, governance and erection of laws is regulated through the fisheries authority of the Canary Islands (*Viceconsejería de Pesca y Aguas*). This database is composed by the captures of 609 (NW), 1138 (NE) and 821 (E) fish traps deployed by the artisanal commercial fishing fleet between May and October 2009. All captured individuals were brought inland; a special permit was provided by the *Viceconsejería de Pesca y Aguas* in this regard. In all cases, traps were circular, ranging between 130–300 cm in diameter, and 30–100 cm in height, which were built with wire mesh (32–51 mm of mesh size) and a single funnel entrance; a door is used to include bait and extract catches (Fig. 2a). Traps were located between *ca.* 20 to 50 m depth (mean depth = 31 m) at the 3 zones, either individually or using a long-line method that joins 2–3 traps together in a gang (Fig. 2b). The number of days that traps were placed on the seafloor varied between 3 and 30 days, depending on oceanographic (wind and swell) conditions and target species. The entire fish catch for each trap (commercial plus the discarded fraction, which is usually returned alive to the sea) was retained for further analyses. The species were then identified, classified (Fischer et al. 1981), weighted and placed within a taxonomic hierarchy according to Nelson's *Fishes of the World* (Nelson 2006).

2.3 Statistical analysis

Data of abundance and biomass were firstly standardized using the catch per unit effort (i.e. per trap and day, CPUE). To

test for differences in the multivariate structure of fish assemblages (CPUEs) between the 3 geographical zones, the non-parametric ANOSIM test was performed (Clarke and Warwick 1994; Tuya et al. 2006a). This analysis compares the average rank similarities within the predefined groups of samples with the average similarity between groups. Values of R close to 1 indicate strong separation in terms of assemblage structure, while values close to 0 indicate a lack of differences (Pusch et al. 2004). When a significant difference ($p < 0.05$) was detected, a similarity percentage breakdown (SIMPER) (Clarke and Warwick 1994) was conducted to determine which species were representatives of specific assemblages (i.e. within each zone) and their contribution to dissimilarities between each pair of zones (Clarke and Warwick 1994).

A permutational analysis of variance via the PERMANOVA package (Anderson et al. 2008) was run on a Euclidean distance matrix to test for differences in catch per unit effort (CPUE) in terms of the total biomass. Although PERMANOVA was originally designed for analysis of multivariate data, it can also be used to analyse univariate data and, unlike ANOVAs, do not assume that data are normally distributed (Anderson et al. 2008; Garside et al. 2014). We performed 9,999 random permutations of the raw data under a reduced model.

To evaluate whether variation in the amount of bottom types (rocky, medium and soft) between the 3 zones contributed to explain variation in the structure of fish captures between zones, a multivariate multiple regression model, using the DISTLM routine (Anderson 2001), was implemented. This analysis tested the significance of these relationships by fitting a linear model based on Bray-Curtis dissimilarities from square-root transformed data and using a “forward” selection procedure.

Finally, for the main commercial fish species in terms of abundance, the mean size per zone was compared via a *t*-student test with the size at first maturity (SFM_{50}), as provided by the local literature. This is an indicator of the level of species' specific exploitation (Sharpe and Hendry 2009).

All multivariate procedures were carried out via the PRIMER v6 (Clarke and Gorley 2006) and PERMANOVA+ (Anderson et al. 2008) statistical package.

3 Results

3.1 Composition and abundance of the fishery

A total of 45 species belonging to 20 families were collected in the NW coast (Table 1). The species *Sparisoma cretense* (33% of the total biomass), the family Sparidae (12 species, 30%) and *Mullus surmuletus* (13%) accounted for more than 75% of the total catch in terms of biomass. Nevertheless, species of low weight, such as *Similiparma lurida* and *Chromis limbata*, were important in terms of abundance (17%). In the NE coast, 37 species (16 families) were captured, where Sparidae (13 species, 43% of the total biomass) and *Sparisoma cretense* (35%) accounted for >75% of catches in terms of biomass (Table 1). *Stephanolepis hispidus* was

Table 1. Fish species collected between May and October 2009. Total abundance (n : number of individuals); total biomass (kg); size range (TL, cm); N , number of fish traps in each area. The first maturity sizes (SFM₅₀) is included according to González et al. (2012). * non-commercial species, ^ endemic species of the Macaronesian region.

