Trawling fishery of the Western Mediterranean Sea: Métiers identification, effort characteristics, landings and income profiles.

Mohamed Samy-Kamal[a]*, Aitor Forcada[ab] and Jose Luis Sánchez Lizaso[ac].

[a]* Corresponding Author: Tel: +34 965 903 400 Ext. 2916; E-mail: mohamedsamy@ua.es

[b] E-mail: forcada@ua.es

[c] E-mail: jl.sanchez@ua.es

[a] Departamento de Ciencias del Mar y Biología Aplicada, Universidad de Alicante, PO Box 99, Edificio Ciencias V, Campus de San Vicente del Raspeig, E-03080 Alicante, Spain.

Highlights

- Mullet, hake, lobster and shrimp are the main métiers in western Mediterranean trawl fishery.
- Management of multi-specific fisheries should start off considering métiers characteristics.
- Effort distribution among métiers can indicate suitable time to reduce effort on target species.
- Controlling fleet capacity could be more effective when done by métier.

Abstract

Due to the diversity of fleet characteristics and catch composition in Mediterranean fisheries, the General Fisheries Commission for the Mediterranean has placed emphasis on the direct control of fishing capacity and effort rather than catch limitation. This paper aims to analyse the evolution of fishing effort, landings and métiers in three trawling ports of the western Mediterranean between 2002 and 2011. Four métiers were identified, using multivariate techniques, in the fishery: Red mullet, European hake, Norway lobster and Red shrimp. The mean catch composition within the same métier was similar between ports, although the relative importance of species differed slightly from one port to another. Variation in fishing effort exerted was observed between métiers reflecting differences in the importance and usage of each métier by port. Temporal variations were found among different métiers at seasonal and annual scales. These temporal variations showed that métiers Red mullet and European hake were alternated. Positive significant correlations were observed between landings and different fishing effort variables with an exception of the relation between landings and engine power in the Norway lobster métier with negative significant correlations. Significant differences in total vessel length, gross tonnage, total CPUE and total income were detected among the four métiers depending on each port with few exceptions. These findings are considered a keystone for more practical implications and to assist fisheries' managers in the decision-making process. As demonstrated in the current paper, the management of multi-specific fisheries should start off considering the characteristics of each métier separately. In the sound of métier-based management, the patterns observed in the effort temporal distribution between métiers can indicate the most suitable time to reduce effort on specific target species.

Key words: Effort distribution, métiers, multi-species trawl fishery, western Mediterranean.

1 Introduction

For many reasons multi-species and multi-gear fisheries (e.g. Mediterranean fisheries) present an immensely more difficult challenge for fisheries management than single-species fisheries (Ulrich et al., 2012). Mediterranean trawl fisheries are multi-specific, with up to 100 species and categories recorded in landings in some areas (Massutí et al., 1996; Caddy, 2009). In Mediterranean trawl fisheries, where some of the target species suffer from overfishing (FAO 2011; Colloca et al., 2013), the effort may be directed towards one or another target species during certain periods, depending on the level of catches obtained at that moment, the respective strength of recruitment and on the price of target species in the market (Oliver, 1993). These characteristics increase the heterogeneity of the fishery and complicate assessment, monitoring and management of the sector (Biseau, 1998). In such management framework, the fishing activity of a given fleet segment in a given area needs to be disaggregated into sub-segments that define specific activities in time, space and catch opportunities closely corresponding to the concept of "métier" (Biseau, 1998; Pelletier and Ferraris, 2000; EC, 2009). Where a "métier" is defined as: a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterised by a similar exploitation pattern (EC, 2008). Usually, the identification of a métier is based on the analysis of the species' composition of large catch datasets, which are available from logbooks or landings data (e.g. Holley and Marchal, 2004; Ulrich and Andersen, 2004; Forcada et al., 2010). This approach consists of conducting multivariate analyses on species' composition in catch data by day or fishing operation, referred to as landings profiles, then associate similar profiles into métiers. This grouping can be performed by direct visual inspection (Biseau and Gondeaux, 1988; Laurec et al., 1991) or statistically through cluster analysis.

Measures to regulate fishing effort are the main measures used for the management of multi-specific fisheries, such as Mediterranean fisheries, in combination with other technical measures, i.e. minimum mesh and landing size or spatio-temporal closures. Due to the diversity of both the characteristics of fleet and the catch composition, the General Fisheries Commission for the Mediterranean (GFCM) has placed emphasis on the direct control of fishing capacity and effort rather than catch limitation as an effective way to reduce fishing mortality (Alemany and Álvarez, 2003). In this context, effort information is needed to interpret changes in the fishery. Understanding how the fishing effort of trawls is distributed among the different métiers and the specific details of each one is valuable for the management of multi-specific fisheries. This can help to improve assessment of alternative management measures and select appropriate and valid management strategies (Salas and Gaertner, 2004).

The Alicante Gulf (SE Spain) supports an important fishing activity, comprising up to 10% of the Spanish Mediterranean fleet, which annually land up to 20,000 tonnes (García-Rodríguez et al., 2006). The wide expanse of the continental shelf in this area has favoured the trawling fishery, the development of a large fleet, which operate in muddy and sandy continental shelf and slope between 50 and 800 meters depth. Furthermore, landings are daily sold to intermediaries at each local port in the fish market "lonja" under the supervision of the fishing guild, which facilitates the monitoring of daily landings by vessels. Trawling fleet in the area is the second most important fleet in terms of the landings, after the purse-seine fleet, providing around 40% of the annual landings in this area (García-Rodríguez et al., 2006). The trawling fleet is the largest in terms of number of vessels, with 109 trawlers distributed in 12 ports (from Dénia to Torrevieja), and in terms of vessel length and engine power (BOE, 2013). Vessels are characterised by the semi-industrial scale of their operations, and each fishing fleet is based in one port where vessels usually return every day or within a few days. Like other Mediterranean trawling fleets, their activities are carried out in well determined fishing grounds that are selected by fishermen according to the target assemblages of species. Generally these fishing grounds are controlled by the fishing fleet of the nearest port (Demestre et al., 2000).

