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Populations of Commercial Molluscs within a Highly Biodiverse Marine Protected Area of the Northern Alboran Sea (W Mediterranean): Preferential Habitats, Seasonal Dynamics and Importance for Artisanal Fisheries

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Abstract

Seasonal dynamics and preferential sedimentary habitats of commercial molluscs have been studied in soft bottoms within the limits of the Special Area of Conservation (SAC) "Calahonda" (S Spain). This SAC harbours a high diversity of invertebrate communities, and it is located in a very touristy area of the littoral of Malaga and within the limits of one of the most productive shellfish fishing areas of the NW Alboran Sea. Here, the artisanal fishery targeting molluscs is a locally important activity because some species (e.g. *Chamelea gallina*, *Callista chione*, *Donax trunculus*) are highly demanded by locals and tourists and therefore reaching high commercial value. More than 200 molluscan species inhabit the soft bottoms of the SAC "Calahonda", from which eight species collected in this study have economic value. The bivalve *C. gallina* was the most abundant and frequent commercial species, mainly at shallow fine and medium sand bottoms, followed by *C. chione* at coarse sand bottoms. Some species displayed higher abundance values of large or small size individuals at different depths, and most of them showed maximum abundances in spring and summer. Many invertebrate species associated with these soft bottoms are potentially very sensitive to dredging activities, especially echinoderms, decapods and cnidarians. Further research regarding the potential impact of fisheries on these assemblages would be desirable, especially considering the high biodiversity existing within this SAC and the increase of tourists in the last years.

Keywords Alboran Sea · Biodiversity · Commercial molluscs · Conservation

Introduction

Molluscs are within the top-three faunistic groups collected in marine fishing areas worldwide and represent ca. 10.4% (above 9 million tons) of the total world fishery landings (FAO 2012). In this line, molluscs are one of the most exploited marine resources in the Mediterranean Sea (Fischer et al. 1987), being most of the bivalve species the same ones than those recorded in the classical works of Greek antiquity by Aristotle, Xenocrates and Athenaeus, among others (Poutiers 1987; Voultsiadou et al. 2010). At the same time, molluscs are within the top dominant faunistic groups in several marine habitats, acting as an important component in trophic webs as they represent one of the main primary consumers of plant productivity and nutrient recyclers from the water column (Snelgrove 1998; Mazzella et al. 1992). Besides, molluscs are of interest for studies describing biodiversity patterns in marine ecosystems and changes in community composition and structure (Chemello et al. 2000; Rueda et al. 2009; Urra et al. 2017a).

The Alboran Sea highlights within the Mediterranean context as it harbours a high biodiversity promoted by its biogeographic location, oceanography and bottom heterogeneity (García Raso et al. 2010; Robles 2010; Templado 2011). This has promoted an important fishing activity with a high

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diversity of fishing gears, techniques and target species (Camiñas et al. 2004; Robles 2010). An important part of the fishing fleet of the northern Alboran Sea is involved in artisanal fisheries, characterized by operating with small vessels in shallow fishing grounds close to the coast and in one day fishing trips using small vessels (Camiñas et al. 2004). Artisanal fisheries target many different species alternating gears and techniques, both spatially and temporally depending on market prices, close seasons and seasonality of resources, in order to optimize catches and maximize benefits (Camiñas et al. 2004). Molluscs represent a very important resource for these fisheries in the Alboran Sea, being targeted by the mechanical dredging fleet that involves 247 vessels in the northern basin (MAGRAMA 2012). Among the target species, the smooth clam *Callista chione* (Linnaeus, 1758), the striped venus clam *Chamelea gallina* (Linnaeus, 1758) and the wedge clam *Donax trunculus* Linnaeus, 1758 represent some of the most important commercial species collected by the this fleet (Tirado 2011), with ca. 192,000 k·y^{-1} collected for *C. chione* (mean annual value: 412,609 €) and more than 20,000 k·y^{-1} collected for *C. gallina* (mean annual value: 165,254 €) and *D. trunculus* (mean annual value: 221,982 €), respectively, in Mediterranean fishing grounds of Andalusia (http://www.juntadeandalucia.es). These species present important populations between Estepona and Vélez-Málaga coastal areas (Málaga province), together with those of other molluscan commercial species, clustering the activity of a great part of the fleet in this area.

One of the main marine molluscs fishing areas of the northern Alboran Sea is “Cala del Moral” (code AND31), where the capture of the smooth clam, the striped venus clam, the wedge clam, the banded carpet-shell clam *Tapes rhomboides* (Pennant, 1777), the warty venus clam *Venus verrucosa* Linnaeus, 1758, the tuberculate cockle *Acanthocardia tuberculata* (Linnaeus, 1758), the king scallop *Pecten maximus* (Linnaeus, 1758), the banded murex *Hexaplex trunculus* (Linnaeus, 1758) and the purple dye murex *Bolinus brandaris* (Linnaeus, 1758) among other species, is allowed by artisanal fishery (BOE 2009). This area also harbours the Special Area of Conservation (SAC) “Calahonda” (code: ES6170030; part of the EU Natura 2000 network), a biodiversity hot-spot within the Alboran and Mediterranean contexts (García Raso et al. 2010; Urra et al. 2017a). Despite widely concerns in the last decades over the environmental impact of different fishing gears (e.g. dredges), which can result in a final loss of biodiversity (Hutchings 1990; Jones 1992; Thrush et al. 1998), the exploitation of commercial molluscs has been coexisting with this high biodiversity in the SAC “Calahonda” for many years, showing a sustainable use of marine resources by artisanal fishermen. Nevertheless, the littoral of Málaga attracts hundreds of thousands of tourists every year, with tourist arrivals increasingly, and molluscs constitute an important element of the local gastronomy. This high demand of seafood in such touristy coasts could affect mollusc stocks.