Species	First maturity SFM ₅₀ (cm)	NW-Agaete ($N = 609$)			NE-Las Palmas ($N = 1138$)			E-Telde ($N = 821$)		
		n	Biomass (kg)	Size range (cm)	n	Biomass (kg)	Size range (cm)	n	Biomass (kg)	Size range (cm)
Aulostomidae										
<i>Aulostomus strigosus</i> *		4	1.200	51–66	–	–	–	–	–	–
Balistidae										
<i>Balistes capriscus</i>	20.0 FL	27	18.980	27–43	111	25.180	20–43	34	11.068	18–39
Bothiidae										
<i>Bothus podas</i> *		62	2.670	10–20	18	1.102	15–21	9	0.330	13–22
Carangidae										
<i>Pseudocaranx dentex</i>	37.0	–	–	–	6	10.833	44–52	10	10.181	40–62
<i>Seriola dumerili</i>		–	–	–	–	–	–	1	1.752	55
<i>Seriola fasciata</i>		3	18.000	71–93	–	–	–	2	3.776	52–55
<i>Seriola rivoliana</i>		1	7.990	80	–	–	–	1	0.594	36
<i>Trachurus trachurus</i>	25.0	35	7.320	17–23	–	–	–	–	–	–
Congridae										
<i>Conger conger</i>	200.0	2	6.290	86–115	3	10.138	73–104	3	7.898	13–93
Haemulidae										
<i>Parapristipoma octolineatum</i>		13	2.140	21–29	5	0.832	20–24	13	1.426	19–24
<i>Pomadasys incisus</i>		97	7.750	15–22	104	7.827	15–24	65	5.007	14–23
Labridae										
<i>Bodianus scrofa</i> ^		4	3.078	31–41	3	3.334	38–42	–	–	–
<i>Coris julis</i> *		2	0.288	23–23	–	–	–	–	–	–
<i>Thalassoma pavo</i> *		1	0.072	18	–	–	–	3	0.135	21
<i>Xyrichtys novacula</i> *		–	–	–	1	0.100	19	–	–	–
Monacanthidae										
<i>Aluterus scriptus</i> *		–	–	–	–	–	–	1	1.400	57
<i>Stephanolepis hispidus</i>	14.9	3	0.190	13–16	737	69.193	9–27	201	16.457	10–26
Mugilidae										
<i>Liza aurata</i> *		–	–	–	–	–	–	8	3.058	31–37
Mullidae										
<i>Mullus surmuletus</i>	16.6	231	43.160	15–28	152	17.980	11–28	113	14.393	18–32
Muraenidae										
<i>Enchelycore anatina</i>		4	1.490	71–86	–	–	–	–	–	–
<i>Gymnothorax unicolor</i>	56.5	11	8.710	69–88	–	–	–	–	–	–
<i>Muraena augusti</i>	55.8	7	4.920	64–88	–	–	–	–	–	–
<i>Muraena helena</i>	75.1	–	–	–	–	–	–	2	3.608	85–98
Phyciidae										
<i>Phycis phycis</i>	37.0	1	3.948	41	–	–	–	–	–	–
Pomacentridae										
<i>Similiparma lurida</i> *^		56	1.278	11–14	137	6.028	10–16	105	4.604	11–15
<i>Chromis limbata</i> *^		511	23.417	11–17	54	4.692	11–14	344	12.361	11–15
Scaridae										
<i>Sparisoma cretense</i>	23.3	634	100.850	15–42	1716	253.450	16–36	564	67.790	15–37
Scianidae										
<i>Argyrosomus regius</i>		–	–	–	–	–	–	5	4.774	44–50
<i>Umbrina canariensis</i>		1	0.180	23	2	0.360	20–21	1	0.130	22
Scorpaenidae										
<i>Scorpaena porcus</i>		–	–	–	12	1.262	14–25	12	1.452	15–26
<i>Scorpaena scrofa</i>		3	0.230	14–15	3	0.254	13–15	–	–	–
Serranidae										
<i>Epinephelus marginatus</i>		2	1.524	42–44	4	3.118	36–52	6	8.667	36–51
<i>Mycteroperca fusca</i> ^	33.5	3	3.750	39–42	9	16.451	25–42	6	13.360	15–42
<i>Serranus atricauda</i>	19.3	24	4.195	13–30	21	3.221	20–34	21	1.847	19–24
<i>Serranus cabrilla</i>	16.6	1	0.060	17	–	–	–	–	–	–
<i>Serranus scriba</i>	17.3	10	1.054	20–24	99	8.414	17–23	64	6.163	16–24

Table 1. Continued.

Species	First maturity SFM ₅₀ (cm)	NW-Agaete (N = 609)			NE-Las Palmas (N = 1138)			E-Telde (N = 821)		
		n	Biomass (kg)	Size range (cm)	n	Biomass (kg)	Size range (cm)	n	Biomass (kg)	Size range (cm)
Sparidae										
<i>Boops boops</i>	13.4	75	6.840	10–33	24	2.590	20–25	41	3.639	18–27
<i>Dentex dentex</i>	50.0	–	–	–	–	–	–	4	7.368	72
<i>Dentex gibbosus</i>	38.6	186	41.795	16–61	284	84.737	12–71	735	95.360	15–44
<i>Diplodus annularis</i>	12.8	–	–	–	78	3.679	13–18	5	0.290	14–18
<i>Diplodus cervinus cervinus</i>	32.7	6	2.046	22–29	31	14.816	15–36	3	0.430	18–28
<i>Diplodus puntazzo</i>	29.2	4	2.404	26–38	4	0.780	18–32	58	5.010	24–36
<i>Diplodus sargus cadenati</i>	21.6	97	10.180	16–26	138	19.610	15–31	416	27.760	13–33
<i>Diplodus vulgaris</i>	20.9	243	25.300	13–28	343	36.213	12–24	521	46.495	11–29
<i>Lithognathus mormyrus</i>	24.6	–	–	–	1	0.410	31	–	–	–
<i>Oblada melanura</i>	–	–	–	–	–	–	–	6	1.386	24–28
<i>Pagellus acarne</i>	19.4	19	2.760	14–24	37	4.530	18–27	16	1.738	19–23
<i>Pagellus erythrinus</i>	23.2	10	2.156	15–32	80	9.814	17–31	220	24.560	16–32
<i>Pagrus auriga</i>	53.3	27	11.601	17–33	61	6.581	8–34	65	8.294	12–27
<i>Pagrus pagrus</i>	26.7	9	22.138	21–50	60	23.990	8–52	63	14.286	13–44
<i>Sarpa salpa</i>	29.4	51	20.615	18–27	525	64.550	19–34	84	21.009	18–38
<i>Sparus aurata</i>	40.0	1	0.124	31	–	–	–	2	0.802	26–34
<i>Spondyliosoma cantharus</i>	22.7	160	22.354	10–29	282	35.409	15–28	212	19.758	14–37
Synodontidae										
<i>Synodus saurus</i> *	–	1	0.032	34	–	–	–	–	–	–
Tetraodontidae										
<i>Canthigaster capistrata</i> *	–	2	0.089	10–13	2	0.034	11–13	3	0.056	10–12
<i>Sphoeroides marmoratus</i> *	–	3	0.190	13–17	2	0.052	13–14	1	0.082	15
Triglidae										
<i>Trigloporus lastoviza</i>	29.6	–	–	–	1	0.154	23	–	–	–
Zeidae										
<i>Zeus faber</i>	–	1	0.357	39	–	–	–	–	–	–

only relevant in terms of abundance (14% of the total abundance). Finally, a total of 43 species (17 families) were collected from the E coast (Table 1). The family most representative, in terms of biomass, was Sparidae (16 species, 60% of the total biomass), followed by *Sparisoma cretense* (15%); *Similiparma lurida* and *Chromis limbata* were, again, important in terms of abundance (11%). Other species (i.e., *Mycteroperca fusca* or *Epinephelus marginatus*) or families (Serranidae or Haemulidae) with a high commercial value were exclusively captured occasionally.