Taking into account the difficulty of obtaining data from Mediterranean fisheries and in response to the need of fisheries statistics, long-time series of landings and effort are very valuable in providing information on changes in the fishery. Therefore, landing and effort data of 10 years (2002 to 2011) in three representative western Mediterranean trawling ports (Dénia, Xàbia and La Vila Joiosa) were collected to provide information on landings, effort and métiers in the fishery that can benefit management decisions. For this: (a) the structure of the fleet, the evolution of fishing effort and landings were evaluated for each port; (b) the main métiers in the fishery were identified and examined according to their activity patterns, catch and income profiles; (c) distribution of fishing effort among métiers and the trends in effort were assessed based on the use of specific métiers in the study area; and finally, (d) relations between total landings (also by métier) and different fishing effort variables were analysed. This will serve as a keystone for more practical implications such as assessment of the applied management measures.

2 Material and methods

2.1. Study area

This study was conducted in three trawling ports, Dénia, Xàbia and La Vila Joiosa, located in the south-western Mediterranean Sea off the coasts of Spain (Fig. 1). Along the gulf of Alicante, there are 12 fishing ports from Dénia to Torrevieja that have traditionally been locations of an important fishing activity. According to the number of trawlers, these three ports are important as they account for about 46% of the total trawlers operating on the Alicante coast (about 7.5% of the total Spanish trawlers in the Mediterranean coast) (BOE, 2013). The Mediterranean trawl fishery in Spain is an input-controlled fishery where effort is controlled by limiting the time at sea: fishing is permitted for 12 hours/day from Monday to Friday, stopping the fishing activity completely on weekends (Maynou et al., 2006). The fishing activity is ceased normally a month by year as a seasonal closures, alternating the North ports (e.g. Dénia and Xàbia) with the south ports (e.g. La Vila Joiosa) to avoid the closure of the whole gulf at once. However, closure is not applied in the same months every year, but mostly applied in May, June, July and

September (Samy-Kamal et al., submitted a). Other technical measures are applied such as prohibiting activity on bottoms shallower than 50m, and limiting of vessel nominal engine power to maximum of 500 hp. In addition, to improve the selectivity of gears, all trawlers have changed to either a 40-mm square-mesh codend or a 50-mm diamond-mesh (instead of the traditional 40-mm diamond-mesh codend) (EC, 2006; Samy-Kamal et al., accepted b).

2.2. Data collection

Data records of daily auctions were obtained from the fishing guild of each port for years 2002 to 2011. For each fishing day, data on species landing weight (kg) and first sale value (€) were available by vessel. Data were arranged in a two-way matrix of daily landings per vessel as samples (rows) and species landed as variables (columns). Vessels with sporadic landings events within the ports were excluded from the analysis, considering only those vessels registered in the studied ports (home port) to avoid possible biases in the data. Most of the included set of vessels have had activity throughout the period considered.

Technical characteristics of vessels within analysis were obtained from the Census of Fleet of the General Secretariat of Maritime Fisheries of Spain (BOE, 2013). Vessel features considered in the analysis were: total vessel length (TL), relative gross tonnage (GRT) and tonnage (GT). In many ports of the western Mediterranean the registered vessel power is known to depart from real values as vessel power is regulated (Goñi et al., 1999, Sánchez Lizaso, 2002). However, it has been also included to give a general idea of the capacity of the fleet. Both databases, landings and vessels characteristics, were crossed to conduct the analysis.

2.3. Data analysis

2.3.1. Description of fleet and temporal changes

In this paper, the fishing effort was defined by six variables: number of vessels, fishing days, TL, GT, GRT, and engine power (HP). While landings (catch) was defined by biomass (landings weight) and income (first sell value), total and by species (Appendix. 1). An exploratory analysis of fleet data was performed to describe the structure of the fleet (by TL, GT, GRT and HP) at each port. To analyse temporal evolution of the fishing effort (for the total fleet and by port) at a year scale, number of vessels, fishing days (within this paper, the term fishing days refers to fishing days per vessel), TL and total GT were used. Additionally, for the total fleet mean HP and mean GT were analysed also to explore effort trends over years. To analyse the possible seasonality (within year) in each port of total fishing effort, as well of effort for each métier (later), the mean number of fishing days for each month were calculated, considering all months including those in management based temporal closures occurred. Moreover, the temporal evolution (for the total fleet and by port) of total landings and Catch per Unit Effort (CPUE), in terms of biomass and income, were evaluated for the10 years studied (2002-2011).

2.3.2. Identification, description and temporal distribution of métier

The target species of each métier in the fishery were first determined by their relative importance in each port, given as the percentage of biomass and income for each species in the total catch. As the three fleets are using the same fishing gear (trawling) and sharing the same fishing ground (gulf of Alicante) the definition of métiers was named (informally) after the main target species to simplify the interpretation. Multivariate techniques (cluster, nMDS and SIMPER, later described in detail) were used to determine catch profiles and to link it back to the vessels by assigning each of the samples (vessel/day) with their characteristics to one of the métiers. Non-parametric approaches were applied combining non-metric multi-dimensional scaling (nMDS) and hierarchical cluster (Clarke, 1993; Clarke and Warwick, 2001), to assess differences in the biomass of the catch composition among samples (vessel/day). Through an iterative process, groups of samples were identified in the cluster with similarity levels between 20% and

45%. The resulting clusters were overlaid on the nMDS ordination. Once groups were identified, the Similarity Percentage Analysis (SIMPER) routine, included in PRIMER v6 software (Clarke and Gorley, 2006), was used to recognise the main species characterising each group of samples by weight and income, and thereby identify the métier. The whole amount of data (114765 daily samples), even annual data, did not fit (at once) into the PRIMER software (it has been already tested), even if it did, the result of cluster and nMDS would be impossible to interpret. Hence, due to the large amount of data, and for more precise identification, this process was made in a monthly base. Therefore, this process was repeated 330 times (11 months · 10 years · 3 ports).

