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Memòria del Treball Final de Grau

Títol del treball:

Bottom trawling impact on benthic communities of both maërl and muddy habitats: a case study in the Costa Brava (NW Mediterranean)

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Abstract

Bottom trawling presents a negative impact on benthic communities, with a direct impact on caught species and an indirect impact on infaunal organisms. Research has shown that heavily trawled areas present lower diversity of species and are dominated by opportunistic infauna, as they present high resilience to trawling. This study aims to understand the impact of bottom trawling on benthic communities, analyzing both regulated and unregulated discards and infauna community. The study was developed in two different habitats, maërl and mud, located in two fishing grounds of Blanes, Capets and Garotes (NW Mediterranean Sea). Biomass and abundance of discarded fraction was analyzed, showing that Capets presented higher unregulated discards and Garotes higher regulated discards in both abundance and biomass. Abundance of infauna was also analyzed, showing that Annelida was the most abundant phylum in Capets, whereas in Garotes those were Annelida and Arthropoda. Furthermore, fishing effort and productivity (biomass and total income) of the two fishing grounds was also studied. Analysis of the species richness and biodiversity of both discarded species (regulated and unregulated) and infauna showed significant differences between the two fishing grounds, being higher in Garotes. Fishing seasonality showed a different level of effort due to the fishing ban, which was on February in Capets, whereas in Garotes it was from April to August. Diet of target species in both fishing grounds was studied comparing both invertebrate discarded fraction and infaunal organisms. The phyla Arthropoda and Mollusca that constituted mostly their diet were found in low abundance because of their vulnerability to trawling. Nevertheless, the opportunistic phylum Annelida was the most abundant and it was found on both fishing grounds. Although productivity in terms of economic value was higher in Capets, Garotes presented a higher ecological value because of its maërl bed. The results of this study pointed out the conservation importance of maërl beds in the Mediterranean. Thus, the creation of Marine Protected Areas (MPAs) in maërl beds of Garotes is proposed in order to avoid further degradation of this habitat. MPAs would increase the complexity of the ecosystems and the biomass of target species in Garotes, which would increase the income of fishers.

Resumen

La pesca de arrastre presenta efectos negativos en las comunidades bentónicas, con un impacto directo en las especies capturadas y un impacto indirecto en los organismos de la infauna. Diferentes trabajos de investigación han demostrado que las zonas más impactadas por el arrastre presentan una baja diversidad de especies y son dominadas por los organismos oportunistas de la infauna, debido a su elevada resiliencia al arrastre. Este estudio pretende entender el impacto de la pesca de arrastre sobre las comunidades bentónicas, analizando el descarte regulado y el no regulado, así como la comunidad de la infauna. El estudio se ha desarrollado en dos hábitats diferentes, maërl y fango, situados en dos caladeros de Blanes, Capets y Garotes (NO Mar Mediterráneo). El análisis de la biomasa y la abundancia del descarte indica que en Capets predomina el no regulado mientras que en Garotes lo hace el regulado, en abundancia y biomasa. También se ha analizado la abundancia de la infauna, y se ha visto que Annelida domina en Capets, mientras que Annelida y Arthropoda dominan en Garotes. Además, también se ha estudiado el esfuerzo de pesca y la productividad (biomasa e ingresos totales) de los dos caladeros. El análisis de la riqueza de especies y la biodiversidad de las especies descartadas y la infauna ha presentado diferencias significativas, siendo más elevada en Garotes. La estacionalidad de la pesca muestra un nivel de esfuerzo diferente debido a que en Capets hubo veda en febrero, mientras que en Garotes fue entre abril y agosto. Se ha estudiado la dieta de las especies objetivo de los dos caladeros comparando los invertebrados del descarte y la infauna. Los phyla Arthropoda y Mollusca que forman principalmente su dieta se han encontrado en poca abundancia debido a su vulnerabilidad al arrastre. No obstante, el phylum Annelida como es oportunista fue el más abundante en los dos caladeros. Aunque la productividad respecto el valor económico es más elevada en Capets, Garotes presenta un valor ecológico más elevado debido a su fondo de maërl. Los resultados de este estudio indican la importancia de conservar los fondos de maërl del Mediterráneo. Así, se propone la creación de Áreas Marinas Protegidas (AMPs) en el fondo de maërl de Garotes para evitar una mayor degradación de este hábitat. Las AMPs aumentarían la complejidad de estos ecosistemas así como la biomasa de las especies objetivo en Garotes, lo que aumentaría los ingresos por parte de los pescadores.

Resum

La pesca d'arrossegament presenta efectes negatius en les comunitats bentòniques, amb un impacte directe en les espècies capturades i un impacte indirecte en els organismes de la infauna. Diferents treballs de recerca han demostrat que les zones més impactades per l'arrossegament presenten una baixa diversitat d'espècies i són dominades pels organismes oportunistes de la infauna, degut a la seva elevada resiliència a l'arrossegament. Aquest estudi pretén entendre l'impacte de la pesca d'arrossegament sobre les comunitats bentòniques, analitzant el rebuig regulat i no regulat, així com la comunitat de la infauna. L'estudi ha estat desenvolupat en dos hàbitats, maërl i fang, situats en dos caladors de Blanes, Capets i Garotes (NO Mar Mediterrani). L'anàlisi de la biomassa i l'abundància del rebuig indica que a Capets hi predomina el no regulat mentre que Garotes ho fa el regulat, en abundància i biomassa. També s'ha analitzat l'abundància de la infauna, i s'ha vist que Annelida és més abundant a Capets, mentre que a Garotes ho són Annelida i Arthropoda. A més, també s'ha estudiat l'esforç de pesca i la productivitat (biomassa i ingressos totals) dels dos caladors. L'anàlisi de la riquesa d'espècies i la biodiversitat tant de les espècies rebutjades com de la infauna ha presentat diferències significatives, essent més elevada a Garotes. L'estacionalitat de la pesca ha mostrat un nivell d'esforç diferent degut al fet que a Capets es va fer veda al febrer, mentre que a Garotes va ser entre abril i agost. S'ha estudiat la dieta de les espècies objectiu dels dos caladors comparant els invertebrats del rebuig i la infauna. Els phyla Arthropoda i Mollusca que formen majoritàriament la seva dieta s'han trobat en poca abundància degut a la seva vulnerabilitat a l'arrossegament. No obstant, el phylum Annelida com és oportunista és el més abundant en els dos caladors. Tot i que la productivitat en termes de valor econòmic s'ha vist que és més elevada a Capets, Garotes presenta un valor ecològic més elevat degut al seu fons de maërl. Els resultats d'aquest estudi indiquen la importància de poder conservar els fons de maërl del Mediterrani. Així, es proposa la creació d'Àrees Marines Protegides (AMPs) en el fons de maërl de Garotes per tal d'evitar una major degradació d'aquest hàbitat. Les AMPs augmentarien la complexitat d'aquests ecosistemes així com la biomassa de les espècies objectiu a Garotes, el que augmentaria els ingressos per part dels pescadors.

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1. Introduction

1.1. Fishing in the Mediterranean Sea

The Mediterranean Sea, formed ~150 million years ago, is surrounded by three continents (Europe, Africa and Asia) and is a marine biodiversity hot spot (Coll et al., 2010; Santinelli, 2015). The term "Mediterranean" comes from the Latin word "Mediterraneus" which means "in the middle of the land" or "between lands" (Santinelli, 2015). It has a surface area of about 2.5 million km^2 (Lionello et al., 2012), an average depth of 1500 m and it communicates with the Atlantic Ocean through the Strait of Gibraltar and with the Red Sea through the Suez Channel (Schroeder, 2019). In the Mediterranean Sea, evaporation is higher than precipitation and this cases a negative water balance that leads to an increase of salinity (between 38 and 39 psu) (Talley et al., 2011). It is subdivided into two main basins: western and eastern (Schroeder, 2019). In the western basin is located the Catalan Coast, which is the area of study.

The bathymetry of the submarine morphology can be divided into three zones, from shallow to deeper: continental shelf, slope and abyssal plain. From a standpoint, the continental shelf and the beginning of the slope are the areas where most of the exploitable resources are found (Demestre, 1986). In some locations the slope can be nearer to the coast, forming submarine canyons and where it circulates high density water rich in nutrients. This results in both high primary production and hot spots of biodiversity in these areas (Durán et al., 2013; Zúñiga et al., 2009). In the Catalan Coast seven submarine canyons can be found. In the area of study is located the Blanes Canyon, which is the largest one in the Catalan Coast with a length of 184 km. This canyon presents an inclination of 10%, a V shape and its head is located very close to the shore, at a distance of only 4 km (Lastras et al., 2011; Durán et al., 2013).

The Catalan Coast, which is 550 km long and has at least 28 ports, can be taken as an example of the fishing practices that take place throughout the Mediterranean. In the Mediterranean many species are exploited by multi-gear fisheries, which can be classified into three main modalities: artisanal fisheries (Gómez and Lloret, 2016; Lloret and Font, 2013), pelagic fisheries (Boubekri et al., 2019; Quattrocchi and Maynou, 2017) and demersal or benthic fisheries (Demestre et al., 2000).

Artisanal fisheries

Artisanal fisheries, also called small-scale fisheries, are characterized by operating in small boats (of 12 m or less) (European Comission, 2004) and by exploiting areas near the coast placed in very diverse bottoms on the continental shelf (Lloret and Font, 2013). The discards and the impact on benthic communities are much lower than those of bottom trawling fisheries (Jacquet and Pauly, 2008).

In general, artisanal fishing in the Catalan Coast can be classified into three types: static fishing, basket traps and towed gears. Static fishing is the most important one and can be divided basically into longline and trammel net (Lloret and Font, 2013). Basket traps, which are very local and specific, capture mainly cuttlefish and octopuses. Towed gears can be divided into two: "rastell" is a type of small beam-trawl that captures gastropods and "gàbies" is a clam-dredge that captures bivalves (Demestre, 1986; Lleonart, 1990).

Longline modality captures a large variety of organisms and can be divided into bottom longline or pelagic longline and thus can fish both pelagic and benthic or demersal species, respectively (Gómez and Lloret, 2016; Lloret and Font, 2013). (a) Bottom longline (Figure 1a) captures benthic and demersal species. It consists of a main long string with thinner strings at the end of which there is a variable size hook, depending on the size of the target species, which is placed on the seabed. Some of the target species are *Pagellus* spp., *Conger conger* and various species of Sparidae such as *Diplodus sargus.* (b) Pelagic longline (Figure 1b) presents a similar structure to the bottom longline but the main string and the hooks are distributed near the surface to capture pelagic target species such as *Sarda sarda, Scomber scombrus* and *S. japonicus.* It also captures tuna during their migratory stages, as well as swordfish and sharks (Demestre, 1986).

Net modality is a passive gear that is fixed on the seabed with different mesh size depending on the target species. The most frequent types in Catalonia are trammel net and gillnet. (a) Trammel net (Figure 1c) is formed by three joined nets, of which the central one is longer and has smaller mesh size. This allows the capture of fishes that reach the central net after passing through the external nets and end up entrapped (Demestre, 1986). The target species have a high commercial value and are benthic and demersal such as *Mullus barbatus, Mullus surmuletus, Scorpaena scrofa, S. porcus, S. notata, Pagellus acarne, Sepia officinalis, Penaeus kerathurus, Palinurus elephas, Scorpaena notata* as well as other small and coastal fish species (Gómez and Lloret, 2016; Demestre, 1986). (b) Gillnet (Figure 1d) is formed by only one net fixed on the seabed that catches fishes by the gills. The target species is mainly *Merluccius merluccius*, but *Pagellus acarne, P. erythrinus, Sparus aurata* and coastal fish species are also caught (Lloret and Font, 2013).

Pelagic fisheries

The purse-seine (Figure 1e) is the most important pelagic fishing technique and one of the main fishing gears in the Mediterranean, capturing basically small pelagic fishes of short life. It works at night because shoals of pelagic fishes are closer to the surface, and consists of attracting fishes with a light and surrounding them with a net supported by floats on the upper side and lead sinkers on the lower side (Lleonart, 1990; Nédélec & Prado, 1990; Palomera et al., 2007).

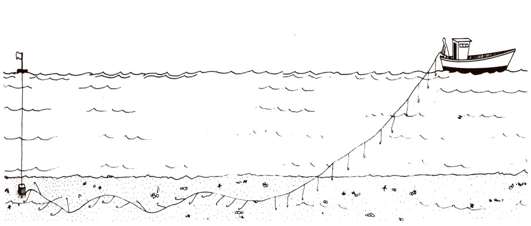
The main target species are *Engraulis encrasicolus, Sardina pilchardus*, *Sardinella aurita* and *Sprattus sprattus*. Recently the sardine (*Sardina pilchardus)* and the European anchovy (*Engraulis encrasicolus)* have showed a decline on their abundance and biomass because of its increasing exploitation (Basilone et al., 2018; Boubekri et al., 2019; Quattrocchi and Maynou, 2017).

Demersal and benthic fisheries

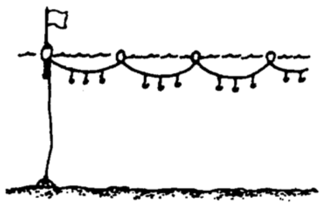
Bottom trawling (Figure 1f) is the most important gear of demersal and benthic fisheries and works on soft bottoms of the continental shelf and upper slope with a minimum depth of 50 m, that captures different target species depending on the seasonality, seabed characteristics and depth. It consists of a bag with floats on the upper side of the opening and lead sinkers on the lower side of them in order to keep it open on the vertical length, and the named “doors” to keep it open on the horizontal side. “Demersal” is a concept only used in fishing terms and referred to the species that habit on the seabed or in its proximities which present a high mobility (Demestre, 1986; Moranta et al., 2008).