The fish assemblage from the E zone was not different, in terms of assemblage structure, relative to those fish assemblages from the NW and NE zones (ANOSIM, $R = 0.042$ and $R = 0.085$; $p > 0.05$, respectively). The fish assemblage from the NW differed relative to that from the NE ($R = 0.185$; $p < 0.05$). The parrotfish, *Sparisoma cretense*, was the fish species with the highest number of individuals at the three zones, followed by *Mullus surmuletus* in the NW, *Stephanolepis hispidus* in the NE and *Diplodus vulgaris* in the E zones (Table 1). *S. cretense* contributed to more than 10% of dissimilarities within each zone. In terms of biomass, *S. cretense* and *Dentex gibbosus* attained the highest values at the three zones, contributing to more than 30% of dissimilarities between zones. These species were followed by *M. surmuletus* in the NW and E zones, and *S. hispidus* in the NE (Table 2).

Differences in the structure (composition and abundance) of the fish assemblages between zones were not predicted by differences in the type of the bottom (rocky, soft, medium) (all terms, $p > 0.05$).

3.2 Fishing yields

The catches of commercial species (González et al. 2012) represented a 91% in the NW, 99% in the NE and 96% in the E, respectively, i.e. only nine species were considered as “discard” (Table 1). Significant differences in the average catch per unit effort (CPUE) were detected between zones (permutation-based ANOVA; pseudo- $F = 109.9$, $p < 0.001$). A posteriori pairwise tests indicated that fishing yields were similar between the NW (0.16 ± 0.02 kg trap⁻¹ day⁻¹) and NE (0.19 ± 0.01 kg trap⁻¹ day⁻¹), being lower at the E zone (0.15 ± 0.01 kg trap⁻¹ day⁻¹).

3.3 Mean size of capture

We evaluated the level of fish overexploitation, in terms of fish sizes relative to their corresponding first maturity sizes (SFM₅₀), for nine Sparids (*Dentex gibbosus* *Diplodus sargus*

Table 2. Results of the SIMPER routine testing for dissimilarities between each pair of zones, based on abundance data. The species are in decreasing order of contribution. δi , mean dissimilarity; $\delta i\%$, contribution of each species to mean dissimilarity; SD: standard deviation.

Agaete vs. Las Palmas $\delta i = 82.11$			Agaete vs. Telde $\delta i = 84.41$			Las Palmas vs. Telde $\delta i = 81.65$		
Species	$\delta i\%$	SD	Species	$\delta i\%$	SD	Species	$\delta i\%$	SD
<i>S. cretense</i>	1.06	14.17	<i>S. cretense</i>	0.99	12.02	<i>S. cretense</i>	1	14.49
<i>M. surmuletus</i>	0.86	9.55	<i>M. surmuletus</i>	0.82	9.61	<i>S. hispidus</i>	0.94	9.48
<i>S. hispidus</i>	0.81	7.67	<i>D. vulgaris</i>	0.88	9.1	<i>D. gibbosus</i>	0.74	9.43
<i>D. vulgaris</i>	0.87	7.67	<i>D. gibbosus</i>	0.64	8.04	<i>D. vulgaris</i>	0.83	8.69
<i>S. cantharus</i>	0.93	6.29	<i>C. limbata</i>	0.61	6.44	<i>S. cantharus</i>	0.92	6.34
<i>D. gibbosus</i>	0.61	5.66	<i>S. cantharus</i>	0.86	6.2	<i>D. sargus cadenati</i>	0.63	5.42
<i>C. limbata</i>	0.55	5.3	<i>D. sargus cadenati</i>	0.67	5.71	<i>P. erythrinus</i>	0.62	5.17
<i>S. salpa</i>	0.55	4.63	<i>P. erythrinus</i>	0.54	4.5	<i>M. surmuletus</i>	0.73	4.9
<i>D. sargus cadenati</i>	0.69	4.28	<i>P. incisus</i>	0.52	4.06	<i>S. salpa</i>	0.51	4.84
<i>P. incisus</i>	0.54	4.04	<i>S. hispidus</i>	0.5	3.84	<i>C. limbata</i>	0.47	3.39
<i>P. erythrinus</i>	0.48	3.42	<i>B. boops</i>	0.54	3.33	<i>S. lurida</i>	0.58	3.36
<i>S. lurida</i>	0.6	3.11	<i>S. salpa</i>	0.51	3.16	<i>B. capriscus</i>	0.42	2.92
<i>B. boops</i>	0.51	3	<i>S. lurida</i>	0.61	2.99	<i>P. pagrus</i>	0.52	2.84
<i>B. podas</i>	0.48	2.32	<i>P. auriga</i>	0.54	2.57	<i>S. scriba</i>	0.58	2.84
<i>P. auriga</i>	0.56	2.32	<i>B. podas</i>	0.46	2.25	<i>P. auriga</i>	0.58	2.65
<i>B. capriscus</i>	0.39	2.3	<i>B. capriscus</i>	0.41	2.14	<i>P. incisus</i>	0.42	2.34
<i>S. scriba</i>	0.48	1.96	<i>P. pagrus</i>	0.48	1.8	<i>S. atricauda</i>	0.41	1.24
<i>P. acarne</i>	0.4	1.85	<i>P. acarne</i>	0.4	1.69			
<i>P. pagrus</i>	0.38	1.72	<i>S. scriba</i>	0.44	1.47			

