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Métiers, effort and catches of a Mediterranean small-scale coastal fishery: The case of the Côte Bleue Marine Park

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Abstract:

The overexploitation of fishery resources has led to a major fisheries crisis. In this context, artisanal fisheries, and in particular small-scale coastal fisheries, appear as relevant alternatives for a sustainable use of coastal resources. Marine Protected Areas (MPA) are more and more used as management tools for these fisheries, as protection effects and targeted access regulations may benefit to commercial fishers. Managers and scientists need then quantitative information not only to adapt their management to the fishing activity present on their territory, but also to estimate the effects of MPA management on it. This study provides catch and effort estimates that are essential for appraising and managing the artisanal fishery in the Côte Bleue Marine Park (CBMP), a French Mediterranean MPA including two No-Take Zones of different age and size. A field protocol was defined and implemented between July 2009 and June 2010 within the CBMP. Seven métiers were identified and characterized by target species, gear type, fishing grounds and fishing periods. During the one-year studied period, 3512 fishing trips and 4645 fishing operations were performed by 30 active boats in the Côte Bleue fishing territory, amounting to 9500 km of immersed nets. In total, approximately 130 tons of catch were landed in the six CBMP harbors, out of which 58% depend on the three main species caught on the Côte Bleue: hake (*Merluccius merluccius*), gilthead seabream (*Sparus aurata*) and common sole (*Solea solea*). The presented methodology could be part of a long term monitoring requiring close collaboration with local fishers. It enables adaptive management with respect to changes in fishing pressure (from inside and outside the MPA) that may impact the environment and its resources

Keywords: Small-scale coastal fisheries ; Marine Protected Areas ; Métiers ; Fishing effort and catches

1. Introduction

Artisanal fisheries - or small-scale fisheries -, are considered as potentially sustainable solutions for the exploitation of fisheries resources (Matthew, 2003; Pauly, 2006). They employ twenty-four times more fishers than large-scale fisheries, for an equivalent annual catch for human consumption (Jacquet and Pauly, 2008). Total annual fuel oil consumption by these fisheries is much lower and discards are small compared to large-scale fisheries (Kelleher, 2005; Jacquet and Pauly, 2008). Artisanal fishing fleet estimates amount to more than 80% of the worldwide fleet and of the European and Mediterranean fleets (European Commission, 2002; Guyader et al., 2007).

In Mediterranean Sea, small-scale coastal fisheries (SSCF) mainly operate on the continental shelf (0–200m depth), in areas which can be reached within a few hours from the home harbors (Farrugio and Le Corre, 1993; Colloca et al., 2004; Tzanatos et al., 2005, 2006; Duarte et al., 2009; Forcada et al., 2010; Maynou et al., 2011). Boats can be active fully or part-time of the year, and their activity is characterized by a diverse array of métiers (or fishing tactics) which can be defined as target species, fishing gears, grounds and techniques, with frequent seasonal and spatial changes to adapt to varying resource availability (Colloca et al., 2004; Forcada et al., 2010). Métiers provide a synthetic description of fishing activities which is useful for understanding the spatio-temporal patterns of effort allocation and the resulting catches (Biseau, 1998; Pelletier and Ferraris, 2000).

In 2010, 88% of the 1120 active boats of the French Mediterranean fleet (excluding Corsica) were equal or smaller than 12 m and mostly fished within 3 nautical miles (nmi; ~5.6 km) from the shore. The main gears were passive ones: 64% of vessels use nets and 23% use hooks e.g. longline and fishing rod (see Leblond et al. (2012) for details). Like most fisheries worldwide, the French Mediterranean SSCF have experienced a significant decrease (53%) in boat number since 1983 (Leonardi et al., 2009).

Published studies concerning Mediterranean SSCF mainly described fleets and their activity through the identification and the description of métiers (Colloca et al., 2004; Tzanatos et al., 2005, 2006; Duarte et al., 2009; Forcada et al., 2010). Due to the complexity of the activity, very few studies quantified effort and catch (Merino et al., 2008; Rocklin, 2010; Maynou et al., 2011), particularly in relation to Marine Protected Areas (MPA). Yet, contribution to the sustainability of adjacent fisheries is often an explicit management goal for MPAs (Claudet and Pelletier, 2004). Devising appropriate measures for this management goal

and tracking progress toward its achievement requires quantitative data at relevant spatial and temporal scales.

The objective of this paper is to characterize the activity and the production of a SSCF located in a French Mediterranean MPA, the Côte Bleue Marine Park (CBMP), and strongly involved in the establishment and management of this specific MPA. We paid particular attention to the seasonal patterns of effort and catch, based on a year-round survey of landing, effort and fisher-related data.

In a first step, the main métiers were characterized from multivariate analyses of landing data on target species, gear used, fishing period and fishing area visited during the fishing trips. Effort and catch were then estimated for the métiers identified, consistently with the complex structure of the sampling protocol. We finally discussed the outcomes in the light of the factors influencing métiers selection and the spatial and seasonal patterns of fishing activity in the MPA.

2. Material and methods

2.1 Study area

The CBMP is an MPA located in the north-western Mediterranean Sea (Provence, France; Fig. 1). This 98.7 km² MPA includes two No-Take Zones (NTZs), namely Carry-le-Rouet (0.85 km²) and Cap Couronne (2.1 km²), respectively established in 1983 and 1996 with the involvement of the local fishers' guilds (*prud'homies des pêcheurs*). In the rest of the CBMP, fishing regulations are similar to those enforced outside the MPA, i.e SSCF is managed through European Union regulations (e.g. maximum fishing net length), French national regulations (e.g. minimum catch size and trawl ban), and local regulations (e.g. minimum mesh size) as established by the *prud'homies* of Marseille and Martigues. According to French regulations, trawling is banned within 3 nautical miles from the shore (an area which includes the MPA). The CBMP holds an administrative concession for establishing artificial reefs within its boundaries; most of these were designed to prevent from illegal trawling, thereby contributing to the enforcement of the 3 nmi trawling ban. The CBMP coordinates the management of the Natura 2000 Site of Community Importance "Côte Bleue Marine" since 2009 (FR9301999, 18928 ha; Fig. 1)

Within both the Natura 2000 site and the MPA (including the two NTZs), habitats are mainly characterized by *Posidonia oceanica* seagrass meadows and rocky substrata between 0 and 30 m, sandy bottom from 30 m with patchy coralligenous banks between 20 and 65 m.