The most regular captured target species are *Merluccius merluccius, Mullus barbatus, M. surmuletus, Solea vulgaris, Lophius piscatorius and L. bogarabeo, Micromesistius poutassou, Pagellus erythinus, P. acarne and P. bogaraveo, Lepidorhombus boscii, Raja clavata, Aristeus antennatuus, Nephrops norvegicus, Loligo vulgaris, Sepia officinalis* and *Eledone cirrhosa* (Demestre et al., 2000; Lleonart, 1990).

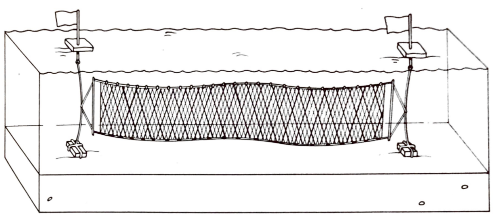
(a) Bottom longline



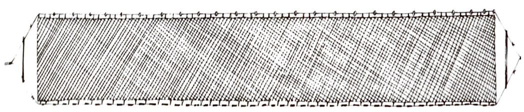
(b) Pelagic longline



(c) Trammel net



(d) Gillnet



(e) Purse-seining (f) Bottom trawling

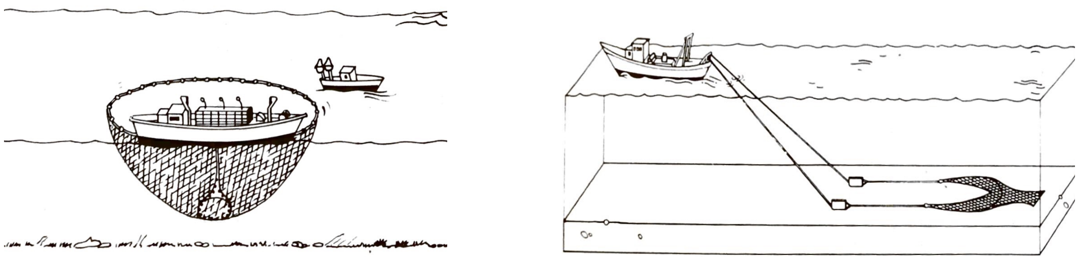


Figure 1. Main fishing gears in the Mediterranean. Adapted [reprinted] from "Quaderns d'Ecologia Aplicada", by M. Demestre, 1986 and National Oceanic and Atmospheric Administration, 2018.

1.2. Blanes fisheries

Blanes is a town located in the Costa Brava (Catalan Coast) belonging to a region called "La Selva", with an area of 17.7 km^2 and a population of 38,790 inhabitants (2018). Fishing grounds in this area are exploited by the artisanal, pelagic and benthic and demersal fishing fleets of the port of Blanes. Fishing grounds correspond to areas of the sea with high fishing activity because of the presence of commercial species (Bas et al., 2003; Matallanas, 1979). Target species belong to different habitats such as rock, gravel, sand, mud or meadow of marine phanerogams and are distributed depending on their biology, depth, seasonality, and characteristics of the seabed (Moranta et al., 2008).

The main fishing grounds (Table 1) exploited by the trawling fleet in Blanes are Capets, Fluviana, Garotes and Planassa (Figure 2) (García de Vinuesa, 2018; Matallanas, 1979). They have different types of bottoms, habitats and target species, which are distributed along the depth and also show a fishing seasonality (Figure 3).

Table 1. Main fishing grounds of Blanes exploited by the trawling fleet.

Fishing ground	Depth (m)	Bottom type	Target species
Garotes	50-88	Maërl	*Mullus surmuletus, M. barbatus, Pagellus erytrhinus*
Capets	90-102	Mud	*M. barbatus Lophius piscatorius, Octopus vulgaris, Merluccius merluccius,*
Planassa	110-199	Mud and muddy-sand	*M. barbatus, M. surmuletus, M. merluccius, Parastichopus regalis, Lophius* spp.
Fluviana	101-130	Sandy-mud (Crinoidea)	*M. barbatus, M. surmuletus, P. regalis, Zeus faber*

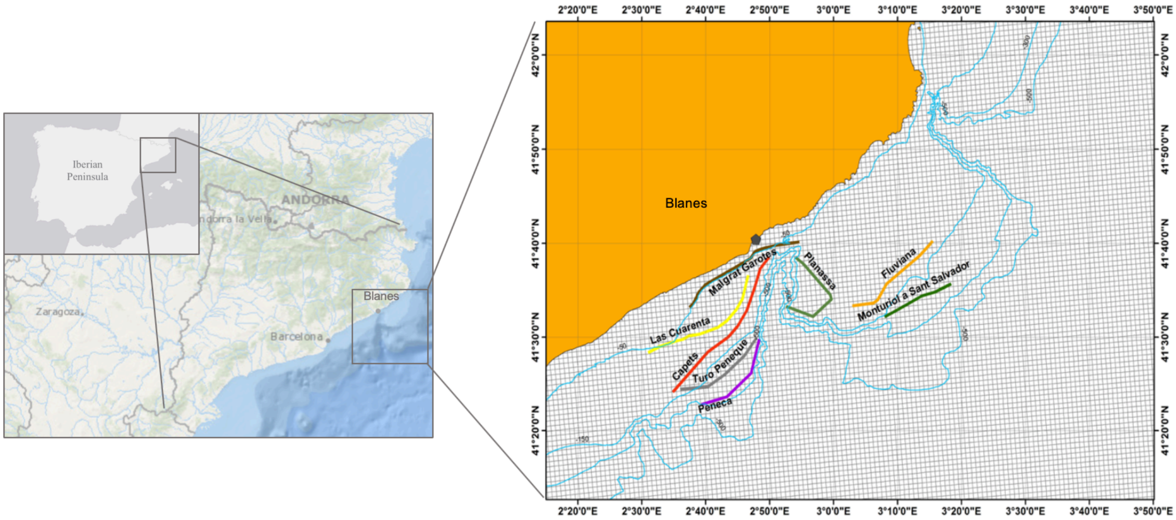


Figure 2. Map of the Catalan Coast and the location of the fishing grounds.

	J	F	M	A	M	J	J	A	S	O	N	D
Mullus barbatus	+	+	+	+	+	+	+	+	*	*	+	+
Mullus surmuletus	+	+	+	+	+	+	+	+	*	*	+	+
Merluccius merluccius	+	+	+	*	*	*	*	*	*	+	+	+

Figure 3. Seasonality of the main species in Capets (*M. barbatus* and *M. merluccius*) and Garotes (*M. surmuletus*). *: correspond to juvenile fish and +: to adults.

1.3. Impact of bottom trawling

Human activities such as fishing, pollution, tourism, introduction of species and climate change have a negative impact on the marine communities and the benthos, causing changes and the loss of native fauna, diversity and abundance, among others. Of all these negative impacts, fishing activity is one of the main drivers. The coastal areas and the continental shelf present the 98 % of the primary production and from 70 to 90 % of the fishing activity, and they have been historically exploited by humans, causing an alteration of their normal functioning (Demestre & Lloret, 2011). Among all the fishing gears, bottom trawling presents the major impact with a direct impact on both target species and discarded ones (Sánchez et al., 2007). At the same time it has an indirect effect on the benthic organisms of the seabed as infauna and epifauna (de Juan et al., 2007).

1.3.1. Direct impact on discards and target species

Fishing of target species in the fishing grounds involves the incidental catch of non-target organisms, generating a discarded fraction. The Catalan Coast presents a chronic exploitation by bottom trawling where fishing discards correspond to 60 or 70% of the catch (Sánchez et al., 2004). It is important to distinguish between by-catch and discards.

By-catch is the unwanted catch of organisms during fishing which corresponds to the non-target species. Furthermore, it also refers to the catch of juveniles of target species, which are fishes that do not reach the minimum legal size. By-catch species can also have economic value and be sold (Demestre, 1986).

Discards refer to the part of the catch, often dead, that is thrown back to the sea. They include unwanted by-catch and can take place for many reasons such as low or non-commercial value of the species, crashed target species or due to fishing regulations (Sánchez et al., 2000).

Recently a new obligation to land all discards has been included in the Article 15 of the reform of the EU Common Fisheries Policy (CFP). It has been fully implemented on 1 January 2019 and it affects all the species subjected to the Minimum Conservation Reference Size (MCRS) (García de Vinuesa, 2018; Tsagarakis et al., 2014) which can't be discarded.

1.3.2. Indirect impact on habitats and benthic communities

Bottom trawling has a negative impact on benthic habitat because the trawls disturb the bottom by removing the sediment (Kaiser & Spencer, 1996), which affects negatively the abundance, biomass and diversity of benthic organisms, from invertebrate to fishes (Jennings et al., 2001). The consequence is a modification of the habitat structure and the elimination of the most vulnerable organisms (de Juan et al., 2007). Thus, chronically disturbed communities are dominated by opportunistic organisms (Muntadas et al., 2014). Besides altering habitats, bottom trawling also causes changes in the ecosystems because of the disruption of food webs (Tillin et al., 2006), since a decrease of the production by infauna and epifauna may affect benthic carnivorous fish with economic importance because of a reduction of food availability (Palanques et al., 2014).

Maërl habitats are very fragile, and thus, badly damaged by bottom trawling, which reduces the diversity and coverage of this algae and it can be substituted by other algae species more resilient to trawling impacts like Peyssonneliacea (Bordehore et al., 2003). Bottom trawling also causes a loss of species richness, density and biomass of macrofaunal species, killing large epibenthos whereas hard-shelled organisms often survive (Althaus, 2009; Hall-Spencer et al., 2003).

On the other hand, trawling takes places in homogeneous benthic habitats of muddy bottom, where trawl "doors" penetrate more deeply than in other sediments, causing important effects on benthic species (Pommer et al., 2016). In the study of Palanques et al. (2001) the tracks of the trawl gears were still observed one year after the first experiment.

Benthic organisms are essential on the marine ecosystem and have become very important to fishing. They are responsible for the nutrient cycle, detrital decomposition and are a food source for higher trophic levels, which correspond to the majority of commercial species. Particularly, infaunal communities have a key role on the habitat structure and constitute most of the diet of demersal fishes, which feed from polychaetes, crustacea and bivalvia, among others (Longhurst, 1957; Muntadas et al., 2014).

2. Objectives

The impact of trawling on benthic communities and the analysis of the discarded fraction are well studied in the NW Mediterranean Sea (Demestre et al., 2018; de Juan et al., 2007; Sánchez et al., 2000; Sánchez et al., 2004), whereas studies linking benthic infauna with discarded catches are scarce. This research studied the possible relationship between the direct effect of bottom trawling through the analysis of discards and the indirect effect on benthic infaunal organisms.

The aim of this study was to evaluate the impact of bottom trawling on the benthic communities, discards and infauna, of two different habitats, maërl and mud. The study was located in Blanes (Costa Brava, NW Mediterranean Sea). Particular attention was paid to highlight the ecological importance of the maërl bed on the Mediterranean Sea.

To develop this main purpose three specific objectives were carried out:

1) The analysis of the biomass and abundance of the discarded fraction from the fishing activity carried out on the two selected habitats located on the fishing grounds.

2) The estimation of the effects of bottom trawling on biodiversity and abundance of the infauna on the two selected habitats.

3) The analysis of the ecological quality of the two fishing grounds according to the infaunal community and the fishing yield (target species and discards).

3. Methodology

3.1. Study area

This study was conducted in Blanes, which is located in the north-western Mediterranean Sea. Two fishing grounds on the continental shelf have been selected for this study: Garotes and Capets, in order to compare two different substrates, maërl and mud, respectively (Bas et al., 2003; Matallanas, 1979). Data was obtained from the European Commission's research project MINOUW, which aim is to minimise unwanted catches in European fisheries.

Fishing ground "Garotes": Maërl habitat

Garotes is a fishing ground located on the western side of the Blanes Canyon, with a depth between 50 and 88 m. It has a seasonal fishing with a major peak from September to January. This fishing ground presents a fishing ban from April to August and a fishermen's agreement to stop fishing on Fridays. One of the main target species is *Mullus surmuletus*, which lives on shallow bottoms of the continental shelf near to the coast and is more important than *Mullus barbatus*, which presents a higher abundance in soft bottoms of mud (Bas et al., 2003; Matallanas, 1979).

Garotes is a habitat characterised by a seabed of maërl and its name is due to the abundance of the sea urchin *Sphaerechinus granularis*, which name in Catalan is "garota" (Matallanas, 1979). Maërl beds are carbonate deposits characterized by accumulations of living and dead calcareous rhodophytes (mostly Corallinaceae but also Peysonneliaceae), also known as rhodolith beds (Barberá et al., 2003; Grall et al., 2006). They form fragile slow-growth habitats which are biodiversity hot spots and have a high conservation importance because they produce a heterogeneous and hard substrate that favours the growth of other algae and invertebrates, including infaunal species (Hall-Spencer et al., 2003; Sciberras, 2009). Maërl beds present a high productivity and provide nursery, feeding and brood-stock areas for commercial species of fish (Bordehore et al., 2003; Kamenos et al., 2004).

Fishing ground "Capets": Muddy habitat

Capets is located on the western side of the Blanes Canyon and it extends in a range of depths from 90 to 102 m, with muddy and muddy-sand bottom. Fishing activity is constant during the whole year except on February due to a stop of the trawl fleet. Target species are *Mullus barbatus, Lophius piscatorius, Octopus vulgaris* and *Merluccius merluccius*, among others (Bas et al., 2003; Matallanas, 1979).