Diplodus vulgaris *Pagellus acarne* *Pagellus erythrinus* *Pagrus auriga* *Pagrus pagrus* *Sarpa salpa* and *Spondylisoma cantharus*), the parrotfish (*S. cretense*), the goat fish (*M. surmuletus*) and the filefish (*S. hispidus*). Independently of the zone, the mean size of Sparids was below the first maturity sizes (SFM₅₀), except for *P. acarne* from the NE and E zones (Fig. 3). The most abundant species, the parrotfish *S. cretense*, had a mean size close to its first maturity sizes (SFM₅₀), while *M. surmuletus* and *S. hispidus* reached a mean size at the three zones larger than their SFM₅₀. All *t*-tests indicated significant differences in mean sizes of all fishes with regard to the SFM₅₀, except both *P. erythrinus*(NW) and *S. cretense* (NW).

4 Discussion

Our study has demonstrated that the artisanal trap fishery at Gran Canaria Island is highly unselective, catching a wide variety of fishes (37–45 species) from many families (16–20). In addition, only a reduced number of families (Scariidae, Sparidae, Mullidae, Pomacentridae and Monacanthidae) and species provided relatively high fishing yields, in terms of biomass, in particular: *S. cretense*, *D. gibbosus* *Diplodus* spp., *M. surmuletus*, *Pagrus* spp., *Pagellus* spp. and *S. salpa*. Despite low weights, three small-sized species were relevant in terms of abundance: *S. hispidus*, *C. limbata* and *S. lurida*. In this sense, small-sized species are not usually considered as of commercial relevance (Golani et al. 2002), but in the Canary Islands these species are appreciated and found in some local markets

Local variation in the structure and abundance of fish assemblages were detected between the NW and NE sectors of Gran Canaria Island. The fish assemblage of the NW zone was differentiated by the abundance of micro-carnivores and meso-carnivores species (e.g. *C. limbata*, *M.*

surmuletus, *P. acarne* and *Pomadasys incisus*), which typically feed on benthic organisms, i.e., shrimps, amphipods, polychaetes, molluscs (Tuya et al. 2004; Domanevskaya and Patokina 1984; Fehri-Bedoui and Gharbi 2008). In contrast, three herbivorous/omnivorous fishes, *S. cretense*, *S. hispidus* and *S. salpa* (Clements and Livingston 1983; Petrakis and Papaconstantinou 1990; Jadot et al. 2000, 2002), dominated the fish assemblage from the NE zone. *S. salpa* is a species that may opportunistically feed upon the POM produced by anthropogenic activities (Boyra et al. 2004; Dempster et al. 2004; Tuya et al. 2005, 2006b), while *S. hispidus* is associated with bottoms of fine sediments (Mancera-Rodríguez and Castro-Hernández 2004, 2015). In addition, this variation could be also related to the presence and abundance of dominant algal functional groups. For example, frondose fucoid species are more dominant on swell-exposed shores (NW) than on swell-protected shores, whereas turf-algae show a reversal pattern (Tuya and Haroun 2006).

Several studies have concluded that the coastal resources off the Canary Islands have long been over-exploited (Bas et al. 1995; Pajuelo and Lorenzo 1995; Falcon et al. 1996; Tuya et al. 2004). Most likely, this is the result of several interplaying factors, such as the improvement in materials for building traps, a large capability and autonomy of artisanal boats, better port infrastructures, increased local market demands and, importantly, the advent of recreational fishing in the last decades, which may capture up to 60% of the total capture at some islands, for example in Gran Canaria Island (RESPESCAN 2008; Castro and Hernández-García 2012). This has been reflected in a progressive decline in the mean fishing yields at Gran Canary island in the last 4 decades, from 2.2 kg trap⁻¹ day⁻¹ in the 1970s at the south of the island (Castro and Hernández-García 2012) to 0.14–0.18 kg trap⁻¹ day⁻¹ (this study) at the north-east of the island,