Analysis of Variance (ANOVA) was used to test for significant differences in total length, gross tonnage, total biomass and total income between the identified métiers within each port, and between ports within each métier (Underwood, 1997). When the ANOVA F-test was significant, post hoc analyses were conducted using Student-Newman-Keuls (SNK) multiple comparisons (Underwood, 1981). Before (ANOVA) analysis, Bartlett's test was used to test for homogeneity of variance (Sokal and Rohlf, 1969). When significant heterogeneity was found, the data were transformed by $\sqrt{(x + 1)}$ or $\ln(x + 1)$. When transformations did not remove heterogeneity, analyses were performed on the untransformed data, with the F-test α-value set at 0.01, since ANOVA is more restricted to departures from this assumption, especially when the design is balanced and contains a large number of samples/treatments (Underwood, 1997). ANOVA was conducted by R statistical computing software (R Development Core Team, 2010) and the R's package GAD (Sandrini-Neto and Camargo, 2011). The experimental design consisted of two factors: Métier (4 levels, fixed) and Port (3 levels, fixed and orthogonal), while an even number of samples were randomly selected to maintain our balanced data within each level of the factors considered in the experimental design. Therefore, with n = 988 replicates for each level, there were a total of 11856 observations.

Finally, the mean percentage and CPUE for each species was used to identify the main species (catch composition) characterising each métier by port in terms of both biomass and market value.

2.3.3. Relationship between "effort" and "landings" overall, and broken down by métier

To explore the relationship between landings (total and also for each métier) and different fishing effort variables (TL, GT, and HP), scatterplots and Pearson's product moment correlation coefficient were used. The significance of each correlation coefficient was tested by mean of Student's t-Tests.

3 Results

3.1. Description of fleet and temporal changes

Over the 10 years studied a total of 106 different fishing vessels were listed in the official fleet register of Dénia, Xàbia and La Vila Joiosa (34, 13 and 59 vessels respectively). The bulk of the fleet is composed of vessels up to 23-25 m length, 40-80 GT, 40-60 GRT and 200-400 registered HP (Fig. 2). On average, vessels based in Xàbia were bigger (length, GT and HP) than those in La Vila Joiosa and Dénia. Mean GRT of La Vila Joiosa fleet however, was slightly higher.

The number of active vessels declined over the study period, from 86 vessels in 2002 to 58 vessels in 2011 (Fig. 3a). The decline is mainly attributable to the fleet of La Vila Joiosa that showed a gradual decline over time, while vessels in Dénia made up substantial decline in 2011. The number of fishing days over the 10 years showed a slight decrease in both La Vila Joiosa and Dénia. Fishing days in Xàbia were consistent with the number of vessels (Fig. 3b). The number of fishing days mirror the trends observed in vessel numbers, including the 2011 decline. The evolution of another two measures of effort capacity, the TL and the total GT, indicate the same gradual decreases (Fig. 3c and d). Horsepower and total GT means vary throughout the period (Fig. 4), with an overall decrease. Fleet activity is regular throughout most of the year, with a slight peak in August (Fig. 5). However, during May, June, July and September, less fishing days were observed coinciding with timing of temporal closure.

Over the 10 years, the total landings ranged around 2400 tonnes annually, except in 2006 and 2007 when landings increased appreciably up to 3000 tonnes (Fig. 6a). This increase is mainly attributable to the ports of La Vila Joiosa and Dénia. Landings in Xàbia increased slowly over the 10 years in a steady way. Disparity in landings occurs between the three ports, the majority (62%) originates from La Vila Joiosa, while Dénia and Xàbia contribute far lower values (27% and 11% respectively). Income at the three ports sustained the same trend (Fig. 6b). The trends of CPUE were quite similar to the previous trend, in addition to a sudden increase in 2011 in both biological and economic terms (Fig. 6c and d). Nevertheless, CPUE along the studied period was apparently higher in La Vila Joiosa, followed by Xàbia and Dénia.

3.2. Identification, description and temporal distribution of métier

In total, about 115 commercial species and categories of species were recorded during the period studied. Despite the large number of species, around 80% of landing was represented by just 15. According to biomass, the most important species were: European hake (*Merluccius merluccius*) (Linnaeus, 1758) (up to 18% in La Vila Joiosa), blue whiting (*Micromesistius poutassou*) (Risso, 1827) (up to 18% in Xàbia), octopuses (*Octopus vulgaris*) (Lamarck, 1798) (up to 14% in Dénia), “morralla” (a Spanish commercial category that refers to a mix of low-valued small fishes of mainly Sparidae and Labridae) (up to 7.5% in La Vila Joiosa) and the Red shrimp (*Aristeus antennatus*) (Risso, 1816) (up to 6.6% in Dénia) (Fig. 7). In economic terms, the most profitable species were: the Red shrimp (*Aristeus antennatus*) (up to 44% in Dénia), European hake (*Merluccius merluccius*) (up to 21% in La Vila Joiosa), the Norway lobster (*Nephrops norvegicus*) (Linnaeus, 1758) (up to 15% in Xàbia) and the Red mullet (*Mullus* spp.) (Linnaeus, 1758) (up to 5% in Xàbia) (Fig. 7). According to these results, the four species *M. merluccius*, *Mullus* spp., *A. antennatus* and *N. norvegicus* were the most targeted by fishermen and accounted for around 57% of the total income of the fishery.