110 Six fishing harbors are located within the MPA: Carro, Sausset-les-Pins, Carry-le-Rouet,
111 La Redonne, Méjean and Niolon (Fig. 1). The fishing territory of Côte Bleue (~13 km²) was
112 defined from the available spatial information (Fig. 1). Based on the data collected, it
113 encompasses more than 95% of the fishing grounds observed, and represents the relevant
114 scale for the CBMP managers.
115
116 **2.2 Data collection**
117 Register fleet data (main gear, overall length, engine power and gross tonnage of the
118 vessels) were obtained through the registries of IFREMER and maritime office. We focused
119 on the boats using nets as main gear. The boats either targeting urchins and coral using scuba
120 diving or exclusively fishing sparids from long-line were not considered in this study, as their
121 activity was marginal compared to the rest of the fishery (only three boats).
122 Catch and effort data were collected over a year-round survey between July 2009 and
123 June 2010 in all harbors of the Côte Bleue area. During this period, a sample of fishers of the
124 active boats and from the six fishing harbors (amounting to 53% of the active fleet) were
125 interviewed approximately three times per month to collect catch and effort data relative to
126 their most recent fishing trips (i.e. over the last 6 days). Gear, target species and fishing
127 ground were recorded for each fishing operation of each fishing trip (a fishing trip usually
128 encompassing several fishing operations and several distinct métiers). Over the study period
129 and within the fishing territory of the Côte Bleue (Fig 1), 1017 fishing trips and 1667 fishing
130 operations were described corresponding to 139 observation days (35 days per harbor on
131 average). In addition to information on last week trips, the overall number of fishing trips
132 realized by each fisher during the study period was recorded.
133 Fishing grounds were plotted on a background map by the fishers, and were
134 subsequently entered into a Geographical Information System (ArcGIS 9.3® ESRI software)
135 for a total of 206 fishing spots. The habitat corresponding to each fishing spot was then
136 determined from Astruch et al. (2011); habitat categories are sandy substrate, rocky habitat,
137 and *Posidonia oceanica* meadows. Depth and distance to the shore were also used to describe
138 fishing ground.
139 Landings (total weight and weight per species or group of species) were recorded for a
140 random subsample of fishing operations representing the different métiers in each observation
141 day.

142 For 47% of the active fleet, catch and effort could not be monitored over the whole
143 study period. Information about the gears used, the species targeted and the fishing grounds
144 exploited during the study period were collected from several interviews with their skippers.
145
146 **2.3 Data analysis**
147 The number of boats and their characteristics (overall length, engine power and gross
148 tonnage) were calculated for Carro, Sausset-les-Pins and Carry-le-Rouet. The rest of the
149 harbors (La Redonne, Méjean and Niolon) have been merged due their small size and the
150 small distance between them.
151 Main métiers were characterized from the method developed by Pelletier and Ferraris
152 (2000), which involves a multiple correspondence analysis (MCA) followed by a Hierarchical
153 Cluster Analysis (HCA) based on a Ward's criterion. Resulting clusters grouped fishing
154 operations with similar gear, target species, season(s) and fishing ground(s) (see cited paper
155 for details), and were thus considered as métiers. Fishing operations were described by four
156 categorical variables: declared target species (7 categories), net type (3 categories), season (4
157 categories), and depth (3 categories; see Leleu (2012) for details). For any explanatory
158 variable, a category was considered to significantly characterize a cluster when the frequency
159 of the category in the cluster was significantly higher than the corresponding frequency in the
160 overall data set (Student test, 95% significance level).
161 Declared target species amounting to less than 1% of the sampled fishing operations
162 were not considered in the analysis. In practice, this corresponded to five extra species
163 (cuttlefish, common dentex, angler, Atlantic bonito and sardine) which were incidentally
164 caught by the fishery (37 fishing operations i.e. 2.2% of fishing operations). Each cluster was
165 further defined by fishing period, main habitats, depth and distance to the shore, soak time
166 and stretched mesh size from the characteristic of the fishing operations included in the
167 cluster.
168 Fishing effort was estimated consistently with the stratified two-stage sampling
169 protocol (Cochran, 1977). Within the Côte Bleue fishing territory, the annual number of
170 fishing trips was estimated per fishing boat and then raised at the scale of the fishing fleet.
171 The mean number of fishing operations and mean length of net set per métier were also
172 estimated, first per fishing boat and then raised at the fleet scale for the whole fishing period
173 of the given métier. Estimates over fishing period had to account for the fact that métiers may
174 be practiced by some boats only during some months of the fishing period. Thus to avoid
175 fishing effort overestimation, elevations by métier were based on the cumulated number of

active months by boat within the fishing period of the métier. A month was considered as active for a given boat when the boat realized at least one fishing trip during that month. Overall estimates of the number of fishing operations and of net length were obtained by summing over métiers. For each estimate, 95% Confidence Intervals (CI) were calculated under a Gaussian approximation (for more details, see Leleu, 2012). Mean length of net set per fishing operation, mean number of métiers practiced, the total net length onboard, and the crew size per fishing trip were also calculated.

Catch per métier was estimated from non-parametric bootstrap (Efron and Tibshirani, 1993), as the number of samples did not enable to compute variance components per fishing boat and per métier. Non-parametric bootstrap is based on random sample with replacement, and does not require any assumption about data distribution. Mean catch, along with estimated variance and 95% CI were derived from the distribution of thousand catch resamples simulated from the initial reference sample. This method was used to estimate mean catch per 100 m of nets, for i) all species together and for ii) target species of each métier. Total landed catch estimates were derived from mean catch estimates, based on the estimated length of set nets calculated above.

3. Results

3.1 Small-scale coastal fleet structure

Thirty boats using nets as the main fishing gear were active at least one time in two different months over the study period. Carro was the most important harbor (16 actives boats), while each of the other harbors was home to less than 7 boats (Table 1). Active boat length ranged from 5 to 16 m (average 9.8 ± 2.9 m), with engine power ranging from 7 to 242 kW (average 66.7 ± 58.1 kW) and gross registered tonnage (grt) ranging from 1.8 to 23.3 (average 7.1 ± 5.9). Boat age ranged between 9 and 86 years in 2010 (36.6 ± 14.4 years old on average; Table 1).