Muddy seabed presents anoxic conditions in the layer immediately below the surface, which turns into a low species diversity. This habitat is very stable and shows a low renovation, therefore organisms that inhabit it are highly adapted and present a K reproductive strategy. (Demestre et al., 1986; Muntadas et al., 2014).

3.2. Sampling method

Commercial and discards fishing samples

Samples of commercial species, unregulated discards and regulated discards were collected on March, July and August 2016 in two field trips each month. Three commercial trawlers were used and biomass and abundance of commercial catch, regulated discards and unregulated discards were analysed on board from 7 hauls.

From each haul, between 7 and 10 kg of the discarded fraction were randomly selected and transported to the Institut de Ciències del Mar (ICM-CSIC) laboratory in order to classify organisms. Discarded species biomass (B) and abundance (AB) were extrapolated to the total catch using the equation (1), according to García de Vinuesa et al. (2018). Then, discarded and commercial species were standardized to hectares (swept area) as shown in the equation (2), where SBW is the mean distance between trawl wings (horizontal opening) and HD is the haul duration.

$$\text{Species AB or B} = \frac{\text{AB or B (species sampled) x AB or B (total discard)}}{\text{AB or B (discard sampled)}} \qquad (1)$$

$$\text{Species AB or B standardized} = \frac{\text{AB or B (species sampled)}}{\text{speed } \frac{\text{m}}{\text{s}} \text{ x SBW(m) x HD(s)}}\, x10000 \qquad (2)$$

Infaunal samples

Samples of infauna were collected during the Deep Vision 2 cruise on 25th October 2016 with a 0.1 m^2 Van Veen grab. 3 stations located in each fishing ground (Capets and Garotes) were selected and 5 replicas were obtained per station, but due to a time limitation, only 2 replicas were analysed in this work. The vessel used was RV "García del Cid" (31 m long).

Samples of infauna were filtered on board with a 1 mm mesh sieve, fixed in 5% formaldehyde and preserved out of sunlight at room temperature. In the laboratory at the ICM-CSIC, samples were re-sieved with the same mesh size, stained with Rose Bengal and stored with ethyl alcohol 96%. Rose Bengal is a biological stain widely used to stain animal tissues, is relatively inexpensive and easily obtained (Mason and Yevich, 1967). Samples were left 24 hours and changed to water before processing. The infaunal organisms were picked wet from a Petri dish, examined under a stereo microscope and classified to order or class using specialized literature on benthos and infaunal organisms from the Mediterranean Sea (Fauna y flora del Mar Mediterráneo, 1986).

The samples were named with the following code: DV2GDR1a, where DV2 stands for the cruise "Deep Vision 2", "G" or "C" depending on the fishing ground (Garotes or Capets), "DR" is dredge, "1" is the station and "a" is the replica. Thus, the three stations located in Garotes are DV2GDR1, DV2GDR2 and DV2GDR3, whereas in the case of Capets they are named DV2CDR1, DV2CDR2 and DV2CDR3.

3.3. Statistical analysis

The PRIMER 6.1.2. (Clarke and Gorley, 2006) statistical software was used to carry out a multivariate analysis on the infaunal and discard data.

For the biodiversity analysis a Shannon's index of diversity (*H*), Pilou's index of evenness (*J*) and the species richness (Margalef's *D*) were calculated for each sample. Then, data for abundance/biomass analysis was log (X+1) or square root transformed prior to analysis, depending on the discards and the infauna data, respectively. A cluster analysis using the Bray-Curtis similarity index was calculated and the resulting similarity matrix was then used to perform non-metric multidimensional scaling (MDS). Similarity Percentage Analysis (SIMPER) was carried out to establish which of the infaunal or discard species contributed most to the similarity among habitats (Capets and Garotes), using the habitat as a factor.

One-way ANOVA and Kruskal-Wallis non-parametric test were performed to detect significant differences on abundance and biomass of discarded fraction and infaunal abundance among Capets and Garotes. Species richness, Pilou's evenness and Shannon-Wienner diversity parameters were analysed between the two studied habitats.

4. Results

To study the first objective, characterization of abundance and biomass for total caught species, commercial fraction and discards was performed. After that, ecological evaluation and fishing seasonality of the two fishing grounds was also studied.
To study the second objective, characterization of abundance and ecological evaluation of infauna was performed.
To study the third objective, relationship between effort fishing seasonality and target species was performed. Also quality of the two fishing grounds was studied, considering diet of commercial species related with infauna and discards, as well as productivity of Capets and Garotes.

4.1. Fisheries analysis

4.1.1. Characterization of abundance and biomass

Abundance

The bottom trawling fisheries in Blanes discarded 84 % and 87 % in abundance of the total catch in Capets and Garotes, respectively (Figure 4). In these two fishing grounds regulated discards represented 6 % of the total catch in Capets and 42 % in Garotes. These differences were mainly due to the abundance of *Boops boops*, which represented 34.9 % of the abundance in Capets and 87.7 % in Garotes (Table 2). Other abundant regulated discarded species were *Trachurus trachurus* (30.1 %) and *Lophius budegasa* (10.9 %) in Capets, and *Octopus vulgaris* (3.8 %) and *Pagellus erythrinus* (3.1 %) in Garotes.

Unregulated discards were 78 % in Capets and 45 % in Garotes. Onuphidae (34.6 %), *Ophiura texturata* (14.8 %) and *Ophisurus serpens* (13.4 %) were the most abundant species in Capets, whereas in Garotes those were *Spicara smaris* (66.4 %) and *Echinus melo* (15.4 %).

Percentage of commercial species was similar between the two studied fishing grounds: 16 % in Capets and 13 % in Garotes. *Triglidae* (38.9 %) and *Sepia orbignyana* (21.6 %) were the most abundant species in Capets, whereas in Garotes those were *Trachurus* spp. (68.1 %) and *Mullus surmuletus* (10 %).

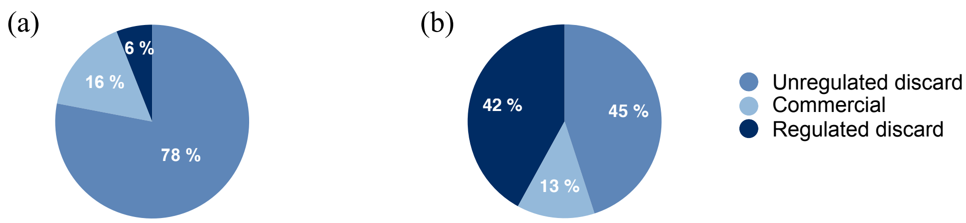


Figure 4. Abundance of total species in Capets (a) and Garotes (b).

Table 2. Abundance of total species in the two fishing grounds, Capets and Garotes.

Capets	%	Garotes	%
Commercial	16		13
Triglidae	38.9	*Trachurus* sp	68.1
Sepia orbignyana	21.6	*Mullus surmuletus*	10
Trisopterus capelanus	8.1	*Mullus barbatus*	5.9
Mullus surmuletus	7.4	*Pagellus erythrinus*	5.75
Ilex coindetii	3.6	*Merluccius merluccius*	4.3
Parastichopus regalis	3.1	*Triglidae*	1.7
Unregulated discard	78		45
Onuphidae	34.6	*Spicara smaris*	66.4
Ophiura texturata	14.8	*Echinus melo*	15.4
Ophisurus serpens	13.4	*Antedon mediterranea*	3.9
Ascidia bola	3.4	*Ophiotrix fragilis*	3.9
Cumbracum cumbracum	2.9	*Chelidonichthys cuculus*	1.6
Regulated discard	6		42
Boops boops	34.9	*Boops boops*	87.7
Trachurus trachurus	30.1	*Octopus vulgaris*	3.8

Lophius budegassa	10.9	*Pagellus erythrinus*	3.1
Pagellus erythrinus	5.6	*Trachurus picturatus*	2.7
Trisopterus capelanus	5.3	*Scomber scombrus*	2.3

The species composition of commercial species showed that benthic and demersal species represented 28 % and 72 % respectively in Capets, whereas in Garotes these values were 1 % and 99 % respectively (Figure 5). *Triglidae* (54 %) and *Sepia orbignyana* (77.3 %) were the most abundant demersal and benthic species in Capets, respectively. In Garotes those were *Trachurus* spp. (68.9 %) in the first case, whereas in the second case they were *Octopus vulgaris* (66.7 %) and *Eledone cirrhosa* (33.3 %) (Table 3).

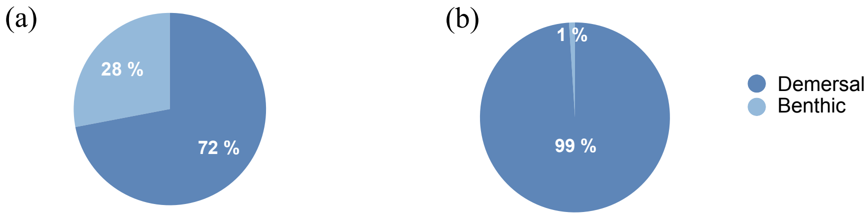


Figure 5. Abundance of commercial species in Capets (a) and Garotes (b).

Table 3. Abundance of commercial species in the two fishing grounds, Capets and Garotes.

Capets	%	Garotes	%
Demersal	72		99
Triglidae	54.0	*Trachurus* spp.	68.9
Trisopterus capelanus	11.2	*Mullus surmuletus*	10.1
Mullus surmuletus	10.3	*Mullus barbatus*	6
Mullus barbatus	7.5	*Pagellus erythrinus*	5.8
Ilex coindetii	5.0	*Merluccius merluccius*	4.4
Benthic	28		1
Sepia orbignyana	77.3	*Octopus vulgaris*	66.7
Parastichopus regalis	11.1	*Eledone cirrhosa*	33.3
Octopus vulgaris	6.9		
Eledone cirrhosa	4.5		
Sepia officinalis	0.2		

Unregulated discarded species were mainly invertebrates in Capets (75 %) and fish (73 %) in Garotes (Figure 6). *Ophisurus serpens* (55.5 %) and *Spicara smaris* (92.1 %) were the most abundant fish in Capets and Garotes, respectively. Presence of cartilaginous was practically insignificant in both sites. *Onuphidae* (46.4 %) and *Ophiura texturata* (19.9 %) were the most abundant invertebrate species in Capets, whereas in Garotes those were *Echinus melo* (56.5 %), *Antedon mediterranea* (14.1 %) and *Ophiotrix fragilis* (14.1 %) (Table 4).

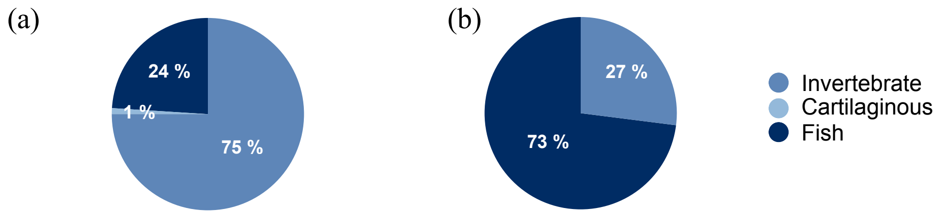


Figure 6. Abundance of discarded species in Capets (a) and Garotes (b).

Table 4. Abundance of discarded species in the two fishing grounds, Capets and Garotes.

Capets	%	Garotes	%
Fish	24		73
Ophisurus serpens	55.5	*Spicara smaris*	92.1
Spicara flexuosa	11.4	*Chelidonichthys cuculus*	2.2
Spicara smaris	8.0	*Sardinela aurita*	2.1
Lepidotrigla cavillone	5.3	*Trigloporus lastoviza*	2.1
Chelidonichthys lucerna	3.3	*Lepidotrigla cavillone*	1.4
Cartilaginous	1		<1
Scyliorhinus canicula	100	*Raja miraletus*	52.7
		Scyliorhinus canicula	47.3
Invertebrate	75		27
Onuphidae	46.4	*Echinus melo*	56.5
Ophiura texturata	19.9	*Antedon mediterranea*	14.1
Ascidia sp2	4.5	*Ophiotrix fragilis*	14.1
Cumbracum cumbracum	3.9	*Echinaster sepositus*	3.7
Pagurus prideauxi	3.1	*Dardanus arrosor*	3.7

Biomass

Bottom trawling fisheries in Blanes discarded 73 % and 78 % in biomass of the total catch in Capets and Garotes, respectively (Figure 7). In these two fishing grounds regulated discards represented 8 % of the total catch in Capets and 47 % in Garotes. These differences were mainly due to the abundance of *Boops boops*, which represented 35.9 % of the abundance in Capets and 77 % in Garotes (Table 9). *Trachurus trachurus* (24.7 %) and *Octopus* vulgaris (15.6 %) were also abundant regulated species in Capets and Garotes, respectively.

Unregulated discards were 65 % in Capets and 31 % in Garotes. *Echinus melo* (17 %), *Astropecten aranciacus* (10.2 %) and *Spicara flexuosa* (7.5 %) were the most abundant species in Capets, whereas in Garotes those were *Spicara smaris* (60.7 %) and *Echinus melo* (24.5 %).

Percentage of commercial species was similar between the two studied fishing grounds: 27 % in Capets and 22 % in Garotes. *Triglidae* (22.7 %), *Lophius* spp. (13.1 %), *Sepia orbignyana* (9 %), *Mullus surmuletus* (7.7 %) and *Octopus vulgaris* (7.4 %) were the most abundant species in Capets, whereas in Garotes that was *Trachurus* spp. (60.6 %).