The four principal métiers, Red mullet, European hake, Norway lobster and Red shrimp, were identified in cluster procedures at a similarity level between 20% and 45%, depending on the data in each month. As an example, results of just a month are presented in (Appendix 2) where cluster analyses revealed 5 groups (4 métiers and one group corresponding to the undefined group of samples) of samples at a similarity level of 45%. The nMDS results provided a 2-dimensional graphical configuration which corroborated clustering results. Further, the SIMPER showed the species that most contributed in the separation of each group, helping to identify the métier of each group of samples. However, the four métiers did not occur each month. Dominance of métiers in relation to fishing days over the period is given in Table 1, from which European hake is dominant (47941), followed by Red shrimp (33441), Red mullet (16689), and lastly Norway lobster (7046). In addition, 9648 intermediate samples (about 8%) for which métier could not be identified, possibly arising when a vessel has used more than one métier on the same day. Hence, these samples were categorised as undefined and, consequently, were excluded to increase the accuracy of the analyses.

For each métier, normally there was a decline of activity in months of temporal closure (Fig. 8). The mean number of fishing days per month indicates that both Norway lobster and Red shrimp métiers, had a relatively parallel activity. This was apparent with some peaks in April, May, July and August in both Xàbia and Dénia, while in La Vila Joiosa, this pattern was not clear. On the contrary, both métiers Red mullet and European hake were counteractive (Fig. 8a, c and e). Annually, this opposing pattern was evident between Norway lobster and Red shrimp métiers, and Red mullet and European hake métiers, in the three ports (Fig. 8b, d and f).

Concerning capacity of vessels directed to each métier, significant variation in TL and GT were observed (Table 2), that reflect differences in the fishing effort exerted in each métier by port. In La Vila Joiosa and Dénia (Fig. 9a, b, e and f), vessels focused on Red shrimp have higher capacity (TL and GT) than the rest of métiers; whereas TL of both European hake and Norway lobster in Dénia were statistically equal. In Xàbia (Fig. 9c), vessels directed to Red mullet were bigger, while in both European hake and Red shrimp, such differences were not detected. Nevertheless, the highest GT was observed for métier Norway lobster, as both Red mullet and European hake métiers were similar (Fig. 9d). Comparisons among ports within the same métier show that for Red shrimp and Norway lobster métiers, higher capacity vessels (TL and GT) were observed in La Vila Joiosa. On the contrary, for Red mullet and European hake métiers, longer vessels with higher tonnage were observed in Xàbia.

In respect to differences in CPUE among the identified métiers, analysis showed differences in the importance and the usage of each métier by port in both biomass and income (Table 2). In La Vila Joiosa, the métier targeting Norway lobster showed the highest biomass and income; while no differences in biomass were detected between métiers targeting European hake and Red mullet (Fig. 10a and b). In Xàbia, the highest biomass was detected for métier Red mullet, followed by European hake although the latter generated higher values (Fig. 10c and d). Economically, the remaining 3 métiers were statistically similar. In Dénia, Red mullet and European hake métiers afforded the highest biomass; however, no statistical differences were detected beween both métiers (Fig. 10e and f). Nevertheless, the highest income was detected for métier Red shrimp, while the rest of the métiers were statistically equal.

With regard to differences among ports within the same métier (Fig. 10), for both Red shrimp and Norway lobster métiers, the dominant ports by biomass were La Vila Joiosa, Xàbia and Dénia respectively. However, no differences in biomass were observed between Dénia and Xàbia for Red shrimp métier. In contrast, for both Red mullet and European hake métiers, the highest biomass was observed for Xàbia, La Vila Joiosa and Dénia respectively. Economically, for the Norway lobster métier, highest incomes were achieved in La Vila Joiosa, Xàbia and Dénia respectively. For the métier Red shrimp, higher income was observed at La Vila Joiosa, Dénia and Xàbia respectively, although differences between La Vila Joiosa and Dénia were not significant. For both métiers Red mullet and European hake, higher income was observed in Xàbia, Dénia and then La Vila Joiosa, despite that La Vila Joiosa and Dénia were not statistically different.

The mean catch composition, as well the mean CPUE of the most important species, is presented in Fig. 11 for each métier by port, in terms of biomass and income. The main species within each métier were similar among the three ports, although with slight differences in their relative importance. We found that only for the métier Red shrimp, the largest catches by weight and income were recorded for its target species (*A. antennatus*) in the three ports. On the contrary, in métier Red mullet, European hake and Norway lobster, the highest catches by weight were not always registered for their respective target species. In some of these métiers, *M. poutassou* and *O. vulgaris* were the most landed species replacing their respective target species. However, as their target species are very valuable in the market, they provided the main income for all métiers along the three ports (Fig. 11).

3.3. Relationship between "effort" and "landings" overall, and broken down by métier

The explorative data analysis conducted by scatterplot matrix (Appendix 3) shows a significant correlation between landings and all the effort variables considered: TL, GT and HP. The landings grew with the increase of all fishing effort variables, but the highest relationship was observed between landings and GT.

Scatterplots of the landings versus the vessel variables disaggregated by métier are shown in (Appendix 4). Significant correlations were observed in all métiers. Positive correlations were observed in all cases, except for the landings versus HP of métier Norway lobster as it showed a negative correlation (Appendix

4c). Generally, landings in all métiers increased with the increase of all fishing effort variables. The highest relationship was observed between landings and TL in European hake métier, while the lowest, of positive correlation, was observed between landings and HP in Red shrimp métier. For both European hake and Red mullet métiers, landings showed higher correlation with TL, while Norway lobster and Red shrimp métiers landings showed higher correlation with GT.

4 Discussion

Our results show the diversity of the fishing practices in a typical trawling fleet in the western Mediterranean. The analysis of long-time series of landings and effort data revealed: the annual decline in the fishing effort, expressed in total number of vessels, fishing days, TL and GT in the two most important ports, La Vila Joiosa and Dénia. The monthly activity was regular throughout the year, except for August and months of temporal closure in the three ports. Positive correlations were observed between landings and effort capacity in general and by métier with the exception of the landings versus HP of métier Norway lobster.

Many authors have pointed out the difficulty in obtaining data in the Mediterranean (Lleonart et al., 1998). The data used in this study are very valuable, due to the difficulty in obtaining such long-time series of unbroken period (2002-2011) in Mediterranean fisheries. In addition, it provides very detailed information of the fishing activity, on biological, economic terms and the exerted fishing effort. Such type of data has been used in many other works in Mediterranean fisheries (e.g. Maynou et al., 2011). However, these data are not controlled under scientific supervision and it may have some biases due to misidentification of some non-target species.