3.2 Métier characterization

Seven clusters (hereafter called métier) were identified from the multivariate analysis (Table 2). This partition explained 68% of the variance of the data set. Each cluster was strongly characterized by the declared target species or group of target species, and comprised all the fishing operations related to that species or species group. Clusters were thus named after the declared target species: “Sparids” (380 fishing operations), “European seabass”

(153), “Mullet” (287), “Hake” (324), “Fish soup[1]” (122), “Rockfishes and spiny lobster” (98) and “Flatfishes” (266).

Each métier used a single gear (Table 2), with the exception of “Sparids”, the only which also used combined nets (38% of the fishing operations of the métier) in addition to gillnet. The two métiers “European seabass” and “Flatfishes” were mainly practiced during autumn-winter (during 5 and 6 months respectively; Tables 2 and 3), whereas the other métiers were practiced during 5 to 9 months between March and November and particularly in spring and summer (Tables 2 and 3).

With respect to fishing grounds, each métier operated in a variety of habitats, except for métiers “Hake” and “Flatfishes” which were exclusively practiced in the largest depths (> 45 m for respectively 100% and 95% of the fishing operations of each métier; Table 2) on sandy substrates (Table 3). Métiers “Sparids” and “European seabass” preferably fished at intermediate depths (20 - 45 m for respectively 65% and 75% of the fishing operations of each métier; Table 2) above rocky habitats close to *Posidonia oceanica* meadows (Table 3). Métiers “Mullet” and “Fish soup” fished close to the shore in shallow waters (depth < 20 m for 71% and 79% of the fishing operations of each métier; Table 2), where “*Posidonia oceanica”* meadows are abundant. Métier “Rockfishes and spiny lobster” was found to exploit a large range of depths and distances to the shore (Tables 2 and 3). The net soak time ranged from 5 to 7 hours for métiers “Mullet” and “Fish soup” and between 14 and 18 hours for “Sparids”, “European seabass”, “Flatfishes” and “Hake” (Table 3). Only “Rockfishes and spiny lobster” has mean soak time longer than 24 hours (Table 3). Finally, stretched mesh size range depended on the métier, with large mesh (~91 mm) for the métiers “Rockfishes and spiny lobster”, “Sparids”, “European seabass” and “Flatfishes”, and small mesh (~42 mm) for the métiers “Mullet” and “Fish soup” (Table 3).

3.3 Effort and catch estimates

On average during a fishing trip, 1.4 ± 0.7 métiers was practiced, 1.6 ± 0.7 fishing operation was realized, and 3616.2 ± 2749.6 meters of net were set. Métiers “Flatfishes” and to a lesser extent “Hake” set the largest nets (respectively 5.8 km (95% CI [4.6; 7.1]) and 2.3 km (95% CI [1.9; 2.7])) on average per fishing operation and caught the largest yield (respectively 38.1 kg (95% CI [23.7; 57.2]) and 60.9 kg (95% CI [39.2; 88.1]); Fig. 2). Catch per 100 m of nets exceeded 2 kg for the métiers “Sparids”, “European seabass” and “Hake”,

[1] ‘Fish soup’ is the local name for a variety of small fishes including Scorpaenidae and Labridae, which are mixed to prepare a soup (Table 2).

and were less than 1 kg in average for the other métiers (Fig. 2). Catch could not be accurately estimated for the métier "Rockfishes and spiny lobster" due to a too small sample size.

Each boat practiced between 1 and 6 métiers during a year, with an average of 3.6 ± 1.9 métiers over one year period of time. Over the sampling year, the average number of fishing trips per boat within the fishing territory of the Côte Bleue was 128.2 (95% CI [104.6; 151.8]), corresponding to an average of 169.5 (95% CI [107.8; 231.3]) fishing operations per boat, and an average of 346.8 (95% CI [221.0; 472.6]) km of nets set per boat.

Depending on the fishing period of the métiers, the length of net set per boat ranged between 32.8 km for "Rockfishes and spiny lobster" and 245.5 km for "Flatfishes", while catch per métier and per fishing boat ranged between 315 kg ("Fish soup", 95% CI [113.6; 608.8]) to 3477 kg ("Hake", 95% CI [1867.7; 5605.9]; Fig. 3).

Over the study period, 3512 (95% CI [2865; 4159]) fishing trips and 4645 (95% CI [2953; 6337]) fishing operations were realized, and more than 9500 km of nets (95% CI [6056; 12950]) were set by the whole fleet. With regard to catch, 130.9 tons (95% CI [58.6; 251.4]) were landed for the 6 métiers. The métiers "Sparids" (135 active months; 16 boats), "Hake" (98; 16), "Flatfishes" (95; 18) and "Mullet" (91; 13) were the most active métiers of the fleet. The métier "Fish soup" was only practiced by 10 fishing boats (equivalent to 50 active months), when "European seabass" and "Rockfishes" were practiced by 13 boats representing 65 active months.

For the whole fleet, the métier "Sparids" displayed the largest total number of fishing operations (1 340, 95% CI [750; 1 928]), whereas "Rockfishes and spiny lobster" concerned only 249 (95% CI [197; 301]) fishing operations (Fig. 3). The métier "Flatfishes" set the largest total net length with more than 3 860 km (95% CI [2 491; 5 241]), while the métiers "European seabass", "Fish soup" and "Rockfishes and spiny lobster" set less than 600 km of nets in average during their respective fishing period (Fig. 3).

The main target species of each métier represented between 51% and 80% of the métier catch, and overall 74% of total landed catch was made of the main targets. The total landings of métiers "Hake", "Sparids" and "Flatfishes" corresponded to 76% of the total landed catch (respectively 42.9 (95% CI [23.0; 69.1]), 32.0 (95% CI [14.3; 57.1]) and 25.3 tons (95% CI [12.9; 42.4]); Fig. 4) and 58% of the total landed catch was made of the three species : hake (*Merluccius merluccius*), gilthead seabream (*Sparus aurata*) and common sole (*Solea solea*).