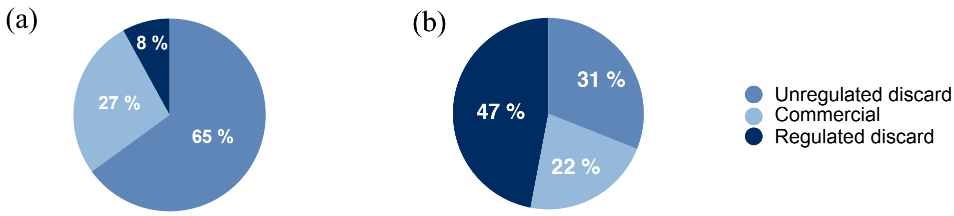


Figure 7. Biomass of total species in Capets (a) and Garotes (b).

Table 9. Biomass of total species in the two fishing grounds, Capets and Garotes.

Capets	%	Garotes	%
Commercial	27		22
Triglidae	22.7	*Trachurus* spp.	60.6
Lophius spp.	13.1	*Zeus faber*	7.7
Sepia orbignyana	9.0	*Mullus surmuletus*	6.5
Mullus spp.	7.7	*Pagellus erythrinus*	6.4
Octopus vulgaris	7.4	*Merluccius merluccius*	6.1
Unregulated discard	65		31
Echinus melo	17.0	*Spicara smaris*	60.7
Astropecten aranciacus	10.2	*Echinus melo*	24.5
Spicara flexuosa	7.5	*Dardanus arrosor*	4.0
Ascidia sp1	7.2	*Sardinela aurita*	3.2
Scyliorhinus canicula	6.5	*Holothuria forskali*	2.3
Regulated discard	8		47
Boops boops	35.9	*Boops boops*	77.0
Trachurus trachurus	24.7	*Octopus vulgaris*	15.6
Lophius budegassa	12.7	*Trachurus picturatus*	2.5
Pagellus erythrinus	7.6	*Pagellus erythrinus*	2.4
Lophius piscatorius	7.5	*Scomber scombrus*	2.2

The species composition of commercial species showed that benthic and demersal species represented 24 % and 76 % respectively in Capets, whereas in Garotes those values were 3 % and 97 % respectively. *Triglidae* (30.1 %), *Lophius* spp. (17.3 %), *Mullus surmuletus* (10.2 %), *Ilex coindetii* (8.2 %), *Mullus barbatus* (7.8 %) and *Trisopterus capelanus* (7.3 %) were the most abundant demersal species in Capets, whereas in Garotes that was *Trachurus* spp. (62.8 %). *Sepia orbignyana* (37 %), *Octopus vulgaris* (30.5 %) and *Eledone cirrhosa* (22.9 %) were the main groups in weight in Capets, whereas in Garotes those were *Octopus vulgaris* (83.3 %) and *Eledone cirrhosa* (16.7 %).

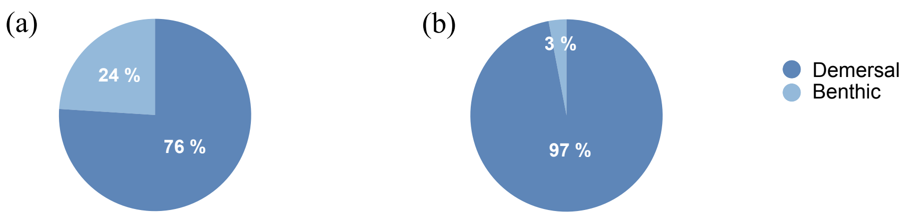


Figure 8. Biomass of commercial species in Capets (a) and Garotes (b).

Table 10. Biomass of commercial species in the two fishing grounds, Capets and Garotes.

Capets	%	Garotes	%
Demersal	76		97
Triglidae	30.1	*Trachurus* spp.	62.8
Lophius spp.	17.3	*Zeus faber*	8.0
Mullus surmuletus	10.2	*Mullus surmuletus*	6.7
Ilex coindetii	8.2	*Pagellus erythrinus*	6.7
Mullus barbatus	7.8	*Merluccius merluccius*	6.4
Trisopterus capelanus	7.3	*Mullus barbatus*	2.6
Benthic	24		3
Sepia orbignyana	37.0	*Octopus vulgaris*	83.3
Octopus vulgaris	30.5	*Eledone cirrhosa*	16.7
Eledone cirrhosa	22.9		
Parastichopus regalis	7.2		
Sepia officinalis	2.4		

Unregulated discarded species were mainly invertebrates (68%) in Capets and fish (66 %) in Garotes. *Spicara flexuosa* (26.8 %), *Ophisurus serpens* (19.7 %) and *Spicara smaris* (10.9 %) were the main species in weight of fish in Capets, whereas in Garotes that was *Spicara smaris* (91.8 %). Presence of cartilaginous was very scarce with 6 % in Capets and *Scyliorhinus canicula* as the only species, whereas in Garotes it was 1 % and *Raja miraletus* was the only found species. *Echinus melo* (23 %) and *Astropecten aranciacus* (13.8 %) were the main invertebrate species in weight in Capets, whereas in Garotes that was *Echinus melo* (74.4 %).

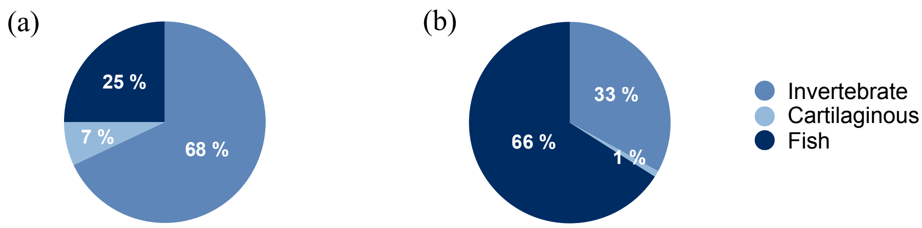


Figure 9. Biomass of discarded species in Capets (a) and Garotes (b).

Table 11. Biomass of discarded species in the two fishing grounds, Capets and Garotes.

Capets	%	Garotes	%
Fish	26		66
Spicara flexuosa	26.8	*Spicara smaris*	91.8
Ophisurus serpens	19.7	*Sardinela aurita*	4.9
Spicara smaris	10.9	*Trigloporus lastoviza*	2.1
Phycis blennoides	6.1	*Lepidotrigla cavillone*	1.2
Conger conger	3.4		
Cartilaginous	6		1
Scyliorhinus canicula	100	*Raja miraletus*	100
Invertebrate	68		33
Echinus melo	23.0	*Echinus melo*	74.4
Astropecten aranciacus	13.8	*Holothuria forskali*	7.0
Ascidia sp1	9.8	*Dardanus arrosor*	12.2
Onuphidae	5.8	*Echinaster sepositus*	2.2
Ophiura texturata	5.3	*Loligo vulgaris*	1.4
Echinaster sepositus	5.1	*Ophiotrix fragilis*	0.7

4.1.2. Ecological evaluation

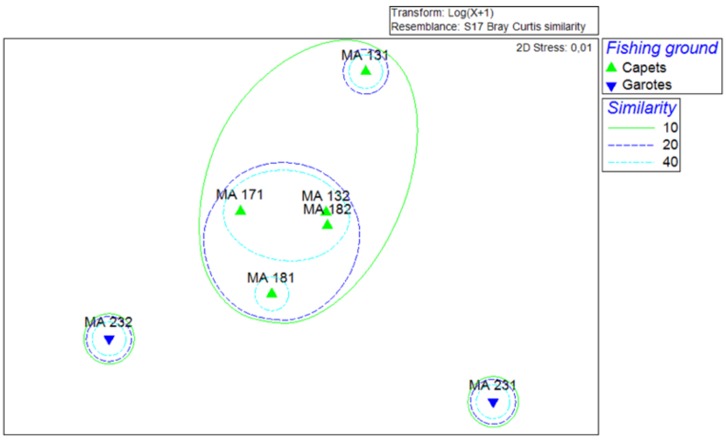
Significant differences were found in species richness between Capets and Garotes in both abundance and biomass of unregulated discarded fraction (Table 12). Diversity Index Shannon-Wienner was significative for abundance.

Table 12. ANOVA results of biodiversity of the discarded fraction. *: significant differences (p<0.05). [1]Kruskal-Wallis non-parametric test.

Parameters	Abundance			Biomass		
	df	*F* value	Pr (>F)	df	*F* value	Pr (>F)
Species richness (Margalef)	1	85.585	0.000248*	1	87.489	0.0002353*
Pilou's evenness (J')	1	5.9886	0.05814	6	-	0.4232[1]
Shannon-Wienner (H')	1	15.16	0.01148*	6	-	0.4232[1]

MDS (Figure 10) showed a clear separation between hauls from the two fishing grounds, with a stress level of 0.01 in abundance and 0.05 in biomass. In abundance, hauls in Capets presented 10 % of similarity, whereas in the case of Garotes it was lower. In Capets hauls from August (MA181 and MA182), July (MA171) and one of March (MA132), presented 20 % of similarity. The highest similarity was between MA132, MA171 and MA181, which corresponded to hauls from the three months. In biomass, hauls in Capets also showed 10 % of similarity. Hauls from August (MA181 and MA182) showed a high percentage similarity between them (20 %) and hauls from March (MA132) and July (MA171) also presented 20 % of similarity.

(a) Abundance



(b) Biomass

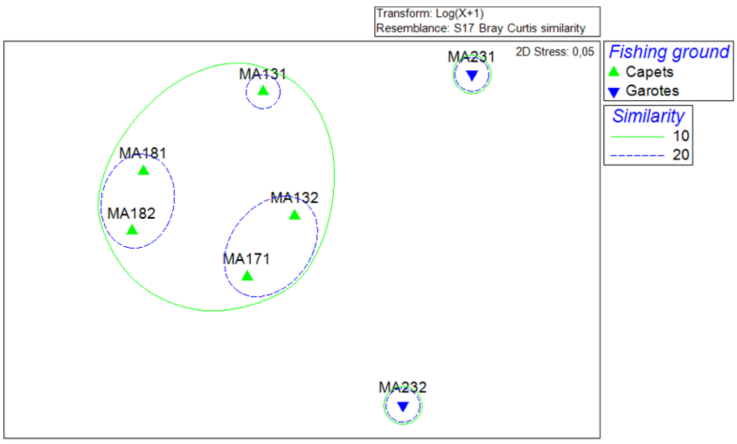


Figure 10. MDS analysis for the abundance (a) and biomass (b). MA232 and MA231 hauls correspond to Garotes. MA181, MA182, MA131, MA132 and MA171 correspond to Capets.

Results of the SIMPER abundance analysis (Table 13) showed a high average dissimilarity value between the two fishing grounds (82.25 %). *Ophiura texturata* presented a high contribution to the similarity in Capets (42.72 %), whereas *Echinaster sepositus* explained 65.95 % of the similarity in Garotes. One of the common species in both fishing grounds was *Spicara smaris*, with a contribution to similarity of 9.21 % in Capets and 34.05 % in Garotes.

Table 13. Abundance SIMPER analysis for the discarded fraction in Capets and Garotes (a) and between them (b). Fishing ground was selected as a factor. Average abundance in individuals per hectare (Av.Abund), average similarity/dissimilarity contribution (Av.Sim/Av.Diss), similarity contribution in percentage (Contrib.) and accumulated similarity contribution in percentage (Cum.) was showed.

(a)

	Av.Abund (ind. ha^{-1})	Av.Sim	Contrib.	Cum.
Capets Av. similarity 42.72				
Ophiura texturata	4.83	5.83	13.66	13.66
Spicara smaris	3.06	3.94	9.21	22.87
Echinaster sepositus	2.70	3.15	7.37	30.23
Echinus melo	2.55	2.98	6.98	37.21
Arnoglossus tori	2.11	2.34	5.47	42.68
Anseropoda placenta	2.35	2.03	4.76	47.44
Cumbracum cumbracum	2.42	1.91	4.47	51.91
Dardanus arrosor	1.76	1.77	4.15	56.06
Chelidonichthys cuculus	1.70	1.71	4.01	60.08
Illex coindetii	1.83	1.71	4.01	64.09
Garotes Av. similarity 10.53				
Echinaster sepositus	1.50	6.94	65.95	65.95
Spicara smaris	3.45	3.59	34.05	100.00

(b)

	Group Capets Av. Abund (ind. ha^{-1})	Group Garotes Av. Abund (ind. ha^{-1})	Av. Diss	Contrib.	Cum.
Capets and Garotes Av. dissimilarity 82.25					
Ophiura texturata	4.83	0.00	5.15	6.26	6.26
Spicara smaris	3.06	3.45	2.89	3.52	9.77
Echinus melo	2.55	2.34	2.53	3.07	12.85
Anseropoda placenta	2.35	0.00	2.48	3.02	15.87
Cumbracum cumbracum	2.42	0.00	2.45	2.98	18.85
Arnoglossus tori	2.11	0.00	2.27	2.77	21.61

Results of the SIMPER biomass analysis (Table 14) showed a high average dissimilarity value between the two fishing grounds (87.89 %). *Ophiura texturata* and *Echinaster sepositus* presented a high contribution to the similarity in Capets, of 10.90 and 9.06 % respectively; whereas *Echinaster sepositus* explained 100 % of the similarity in Garotes. Common species in both fishing grounds were *Ophiura texturata, Echinaster sepositus, Cumbracum cumbracum, Ilex coindetii, Microcosmus sulcatus* and *Scyliorhinus canicula*.

Table 14. Biomass SIMPER analysis for the discarded fraction in Capets and Garotes (a) and between them (b). Fishing ground was selected as a factor. Average abundance in kg per hectare (Av.Abund), average similarity/dissimilarity contribution (Av.Sim/Av.Diss), similarity contribution in percentage (Contrib.) and accumulated similarity contribution in percentage (Cum.) was showed.