For multispecies fisheries, such as those of the current study, albeit a large number of commercial species, only a small number of species accounts for a large proportion of the catch and its economic value.

Cluster analysis, based on disaggregated landings by catch composition, has permitted the identification of four métiers: Red mullet, European hake, Norway lobster and Red shrimp (Table 3). Generally, the mean catch composition within the same métier was very similar between ports, although relative importance of species differed slightly from one port to another. The different fishing tactics or métiers and their characteristic species are quite known in the western Mediterranean trawling fishery (e.g. Carbonell et al., 1999; Moranta et al., 2000; García-Rodríguez, 2003; Massutí and Reñones, 2005). There is considerable agreement among authors about which are the main métiers underpinning trawling fishery. Moranta et al. (2000) have found three groups between 300 and 600 meter in fishing ground off Balearic Islands. These three groups were dominated by *N. norvegicus* and *A. antennatus*, correspondingly to the same métiers in our results. García-Rodríguez (2003) has identified three métiers in the gulf of Alicante dominated by: *M. merluccius, M. poutassou* and *A. antennatus*. This result does not contradict with the present study, as mentioned in our results that *M. poutassou* was one of the most landed species in the Norway lobster métier (more than *N. norvegicus* itself), in this sense both results are in accordance. The blue whiting *M.* poutassou is not a target species although it appears in large schools that are caught in areas of common trawling. The blue whiting does not have high market value, plus that it is a very delicate species to get it arrive in good condition for sale, especially for trawlers. We also have been able to differentiate two métiers targeting fish on the continental shelf the shallower Red mullet métier and the deeper European hake métier, that were aggregated in the work of García-Rodríguez et al (2003). Moreover, Massutí and Reñones (2005) have observed the existence of six main groups in fishing ground off Balearic Islands, associated to smaller depth intervals. This work also agreed with the current analysis in three métiers.

The common fisheries policy European Union has traditionally included both aid for construction and modernisation, as well as aids for permanent withdrawals (Hatcher 2000) which may have produced a lower number of vessel, but more effective limiting the adjustment of fleet capacity. However, we have observed a reduction in fishing effort (e.g. number of fishing days) but also reductions in vessel mean horsepower and GT, indicating that more powerful vessels have been withdrawn from the fishery. This removal is probably linked to the higher fuel prices during last years that make fishing for this fleet segment less profitable. Moreover, positive correlation was found between landings and effort as it make sense that a bigger vessel with higher GT and more powerful engine catches more than a smaller one, but probably these higher catches, at this moment, do not compensate the higher expenses.

Variation in the exerted fishing effort was revealed among métiers that reflect differences in the importance and the usage of each métier by port. The distribution of vessels among different métiers is linked with the availability of fishing grounds. The wide expanse of the continental shelf in the south of the gulf of Alicante, in front of La Vila Joiosa (Fig. 1), has favoured the development (more powerful vessels) of the fleet that target in a greater proportion continental shelf métiers (Red mullet and European hake) in comparison with Dénia and Xàbia with a smaller continental shelf (Fig. 1). Moreover, the larger distance to the slope resources (Norway lobster and Red shrimp métiers) from La Vila Joiosa port rationalises the observed higher capacity, in terms of TL and GT of these vessels. However, in the north of the gulf of Alicante, near Xàbia and Dénia, such differences were not evident due to the stretch continental shelf.

Exploring the pattern of métier succession throughout the year in a large sample (10 years) of fishing vessels provided more insights into the fishing activity and the seasonality of the target species. Temporal variations were also found in the practice of different métiers at seasonal and annual scales. Observed peaks in August and October are mainly associated with the reopening of the fishery after the temporal closure. This may result from fishers taking advantage of the increased catches after the closure. Furthermore, switching between both Red mullet and European hake métiers was clear on both monthly and annually scales. From a biological point of view, the European hake *M. merluccius* represents a spawning period extending almost throughout the year that is interpreted as an adaptive strategy to maximize the survival of early stages (Martin et al., 1999; Domínguez-Petit, 2008). This is reflected in the usage of this métier throughout the year. In contrast, Red mullet *Mullus* spp. recruits mostly during a well-defined and regular season. The reproduction of both *M. barbatus* and *M. surmuletus* in the western Mediterranean occurs mainly between spring and summer, almost exclusively from May to July (Relini et al., 1999; Voliani, 1999; Sieli et al., 2011). In this sense, some trawlers along the three ports shift from targeting European hake métier to the Red mullet métier, specifically in the last three months of the year, as mullet recruits in late autumn. Changes in métier preferences are also driven by economic forces. Market values determine the decision of fishermen, while fish prices are largely governed by local patterns of demand and supply. This is another possible explanation for the seasonality between métiers. Guillen and Maynou (2014) found out that seasonality in Red shrimp prices (where prices increase at the end of the year) is due to the higher demand for the Christmas and New Year's period (December registers a 40% price increase). This is the main reason that induces fishers to devote more effort to Red shrimp métier in this period.

Total catches (biomass and income) demonstrated variability between and within métiers. Such variability within the same métier may be attributable to the difference in abundance of the target assemblage in each port. However, variability between métiers, are because the abundance of deep-sea Mediterranean fishes decreases with depth with a tendency to stabilise at depths greater than 500 m (Moranta et al., 2007). This is evident in both Xàbia and Dénia where the biomass of deep-sea métiers is less than continental shelf métiers. It is noteworthy that the pattern of differences in biomass was quite similar among métiers in the three ports except for métier Norway lobster in La Vila Joiosa which was fairly high. Comparing the catch composition of this métier in the three ports indicates that these differences in biomass are due to the higher abundance of *M. poutassou* in La Vila Joiosa.