Regarding commercial species, previous works in the Alboran Sea have focussed on selectivity with different trawling techniques (Baro et al. 2004a, b; Baro and Muñoz de los Reyes 2007), stock assessments of commercial fishes (Pérez Gil et al. 2004; Quetglas et al. 2004) and the growth and reproduction of different commercial molluscs (Tirado and Salas 1998; Tirado et al. 2002, b, 2003; Rodríguez de la Rua et al. 2003). Nevertheless, there is scarce information regarding the spatial patterns of commercial mollusc species that are generally exploited by artisanal fisheries in the southern Iberian Peninsula (Chicharo et al. 2002; Rufino et al. 2010). This work aims to identify preferential sedimentary habitats of commercial molluscs within the SAC “Calahonda”, located within “Cala del Moral” fishing area. We also analyzed some information regarding the biota occurring in these fishing grounds, and discuss the importance of the establishment of the SAC for the artisanal fisheries.

Material and Methods

Study Site

The SAC “Calahonda” is located between Punta de Calaburras (36°30.4’N 04°38.3’W) and the marina of Cabopino (36°29’N 04°44.3’W) (S Spain), close to the Strait of Gibraltar (Fig. 1a). The northwestern coast of the Alboran Sea, where this SAC is located, is highlighted by its high biological productivity, promoted by the presence of almost permanent nutrient upwellings of deep Mediterranean waters (Sarhan et al. 2000). Main habitats within the SAC “Calahonda” include fragmented beds of the endemic Mediterranean seagrass *Posidonia oceanica* (Linnaeus) Delile, and of the subtropical seagrass *Cymodocea nodosa* (Ucria) Ascherson, both of them occurring amongst shallow rocky outcrops down to ca. 5 m depth; soft bottoms that include those with fine, medium and coarse sand as well as with bioclasts, which extend beyond the patchy seagrass beds; and finally a rocky outcrop at 15–20 m depth harbouring a highly diverse coralligenous community (García Raso et al. 2010; Urra et al. 2012) (Fig. 1b). The soft bottoms harbour biodiverse molluscan assemblages with more than 200 species, including well sorted fine sands assemblages at 5 m depth (Sables Fins Bien Calibrás or SFBC), muddy bioclastic sands assemblages between 15 and 25 m depth (Détritiques Envasés or DE) and coastal bioclastic sands assemblages at 25 m depth (Détritiques Côtiers or DC) (Urra et al. 2011), according to the

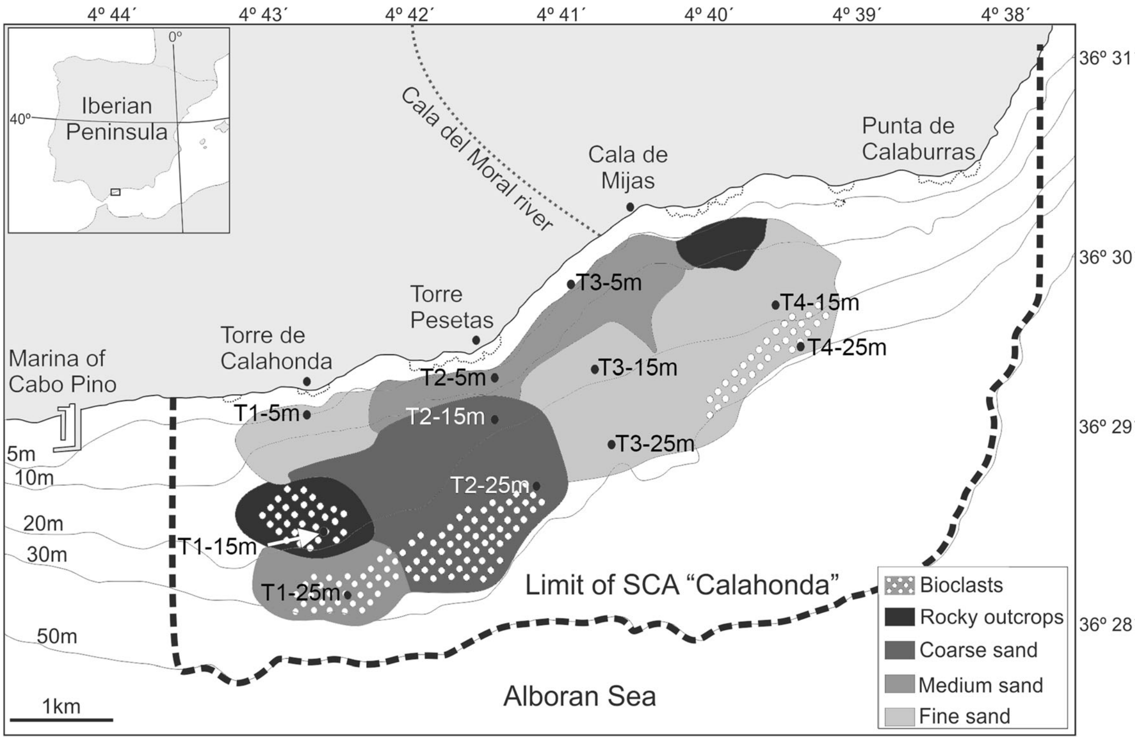


Fig. 1 Location of the Special Area of Conservation (SAC) “Calahonda” in southern Spain and sampling stations. The spatial distribution of different soft bottoms according to their granulometric composition within the limits of the SAC is indicated with different colours (see more details in Urra et al. 2011b)