(a)

	Av.Abund (kg ha^{-1})	Av.Sim	Contrib.	Cum.
Capets Av. similarity 38.87				
Ophiura texturata	6.15	4.24	10.90	10.90
Echinaster sepositus	5.53	3.52	9.06	19.96
Cumbracum cumbracum	4.96	2.85	7.32	27.28
Serranus cabrilla	4.24	2.64	6.79	34.07
Illex coindetii	4.15	2.36	6.08	40.14
Microcosmus sulcatus	4.68	2.30	5.93	46.07
Ascidia mentula	4.23	2.16	5.55	51.62
Scyliorhinus canicula	4.60	1.76	4.52	56.14
Anseropoda placenta	3.20	1.62	4.17	60.31
Dardanus arrosor	3.34	1.59	4.08	64.39
Garotes Av. similarity 11.01				
Echinaster sepositus	4.37	11.01	100.00	100.00

(b)

	Group Garotes Av. Abund (kg ha^{-1})	Group Capets Av. Abund (kg ha^{-1})	Av. Diss	Contrib.	Cum.
Capets and Garotes Av. dissimilarity 87.89					
Ophiura texturata	6.15	0.00	3.67	4.18	4.18
Cumbracum cumbracum	4.96	0.00	2.90	3.30	7.48
Microcosmus sulcatus	4.68	0.00	2.77	3.15	10.63
Scyliorhinus canicula	4.60	0.00	2.67	3.03	13.67
Illex coindetii	4.15	0.00	2.57	2.93	16.59
Serranus cabrilla	4.24	0.00	2.49	2.83	19.42

4.1.3. Fishing seasonality in Capets and Garotes

4.1.3.1. Temporal evaluation of Capets

Abundance

Abundance of total, commercial and discarded species during March, July and August in Capets is shown in Figure 11. March presented the lowest percentage of commercial species (8 %) and the highest unregulated discard (91 %). July showed the highest value of commercial species (38 %) and August presented the highest percentage of regulated discard (20 %).

Commercial species presented similar percentages of benthic and demersal species during the three months. July presented the highest percentage of benthic organisms (34 %) and the lowest of demersal species (66 %). August presented the highest value of demersal organisms (78 %).

March showed the highest percentage of discarded cartilaginous (15 %) and the lowest of fish (15 %). July presented the highest value of discarded invertebrate (74 %). August presented the highest percentage of discarded fish (35 %) and the lowest of invertebrate (64 %) and cartilaginous (1 %).

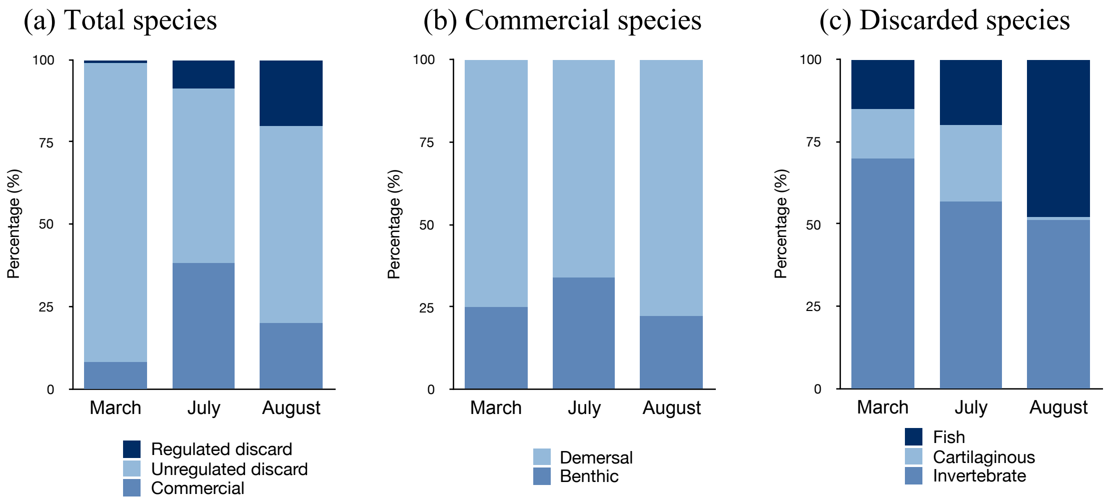


Figure 11. Seasonality of total (a), commercial (b) and discarded (b) species during March, July and August in abundance.

Biomass

Biomass of total, commercial and discarded species during March, July and August in Capets is shown in Figure 12. March presented the lowest percentage of commercial species (21%) and the highest unregulated discard (77 %). July showed the highest value of commercial species (55 %) and August presented the highest percentage of regulated discard (20 %).

Commercial species presented similar percentages of benthic and demersal species during the three months. July presented the highest percentage of benthic organisms (34 %) and the lowest of demersal species (66 %). August presented the highest value of demersal organisms (82 %).

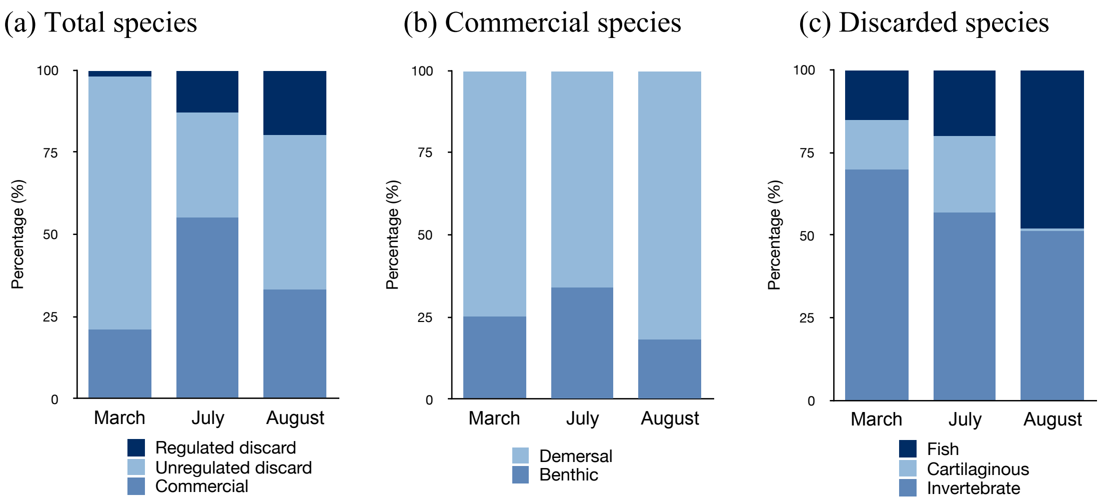


Figure 12. Seasonality of total (a), commercial (b) and discarded (b) species during March, July and August in biomass.

March showed the highest percentage of discarded invertebrate (70 %) and the lowest of fish (15 %). July presented the highest value of discarded cartilaginous (23 %). August presented the highest percentage of discarded fish (48 %) and the lowest of invertebrate (51 %) and cartilaginous (1 %).

Significative differences were found in abundance between March, July and August in Capets, showing different fishing effort dynamics during the three months (Table 15).

Table 15. Kruskal-Wallis test for Capets on March, July and August. * significative differences (p<0,05).

Parameters	X^2	df	p-value
Abundance	138.94	83	0.0001169*
Biomass	140.47	117	0.06875

4.1.3.2. Spatial evaluation of Garotes

Abundance of total, commercial and discarded species during March on 62 and 93 m depth in Garotes is shown in Figure 13. Depth of 62 m presented a higher unregulated discarded fraction (46 %) and lower percentage of commercial species (5 %). Commercial species were mainly demersal (93 %) with low abundance of benthic organisms (7 %). Discarded species were mainly fish (95 %). Depth of 93 m showed higher commercial species (28 %) and lower unregulated discards (18 %). All commercial species were demersal and discarded species were mainly invertebrate (93 %), with low fraction of fish (7 %).

(a) Total species (b) Commercial species (c) Discarded species

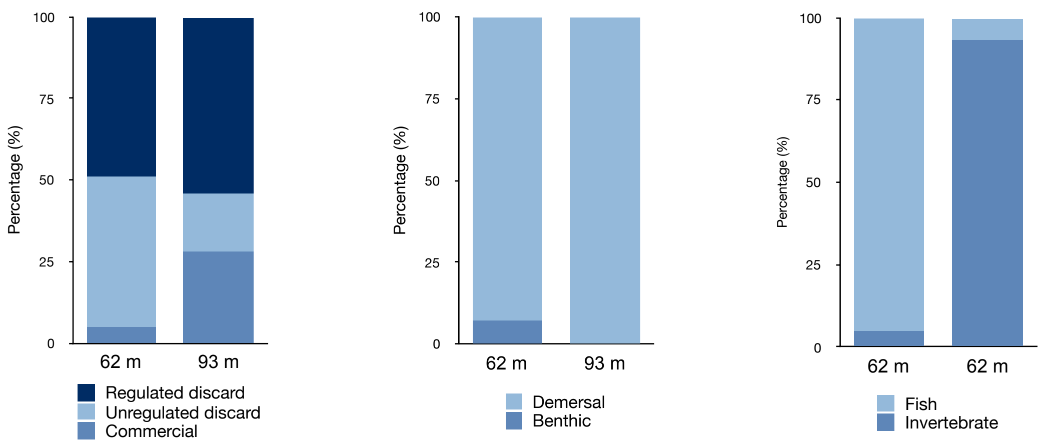


Figure 13. Abundance of total (a), commercial (b) and discarded (b) species on the two studied depths (62 and 93 m) in Garotes.

Biomass of total, commercial and discarded species during March on 62 and 93 m depth in Garotes is shown in Figure 14. Depth of 62 m presented higher regulated discarded fraction (66 %) and lower percentage of commercial species (11 %). Commercial species were mainly demersal (86 %) with low abundance of benthic organisms (13 %). Discarded species were mainly fish (82 %). Depth of 93 m showed higher commercial species (47 %) and lower regulated discards (44 %). All commercial species were demersal and discarded species were only invertebrates.

(a) Total species (b) Commercial species (c) Discarded species

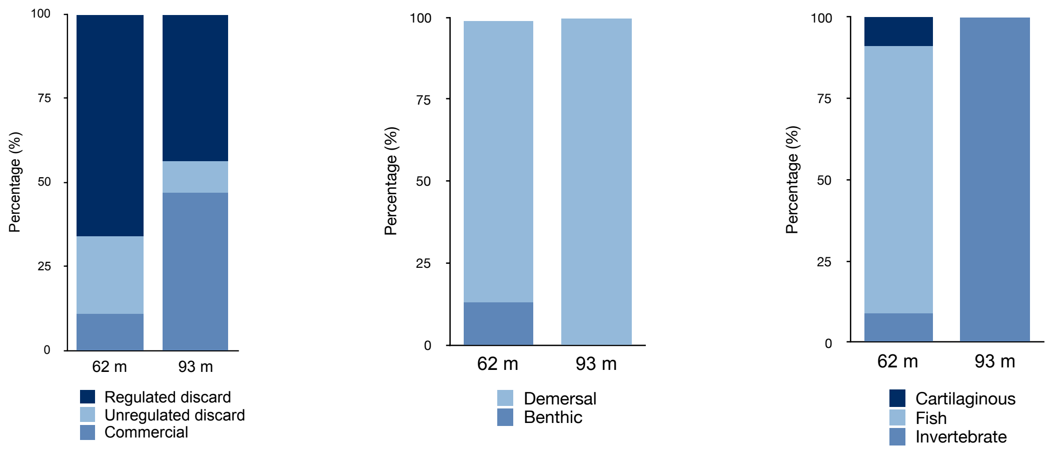


Figure 14. Biomass of total (a), commercial (b) and discarded (b) species on the two studied depths (62 and 93 m) in Garotes.

Significative differences were found in biomass species of Capets and Garotes in March (Table 16).

Table 16. Kruskal-Wallis test for the two studied depths (62 and 93 m) in Garotes. * significative differences ($p<0.05$).

	Depths in Garotes (62 and 93 m)			March in Capets and Garotes		
Parameters	X^2	df	p-value	X^2	df	p-value
Abundance	13.685	13	0.3964	68.691	55	0.1015
Biomass	13.944	16	0.6029	157	57	2.762e-11*

4.2. Infaunal analysis

Only abundance of infauna was studied, with a characterization and ecological evaluation on the two fishing grounds.

4.2.1. Characterization of abundance

Abundance of species found in Capets and Garotes is shown in Figure 15. Annelida (84 %) was the dominant phylum in Capets, followed by Mollusca (14 %), Nematoda (1 %) and Arthropoda (1 %). Garotes showed a high diversity in phyla. Annelida (42 %) was the dominant phylum, followed by Arthropoda (22 %), Nematoda (22 %), Mollusca (10 %), Sipuncula (3 %) and Echinodermata (1 %).

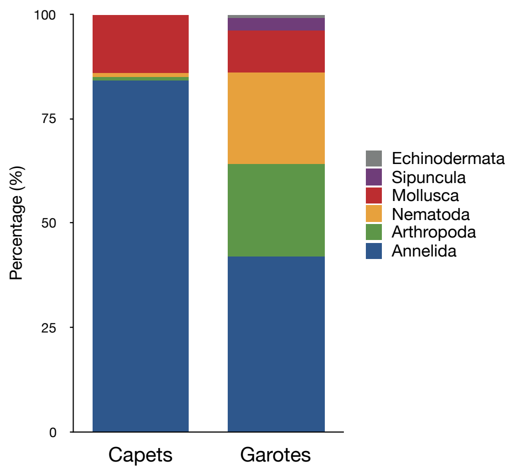


Figure 15. Abundance of infauna in Capets and Garotes.