The concepts of fleet(s) and métier(s) are important providing a convenient and valuable balance between decreasing the complexity of the fishery into few manageable categories, while preserving sufficient information on its characteristics and dynamics (Ulrich et al., 2012). The fleet describes the vessels while the métier(s) describes the fishing activities in which the fleet engages. Such information were essential for a variety of fisheries researches analysing discards (e.g. Tzanatos et al., 2007) and different management strategies (e.g. Maynou et al., 2006; Samy-Kamal et al., submitted a; b). However, actually there are few cases where these interactions have been taken into account in EU fisheries management plans. For instance, the case of the North Sea flatfish (sole and plaice) management plan (EC, 2007), is based on a long previous studies of mixed-fishery interactions in the Dutch beam trawl fishery (e.g. Kraak et al., 2008). Noteworthy that, this fishery is relatively simple with only two species and relatively few and homogeneous fleets involved (Ulrich et al., 2012), which means that the pre-required categorization of fishing activity described above was easier than Mediterranean case.

5 Conclusions and recommendations

Our analysis represents a contribution to identify métiers and the distribution of fishing effort between them in one of the most important fisheries of the western Mediterranean. These findings may be considered as a keystone for more practical implications. In the absence of TACs or quotas in the Mediterranean, the GFCM strategy relies mainly on technical measures and effort-control programmes. Consequently, the development of management at the métier level (métier-based measures) may aid in maintaining or rebuilding of specific stocks, through protection spatially or temporally of vulnerable life cycle stages.

Management regulations are constantly subject to adaptation and modification towards the improved sustainability and health of fisheries. However, in many cases, it may lead to unexpected consequences, as it is difficult to anticipate the reaction of fleets and fishers. The improved detailed information of métiers and distribution of fishing effort acquired here could be useful in two ways: firstly in understanding how fishers adapt their behaviour under changeable management strategies (e.g. temporal closures), and secondly an improved ability to evaluate regulations taking into account the characteristics of each métier.

The inconsistency of single-stock management approaches in a multi-specific fisheries context has repeatedly been highlighted as a key issue in the European Common Fishery Policy, and it has long been suggested that this issue would be better addressed through fleet and métier-based measures (Ulrich et al., 2012). The management of multi-specific fisheries should start off considering the characteristics of each métier separately, and not to manage them as a same fishery. In this paper we quantify the effort allocated to different trawling métiers in different ports, which is the first step to improve the fishery management. Since fishing effort regulations are the main management measures in the Mediterranean fisheries, the patterns observed in the distribution of effort can indicate when is the most suitable time to reduce the overall effort (e.g. to set a seasonal closure). For example, closing the fishing ground during months of lower activity would have fewer effects on fishing sector and may be easily accepted, but it will produce a lower reduction in fishing mortality than if the closure was established in months with higher activity. On the other hand, closure can be set in months of the most intense fishing effort directed on certain métier when there is a need to protect a specific target species or an accessory species of this métier. Moreover, effort variables: TL, GT and HP are not very important in predicting overall landings, unless broken down by métier. Taking into account that landings of each métier were differently correlated to each effort variable, a management implication would be that controlling fleet capacity could be effective when done by métier. This might indicate that management for Red mullet and European hake would benefit mostly by controlling vessels TL while lobster and red shrimp by GT capacity. However, such measure is quite difficult in the Mediterranean.

Furthermore, as observed in this paper, many economic forces (e.g. market prices or fuel prices) are the main forces that affect fishers' critical decision (e.g. shift from a métier to another or exit the fishery). More attention should be given to socio-economic management measures as it could be more effective way to achieve management goals. Managers should also strengthen means to ensure effective regulation of vessel capacity, as it is significantly related to catch.

It is important to note that trawl fisheries in the Mediterranean target the same species but the relative importance of each métier may be different in different areas and it has to be quantified for a better management within a national or regional (GFCM) scale.

6 Acknowledgements

The authors acknowledge the cooperation of the staff at the La Vila Joiosa, Xàbia and Dénia fishermen's guilds for their important role in collecting the data. This study was supported by a grant of the Spanish Agency for International Development Cooperation (AECID). The authors appreciate the constructive criticism of the editor and three anonymous reviewers. Finally we acknowledge Julie Smith and Monica V. Brissette for language revisions.

7 References

Alemany, F., Álvarez, F., 2003. Determination of effective fishing effort on hake, Merluccius merluccius, in Mediterranean trawl fishery. Sci. Mar. 67, 491–499.

Biseau, A., Gondeaux, E., 1988. Apport des méthodes d'ordination en typologie des flottilles. ICES J. Mar. Sci. 44, 286–296.

Biseau, A., 1998. Definition of a directed fishing effort in a mixed-species trawl fishery, and its impact on stock assessments. Aquat. Living resour. 11, 119–136.

BOE. 2013. Boletin Oficial del Estado. Ministerio de Agricultura, Alimentación y Medio Ambiente. Resolución de 27 de marzo de 2013, de la Secretaría General de Pesca, por la que publican los censos actualizados de las modalidades de arrastre de fondo, artes menores, cerco y palangre de fondo del caladero Mediterráneo.BOE nº 88, Sec. III. Pág. 27442.

Caddy, J.F., 2009. Practical issues in choosing a framework for resource assessment and management of Mediterranean and Black Sea fisheries. Med. Mar. Sci. 10 (1), 83–119.

Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. Aus. J. of Eco. 18, 117–143.

Clarke, K.R., Warwick, R.M., 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E, Plymouth.

Clarke, K. R., Gorley, R. N., 2006. PRIMER v6: User Manual/ Tutorial. PRIMER-E, Plymouth, UK. 190 pp.

Colloca, F., Cardinale, M., Maynou, F., Giannoulaki, M., Scarcella, G., Jenko, K., ... & Fiorentino, F., 2013. Rebuilding Mediterranean fisheries: a new paradigm for ecological sustainability. Fish Fish. 14, 84–109.