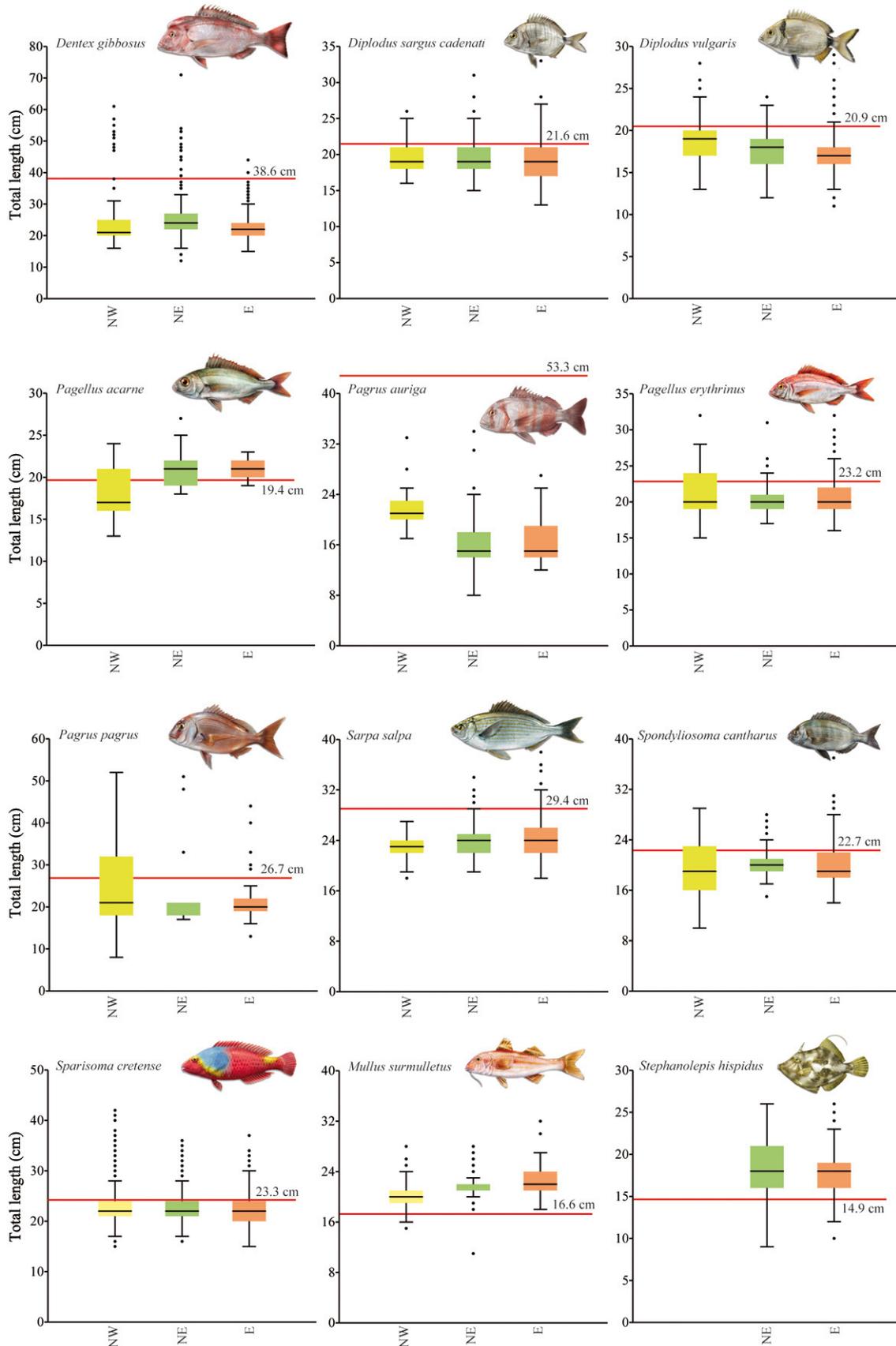


Fig. 3. Mean size of captured fish species at each zone; the SFM₅₀ (red line) is included, according to González et al. (2012). All *t*-tests indicated significant differences in mean sizes of all fishes with regard to the SFM₅₀, except both *P. erythrinus* (NW) and *S. cretense* (NW).

although this value is similar to that provided by Hernández-García et al. (1998) for the eastern side of Gran Canary island (0.15 and 0.21 kg trap⁻¹ day⁻¹) from 1989 to 1996. In any case, the average number of fish traps per artisanal fishing vessel has decreased (approximately from 275 in the 1990s to 180), following a 65% reduction in the size of the operating fleet from 1996 to nowadays (Bas et al. 1995; Hernández-García et al. 1998; Couce-Montero 2009). Despite a lack of specific studies, the regional government (through the local fisheries authority) and fishermen are aware that fishing yields have severely decreased in the last 4 decades (REPESCAN 2008), but relevant management implications have not been accomplished, as a result of a lack of political willingness.

Fisheries regulations are often difficult to enforce in areas facing overexploitation; the size of fishery species become smaller through time, and fishermen claim for a decrease in the minimum size of commercialization, despite local fishermen has also willingness to increase other minimum size of captures (e.g. *Mullus surmuletus* and *Epinephelus marginatus*). However, a well-managed fishery is expected to use fishing gears that catch most of the available species at sizes that do not undermine sustainability (McClanahan and Mangi 2001). In our case study, the majority of commercially captured species were juveniles and sub-adults; in the case of hermaphrodite species, most individuals have not reversed sex. In any case, it is important to point out that, under normal conditions, fishermen should have released these captures back to the sea. Only those fish species maturing at small sizes, e.g. *M. surmuletus* and *S. hispidus* (Pajuelo et al. 1997; Mancera-Rodríguez and Castro-Hernández 2004, 2015), which have short life-cycles and high turnover rates might be able to withstand overexploitation. These species are trappable because their life history characteristics enable them to persist despite high rates of fishing mortality. However, remaining species, particularly in the case of Sparids, could be overexploited, as previously indicated by other works (Pajuelo and Lorenzo 1995, 1996, 1999; REPESCAN 2008). It is worth noting, moreover, that the first maturity size (SFM₅₀) of most fish species were obtained many years ago, and might have changed.

A limitation of this study is that data only corresponds to a reduced temporal window (May to September 2009), what could limit our conclusions and so our inference capacity to other circumstances. Nevertheless, at the light of our results and previous studies in the study region, it is recommended an effective management of resources, implying a reducing fishing pressure (professional and, importantly, recreational), to study the proper use of fish traps (e.g. mesh structure and redesign systems to reduce ghost fishing, systems to locate lost traps), study and update first maturity sizes (SFM₅₀) of the main commercial species, socio-educative programmes to raise awareness in the necessity of conservation and a larger number of marine reserves providing essential refuges for species that are particularly vulnerable to overexploitation (Francour et al. 2001; Roberts 2005; Kellner et al. 2007; Kerwath et al. 2013; Buxton et al. 2014).