classification of benthic communities defined for the Mediterranean by Pérès and Picard (1964).

Sample Collection and Laboratory Procedures

Faunistic samples were collected seasonally in summer (September 04), autumn (November 04), winter (February 05) and spring (May 05) with a small rock dredge (42 cm width, 22 cm height, mesh size: 4 mm) at three different depths (5, 15, 25 m) along four transects oriented perpendicularly to the coastline (Fig. 1a). A total of 117 samples were collected on the soft bottoms considered in this study. A detailed description of the sampling method is presented by Urra et al. (2017b). Faunistic samples were processed in the laboratory, with live molluscs extracted from the sediment, identified and counted. The characterization of the sediment was done from sediment samples collected in each sampling station following the classification of Buchanan (1984) (see Urra et al. 2011 for more details).

Data Analysis

The temporal variability of the eight commercial molluscan species identified from the faunistic samples was studied through the analyses of seasonal dynamics for the abundance values. Individuals of the bivalves *Acanthocardia tuberculata*, *Callista chione*, *Pecten maximus*, *Venus verrucosa* and the gastropod *Hexaplex trunculus* with a shell length lower than 10 mm were considered small individuals, and those with a shell length higher than 10 mm were considered large individuals. On the other hand, individuals of *Chamelea gallina*, *Tapes rhomboides* and *Donax trunculus* with a shell length of less than 5 mm were considered small individuals, and those with a shell length higher than 5 mm were considered large individuals. One-factor ANOVA (Analysis of Variance) analyses were carried out for testing statistical differences in seasonal abundance values. Analyses to test the normality (Kolmogorov-Smirnov) and to verify the homogeneity of variances (Levene) were done prior to ANOVA analyses. A post-hoc Tukey test ($p < 0.05$) was used for posterior multiple comparisons. These statistical procedures were performed using the software SPSS.

A canonical correspondence analysis (CCA) was carried out in order to elucidate the relationships between the commercial species studied and their environment. This method extracts synthetic environmental gradients from the ecological data-sets, providing a general framework for statistical testing of the effects of sediment characteristics on the distribution of the species (ter Braak 1986). The statistical significance of the effect of each variable was tested by a Monte Carlo permutation test. This multivariate analysis was executed using the software CANOCO.

Results

Commercial Molluscs

Acanthocardia tuberculata was represented by 222 individuals. About ca. 69% of them were collected in fine and medium sand bottoms at 5 m depth, followed by ca. 18% in coarse sand bottoms (T2-15 m) and ca. 13% in muddy bioclastic sand bottoms (T3-15 m, T4-15 m) (Fig. 2; Table 1). Most of the collected individuals (ca. 77%) displayed a shell length higher than 10 mm (large individuals), and included adults with commercial size (45 mm). A similar number of small individuals (shell length < 10 mm) were found at 5 and 15 m depth, whereas large individuals were quantitatively more abundant at 5 m depth (Table 1). Mean abundance (N) values of *A. tuberculata* at 5 m depth, where this species was among the top-10 dominant (2.10% of total abundance) and frequent (66.6% Frequency of occurrence in total samples) species, displayed significant seasonal changes (one-factor ANOVA, $F = 5.359$, $p < 0.05$), with the highest N value for large and small *A. tuberculata* individuals observed in September (summer) and, on the other hand, the absence of individuals in May (spring) (Fig. 3).

A total of 219 individuals of *Callista chione* were collected. Although this species was present in most of the sampling stations, many of them were found at T2-15 m (ca. 48%) and at T1-5 m (ca. 24%), where it was one of the top-10 dominant (ca. 2.5%) and most frequent species (up to 100% F at T2-15 m) (Fig. 2; Table 1). Small individuals were more abundant at coarse sand bottoms (T2-15 m; 53% of small individuals) and large ones at shallow fine-medium sand bottoms (70% of large individuals), with maximum N values in November (autumn) at both depths. The mean N values, clustering the data from T2-15 m and T1-5 m, displayed significant seasonal changes (one-factor ANOVA, $F = 9.303$, $p < 0.05$), with maximum abundances in November and minimum ones in September for both large and small individuals (Fig. 3).

Chamelea gallina was mainly found inhabiting well sorted fine sands at T1-5 m (ca. 66%) and T3-5 m (ca. 23%) (Fig. 2; Table 1). This bivalve was present in every sample collected in this type of soft bottoms (100% F), where it displayed dominance values ranging between ca. 22% in spring and ca. 6% in winter, being one of the top-5 dominant species. Mean N values displayed a significant seasonal trend (one-factor ANOVA, $F = 6.229$, $p < 0.05$) with maxima in warm months (September and May) and minima in cold months (November and February), and the highest number of large and small individuals observed in September and May, respectively (Fig. 3).