Amphipoda was the only Arthropoda order in Capets, whereas in Garotes the most abundant were Hexanauplia (53.6 %) and Amphipoda (21.1 %) (Table 17). Bivalvia (100 %) was also the only Mollusca order in Capets, whereas in Garotes those were Bivalvia (74.8 %), Polyplacophora (13.7 %) and Gastropoda (11.2 %). Holothuroidea (45.6 %), Echinoidea (37.7 %) and Ophiuroidea (14.7 %) were the most abundant Echinodermata in Garotes.

Table 17. Abundance of infaunal phyla and families in Capets and Garotes.

Capets	%	Garotes	%
Annelida	84		42
Polychaeta	100	Polychaeta	100
Arthropoda	1		22
Amphipoda	100	Hexanauplia	53.6
		Amphipoda	21.1
		Decapoda	7.3
		Isopoda	6.8
		Tanaidacea	4.7
Echinodermata	0		1
		Holothuroidea	45.6
		Echinoidea	37.7
		Ophiuroidea	14.7
		Asteroidea	2
Mollusca	14		10
Bivalvia	100	Bivalvia	74.8
		Polyplacophora	13.7
		Gastropoda	11.2
Nematoda	1		22
Sipuncula	0		3.0

4.2.2. Ecological evaluation of infauna

Significant differences were found on species richness and diversity index Shannon-Wienner between Capets and Garotes (Table 18).

Table 18. ANOVA results of biodiversity of the infauna in Capets and Garotes. *: significant differences ($p<0.05$).

Parameters	df	*F* value	Pr (>F)
Species richness (Margalef)	1	132.25	0.0003264*
Pilou's evenness (J')	1	3.8311	0.1219
Shannon-Wienner (H')	1	50.297	0.002087*

MDS (Figure 16) showed a clear separation between the two studied fishing grounds, with 60 % of similarity in the stations of each fishing ground. GDR1 and GDR3 stations in Garotes showed 70 % of similarity, whereas CDR3 and CDR2 stations in Capets represented 80 % of similarity between them.

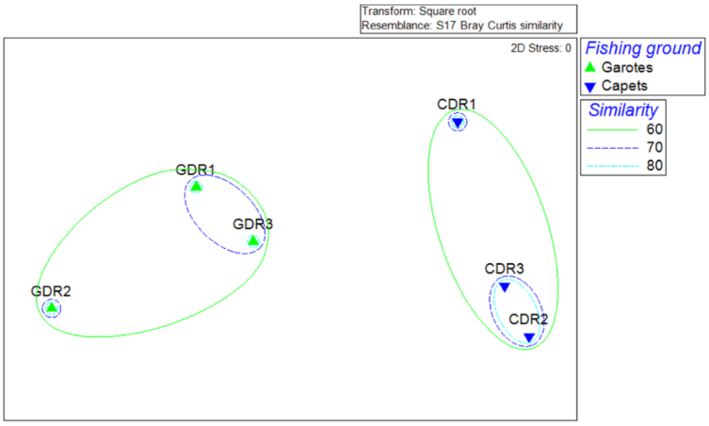


Figure 16. MDS analysis for the abundance of infauna in Capets (CDR1, CDR2 and CDR3) and Garotes (GDR1, GDR2 and GDR3).

Results of SIMPER analysis (Table 19) showed a high average dissimilarity value between the two fishing grounds (84.16 %). Polychaeta, Nematoda and Bivalvia presented a high contribution to the similarity in Garotes, of 27.64, 13.16 and 11.72 % respectively. Polychaeta (78.58 %) and Bivalvia (17.61 %) were the most abundant phyla in Capets.

Polychaeta (18.07 %), Nematoda (15.18 %), Hexanauplia (9.21 %) and Bivalvia (8.09 %) were the phyla that contributed most to the dissimilarity between the two fishing grounds.

Table 19. Abundance SIMPER analysis for the infauna in Capets and Garotes (a) and between them (b). Fishing ground was selected as a factor. Average abundance in individuals per hectare (Av.Abund), average similarity/dissimilarity contribution (Av.Sim/Av.Diss), similarity contribution in percentage (Contrib.) and accumulated similarity contribution in percentage (Cum.) was showed.

(a)

	Av.Abund (ind m^{-2})	Av.Sim	Contrib%	Cum.%
Garotes Av. similarity: 68.71				
Polychaeta	11.97	18.99	27.64	27.64
Nematoda	7.97	9.04	13.16	40.80
Bivalvia	5.08	8.05	11.72	52.52
Hexanauplia	5.16	4.27	6.21	58.73
Amphipoda	3.66	4.22	6.14	64.87
Polyplacophora	2.15	3.13	4.56	69.43
Decapoda	2.20	2.78	4.05	73.48
Capets Av. similarity: 74.62				
Polychaeta	2.92	58.64	78.58	78.58
Bivalvia	1.04	13.14	17.61	96.18

(b)

	Group Garotes Av. Abund (ind m^{-2})	Group Capets Av. Abund (ind m^{-2})	Av. Diss	Contrib%	Cum.%
Capets and Garotes Av. dissimilarity 84.16					
Polychaeta	11.97	2.92	15.21	18.07	18.07
Nematoda	7.97	0.20	12.78	15.18	33.25
Hexanauplia	5.16	0.00	7.75	9.21	42.45
Bivalvia	5.08	1.04	6.81	8.09	50.54
Amphipoda	3.66	0.31	5.25	6.23	56.78
Sipuncula	2.66	0.00	4.86	5.77	62.55
Polyplacophora	2.15	0.00	3.61	4.29	66.83
Decapoda	2.20	0.00	3.55	4.22	71.05

4.3. Quality of the two fishing grounds

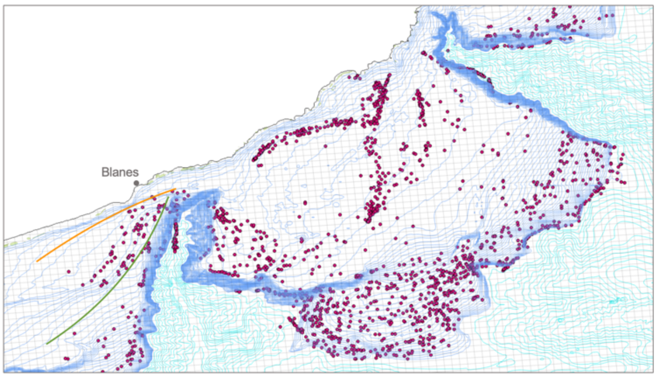
4.3.1. Fishing effort seasonality in Capets and Garotes

Vessel Monitoring System (VMS) are used to control fleet movements but also to estimate the spatial and seasonal fishing effort. Figure 17 shows VMS data of 28 trawlers from Blanes between 2012 and 2014. Only VMS positions with speeds below 4 knots were considered because this corresponds the speed of vessels when fishing (García de Vinuesa, 2018; Muntadas, 2015). Fishing effort was estimated with the equation (3) and represented on a grid with a cell size of 1 km^2, where $NVMS_i$ is the number of VMS points of each vessel per cell in a specific month and GT_i is the GT value of each vessel (García de Vinuesa, 2018).

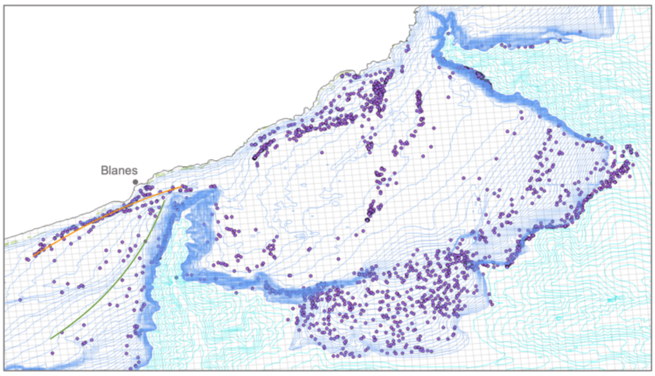
$$\text{Fishing effort} = \sum_i NVMS_i \times GT_i \qquad (3)$$

We analysed as an example of seasonality three months: April, September and November. Capets showed similar fishing effort during the three months. Garotes presented similar fishing effort in September and November mainly due to the fishing of the target species *Mullus surmuletus,* whereas in April no fishing effort was found.

(a) April



(b) September



(c) November

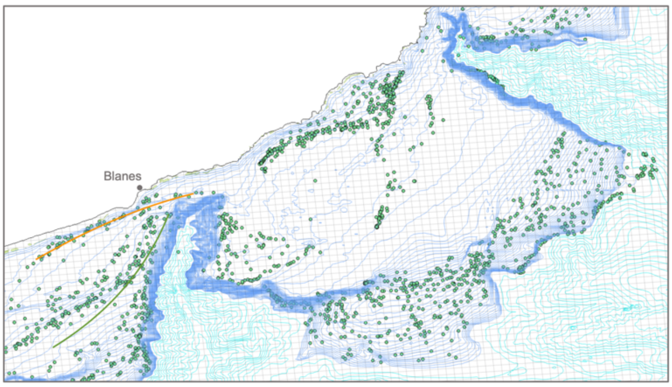


Figure 17. Fishing effort distribution in Capets (green) and Garotes (orange) on April (a), September (b) and November (c).

4.3.2. Characterization of the invertebrate discarded fraction

In the 4.1.1 section, classification of discarded fisheries including cartilaginous, fish and invertebrate was performed. In this section analysis of the invertebrate discarded fraction was studied in order to compare it with both the phyla found in the infauna sampling and diet of commercial species.

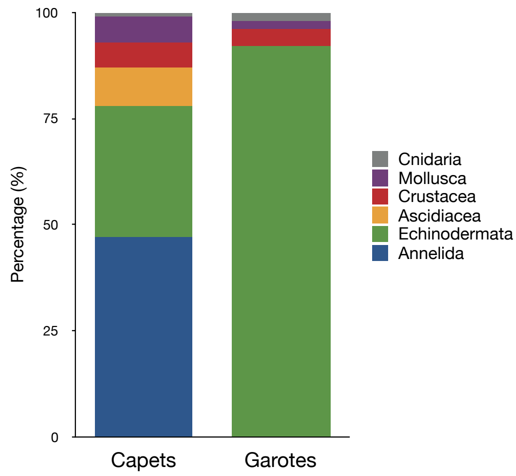


Figure 18. Abundance of discarded invertebrate in Capets (a) and Garotes (b).

Abundance of discarded invertebrate species in Capets and Garotes is shown in Figure 18. Annelida (47 %) was the dominant phylum in Capets, followed by Echinodermata (31 %), Ascidiacea (9 %), Crustacea (6 %), Mollusca (6 %) and Cnidaria (1 %). Echinodermata (92 %) was the most abundant phylum in Garotes.

Table 19. Abundance of discarded invertebrates in Capets and Garotes.

Capets	%	Garotes	%
Echinodermata	31		92
Ophiura texturata	65.98	*Echinus melo*	62.7
Anseropoda placenta	7.2	*Antedon mediterranea*	15.7
Echinaster sepositus	6.2	*Ophiotrix fragilis*	15.7
Echinus melo	5.3	*Echinaster sepositus*	3
Astropecten irregularis	3.4	*Cidaris cidaris*	1.4
Crustacea	6		4
Pagurus prideauxi	48.7	*Dardanus arrosor*	72.7
Dardanus arrosor	14.4	*Macropipus tuberculatus*	27.3
Pisa nodipes	10.7		
Macropipus tuberculatus	8.8		
Macropodia spp.	5.9		
Mollusca	6		2
Cumbracum cumbracum	60.9	*Loligo vulgaris*	100
Illex coindetii	19.3		
Sepia elegans	7.3		
Sepietta oweniana	3.3		
Calliostoma granulatum	2.8		
Chlamys opercularis	2.8		
Cnidaria	1		2
Pennatula phosphorea	31.1	*Pteroides spinosum*	100
Alcyonium palmatum	24.2		
Pteroides spinosum	23.6		
Calliactis parasitica	21.1		
Ascidiacea	9		0
Ascidia sp1	49.7		
Microcosmus sulcatus	20.3		
Ascidia mentula	13		
Diazona violacea	10.9		
Ascidia sp2	3.6		
Annelida	47		0
Onuphidae	98		
Aphrodita aculeata	2		

Biomass of discarded invertebrate species in Capets and Garotes is shown in Figure 19. Echinodermata (61 %) and Ascidiacea (18 %) were the main groups in weight of the invertebrate discarded fraction in Capets, whereas in Garotes those were Echinodermata (86 %) and Crustacea (13 %).

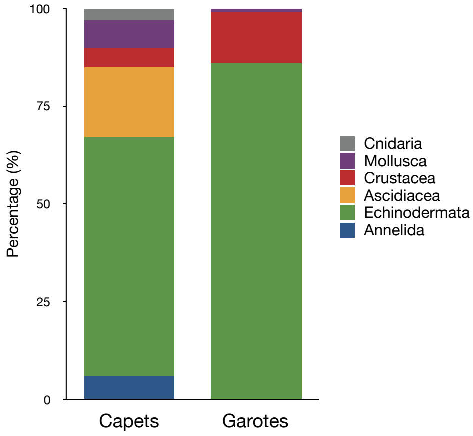


Figure 19. Biomass of discarded invertebrate species in Capets and Garotes.

Table 20. Abundance of discarded invertebrate species in Capets and Garotes.