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References

- Anderson M.J., 2001, A new method for non-parametric multivariate analysis of variance. *Austr. Ecol.* 26, 32–46.
- Anderson M.J., Gorley, R.N., Clarke, K.R., 2008, PERMANOVA+ for PRIMER: Guide 483 to Software and Statistical Methods. PRIMER-E, Plymouth, UK 214 p.
- Ayala B., 2006, Propuesta de red representativa de Áreas Marinas Protegidas en España. Archipiélago Canario. World Wildlife Fund (WWF)/Adena, 26 p.
- Bas C., Castro J.J., Hernandez-Garcia V., Lorenzo J.M., Moreno T., Pajuelo J.G., Ramos A.G., 1995, La Pesca en Canarias y Areas de Influencia. Ediciones del Cabildo Insular de Gran Canaria, Madrid, 300 p.
- Brito A., 1984, Zoogeografía Marina de las Islas Canarias. En Fauna Marina y Terrestre del Archipiélago Canario. Gran Biblioteca Canaria. Tomo XIII, Ed. Edirca S.L. Las Palmas de Gran Canaria, pp. 66–86.
- Brito A., 1991, Catálogo de los Peces de las Islas Canarias. Francisco Lemus Editor, La Laguna.
- Boyra A., Sanchez-Jerez P., Tuya F., Espino F., Haroun R., 2004, Attraction of wild coastal fishes to Atlantic subtropical cage fish farms, Gran Canaria, Canary Islands. *Environ. Biol. Fish.* 70, 393–401.
- Buxton C.D., Hartmann K., Kearney R., Gardner C., 2014, When is spillover from marine reserves likely to benefit fisheries? *PLoS One* 9, e107032.
- Carracedo J.C., Pérez F.J., Ancochea E., Meco J., Hernán F., Cubas C.R., Casillas, R., Rodríguez E., Ahijado A., 2002, Cenozoic volcanism II: The Canary Islands. In: Gibbons W., Moreno T. (eds.), *The Geology of Spain*. The Geol. Soc. Lond., pp. 439–472.
- Castro J.J., Hernández-García V., 2012, Caracterización del poder de pesca de la flota artesanal canaria, con especial referencia a la fracción con eslora superior a 12m., y análisis del estado de los recursos que explota. Informe Técnico. Viceconsejería de Pesca del Gobierno de Canarias, 127 p.
- Clarke, K.R., Warwick R.M., 1994, Change in Marine Communities. Plymouth Marine Laboratory, 144 p.
- Clarke K.R., Gorley R.N., 2006, PRIMER v6: User Manual/Tutorial, PRIMER-E, Plymouth, 192 p.
- Clements W.H., Livingston J., 1983, Overlap and pollution-induced feeding habits of filefish (Pisces: Monacanthidae) from Apalachee Bay, Florida. *Copeia*, 331–338.
- Collie J.S., Escanero G.A., Valentine P.C., 1997, Effects of bottom fishing on the benthic megafauna of Georges Bank. *Mar. Ecol. Prog. Ser.* 155, 159–172.
- Couce-Montero, M.L., 2009, Diagnóstico de la pesquería artesanal en el Puerto de Mogán. Tesina de Máster. Universidad de las Palmas de Gran Canaria, 37 p.
- Dempster T., Sanchez-Jerez P., Bayle-Sempere J.T., Kingsford M.J., 2004, Extensive aggregations of wild fish at coastal seaweed fish farms. *Hydrobiologia* 525, 245–248.
- Domanevskaya M.V., Patokina F.A., 1984, Feeding of the large-eyed dogtooth, *Dentex macrophthalmus*, and Spanish bream, *Pagellus acarne*, from the entral-Eastern Atlantic Ocean. *J. Ichthyol.* 24, 107–112.
- Eno N.C., Frid C.L.J., Hall K., Ramsay K., Sharp R.A.M., Brazier D.P., Hearn S., Dernie K.M., Robinson K.A., Paramor O.A.L.,