4. Discussion

The local small-scale coastal fishery of the Côte Bleue appears to be a typical north-western Mediterranean artisanal fishery. The boats' mean size (<10 m), engine power (<75 kW) and tonnage (<10 grt) are consistent with those observed in the majority of French Mediterranean fisheries (Leblond et al., 2012) and of other Mediterranean countries (Colloca et al., 2004; Battaglia et al., 2010; Forcada et al., 2010). In the Côte Bleue area, the fishery relies on seven main métiers using gillnets, trammel nets and to a lesser extent combined nets. Fishing takes place in multiple fishing grounds mainly located within 3 nmi from the shore, and corresponding to a variety of small-scale habitats (Farrugio and Le Corre, 1993; Colloca et al., 2004; Forcada et al., 2010; Leleu, 2012). Métiers are highly seasonal and catch per fishing trip remains relatively small (less than 40 kg per fishing operation in average with the exception of the "Hake" métier).

4.1 Main métiers

Given the small size of the fishery, fishing activity is quite divers over the year and between fishers. Seven main métiers were identified and characterized by a single declared target species (in all but one case), particular fishing grounds in relation to fishing depth and by well-defined seasons.

For a given métier, fishing effort is adapted to the ecology of the target species, e.g. through soak time, mesh size and net height used, and also by adjusting fishing ground selection and fishing period.

Fishing grounds correspond to target species habitat *preferenda. Posidonia oceanica* meadows and associated sandy substrata are visited by both "Fish soup" and "Mullets" métiers, while "Hake" and "Flatfishes" métiers fish in deeper sandy substrata. Fishing grounds for "Sparids" and "European Seabass" often correspond to a mix of the different habitats as these species are more demersal. Additional factors may interfere in fishing ground selection: seabed topography, fishers' informal agreements as well as the vicinity of the NTZ or of home harbor (Forcada et al., 2010; Leleu et al., 2012). The fine-scale spatial distribution of fishing effort in the CBMP will be addressed in a forthcoming paper.

Regarding the fishing season of a métier, it often corresponds to the period when individuals aggregate for reproduction or seasonal migration. This was the case for "European seabass", "Flatfishes" and "Sparids" or for more anecdotal métiers targeting common dentex (April – May) or cuttlefish (May – June; results not shown). For the métier "Sparids" in particular, two main seasons were identified: (i) April to Mid-June when young adults of

310 *Sparus aurata* migrate from the sea to the Berre Lagoon for the feeding period (Fig. 1); and
311 (ii) Mid-September to October for the return migration from the Berre Lagoon to the sea
312 along the shore for reproduction. Although no published reference could be found, these
313 features have been long known to fishers. Fishing seasons may also depend on market
314 opportunities, especially during the summer when the large number of tourists encourages
315 fishers to propose a large panel of local species to consumers (métiers "Rockfishes", "Fish
316 soup").
317 The main target species identified in the present study were also found in other north-
318 western Mediterranean fisheries (Colloca et al., 2004; Boudouresque et al., 2005; Tzanatos et
319 al., 2006; Cadiou et al., 2009; Battaglia et al., 2010; Forcada et al., 2010; Maynou et al.,
320 2011), although the gears used and the fishing period depends of the natural, cultural and
321 socio-economical characteristics of each area. For example, hakes or mullets are targeted
322 using trammel nets in south-east of Spain or Aeolian Islands in Italy (Battaglia et al., 2010;
323 Garcia-Rodriguez et al., 2006; Forcada et al., 2010). Moreover, species that are rarely targeted
324 by the Côte Bleue fishery may be of major importance in other Mediterranean fisheries
325 (common dentex or cuttlefish for example; Jabeur et al., 2000; Garcia-Rodriguez et al., 2006;
326 Gomez et al., 2006).
327
328 **4.2 Effort and catch**
329 Fishers use several métiers throughout the year. Métier selection mainly depends on
330 fishing periods, but also on other factors like recent catch and income, market demand,
331 information and rumors about the catch of other fishers and fishers' experience (Tzanatos et
332 al., 2006; Merino et al., 2008; Battaglia et al., 2010; Maynou et al., 2011, 2013). The use of
333 fixed fishing gears also favors the diversity of fishing tactics and their succession throughout
334 the year (Colloca et al., 2004; Forcada et al., 2010). Finally, the weather forecast also plays a
335 role in day-to-day métier selection. For instance, windy conditions due to the prevailing north-
336 western wind (*mistral)* lead fishers to operate near shore in order to benefit from the coast
337 shelter.
338 In contrast to métier selection, the number of fishing operations, the number of métiers
339 practiced, and the total net length deployed per fishing trip were found to mainly depend on
340 boat characteristics (length, power, grt) and on crew size.
341 Fishing takes place all over the year, as in other Mediterranean SSCF (Colloca et al.,
342 2004; Tzanatos et al., 2006; Cadiou et al., 2009; Battaglia et al., 2010; Forcada et al., 2010;
343 but see Bonhomme et al., 2010; Le Diréach et al., 2010a; Rocklin, 2010). Fishing effort per

métier depends on fishing period duration, the number of active months, the average catch per fishing operation but also on species market price. The highest catches were obtained by métiers combining high catch rates and a large number of active months. Exceptions were for "European seabass", with a relatively short fishing period and a highly variable catch; and for "Flatfishes", which compensate a low catch per 100 m of nets by a large length of net set per fishing operation. Catch estimates displayed a high variability, illustrating variable catch rates by fishers during the fishing period. This is due to natural conditions such as water temperature, moon phases or current (Lloret et al., 2001; Darnaude et al., 2004; Stergiou et al., 2006). The majority of the catches are landed and more than 70% of the fishers declared selling 75% of their catch on harbor market. As in the majority of SSCF, fisher's family is involved in the fishing activity and selling of catch (Frangoudes and Keromnes, 2008; Leleu, 2012). In the present study, total catch could not be estimated as the fishery discards could not be assessed from the sampling protocol. Nevertheless, several onboard samples collected over the study period (Leleu, unpublished data) show average discards rates less than 10% of the total catch per fishing operation. This figure is consistent with several other studies in north-western Mediterranean (Le Diréach and Cadiou, 2006; Tzanatos et al., 2007; Forcada et al., 2010).