Capets	%	Garotes	%
Echinodermata	61		86
Echinus melo	40.8	*Echinus melo*	91.2
Astropecten aranciacus	22.5	*Holothuria forskali*	3.9
Ophiura texturata	10.6	*Echinaster sepositus*	2.2
Echinaster sepositus	8.5	*Ophiotrix fragilis*	0.9
Marthasterias glacialis	4.9	*Cidaris cidaris*	0.8
Crustacea	5		13
Dardanus arrosor	49.8	*Dardanus arrosor*	95.9
Pagurus prideauxi	28.5	*Macropipus tuberculatus*	4.1
Macropipus tuberculatus	8.8		
Pisa nodipes	6.7		
Pagurus alatus	2.4		
Mollusca	7		1
Cumbracum cumbracum	67.6	*Loligo vulgaris*	100
Illex coindetii	22.4		
Sepia elegans	5.7		
Allotheuthis sublata	1.5		
Chlamys opercularis	1.2		
Cnidaria	<1		<1
Lytocarpia myriophyllum	42.1	*Pteroides spinosum*	100
Nemertesia ramosa	18.9		
Alcyonium palmatum	18.6		
Pennatula phosphorea	13		
Pteroides spinosum	3.1		
Ascidia	18		0
Ascidia sp1	52.8		
Microcosmus sulcatus	23		
Diazona violacea	13		
Ascidia mentula	9.6		
Ascidia sp2	1,2		
Porifera	3		0
Porifera sp 1	74		
Axinella polypoides	23.2		
Suberites sp	2.7		

Annelida	6	0
Onuphidae	96.4	
Aphrodita aculeata	3.6	

4.3.3. Diet of commercial species subjected to benthic communities

Arthropoda (53 %) and Mollusca (21 %) were the main phyla in Capets (Figure 20), followed by fish (12 %), Annelida (10 %) and Echinodermata (5 %). Decapoda (28.1 %), Amphipoda (20.3 %) and Mysidiacea (17.2 %) were the main Arthropoda classes. Cephalopoda (36 %), Bivalvia (28 %) and Gastropoda (24 %) were the main Mollusca classes.

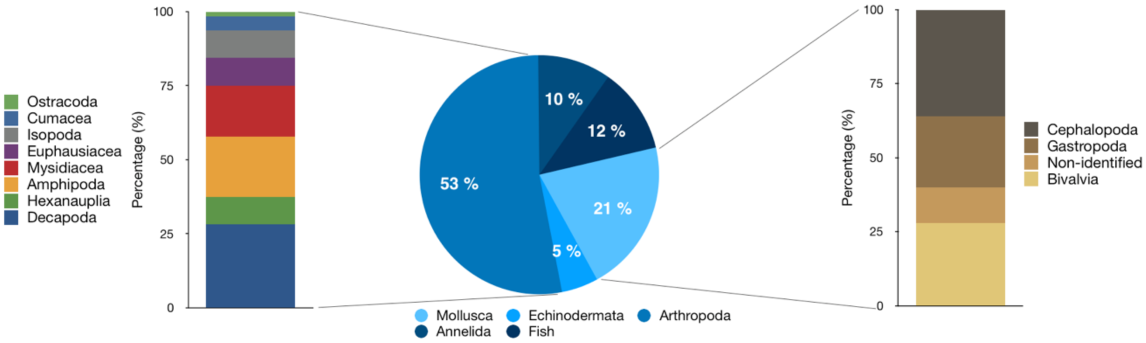


Figure 20. Diet of commercial species in Capets.

In Garotes Arthropoda (46 %) and Mollusca (27 %) were the main phyla, followed by fish (17 %), Annelida (6 %) and Echinodermata (4 %) (Figure 21). Decapoda (36.4 %), Mysidiacea (22.7 %) and Hexanauplia (13.6 %) were the main Arthropoda classes. Cephalopoda (36 %), Bivalvia (28 %) and Gastropoda (24 %) were the main Mollusca classes.

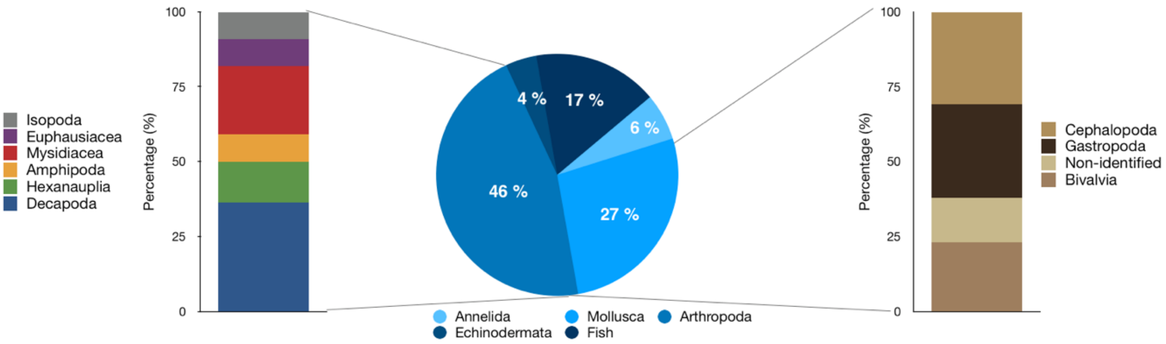


Figure 21. Diet of commercial species in Garotes.

Relationship between diet of commercial species, infaunal and invertebrate discarded organisms in Capets and Garotes is shown in Table 21. Diet of commercial species in Capets was composed mainly of Arthropoda (53 %), Annelida (10 %) and Mollusca (25 %). Infaunal and discarded organisms found in this fishing ground were composed mainly of Annelida and Mollusca, but Arthropoda showed a low fraction of infauna (1 %) and discards (6 %). In Garotes diet of commercial species was composed mainly of Arthropoda (45.8 %), Mollusca (27 %) and Annelida (6.3 %). Infaunal organisms were composed mainly of Annelida (42 %), Arthropoda (22 %), Nematoda (22 %) and Mollusca (10 %) and discarded ones were mainly Echinodermata (92 %).

Table 21. Percentage of infauna, invertebrate discards and diet of commercial species in Capets and Garotes for the studied phyla and families.

	Capets			Garotes		
	Infauna	Invertebrate discards	Diet	Infauna	Invertebrate discards	Diet
Annelida	84	47	10	42	0	6.3
Polychaeta	100	0	0	100	0	0
Arthropoda	1	6	53	22	4	45.8
Hexanauplia	0	0	9.4	53.6	0	13.6
Amphipoda	100	0	20.3	21.1	0	9.1
Decapoda	0	100	28.1	7.3	100	36.4
Isopoda	0	0	9.4	6.8	0	9.1
Tanaidacea	0	0	0	4.7	0	0
Echinodermata	0	31	5.0	1	92	4.2
Holothuroidea	0	0	0	45.6	0	0
Echinoidea	0	0	0	37.7	0	0
Ophiuroidea	0	0	0	14.7	0	0
Asteroidea	0	0	0	2	0	0
Mollusca	14	6	25	10	2	27
Bivalvia	100	0	28.0	74.8	0	23.1
Polyplacophora	0	0	0	13.7	0	0
Gastropoda	0	0	24	11.2	0	30.8
Nematoda	1	0	0	22	0	0
Sipuncula	0	0	0	3	0	0

4.3.4. Productivity of Capets and Garotes

Economic value and biomass of commercial species in September and November in Capets and Garotes is shown in Figure 22, in order to compare productivity in both fishing grounds. September and November were selected because there is trawling activity on both fishing grounds due to dynamics of fishing seasonality and presence of target species in both fishing grounds.

Merluccius merluccius, Mullus barbatus and *Lophius* spp. were the species with higher economic value in Capets, whereas in biomass the most important were *Mullus barbatus, Merluccius merluccius, Lophius* spp. and *Trachurus* spp. In Garotes the species that showed a higher commercial value was mainly *Mullus surmuletus*, whereas in biomass those were *Mullus surmuletus* and *Pagellus erythrinus*.

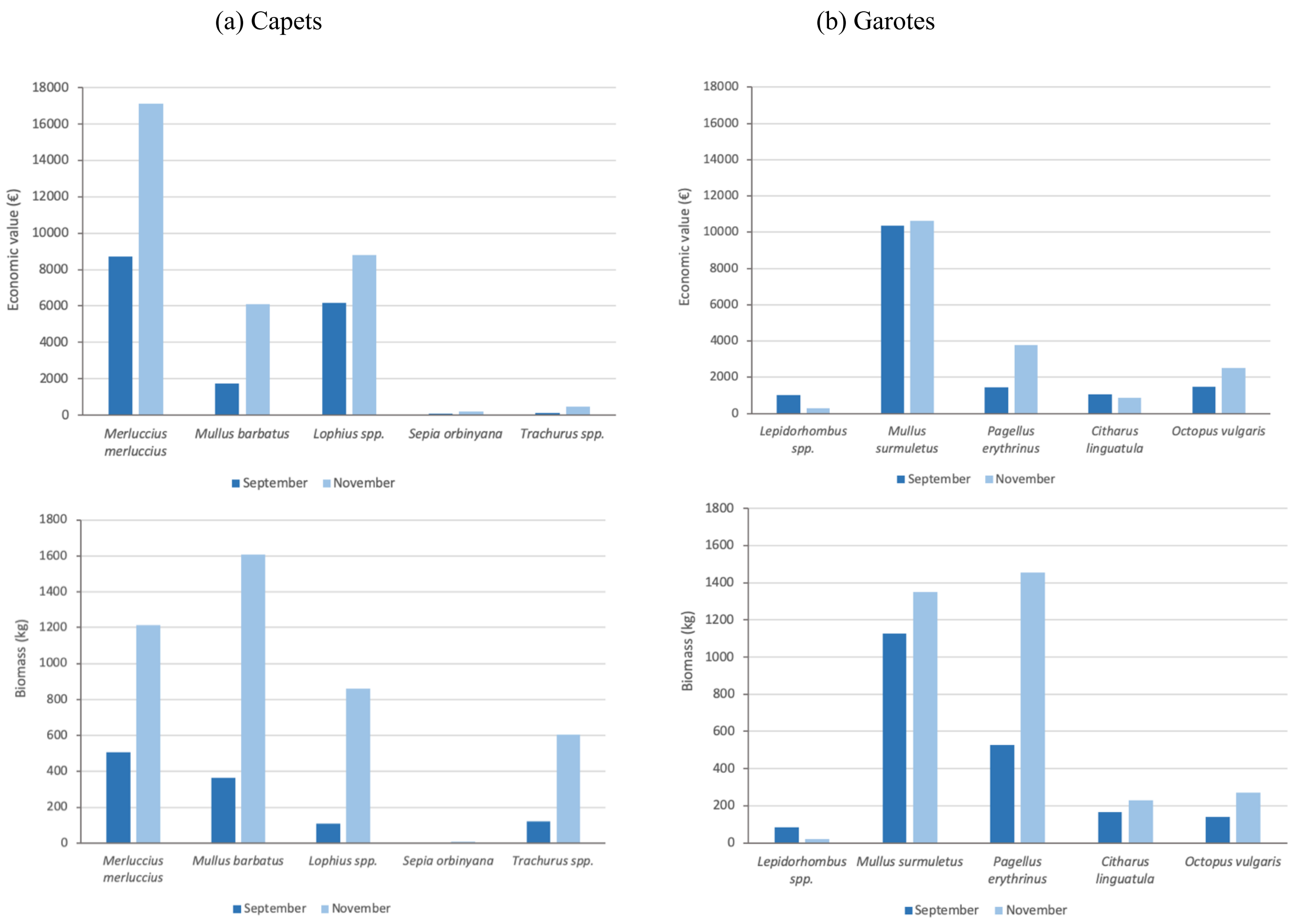


Figure 22. Total biomass and economic value of target species in Capets (a) and Garotes (b).

5. Discussion

The present work studied the relationship between the fishing activity of the trawling fleet in the two selected fishing grounds of Blanes (Catalan Coast) and its impact on exploited benthic habitats and communities. Abundance and biomass of discarded fraction were studied, in addition to abundance of infaunal organisms. Conservation measures and management considerations were proposed in order to protect maërl ground in the NW Mediterranean.

In the analysis of the fishing activity, bottom trawling in Capets and Garotes showed a high percentage of regulated and non-regulated discarded fraction in abundance (84 and 87 % respectively) and biomass (73 and 78 % respectively). Discarded fraction was mainly due to the absence or low commercial value of the species or because they did not reach the minimum legal size. Although this fraction is variable depending on the depth, in the present study the discarded fraction represented on average more than two thirds of the total catch, whereas in the study of Sánchez et al. (2004) trawl discards represented one third. The new EU legislation obligates to land all catches of discarded regulated fraction, and this could present negative consequences such as the creation of a market for the incidental catches (Bellido et al., 2011) and the decrease of research focused on studying both increasing fishing selectivity gears and reducing their impact on benthic habitats (Demestre et al., 2018).

Mediterranean fisheries are characterized by clear seasonality (Halley and Stergiou, 2005) as seen in the studied fishing grounds. Fishing seasonality is mainly due to the fact that fishers follow the biological cycle of target species (Demestre et al., 1997). In Capets the trawling ban takes place in February whereas in Garotes is from April to August and there is also a fishermen's agreement to stop fishing on Fridays. In some cases trawl fleet aggregates in recruitment zones of some species, as seen in Garotes, which has led to an overexploitation of commercial stocks (Colloca et al., 2013). In Garotes the main target species is *M. surmuletus* and recruitment of juveniles starts in September (Figure 3), which corresponds to the beginning of fishing activity after the ban. Therefore, fishing bans should protect recruitment period of the target species (Demestre et al., 2008) because otherwise the positive effects of this management actions are minimized (Muntadas, 2015).