- Robinson L.A., 2013, Assessing the sensitivity of habitats to fishing: from seabed maps to sensitivity maps. *J. Fish Biol.* 83, 826–846.
- Erzini K., Bentes L., Coelho R., Lino P.G., Monteiro P., Ribeiro J., Gonçalves, J.M.S., 2008, Catches in “ghost-fishing” octopus and fish traps in the north-eastern Atlantic (Algarve, Portugal). *Fish. Bull.* 106, 321–327.
- EU Fisheries in Canary Islands 2013. Document of the European Parliament’s Committee on Fisheries, 62 p.
- FAO (2011) Spain Artisanal trap finfish fishery – Canary Islands <http://firms.fao.org/firms/fishery/581/en>
- FAO, 2012. The State of World Fisheries and Aquaculture. FAO, Rome, 209 p.
- Falcón J.M., Bortone S.A., Brito A., Bundrick C.M., 1996, Structure and relationships within and between the littoral, rock-substrate fish communities off four islands in the Canarian Archipelago. *Mar. Biol.* 125, 215–231.
- Fehri-Bedoui R., Gharbi H., 2008, Sex ratio, reproduction and feeding habits of *Pomadasyus incisus* (Haemulidae) in the Gulf of Tunis (Tunisia). *Acta Adriat.* 49, 5–19.
- Fischer W., Bianchi G., Scott W.B., 1981, FAO species identification sheets for fishery purposes. Eastern Central Atlantic: Fishing Areas 34, 47 (in part). FAO, Rome, vols. I–VI.
- Francour, P. Harmelin J.G., Pollard D., Sartoretto S., 2001, A review of marine protected areas in the northwestern Mediterranean region: sitting, usage, zonation and management. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 11, 155–188.
- García-Cabrera C., 1970, La pesca en Canarias y Banco Sahariano. Consejo Económico Sindical Interprovincial de Canarias, 176 p.
- García-Díaz M., Tuset V.M., González J.A., Socorro J., 1997, Sex and reproductive aspects in *Serranus cabrilla* (Osteichthyes: Serranidae): Macroscopic and histological approaches. *Mar. Biol.* 127, 379–386.
- García-Díaz M., González J.A., Lorente M.J., Tuset V.M., 2006, Spawning season, maturity sizes, and fecundity in black-tail comber (*Serranus atricauda*) (Serranidae) from the eastern-central Atlantic. *Fish. Bull.* 104, 159–166.
- Garside C.J., Coleman M.A., Glasby T.M., Kelaher B.P., Bishop M.J., 2014, The frequency of connection of coastal water bodies to the ocean predicts *Carcinus maenas* invasion. *Limnol. Oceanogr.* 59, 1288–1296.
- Golani D., Orsi-Relini L., Massuti E., Quignard J.P., 2002, CIESM Atlas of exotic species in the Mediterranean. CIESM Publishers, Monaco.
- González J.A., Lozano I.J., 1992, Determinación de curvas de madurez sexual en la vieja, *Sparisoma (Euscarus) cretense* (L.) (Osteichthyes, Scaridae), de Canarias. *Bol. Inst. Esp. Oceanogr.* 8, 271–297.
- González J.A., Pajuelo J.G., Lorenzo J.M. Santana J.I., Tuset V.M., Jiménez S., Perales-Raya C., González-Lorenzo G., Martín-Sosa P., Lozano I.J., 2012, Talla mínima de captura: peces, crustáceos y moluscos de interés pesquero en Canarias: una propuesta científica para su conservación. *Consejería de Agricultura, Ganadería Pesca y Alimentación*, 248 pp. http://issuu.com/oceanografica/docs/maqueta_libro_web
- GRAFCAN, 2008, Cartográfica de Canarias, S.A. www.grafcan.es
- Hernández-García V., Hernández-López J.L., Castro J.J., 1998, The octopus (*Octopus vulgaris*) in the smallscale trap fishery off the Canary Islands (Central-East Atlantic). *Fish. Res.* 35, 183–189.
- Hubert W.A., Pope K.L., Dettmers J.M., 2012, Passive capture techniques. In: Zale, Parrish D.L., Sutton T.M., (eds.), *Fisheries techniques*, 3rd edition. American Fisheries Society, Bethesda, Maryland, pp. 223–265.
- Jadot C., Graux D., Michel C., Voss J., 2000, Contribution à la caractérisation du comportement reproducteur et alimentaire de la Saupe (*Sarpa salpa* (Linné, 1758)). *Cah. Ethiol.* 20, 33–44.
- Jadot, C., Ovidio M., Voss J., 2002, Diel activity of *Sarpa salpa* (Sparidae) by ultrasonic telemetry in a *Posidonia oceanica* meadow of Corsica (Mediterranean sea). *Aquat. Living Resour.* 15, 343–350.
- Kellner J.B., Tetreault I., Gaines S.D., Nisbet R.M., 2007, Fishing the line near marine reserves in single and multispecies fisheries. *Ecol. Appl.* 17, 1039–1054.
- Kerwath S.E., Winker H., Götz A., Attwood C.G., 2013, Marine protected area improves yield without disadvantaging fishers. *Nat. Commun.* 4, 2347.
- Landaeta M.F., López G., Suárez-Donoso N., Bustos C.A., Balbontín F., 2012, Larval fish distribution, growth and feeding in Patagonian fjords: potential effects of freshwater discharge. *Environ. Biol. Fishes* 93, 73–87.
- Langlois T.J., Newman S.J., Cappo M. Harvey E., Rome B.M., Skepper C.L., Wakefield C.B., 2015, Length selectivity of commercial fish traps assessed from in situ comparisons with stereovideo: Is there evidence of sampling bias? *Fish. Res.* 161, 145–155.
- McClanahan T.R., Mangi S., 2001, The effect of a closed area and beach seine exclusion on coral reef fish catches. *Fish. Manage. Ecol.* 8, 107–121.
- Mancera-Rodriguez N.J., Castro Hernandez J.J., 2004, Age and growth of *Stephanolepis hispidus* (Linnaeus, 1766) (Pisces, Monacanthidae) in the Canary Islands area. *Fish. Res.* 66, 381–386.
- Mancera-Rodriguez N.J., Castro Hernandez J.J., 2015, Reproductive biology of the planehead filefish *Stephanolepis hispidus* (Pisces: Monacanthidae), in the Canary Islands area. *Ichthyol. Res.* 62, 258–267.
- Martín-Sosa P., 2012. Fisheries around Outermost Regions: Canary Islands. Report for the Scientific, Technical and Economic Committee for Fisheries, European Commission. *Inst. Esp. Oceanogr.*, Centro Oceanográfico de Canarias, 61 p.
- Melnichuk M., Guénette S., Martín-Sosa P., Balguerías E., 2001, Fisheries in the Canary Islands, Spain. In Zeller D., Watson R., Pauly D., (eds.), *Fisheries Impacts on North Atlantic Ecosystems: Catch, Effort and National/Regional Data Sets*. Fisheries Centre Research Reports 9, pp. 221–224.
- Méndez-Villamil M., Lorenzo J.M., González Pajuelo J.M., Soto Aguilera R., 1997, Periodo reproductor y madurez sexual de la sardina *Sardina pilchardus* (Walbaum, 1792) en aguas de Gran Canaria (Islas Canarias). *Bol. Inst. Esp. Oceanogr.* 13, 47–55.
- Menezes G.M., Diogo H., Giacomello E., 2013, Reconstruction of demersal fisheries history on the Condor seamount, Azores archipelago (Northeast Atlantic). *Deep-Sea Res. Part II-Trop. Stud. Oceanogr.* 98, Part A, 190–203.
- Messieh S.N., Rowell T.W., Peer D.L., Cranford P.J., 1991, The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seafloor. *Cont. Shelf. Res.* 11, 1237–1263.
- Mitcheson Y. (Sadovy de), Craig M.T., Bertocini A.A., Carpenter K.E., Cheung W.W.L., Choat J.H., Cornish A.S., Fennessy S.T., Ferreira B.P., Heemstra P.C., Liu M., Myers R.F., Pollard D.A., Rhodes K.L., Rocha L.A., Russell B.C., Samoilys M.A., Sanciangco J., 2013. Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion dollar fishery. *Fish Fish.* 14, 119–136.
- Nelson J.S. (4th edn.), 2006, *Fishes of the world*, Wiley press, NY.