Our results show that the Côte Bleue fishery mainly depends on few métiers and species, as it is the case for numbers of SSCF (Papaconstantinou and Farrugio, 2000; Garcia-Rodriguez et al., 2006; Gomez et al., 2006; Merino et al., 2008; Battaglia et al., 2010; Maynou et al., 2011; Colloca et al., 2013). This illustrates the vulnerability of these fisheries facing possible changes in resources. In the CBMP, the mean length of nets for the métier "Flatfishes" has been multiplied by 2.3 since 1988 (Bachet F., pers. comm.). Net lengths over 10 km per fishing operation are now commonly used (with a maximum observed of 14 km), which exceeds the lengths authorized by European regulations (Council Regulation n° 1967/2006, i.e. 4000 m per boat, plus 1000 m per extra fisher with a maximum of 6000 m). The "Flatfishes" métier exhibits the lowest catch rates observed in this study. All fishers reported either a decrease (35% of them) or stability (65%) in *Solea solea* catch over the last decade, whereas 64% of fishers declared having increased their net length (Leleu, 2012). *Solea solea* stocks could be certainly considered as overexploited in the Côte Bleue area as it is probably the case in the whole Mediterranean Sea (de Séligny and Grainger, 2010), but environmental factors, e.g. continental Particular Organic Matter (POM) episodic inputs via river floods, may also partly explain the availability of this resource (Darnaude et al., 2004).

Such changes will inevitably induce an evolution of fishing activities in the near future, with effort shifting to other métiers and associated consequences on resources.

Given this evolution, the potential of the CBMP NTZ to contribute to (partially) replenish exploited resources may be key in the future. Several studies provide scientific evidence for biomass export from CBMP's NTZs for some target species of the métiers "Sparids" and "European seabass" (*Diplodus* spp.), but also "Mullets" (*Mullus surmuletus*), "Fish soup" (*Scorpaena* spp., *Symphodus* spp.) and "Rockfishes" (*Scorpaena* spp., *Labrus* spp.) (Goñi et al., 2008; Harmelin-Vivien et al., 2008; Le Diréach et al., 2010b; Leleu et al., 2012). If the effect of NTZs on the flatfishes was not studied, it may be positive, particularly in the reserve of Cap Couronne which includes wide areas of sandy substrate beyond ~30 m depth (Charbonnel, pers. comm). In the future, the vicinity of the recently created Calanques National Park may also play a role in the evolution of exploited resources.

It was difficult to achieve a comparison between effort and catches of different north-western Mediterranean SSCF because papers report distinct indicators, and because this information was rarely displayed in the literature. To achieve such a comparison, it would be necessary to compute similar indicators for each fishery, especially in terms of catches. Such a study would provide valuable information on the biology of exploited species and associated stocks, but also on the dependence of the fisheries upon ecological features. For this last point, the production of the Métier-Sustainability-Index (MSI25) by Tzanatos et al. (2013) is an interesting avenue.

4.3. An adapted sampling protocol

Through an extensive year-round survey of this SSCF, we could document fishing practices and provide quantitative estimates of effort and catch, together with precision estimates. This was made possible through a sampling protocol adapted to two features that are common to most temperate small-scale fisheries: i) multiple target species and several métiers, and ii) a strong seasonality of fishing activities with fishers practicing a succession of métiers along the year depending on changes in resource distribution and availability.

These results may be useful for designing monitoring protocols for SSCF in a context where coastal fishing activities are likely to be impacted by environmental changes, changes in management regulations and changes in pressures due to other human activities (including larger fisheries) in the coastal area.

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7. Figure captions

Fig. 1. Study area: The Côte Bleue Marine Park (CBMP; dotted area), its two no-take zones (NTZ; dark grey areas) and the limit of the Natura 2000 site (crossed line). The hatched area represents the fishing territory of the Côte Bleue small-scale coastal fishery.

Fig. 2. Estimations and 95% confidence intervals of the net length (left), the catch landed per 100 m of nets (middle) and the total landed catch (right) per fishing operation and per métier. Catch was not estimated for the métier "Rockfishes and spiny lobster" due to low sample size.

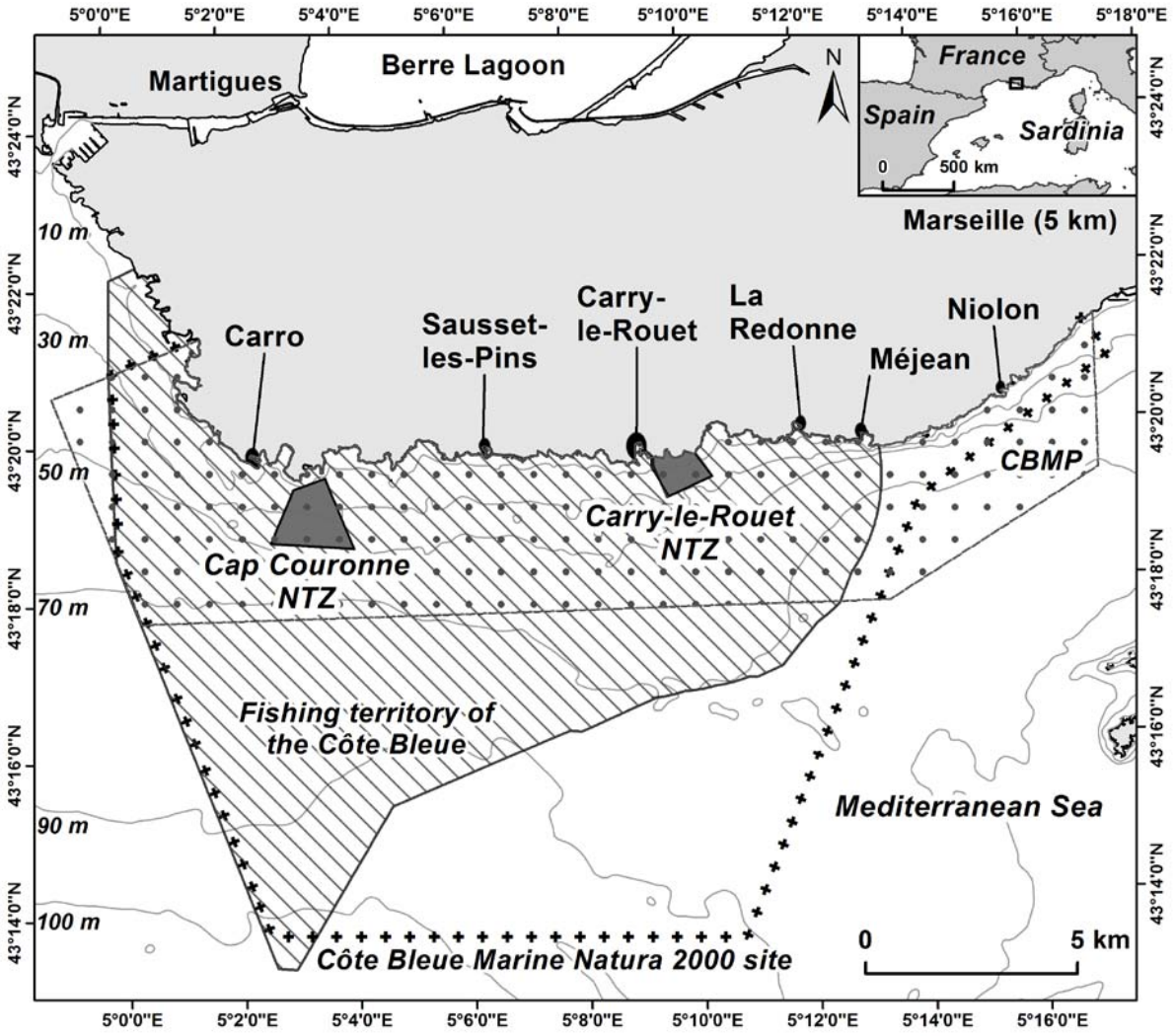
Fig. 3. Estimations and 95% confidence intervals of the number of fishing operations (left), net length (middle), and the total landed catch (right) per boat and fleet for each métier. Catch was not estimated for the métier "Rockfishes and spiny lobster" due to low sample size.