Tapes rhomboides was found in deep sampling stations (15 and 25 m depth) (Fig. 2). This species was mainly represented by small individuals (ca. 98% from a total of 145 ind. collected) (Table 1). The highest N value was found in muddy bioclastic sand bottoms at T4-25 m (ca. 69%), where it displayed a dominance value of ca. 2.6%, followed by coastal bioclastic sands at T2-25 m (21%) (Fig. 2). Most individuals found in these and other sampling stations were collected in May (ca. 95% from the total collected) (one-factor ANOVA, $F = 40.87$, $p < 0.05$) (Fig. 3).

Other commercial species were minoritarian and represented by less than 20 individuals such as in the case of *Donax trunculus*, only collected at the shallow stations T1-5 m (4 large ind. and 3 small ind.) and T2-5 m (1 large ind. and 9 small ind.) (one-factor ANOVA, $p > 0.05$) (Figs. 2 and 3), and *Hexaplex trunculus*, collected at the deep stations T2-15 m (6 large ind. and 2 small ind.), T2-25 m (6 large ind.) and T4-25 m (1 large ind.) (one-factor ANOVA, $p > 0.05$) (Figs. 2 and 3). Finally, *Pecten maximus* and *Venus verrucosa* were represented by four large individuals (two individuals collected in September and November, respectively) and one large individual (November) collected at 25 m depth, respectively (Fig. 2, Table 1; not shown in Fig. 3).

The CCA selected depth and percentage of bioclasts, for the first axis, and medium and very fine sand, for the second axis, as the variables explaining most of the species distribution, as detailed in Fig. 4. Thus, a gradient with depth can be observed from the left, with those species that inhabite soft bottoms between 5 and 15 m depth with low size granulometric fractions (very fine-medium sand) such as *C. gallina* and *D. trunculus*, to the right of axis I, with those ones that prefer deeper bottoms (15–25 m depth) with a higher content of coarse sand and bioclasts such as *H. trunculus* and *T. rhomboides* (Fig. 4). The Monte Carlo test was significant for the first axis ($p < 0.05$).

Associated Biota

Within the SAC "Calahonda", rich faunistic assemblages have been found associated with the soft bottoms where commercial molluscs are collected. Regarding the well sorted fine sand bottoms where *D. trunculus* and *C. gallina* inhabit, the assemblage is represented by decapods including the dominant *Diogenes pugilator* (Roux, 1829) (79% of all decapods collected in the same samples) and *Philocheras trispinosus* (Hailstone in Hailstone and Westwood, 1835), echinoids such *Echinocardium mediterraneum* (Forbes, 1844) and ophiuroids such as *Amphipholis squamata* (Delle Chiaje, 1828). Detritic sandy bottoms with population of *H. trunculus*, *C. chione* and *P. maximus* are home of the hermit-crabs *Anapagurus hyndmanni* (Bell, 1846) and *Paguristes eremita* (Linnaeus, 1767), the echinoids *Genocidaris maculata* A. Agassiz, 1869 and *Echinocyamus pusillus* (O.F. Müller, 1776), the ophiuroids *Ophiopsila aranea* Forbes, 1843 and *Ophiothrix quinquemaculata* (Delle Chiaje, 1828), as well as of individuals of the gorgoniid anthozoans *Eunicella gazella*

Fig. 2 Spatial distribution of commercial molluscs identified within the Special Area of Conservation "Calahonda" and total abundance of specimens collected in each sampling station ▶