Demestre, M., Sánchez, P., Abelló, P., 2000. Demersal fish assemblages and habitat characteristics on the continental shelf and upper slope of the north-western Mediterranean. J. Mar. Biol. Assoc. UK 80, 981–988.

Domínguez-Petit, R., Korta, M., Saborido-Rey, F., Murua, H., Sainza, M., Piñeiro, C., 2008. Changes in size at maturity of European hake Atlantic populations in relation with stock structure and environmental regimes. J. Mar. Sys. 71(3), 260–278.

EC, 2006. Council Regulation (EC) No. 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, amending Regulation (EEC) No. 2847/93 and repealing Regulation (EC) No. 1626/94.

EC, 2007. Council Regulation (EC) No 676/2007 of 11 June 2007 establishing a multiannual plan for fisheries exploiting stocks of plaice and sole in the North Sea. Off. J. Eur. Union. L 157/1.

EC, 2008. Commission decision (EC) No. 2008/949/EC of 2008 adopting a multi annual community programme pursuant to Council regulation No. 199/2008 establishing a community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

EC (European Commission). 2009. Green Paper. Reform of the Common Fishery Policy. COM (2009)163, 28 pp.

FAO, 2011. Review of the state of world marine fishery resources. FAO Fisheries and Aquaculture Technical Paper No. 569. Rome, FAO. 2011. 334 pp.

Forcada, A., Valle, C., Sánchez-Lizaso, J. L., Bayle-Sempere, J. T., Corsi, F., 2010. Structure and spatio-temporal dynamics of artisanal fisheries around a Mediterranean marine protected area. ICES J. Mar. Sci. 67(2), 191–203.

García Rodríguez, M., 2003. Characterisation and standardisation of a red shrimp Aristeus antennatus, (Risso, 1816) fishery off the Alicante gulf (SE Spain). Sci. Mar. 67(1), 63–74.

García-Rodríguez, M., Á.M. Fernández, A. Esteban., 2006. Characterisation, analysis and catch rates of the small-scale fisheries of the Alicante Gulf (SE Spain) over a 10 years time series. Fish. Res. 77, 226–238.

Goñi, R., Alvarez, F., Adlerstein, S., 1999. Application of generalized linear modeling to catch rate analysis of Western Mediterranean fisheries: the Castellón trawl fleet as a case study. Fish. Res. 42(3), 291–302.

Guillen, J., Maynou, F., 2014. Importance of temporal and spatial factors in the ex-vessel price formation for red shrimp and management implications. Mar. Policy. 47, 66–70.

Hatcher, A., 2000. Subsidies for European fishing fleets: the European Community's structural policy for fisheries 1971–1999. Mar. Policy, 24(2), 129–140.

Holley, J. F., Marchal, P., 2004. Fishing strategy development under changing conditions: examples from the French offshore fleet fishing in the North Atlantic. ICES J. Mar. Sci. 61, 1410–1431.

Jimenez, M. P., Sobrino, I., Ramos, F., 2004. Objective methods for defining mixed-species trawl fisheries in Spanish waters of the Gulf of Cádiz. Fish. Res. 67, 195–206.

Kraak, S.B.M., Buisman, E.C., Dickey-Collas, M., Poos, J.J., Pastoors, M.A., Smit, J.G.P., van Oostenbrugge, J.A.E., Daan, N., 2008. The effect of management choices on the sustainability and economic performance of a mixed fishery: a simulation study. ICES J. Mar. Sci. 65, 697e712.

Lleonart, J., Lloret, J., Touzeau, S., Salat, J., Recasens, L., Sardà, F., 1998. Mediterranean fisheries, an overview. Barcelona, España. SAP.

Laurec, A., Biseau, A., Charuau, A., 1991. Modelling technical interactions. ICES Mar. Sci. Symp. 193, 225–236.

Martin, P., Sartor, P., García-Rodríguez, M., 1999. Exploitation patterns of the European hake *Merluccius merluccius*, red mullet Mullus barbatus and striped red mullet *Mullus surmuletus* in the western Mediterranean. J. of App. Ichthyol. 15(1), 24–28.

Massutí, E., Reñones, O., Carbonell, A., Oliver, P., 1996. Demersal fish communities exploited on the continental shelf and slope off Majorca (Balearic Islands, NW Mediterranean). Vie et Milieu. 46, 45–55.

Massutí, E., Reñones, O., 2005. Demersal resource assemblages in the trawl fishing grounds off the Balearic Islands (western Mediterranean). Sci. Mar. 69(1), 167–181.

Maynou, F., Sardà, F., Tudela, S., Demestre, M., 2006. Management strategies for red shrimp (Aristeus antennatus) fisheries in the Catalan Sea (NW Mediterranean) based on bioeconomic simulation analysis. Aquat. Living resour. 19(2), 161–172.

Maynou, F., Recasens, L., Lombarte, A., 2011. Fishing tactics dynamics of a Mediterranean small-scale coastal fishery. Aquat. Living resour. 24(02), 149–159.

Moranta, J., Massutí, E., Morales-Nin, B., 2000. Fish catch composition of the deep-sea decapod crustacean fisheries in the Balearic Islands (western Mediterranean). Fish. Res. 45(3), 253–264.

Moranta, J., Massutí, E., Palmer, M., Gordon, J. D., 2007. Geographic and bathymetric trends in abundance, biomass and body size of four grenadier fishes along the Iberian coast in the western Mediterranean. Prog. in Oceanog.72(1), 63–83.

Pelletier D., Ferraris J., 2000. A multivariate approach for defining fishing tactics from commercial catch and effort data. Can. J. Fish. Aquat. Sci. 57, 51–65.

Oliver, P., 1993. Analysis of fluctuations observed in the trawl fleet landings of the Balearic Islands. Sci. Mar. 57, 219–227.

R Development Core Team., 2010: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Relini, G., Bertrand, J., Zamboni, A., 1999. Synthesis of the knowledge on Bottom Fishery Resources in Central Mediterranean (Italy and Corsica). Biol. Mar. Medit., 6(Supl. 1), 1–868.