Both studied fishing grounds presented invertebrate discarded species that were related to commercial species and benthic habitat. Both Capets and Garotes showed higher regulated discards because of the abundance of *Boops boops,* a low commercial value species that is part of the unwanted catch (Sánchez et al., 2004). Regarding biomass, 74.4 % of discarded invertebrate in Garotes is due to the echinoderm *Echinus melo.* As echinoderms have a key role on benthic communities regulating community structure and allowing the survival of other organisms, seabed areas with abundant echinoderms should be protected (Petović and Krpo-Ćetković, 2016).

For the ecological evaluation, the comparison of species richness and diversity of the two fishing grounds is important in order to design conservation areas and strategies that maintain biodiversity. In this study higher species richness in abundance and biomass and higher diversity in abundance was found in Garotes, which presents a maërl bottom, and therefore shows a higher ecological importance than Capets. Marine biodiversity provides Goods and Services that benefit human societies (Beaumont et al., 2007). These Goods and Services are focused on the fish population that present economic value, however species with non-commercial value also play an active role in the maintenance of marine ecosystems (Holmlund and Hammer, 1999).

In this study *M. surmuletus* and *P. erytrhinus* were the main commercial species in Garotes, which have also been found in other maërl habitats such as in the Maltese Islands (central Mediterranean) and in the Balearic Islands (western Mediterranean) (Barberá et al., 2012). *M. surmuletus* and *P. erytrhinus* are bottom-foraging fish (Sciberras, 2009), so protection of the maërl would benefit them as they might found more food. Also, maërl bed in Garotes has a great abundance of the sea urchin *Sphaerechinus granularis* and it has been demonstrated that they are vulnerable to trawling, which causes a negative impact by reducing this community (de Juan et al., 2007). In Capets *M. merluccius* was one of the main target species but it was also a target species in other muddy bottoms located in Mallorca (Mediterranean) (Alemany and Álvarez, 2003) and in the Bay of Biscay (Atlantic) (Woillez et al., 2007). Other target species in this fishing ground was *M. barbatus,* which also corresponded to target species in other muddy bottoms located in a gulf of western Greece (Mediterranean) (Vasssilopoulou and Papaconstantinou, 1993) and in the Izmar Bay (Aegean Sea) (Özbilgin et al., 2004).

Biomass of target species in both fishing grounds was similar, but Capets showed a higher economic value of the species (40,420 €) than that of Garotes (33,480 €). Even though Garotes does not show a higher income, it presents a great ecological value as mentioned before. Hence, its protection would increase the complexity of the ecosystem achieving a Good Environment Status (GES), which could benefit fisheries by providing stable and sustainable Goods and Services.

Diet of commercial species for the two fishing grounds was studied in order to establish a relationship between these species and benthic communities that feed them, such as infauna. Main target species in Capets were *M. barbatus* and *M. merluccius,* whereas in Garotes those were *M. surmuletus* and *P. erythrinus.* Diet of target species was composed mainly of Arthropoda in both Capets (53 %) and Garotes (45.8 %). Arthropoda showed low abundance in the infauna (1 %) and in the discarded fraction (6 %) of Capets, but higher abundance in the infauna and discards of Garotes (22 and 4 %, respectively). Gastropoda and Bivalvia are the main Mollusca that constitute the diet of target species. They have been found in a low percentage in the area of study because they are highly vulnerable to trawling (de Juan et al., 2007). Several studies have observed in trawled areas aggregations of scavengers and the elimination of filter-feeding species, the latter being the more vulnerable (Groenewold and Fonds, 2000). Annelida (84 %) and Mollusca (14 %) were the most abundant infaunal phyla found in Capets, whereas the main discarded invertebrates from fishing were Annelida (47 %), Echinodermata (31 %) and Ascidiacea (9 %). Annelida were mainly deposit-feeders and presented low resilience and high vulnerability (de Juan et al., 2007). Polychaeta (Annelida), which is part of the *M. surmuletus* diet (Serrano et al., 2003), was found in both fishing grounds. Other species found such as the crustacean *Pagurus prideauxi* and the echinodermata *Astropecten irregularis* presented lower vulnerability because of the hard-shells, and hard external body respectively, as it is shown in de Juan et al. (2007).

Several studies have demonstrated that indirect effects of trawls on benthic habitats cause negative consequences on the ecosystem structure (Botsford et al., 1997; Estes et al., 1998), in both infaunal and discarded invertebrate organisms. In Garotes Annelida (42 %), Arthropoda (22 %) and Mollusca (10 %) were the most abundant infaunal phyla found, whereas the main discarded invertebrates from fishing was Echinodermata (92 %). These differences were mainly due to the fact that infaunal samples were taken with a dredge and discarded ones were taken with trawl fishing. On the other hand, there may be differences between groups due to depth, as the infaunal sampling was carried out between 50 and 62 m, whereas fishing hauls were carried out between 67 and 87 m. The study of García de Vinuesa et al. (2018) found that hauls in Garotes carried out at lower depths, where fishing intensity was very low or absent from April to August, showed maërl rhodoliths, whereas in the hauls of deeper areas and constant fishing effort throughout the year rhodoliths were not found. This explains the high presence of organisms more vulnerable to trawling such as Polychaeta (Annelida) at lower depths (de Juan et al., 2007), whereas in higher depths mainly *Echinus melo*, *Antedon mediterranea* and *Ophiotrix fragilis* from Echinodermata were found. Although *Echinus melo* (62.7 %) was found to be susceptible of being damaged by trawling with 63 % broken in the study of Hall-Spencer et al. (1999), the food inputs such as inorganic material from the Tordera River and the Blanes submarine canyon might favor its presence (Würtz, 2012).

The aim of this study is to highlight the ecological importance of maërl beds in the Mediterranean Sea, as it is shown in Barberá et al. (2003) and Hall-Spencer et al. (2003). In Garotes the high abundance (99 %) and biomass (97 %) of demersal species show the importance of the conservation of benthic ecosystems, as those species use maërl for many biological processes such as feeding, nursery, seeking refuge and spawning, among others (Auster and Langton, 1998; Grall, 2006; Kamenos et al., 2004;). Thus, in order to maintain good levels of exploitation of the target species' stocks, maërl habitats should be regulated and fishery management should be developed to achieve their conservation (Caddy, 1993). The protection of maërl habitat is very important for fisheries, because maërl beds support a highly diverse specific fauna and flora and European Commission's 'Habitats Directive' (Council Directive 92/43/EEC) protects two maërl-forming species: *Phymatolithon calcareum* and *Lithothamnion corallioides* (in Annex V priority species). In the Mediterranean, maërl bed communities have received very little attention although they are protected by the Annex I of 'Habitats Directive', and research and conservation have mainly focused on protecting seagrass meadows from the impacts of bottom trawling, with EU legislation protecting them (Council Directive 92/43/EEC) (Bordehore et al., 2000).

Although some projects have been developed with the aim to explain the necessity to protect maërl beds in the Mediterranean, such as BIOMAERL and UNEP-MAP (United Nations Environment Programme's Mediterranean Action Plan) (Sciberras, 2009), it is necessary that conservation and management strategies are applied as described in Barberá et al. (2003), because maërl beds present a great vulnerability and they are a very low renewable resource. In consequence, the prohibition of trawl gears on this bottom and the creation of Marine Protected Areas (MPAs) should be achieved. MPAs favor the growth, reproduction and recruitment of individuals and populations as well as the recovery and the increase of complexity of benthic communities (de Juan et al., 2011; Harmelin-Vivien et al., 2008; Tsikliras and Stergiou, 2007). According to Sala & Giakoumi (2017), MPAs allow communities to increase by over 600 % fish biomass, by over 25 % organism size and by 20 % species richness relative to adjacent unprotected areas.

Management fisheries in the Mediterranean are based on single stock assessment (Spagnolo, 2012). In order to reduce fishing impacts of trawling on benthic communities is necessary to establish an Ecosystem Approach to Fisheries (EAF), by which economy, society and environment are integrated in order to establish an environmental management system (Beaumont et al., 2007). As described in Muntadas (2015), creation of MPAs is a first step to achieve EAF in the Mediterranean. MPAs must have a minimum size in order to allow the ecosystem to recover and to present significant beneficial changes on target species, as several studies have shown a recovery and increase of complexity of benthic communities (de Juan et al., 2011). A network following ecological considerations would benefit Mediterranean fisheries, as most of the current ones have been established following socio-political decisions (Coll et al., 2012) and are located in rocky coastal areas. Therefore, deep and soft habitats from fishing grounds are not represented (Lloret et al., 2008). MPAs should be considered as a management tool of the Marine Spatial Planning (MSP), which main focus is to manage the multiple uses of the sea (Douvere, 2008). In this way, both fishing interests and conservationists are taken into account in order to contribute to a sustainable exploitation of marine ecosystems (Gaines et al., 2010; Salomon et al., 2011).

This study presents some limitations mainly related to sample size and replicas. For the fishing sampling, hauls from March, July and August in 2016 were analysed in Capets, and only hauls from March in Garotes. Hence, for more reliable results hauls from at least three months should be analysed in both fishing grounds. Also, species that live in schools can cause sample bias, such as *Trachurus* spp., which is not a target species in Garotes but in the moment of the haul a school of this species was caught, giving a high abundance (68.1 %) and biomass (62.8 %) in this fishing ground. For the infaunal sampling, as mentioned in Methodology (section 3), 2 out of 5 replicas of infaunal samples in the stations of Capets and Garotes were analysed in this work. Therefore, for more consistent results all 5 replicas should be analysed. Additionally, samples were obtained during October 2016, hence, for more significant results samples from at least three months should be analysed.

6. Ethical and sustainability considerations

For the sampling of fishing hauls and infaunal organisms, ethical and sustainability considerations were taken into account. Nevertheless, sampling was necessary to increase knowledge about the impact that trawlers cause in benthic communities. Fishing samples were obtained from commercial trawling activities following the same procedure of their daily activity.

7. Conclusions

1. The main commercial species in weight were *Triglidae, Lophius* spp. and *Sepia orbignyana* in Capets, whereas in Garotes those were *Zeus faber, Mullus surmuletus* and *Pagellus erytrhinus.*

2. The unregulated discarded fraction in weight was mainly due to *Echinus melo, Astropecten aranciacus* and *Spicara flexuosa* in Capets, whereas in Garotes those were *Spicara smaris* and *Echinus melo.* On the other hand, the regulated discarded fraction in Capets was mainly due to *Boops boops* and *Trachurus trachurus*, whereas in Garotes those were *Boops boops* and *Octopus vulgaris.*

3. The analysis of similarity using MDS and SIMPER confirmed that both fishing grounds were different, with a high average dissimilarity between them. In abundance, *Ophiura texturata* was the species that most contributed to the dissimilarity (6.26 %) and was present in Capets. It was followed by *Spicara smaris* (3.52 %) and *Echinus melo* (3.07 %), which were found in both fishing grounds. In biomass, *Ophiura texturata* (6.15 %)*, Cumbracum cumbracum* (4.96 %) and *Microcosmus sulcatus* (4.68 %) contributed most to the dissimilarity and were found in Garotes.

4. Garotes presented higher species richness and higher biodiversity of infauna than Capets. This suggests the protection of benthic communities from trawling activity in order to increase the complexity of the ecosystems, particularly of maërl habitat.

5. The main groups that constitute the diet of target species, *M. surmuletus* and *M. merluccius,* were found in low percentages, such as Arthropoda and Mollusca, because of their vulnerability to trawling. On the other hand, opportunistic families such as Polychaeta were found in higher abundance.

6. High species richness and biodiversity in the discarded fraction and infauna in Garotes, together with the presence of maërl in this fishing ground suggests that an MPA could be created in this area. This could help to avoid further habitat degradation and increase the biomass of target species in Garotes, which in turn would increase the income of this fishing ground.

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Annex

List of infaunal organisms and lists of commercial, regulated discarded and unregulated discarded species from fishing hauls were too long to fit in this work. Thus, the number of species considered for the previous analyses is shown in Table 1, for the hauls of Capets and Garotes. On the other hand, number of infaunal organisms of every station for both fishing grounds is shown in Table 2.

Table 1. Number of commercial, regulated discarded and unregulated discarded species of each haul of Capets and Garotes.

	Capets					Garotes	
	MA131	MA132	MA171	MA181	MA182	MA 231	MA 232
Commercial species	11	11	18	12	11	13	14
Regulated discarded species	5	6	6	6	8	6	7
Unregulated discarded species	35	37	31	32	34	10	12

Table 2. Number of infaunal organisms of each station in Capets and Garotes.

	Capets			Garotes		
Phylum/Class/Order	CDR1	CDR2	CDR3	GDR1	GDR2	GDR3
Actiniaria	0	0	0	0	0	0
Amphipoda	0	0	1	28	98	11
Arachnida	0	0	0	1	13	0
Asteroidea	0	0	0	0	0	1
Bivalvia	21	2	4	62	119	50
Branchiopoda	0	0	0	5	0	0
Crinoidea	0	0	0	0	0	0
Cumacea	2	0	0	4	11	4
Decapoda	0	0	0	10	31	5
Echinoidea	0	0	0	5	1	9
Euphausiacea	0	0	0	0	0	0
Foraminifera	0	0	0	7	13	2
Gastropoda	0	0	0	9	24	3
Hexanauplia	0	0	0	13	300	23
Holothuroidea	0	0	0	13	7	3
Isopoda	0	0	0	8	34	3
Nematoda	2	0	0	42	439	163
Nemertea	0	0	0	3	0	0
Ophiuroidea	0	0	0	4	2	0
Ostracoda	0	0	0	0	5	0
Polychaeta	37	63	74	373	630	286
Polyplacophora	0	0	0	17	20	6
Porifera	0	0	0	0	0	0
Pycnogonida	0	0	0	0	1	0
Scaphopoda	0	0	0	1	0	0
Sipuncula	0	0	0	66	6	8
Tanaidacea	0	0	0	8	18	5