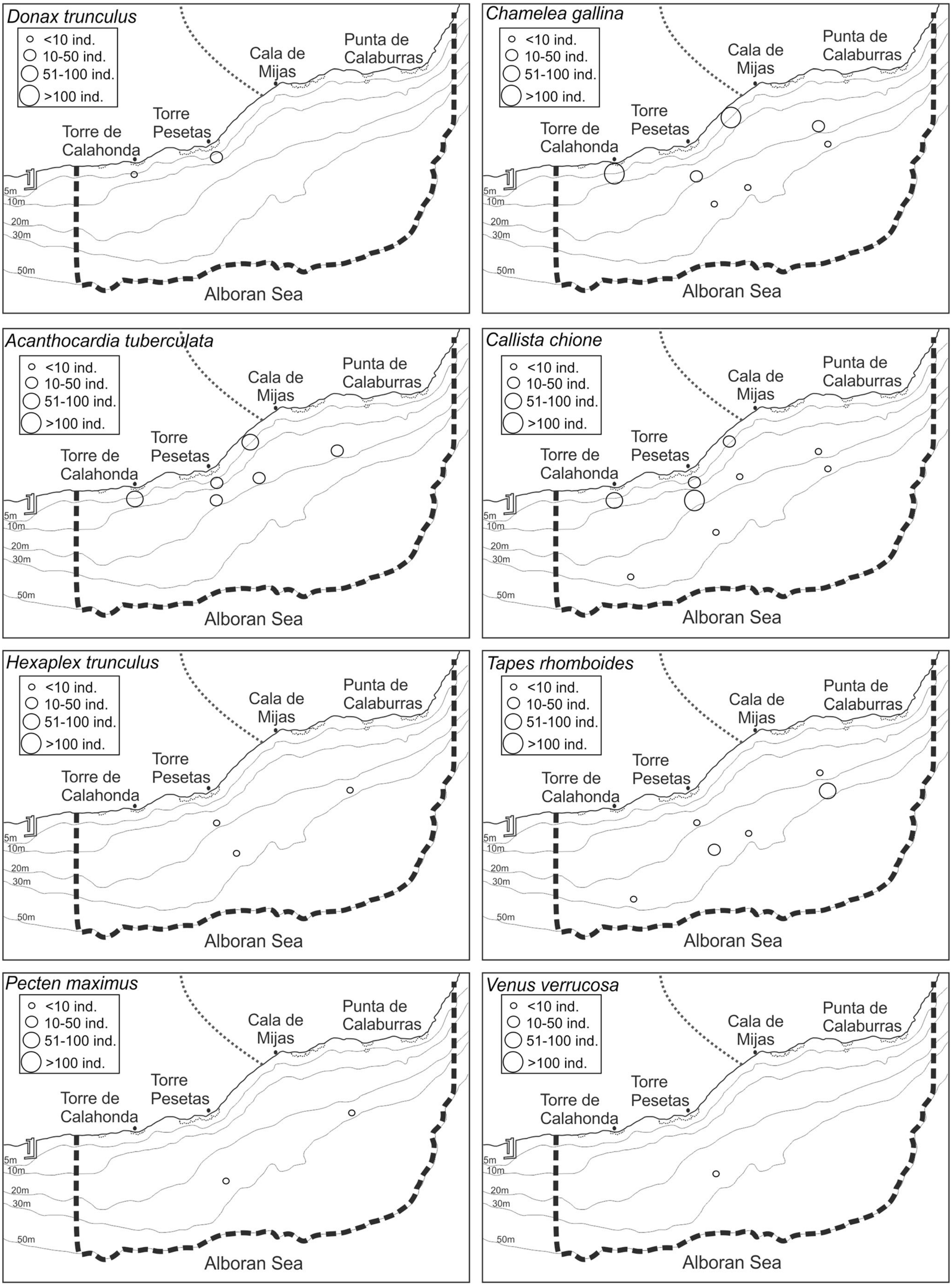

Donax trunculus
<10 ind.
10-50 ind.
51-100 ind.
>100 ind.
Cala de Mijas
Punta de Calaburras
Torre Pesetas
Torre de Calahonda
5m
10m
20m
30m
50m
Alboran Sea
Chamelea gallina
<10 ind.
10-50 ind.
51-100 ind.
>100 ind.
Cala de Mijas
Punta de Calaburras
Torre Pesetas
Torre de Calahonda
5m
10m
20m
30m
50m
Alboran Sea
Acanthocardia tuberculata
<10 ind.
10-50 ind.
51-100 ind.
>100 ind.
Cala de Mijas
Punta de Calaburras
Torre Pesetas
Torre de Calahonda
5m
10m
20m
30m
50m
Alboran Sea
Callista chione
<10 ind.
10-50 ind.
51-100 ind.
>100 ind.
Cala de Mijas
Punta de Calaburras
Torre Pesetas
Torre de Calahonda
5m
10m
20m
30m
50m
Alboran Sea
Hexaplex trunculus
<10 ind.
10-50 ind.
51-100 ind.
>100 ind.
Cala de Mijas
Punta de Calaburras
Torre Pesetas
Torre de Calahonda
5m
10m
20m
30m
50m
Alboran Sea
Tapes rhomboides
<10 ind.
10-50 ind.
51-100 ind.
>100 ind.
Cala de Mijas
Punta de Calaburras
Torre Pesetas
Torre de Calahonda
5m
10m
20m
30m
50m
Alboran Sea
Pecten maximus
<10 ind.
10-50 ind.
51-100 ind.
>100 ind.
Cala de Mijas
Punta de Calaburras
Torre Pesetas
Torre de Calahonda
5m
10m
20m
30m
50m
Alboran Sea
Venus verrucosa
<10 ind.
10-50 ind.
51-100 ind.
>100 ind.
Cala de Mijas
Punta de Calaburras
Torre Pesetas
Torre de Calahonda
5m
10m
20m
30m
50m
Alboran Sea

Table 1 Commercial molluscan species identified within the Special Area of Conservation (SAC) "Calahonda", with quantitative data regarding the abundance of large and small individuals in fine and medium sand bottoms (Sables Fins Bien Calibrás or SFBC, according to Pérès and Picard 1964), mixed coarse sand bottoms (MX), muddy bioclastic sand bottoms (Détritiques Envasés or DE, according to Pérès and Picard 1964) and coastal bioclastic sand bottoms (Détritiques Côtiers or DC, according to Pérès and Picard 1964)