Fig. 4. Estimation and 95% confidence interval of the landed catches (tons) per target species and per métier (except Rockfishes and spiny lobster) over the studied year.

Table 1. Number of boats using nets (registered and active at least two months during the study period) and fleet characteristics (range, mean and standard deviation (sd) of the overall length (m), of the engine power (kW), of the gross tonnage (grt) and of the year of construction) for each of the CBMP harbors.

Table 2. Characterization of the métiers obtained from the classification of fishing operations based on the four categorical variables.

Table 3. Description of the métiers according to the characteristics of the fishing operations included in each cluster. Each métier is described through its target species, its fishing period, the habitat visited (P, *Posidonia oceanica* meadow; R, rocky substrata; S, sandy substrata), the range of fishing depth, distance from the shore, net mesh size (stretched), height when fishing, and soak time. Fishing period of each métier corresponds to the grey shading: no shading: less than 5% of the whole fishing operations observed during the specific month; light grey shading: between 5 and 10%; dark grey shading: more than 10%.



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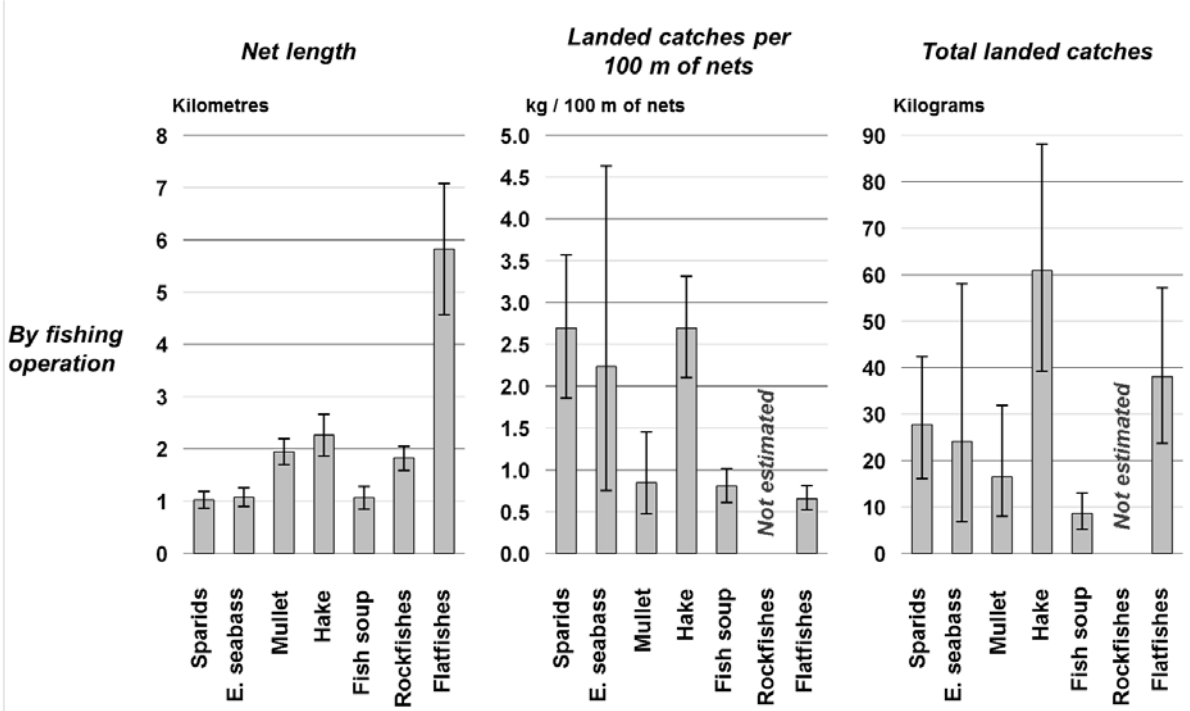