- Pajuelo J.G., Lorenzo J.M., 1995, Biological parameters reflecting the current state of the exploited pink dentex *Dentex gibbosus* (Pisces: Sparidae) population off the Canary Islands. *S. Afr. J. Mar. Sci.* 16, 311–319.
- Newman S.J., Skepper C.L., Mitsopoulos G.E.A., Wakefield C.B., Meeuwig J.J., Harvey E.S., 2011. Assessment of the potential impacts of trap usage and ghost fishing on the Northern demersal scalefish. *Fish. Rev. Fish. Sci.* 19, 74–84.
- Pajuelo J.G., Lorenzo J.M., 1996, Life history of the red porgy *Pagrus pagrus* (Teleostei: Sparidae) off the Canary Islands, central east Atlantic. *Fish. Res.* 28, 163–177.
- Pajuelo J.G., Lorenzo J.M., 1999, Life history of black sea-bream, *Spondyliosoma cantharus*, off the Canary Islands, Central-east Atlantic. *Environ. Biol. Fish.* 54, 325–336.
- Pajuelo J.G., Lorenzo, J.M., Ramos A.G., Méndez-Villamil, M., 1997, Biology of the red mullet *Mullus surmuletus* (Mullidae) off the Canary Islands, central east Atlantic. *S. Afr. J. Mar. Sci.* 18, 265–272.
- Pajuelo J.G., Socorro J., Gonzalez J.A., Lorenzo J.M., Perez Peñalvo J.A., Martinez I., Hernandez Cruz C.M., 2006, Life history of the red-banded seabream *Pagrus auriga* Sparidae from the coasts of the Canarian archipelago. *J. Appl. Ichthyol.* 22, 430–436.
- Pascual Fernández J., 1991. Entre el mar y la tierra. Los pescadores artesanales canarios. Santa Cruz de Tenerife: Ministerio de Cultura – Interinsular Canaria, 310 p.
- Pascual Fernández J., 2004, Littoral fishermen, aquaculture and tourism in the Canary Islands: attitudes and economic strategies. In Boissevain J., Selwyn T. (eds.), *Contesting the Foreshore: Tourism, Society and Politics on the Coast*. Amsterdam University Press, MARE series, Amsterdam, pp. 61–82.
- Pauly D., 2008, Global fisheries: a brief review. *J. Biol. Res. Thessaloniki* 9, 3–9.
- Petrakis G., Papaconstantinou C., 1990, Biology of *Sparisoma cretense* in the Dodecanese (Greece). *J. Appl. Ichthyol.* 6, 14–23.
- Pusch, C., Hulley P.A., Kock K.H., 2004, Community structure and feeding ecology of mesopelagic fishes in the slope waters of King George Island (South Shetland Islands, Antarctica). *Deep-Sea Res.* I 51, 1685–1708.
- REPESCAN González J.A., (ed.), 2008, Memoria científico-técnica final sobre el Estado de los Recursos Pesqueros de Canarias. Instituto Canario de Ciencias Marinas, Agencia Canaria de Investigación, Innovación y Sociedad de la Información, Gobierno de Canarias. Telde (Las Palmas), 210 p.
- Rhodes K.L., Taylor B.M., McIlwain J., 2011, Demographic profile of a spawning aggregation of camouflage grouper, *Epinephelus polyphekadion*. *Mar. Ecol. Prog. Ser.* 421, 183–198.
- Sangil C., Martin-Garcia L., Clemente S., 2013, Assessing the impact of fishing in shallow rocky reefs: A multivariate approach to ecosystem management. *Mar. Pollut. Bull.* 76, 203–213.
- Sharpe D.M.T., Hendry A.P., 2009, Life history change in commercially exploited fish stocks: An analysis of trends across studies. *Evol. Appl.* 2, 260–275.
- SPC, 2013, Priority adaptations to climate change for fisheries and aquaculture in Vanuatu. Noumea, New Caledonia, Secretariat of the Pacific Community.
- Tuya F., Boyra A., Sanchez-Jerez P., Barberá C., Haroun R.J., 2004, Relationships between rocky-reef fish assemblages, the sea urchin *Diadema antillarum* and macroalgae throughout the Canarian archipelago. *Mar. Ecol. Prog. Ser.* 278, 157–169.
- Tuya F., Boyra A., Sánchez-Jerez P., Haroun R.J., 2005, Multivariate analysis of the benthic-demersal ichthyofauna along soft bottoms of the Eastern Atlantic: comparison between unvegetated substrates, seagrass meadows and sandy bottoms beneath sea-cage fish farms. *Mar. Biol.* 147, 1229–1237.
- Tuya F., Haroun R.J., 2006, Spatial patterns and response to wave exposure of photophilic algal assemblages across the Canarian Archipelago: a multiscaled approach. *Mar. Ecol. Prog. Ser.* 311, 15–28.
- Tuya F., Garcia-Diez C., Espino F., Haroun R.J., 2006a, Assessment of the effectiveness of two marine reserves in the Canary Islands (eastern Atlantic). *Cienc. Mar.* 32, 505–522.
- Tuya F., Sanchez-Jerez P., Dempster T., Boyra A., Haroun R.J., 2006b, Changes in demersal wild fish aggregations beneath a sea-cage fish farm after the cessation of farming. *J. Fish Biol.* 69, 682–697.
- Tuya F., Ribeiro-Leite L., Arto-Cuesta N., Coca J., Haroun R.J., Espino F., 2014, Decadal changes in the structure of *Cymodocea nodosa* seagrass meadows: Natural vs. human influences. *Estuar. Coast. Shelf Sci.* 137, 41–49.
- Watling L., Norse E.A., 1998, Disturbance of the seabed by mobile fishing gear: a comparison with forest clear-cutting. *Conserv. Biol.* 12, 1180–1197.