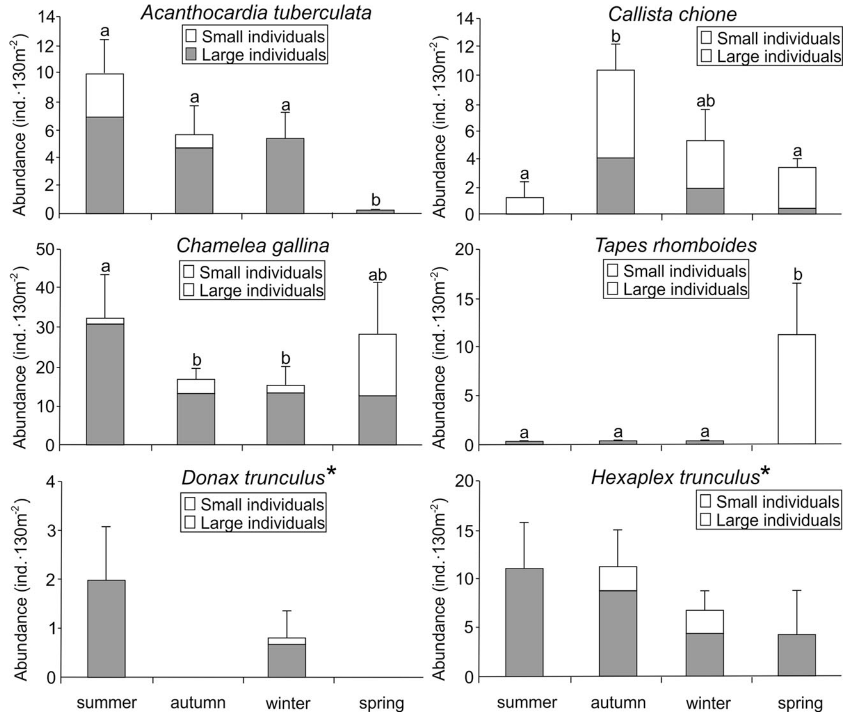
	SFBC			MX	DE				DC		Total
	T1-5 m	T2-5 m	T3-5 m	T2-15 m	T3-15 m	T4-15 m	T3-25 m	T4-25 m	T1-25 m	T2-25 m	
Acanthocardia tuberculata											0
Small indiv.		3	17	17	6	9					52
Large indiv.	63	23	48	22	11	3					170
Total	63	26	65	39	17	12					222
Callista chione											0
Small indiv.	26	17	10	94	6	8		3	9	6	179
Large indiv.	27		1	12							40
Total	53	17	11	106	6	8		3	9	6	219
Chamelea gallina											0
Small indiv.	161	6	30	6		7	1	1		1	213
Large indiv.	418	43	174	17		4				3	659
Total	579	49	204	23		11	1	1		4	872
Tapes rhomboides											0
Small indiv.				3		1	5	100	3	29	141
Large indiv.				2						2	4
Total				5		1	5	100	3	31	145
Donax trunculus											
Small indiv.	1										1
Large indiv.	6	10									16
Total	7	10									17
Hexaplex trunculus											0
Small indiv.				2							2
Large indiv.				6				1		6	13
Total				8				1		6	15
Pecten maximus											0
Small indiv.											0
Large indiv.								3		1	4
Total								3		1	4
Venus verrucosa											0
Small indiv.										1	1
Large indiv.											0
Total										1	1

Studer, 1878 and *Leptogorgia sarmentosa* (Esper, 1789) that are found attached to small hard substrates such as rocks. Finally, detritic muddy bottoms harbour the echinoid *E. cordatum* (Pennant, 1777), the asteroid *Astropecten irregularis* (Pennant, 1777), dense groups of the epizoanthid anthozoan *Epizoanthus incrustatus* (Düben and Koren, 1847) with some rare architectonicid gastropods that feed on them including *Pseudotorinia architae* (O. G. Costa, 1841), *Basisulcata lepida* (Bayer, 1942) and *Heliacus fallaciosus* (Tiberi, 1872), abundant hermit-crabs such as *Anapagurus alboranensis* García-Gómez, 1994 and *Anapagurus petiti* Dechancé and Forest, 1962, and the pennatulid anthozoan *Pteroeides spinosum* (Ellis, 1764), among other taxa.

Discussion

The marine area of Calahonda was officially declared as a Site of Community Importance (SCI, code ES6170030) in 2006 (EU official journal 2006, September 21st), to protect some of the westernmost populations of the endangered Mediterranean seagrass *Posidonia oceanica*. Further studies focussed on the

Fig. 3 Seasonal dynamics of the commercial molluscs identified within the Special Area of Conservation "Calahonda". White bars: small individuals (shell length < 10 mm for *A. tuberculata*, *C. chione* and *H. trunculus*, and <5 mm for *C. gallina*, *T. rhomboids* and *D. trunculus*); grey bars: large individuals (shell length > 10 mm for *A. tuberculata*, *C. chione* and *H. trunculus*, and >5 mm for *C. gallina*, *T. rhomboids* and *D. trunculus*). Mean + SE. Letters above error bars display the results of post-hoc test; different letters distinguish significantly different means at $p < 0.05$. Those species with non-significant seasonal differences in their abundance values are indicated with *