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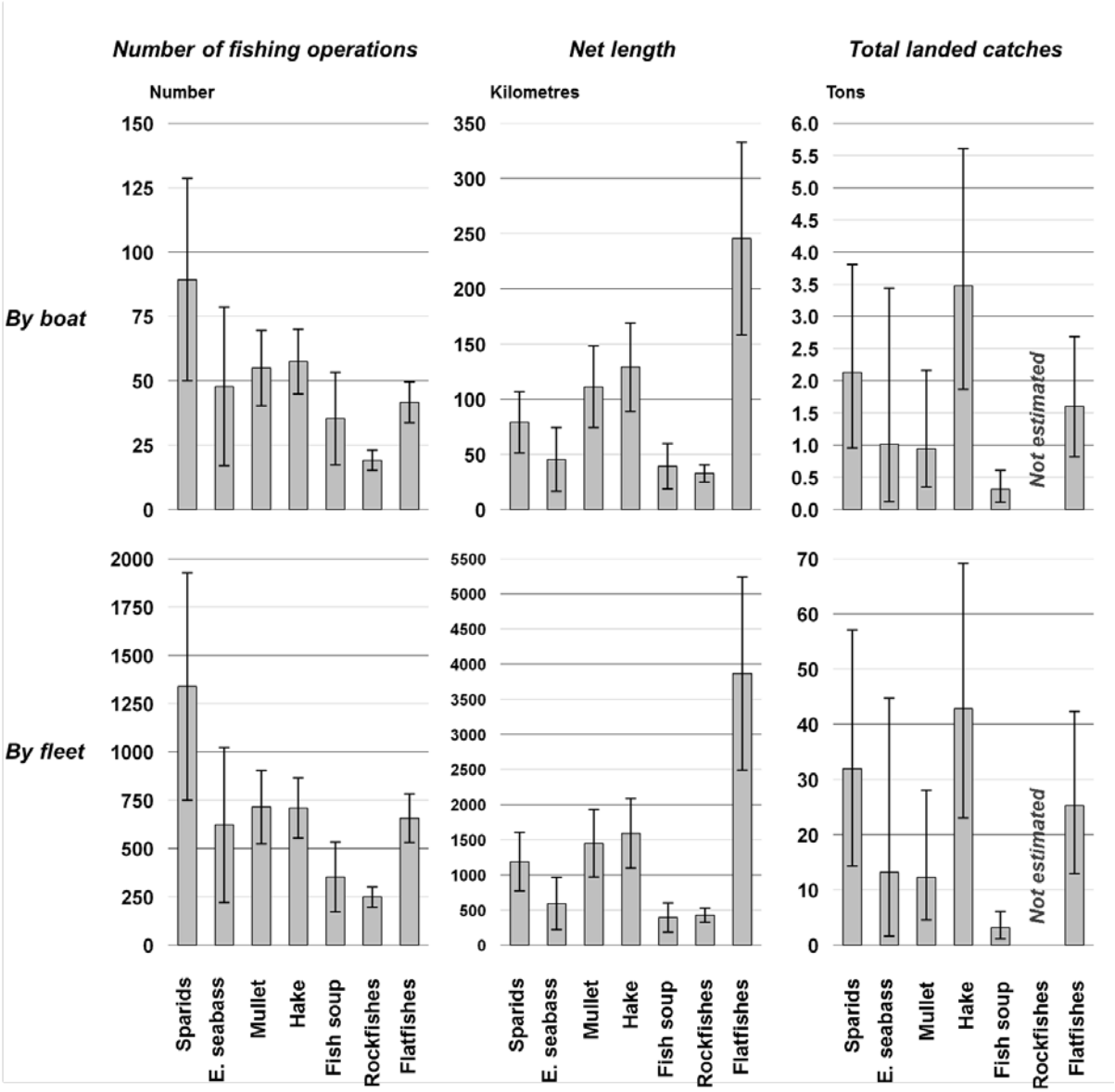

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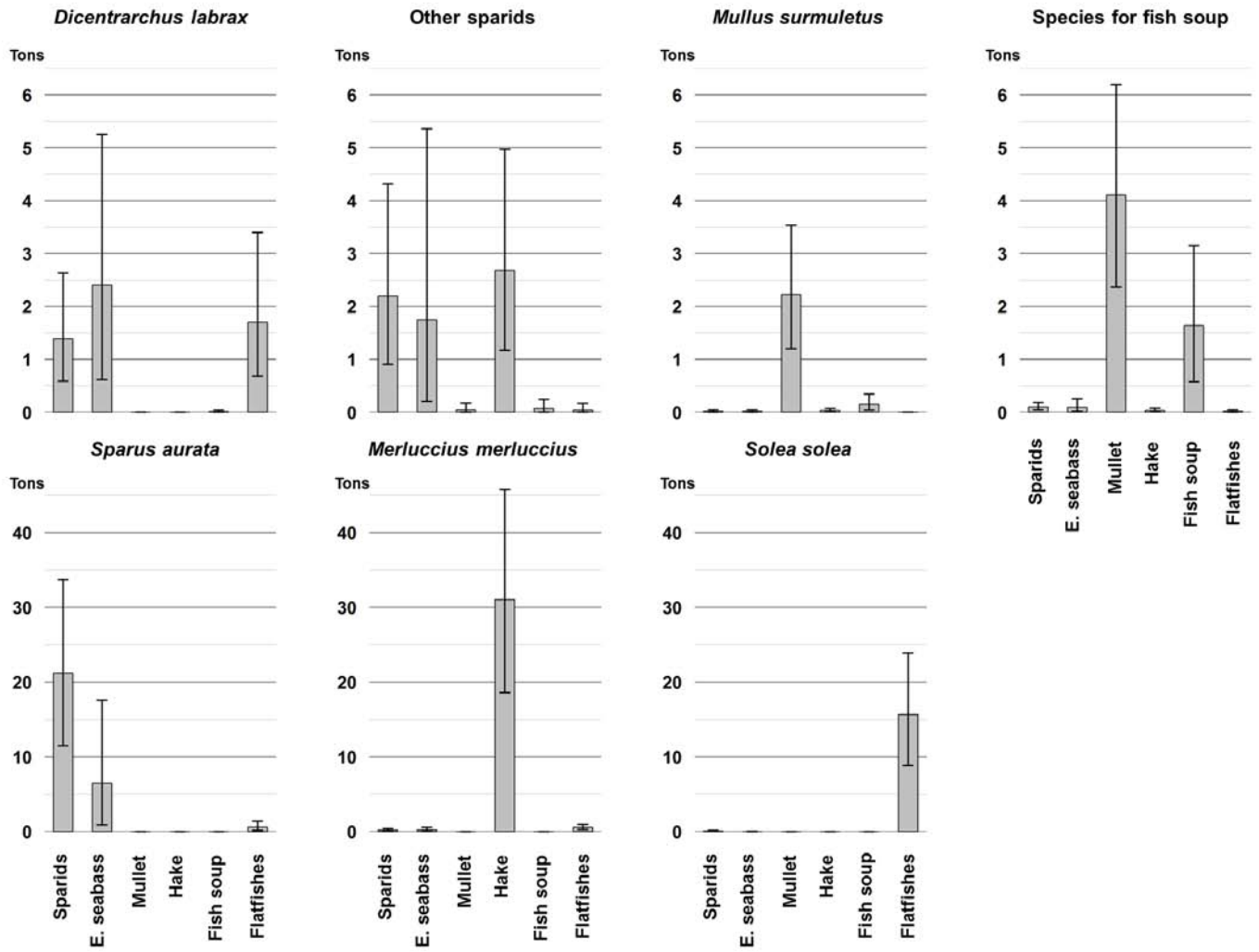