invertebrate communities inhabiting the different soft and hard bottoms around these seagrass meadows pointed out a high biodiversity that leaded to an increase of its extension in 2009 (García Raso et al. 2010). The SCI "Calahonda" was confirmed as a Special Area of Conservation (SAC) in 2015 (DECRETO 369/2015, Andalusian Government official journal 2015, August 7th). Among this richness and regarding molluscs, approximately one third of the 1200 species coexisting in southern Spain can be found within the SAC (Gofas et al. 2011; Urra et al. 2017a), which makes this coastal area of the northwestern Alboran Sea one of the molluscan hot-spots of European waters identified so far. Regarding molluscs with commercial value, eight species were collected in this study, including *Donax trunculus*, *Chamelea gallina, Callista chione*, *Acanthocardia tuberculata*, *Tapes rhomboides*, *Pecten maximus*, *Venus verrucosa* and *Hexaplex trunculus*. Besides, other commercial molluscs are found with the limits of the SAC such as the Mediterranean mussel *Mytilus galloprovincialis* Lamarck, 1819, with juveniles and adults settling on different hard substrates, the solid surf clam *Spisula solida* (Linnaeus, 1758) that presents small populations (<10 ind. collected) in the area, as well as different species of razor clams (*Ensis* spp.) and cephalopods (*Octopus vulgaris* Cuvier, 1797). In this context, and considering the presence of small-scale artisanal fisheries targeting molluscs of economic interest in the area, it is necessary to know the preferential habitat of each one of these species, together with the time period when recruitment events take place (Tirado et al. 2002a), as this information has important implications in terms of management and sustainable use of living resources, as well as for biodiversity conservation purposes.

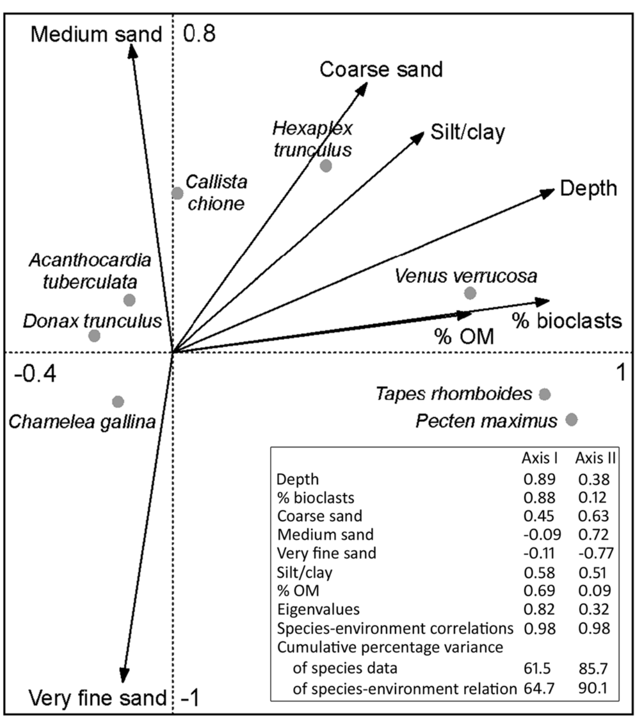


Fig. 4 Graphical representation of the commercial molluscan species distribution with respect to the first two axes of the canonical correspondence analysis (CCA). The summary of the results of the CCA is also presented. % bioclasts, percentage of bioclasts; OM, organic matter

A depth-related pattern associated with the granulometric composition of the seabed has been observed for the spatial distribution of the commercial molluscan species found in the SAC "Calahonda". The most abundant and frequent commercial species found in the study area was *C. gallina*, which has been mainly found inhabiting well sorted fine sand bottoms at 5 m depth (Pérès and Picard 1964; Gofas et al. 2011). In the other hand, the highly demanded *D. trunculus* was poorly represented in samples because it presents the bulk of its population at shallower depths (0–3 m), being usually replaced by populations of other Donacidae such as *D. venustus* Poli, 1795 from 5 m down to 10 m depth (Tirado and Salas 1999; Gaspar et al. 2002), as in the case presented here. Large individuals of *C. chione* and *A. tuberculata* were frequently collected at 5 m depth, whereas smaller individuals were collected at greater depths, being this trend more acute for *C. chione*. This could be due to the fishing activity in the area, as the artisanal fleet targets *C. chione* in bottoms deeper than 10 m, capturing every individual above minimum legal size. On the other hand, *A. tuberculata* displayed quantitatively larger individuals at shallower bottoms, but it showed a uniform distribution pattern of small individuals at 5 and 15 m depth. A true depth segregation pattern between size classes have previously been documented in other European coastal waters, especially concerning *Donax* species, and related to biological factors such as intraspecific competition among juveniles and adults (Ansell and Lagardère 1980; Tirado et al. 2002a; Gaspar et al. 2002). The only commercial gastropod identified from samples was *H. trunculus* and it was collected at deep stations, especially on rocky and coarse sand bottoms at 15 m depth, probably related to its trophic behaviour (i.e. carnivorous) and prey availability, including barnacles, bivalves and other gastropods usually inhabiting these bottoms. Minoritarian commercial bivalves included *T. rhomboides*, *P. maximus* and *V. verrucosa*, which were collected on deep bioclastic bottoms. The habitat preference for the abovementioned species is in line with data available in the literature and regarding European waters (Pérès and Picard 1964; Gofas et al. 2011). The spatial distribution pattern observed for these species is promoted by (1) depth related environmental factors such as granulometric characteristics of sediments and food supply, with a significant increasing trend of clay and mud fractions and of percentage of organic matter with depth (García Raso et al. 2010), and by (2) their different adaptive responses to the environment, with intense current, wave action and sediment instability in high energy environments (i.e. shallow bottoms) (Morin et al. 1985; Brown and McLachlan 1990; Koulouri et al. 2006).

Maximum abundances for most of the studied species were observed in spring and summer months, coinciding with the season of highest shellfish demand by markets. Several studies focussed on reproductive biology and population dynamics of commercial molluscan species in European coastal areas, especially in the Mediterranean Sea, have previously reported maximum abundances in warm months, coinciding with important spawning periods (i.e. most intense release of gametes) and hatching juveniles (Tirado et al. 2002a; Rodríguez de la Rúa et al. 2003; Lahbib et al. 2011; Tirado et al. 2017). In the case of *A. tuberculata*, it is collected between autumn and winter only when the canning industry demands it. This practice can be considered a resting period for other exploited species as most artisanal fishing vessels targeting molluscs focus their activity on the tuberculate cockle during a period of two to three months of intensive fishing, being likely related to the absence of individuals collected in spring in the study area. In the case presented here, the environmental conditions registered in the northwestern Alboran Sea are characterized by mild seawater temperature and highly nutrient upwellings (Sarhan et al. 2000), which would provide good conditions for long reproductive cycles of commercial species such as molluscs (e.g. *Callista chione*, Tirado et al. 2002b, 2003). Nevertheless, a detailed environmental monitoring should be carried out in this and other areas of interest for artisanal fisheries along the northwestern Alboran Sea, as 1) sea surface temperature values have increased in the western Mediterranean Sea in the last years, including the Alboran basin (Vargas-Yáñez et al. 2010), and 2) an intensification of the decrease of the Ekman transport has been documented for the area (Vargas-Yáñez et al. 2010). The combination of these two processes could have negative effects in the food web structure and productivity, as the decrease of the intensity of upwellings will reduce the contribution of nutrients to the photic zone, with consequences in the primary production and in the rest of the trophic chain, which could be strengthened by warming (O'Connor et al. 2009).

An important issue to be considered, given that the SAC "Calahonda" is within the limits of the fishing area "Cala del Moral", is the potential impact that dredging can have on the benthic fauna inhabiting the soft bottoms where these commercial species are collected. Bottom dredging and trawling can remove or damage a large part of the macro-epibenthic fauna as the fishing gear is towed across the seafloor (Hutchings 1990; Jennings and Kaiser 1998; Thrush et al. 1998). This can affect biomass, production and species richness of benthic invertebrate communities at a large scale, reducing the abundance of benthic food for commercial fish, and can lead to a loss of habitat heterogeneity and substrate complexity, as well as changes in community composition and size structure (Thrush et al. 1998; Kaiser and de Groot 2000; Queirós et al. 2006). The effects of trawling are more acute in sensitive environments such as detritic soft bottoms and especially hard bottoms, where large, long-lived and high ecologically value species (e.g. cnidarians) inhabit (Hiddink et al. 2006; Queirós et al. 2006).

Benthic communities associated with sedimentary environments within the SAC "Calahonda" seem to have a relative good conservation status, as most of the species characterizing these communities (e.g. see Pérès and Picard 1964) have been found in the collected samples, besides a high species richness regarding different faunistic groups (García Muñoz et al. 2008; García Raso et al. 2010; Urra et al. 2011). In this line, Urra et al. (2017b) reported that only the 15% of the discarded individuals in the wedge clam mechanized dredging fisheries of the northern Alboran Sea, including the study area, displayed any type of damage. Decapods and specially echinoderms were reported by these authors to be vulnerable to dredging, as their bodies are fragile and easily fragmented by fishing gears, besides their autotomize capacity when subjected to stress (Bergmann and Moore 2001a, b). Urra et al. (2017b) also highlighted that the target species (*Donax trunculus*) displayed a high proportion of undamaged individuals to fishing impacts, representing an important factor for the maintenance of populations of this commercial species on the fishing grounds. Moreover, faunistic assemblages inhabiting shallow and dynamic environments have showed a greater capacity to recover from fishing disturbances (Jones 1992; Currie and Parry 1996; Kaiser et al. 1998), and in the case presented here faunistic assemblages could also benefit from the high local productivity of the northern Alboran Sea (Sarhan et al. 2000). Furthermore, discards of dredging fisheries targeting molluscs in the northern Alboran Sea are released on suitable sedimentary habitats just after on-deck sorting, which would support the survival of discarded individuals. Nevertheless, an exhaustive program should be carried out to monitor 1) the conservation of species protected under different national and international frameworks (e.g. *Pinna nobilis*, *Charonia lampas*) and that have been observed within the limits of the SAC, 2) the different sedimentary habitats (habitat 1110 of the Natura 2000 Habitat Directive), vegetated meadows (e.g. *Posidonia oceanica* meadows, habitat 1120) and infralittoral rocky bottoms with coralligenous communities (habitat 1170) and the associated fauna existing within the SAC “Calahonda”, and 3) the amount of discards generated by the artisanal fleet, as well as the damage caused to invertebrate species, both commercial and non-target ones, by mechanical dredges, in order to maintain the good environmental status of this area.

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Compliance with Ethical Standards

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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