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653 standard deviation (sd) of the overall length (m), of the engine power (kW), of the gross tonnage (grt) and of the year of construction) for each of
654 the CBMP harbors.
655

Harbors	**Number of active boats using nets**	**Characteristics of active boats using nets**			
		Overall length (m)	**Engine power (kW)**	**Gross tonnage (grt)**	**Year of construction**
		Range (mean ± sd)	**Range (mean ± sd)**	**Range (mean ± sd)**	**Range (mean ± sd)**
Carro	16	5.5 - 16.2 (10.7 ± 3.3)	6.7 - 241.7 (79.5 ± 64.5)	1.9 - 23.3 (9.4 ± 6.9)	1958 - 1994 (1976 ± 9.2)
Sausset-les-Pins	5	6.9 - 12.5 (9.3 ± 2.4)	16.4 - 56.0 (35.8 ± 14.3)	1.8 - 9.9 (4.9 ± 3.5)	1924 - 1989 (1965 ± 25.2)
Carry-le-Rouet	2	11.2 - 12.0 (11.6 ± 0.6)	83.6 - 119.4 (101.5 ± 25.3)	7.0 - 9.3 (8.2 ± 1.6)	1973 - 1981 (1979 ± 5.7)
La Redonne - Méjean - Niolon	7	7.0 - 9.6 (7.8 ± 1.0)	16.4 - 186.5 (49.8 ± 60.9)	2.2 - 5.5 (3.2 ± 1.2)	1958 - 2011 (1971 ± 16.4)

656

657 Table 2. Characterization of the métiers obtained from the classification of fishing operations based on the four categorical variables.

658

Cluster/ Métier	Gear used	Seasons	Depth	Number of fishing operations by cluster
Sparids	Gillnet Combined net	Autumn, Spring	20 – ≤ 45 m	380
European seabass	Gillnet	Autumn, Winter	20 – ≤ 45 m	153
Mullet	Gillnet	Summer, Spring	≤ 20 m	287
Hake	Gillnet	Summer	> 45 m	324
Fish soup	Trammel net	Summer	≤ 20 m	122
Rockfishes and spiny lobster	Trammel net	Summer, Spring	20 – ≤ 45 m	98
Flatfishes	Trammelnet	Winter	> 45 m	266

659

Table 3. Description of the métiers according to the characteristics of the fishing operations included in each cluster. Each métier is described through its target species, its fishing period, the habitat visited (P, *Posidonia oceanica* meadow; R, rocky substrata; S, sandy substrata), the range of fishing depth, distance from the shore, net mesh size (stretched), height when fishing, and soak time. Fishing period of each métier corresponds to the grey shading: no shading: less than 5% of the whole fishing operations observed during the specific month; light grey shading: between 5 and 10%; dark grey shading: more than 10%.

																		Fishing ground		Net characteristics		
																		Depth (m)	Distance to the shore (m)	Mesh size (mm)	Height when fishing (m)	Soak time (h)
Cluster/ Métier	**Target species**		**Fishing period (month)**														**Habitat**	**Range (mean ± sd)**	**Range (mean ± sd)**	**Range (mode)**	**Range (mean ± sd)**	**Range (mean ± sd)**
	Main	**Associated**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**							
Sparids	*Sparus aurata*	*Dicentrarchus labrax* Other sparids													P, R, S	5 – 60 (23.3 ± 7.4)	10 – 2295 (519.2 ± 587.0)	80-143 (91–100)	6 – 17 (10.0 ± 3.5)	2 – 27 (15.3 ± 3.5)
European seabass	*Dicentrarchus labrax*	*Sparus aurata* *Diplodus* spp.													P, R	6 – 60 (22.4 ± 7.8)	10 – 2750 (588.2 ± 348.7)	80-111 (91–100)	8 – 17 (10.0 ± 2.8)	5 – 24 (16.5 ± 2.7)
Mullet	*Mullus surmuletus*	*M. barbatus* *Scorpaena* spp.													P, S	3 – 50 (16.8 ± 11.4)	10 – 2135 (526.4 ± 458.5)	38-45 (42–45)	1 – 1.5 (1.2 ± 0.1)	2 – 10 (5.0 ± 1.4)
Hake	*Merluccius merluccius*	*Pagellus* spp.													S	40 – 100 (74.2 ± 16.2)	942 – 10868 (4971.1 ± 3091.9)	63-91 (71–77)	3 – 4 (3.5 ± 0.4)	2 – 24 (14.5 ± 3.4)
Fish soup	*Scorpaena* spp. *Symphodus* spp.	*Mullus surmuletus*													P	2 – 60 (15.3 ± 10.5)	10 – 2659 (368.8 ± 461.3)	42-71 (42–63)	1 – 2 (1.5 ± 0.3)	3 – 23 (7.0 ± 4.7)
Rockfishes and spiny lobster	*Scorpaena scrofa* *Palinurus elephas*	*Labrus merula* *Labrus viridis*													R, S	5 – 87 (34.7 ± 19.5)	10 – 5300 (1679.1 ± 1290.9)	71-125 (91)	1 – 4 (1.5 ± 1.0)	5 – 63 (24.9 ± 14.8)
Flatfishes	*Solea solea*	*Scophthalmus rhombus* *Dicentrarchus labrax*													S	10 – 90 (66.2 ± 5.5)	177 – 11329 (4008.7 ± 1331.9)	83-91 (91)	1 – 2 (1.8 ± 0.2)	13 – 65 (17.5 ± 6.2)