Salas, S., Gaertner, D., 2004. The behavioural dynamics of fishers: management implications. Fish Fish. 5, 153–167.

Samy-Kamal, M., Forcada, A., Sánchez-Lizaso, J.L., submitted a. Effects of seasonal closures in a multi-specific fishery. Submitted to Fish. Res.

Samy-Kamal, M., Forcada, A., Sánchez-Lizaso, J.L., accepted b. Short-term effect of selectivity change in a trawling fishery in the Western Mediterranean. Accepted. J. of App. Ichthyol.

Sandrini-Neto, L., Camargo, M.G., 2011. GAD: an R package for ANOVA designs from general principles. Available on CRAN.

Sanchez Lizaso., 2002. ¿Resulta aplicable la legislación pesquera en el Mediterráneo? In Sánchez-Lizaso, J.L.; Lleonart, J. Actas de la VI reunión del Foro científico sobre la pesca española en el Mediterráneo.pp. 29 - 32. Ed Club Universitario, Alicante.

Sieli, G., Badalucco, C., Di Stefano, G., Rizzo, P., D'Anna, G., Fiorentino, F., 2011. Biology of red mullet, *Mullus barbatus* (L. 1758), in the Gulf of Castellammare (NW Sicily, Mediterranean Sea) subject to a trawling ban. J. of App. Ichthyol.27(5), 1218–1225.

Sokal, R., Rohlf, F. J., 1969. Bartlett's test of homogeneity of variances. In Biometry, 370–371. San Francisco: W. H. Freeman and Co.

Tzanatos, E., Somarakis, S., Tserpes, G., Koutsikopoulos, C., 2007. Discarding practices in a Mediterranean small-scale fishing fleet (Patraikos Gulf, Greece). Fish. Manage. Ecol. 14, 277–285.

Ulrich, C., Andersen, B. S., 2004. Dynamics of fisheries, and the flexibility of vessel activity in Denmark between 1989 and 2001. ICES J. Mar. Sci. 61, 308–322.

Ulrich, C., Wilson, D. C., Nielsen, J. R., Bastardie, F., Reeves, S. A., Andersen, B. S., Eigaard, O. R., 2012. Challenges and opportunities for fleet-and métier-based approaches for fisheries management under the European Common Fishery Policy. Ocean Coast. Manage., 70, pp. 38–47.

Underwood, A.J., 1997. Experiments in ecology: their logical design and interpretation using analysis of variance. Cambridge University Press, Cambridge.

Underwood, A.J., 1981. Techniques of analysis of variance in experimental marine biology and ecology. Oceanography and Marine Biology: An Annual Review. 19, 513–605.

Voliani, A., 1999. *Mullus barbatus*. In: Synthesis of knowledge on bottom fishery resources in central Mediterranean (Italy and Corsica). G. Relini, J. Bertrand and A. Zamboni (Eds). Biol. Mar. Medit. 6 (Suppl. 1), 276–291.

8 Tables

Table 1: Number of fishing days (samples vessel/day) by port and métier

Métiers	La Vila Joiosa	Xàbia	Dénia	Total
Red mullet	5853	988	9848	16689
European hake	36531	3591	7819	47941
Norway lobster	3806	1590	1650	7046
Red shrimp	11653	5228	16560	33441
Undefined	2229	1181	6238	9648
Total	60072	12578	42115	114765

Table 2: Analysis of variance (ANOVA) results with 2 factors (M: métier; P: port) for mean characteristics by total length and Gross Tonnage and for the total catch by biomass and income. D.f.: degrees of freedom; MS: mean square. Dash (–) indicates that there is no transformation. (a) indicates that there is no homogeneity of variance, the level of significance being **p < 0.001.

Sources of variation	D.f.	Total length		Gross tonnage		Total biomass		Total income	
		MS	F value	MS	F value	MS	F value	MS	F value
M	3	3152.5	645.89**	329048	980.12**	20275874	1002.16**	204270560	259.52**
P	2	3661.0	750.07**	447582	1333.20**	7907447	390.84**	263248630	334.45**
M×P	6	2613.4	535.43**	204833	610.13**	4661073	230.38**	194607826	247.24**
Residual	11844	4.9		336		20232		787111	
Transform.		–a		–a		–a		–a	

Table 3. A complete typology of the métier identified based on the different analysis made in the paper. *Morralla* is a Spanish category that refers to a mix of low-valued small fishes (mainly Sparidae and Labridae).

Métiers	**Main gear**	**Target species**	**Main accessory species**	**Peak Months**	**Mean vessels characteristics (**± standard error**)**			**Fishing grounds**	**Main port**
					TL	**GT**	**HP**		
Red mullet	**Demersal trawl**	*Mullus* spp.	O. *vulgaris* *Trachurus* spp. M. *merluccius* S. *officinalis*	Apr., May Oct. and Nov.	19.2 ± 0.019	46.4 ± 0.12	254.2 ± 0.84	The continental shelf (> 100 m)	Denía
European hake		*Merluccius merluccius*	Morralla* O. *vulgaris* *Lophius* spp.	Mar. and Aug.	20.6 ± 0.1	61.2 ± 0.12	292.2 ± 0.55	The shelf edge and the beginning of the continental slope (100-199 m)	Villajoyosa
Norway lobster		*Nephrops norvegicus*	M. *poutassou* P. *blennoides* M. *merluccius*	Jul. and Aug.	22.3 ± 0.02	79.7 ± 0.27	308.2 ± 1.48	Deeper areas of the slope (200-399 m)	Javea
Red shrimp		*Aristeus antennatus*	M. *poutassou* P. *blennoides* G. *longipes*	Mar., Apr., Jul., Oct., Nov. and Dec.	22.5 ± 0.01	76.1 ± 0.12	298.2 ± 0.55	Deeper areas of the slope (400-800 m)	Denía, Javea

9 Figure legends

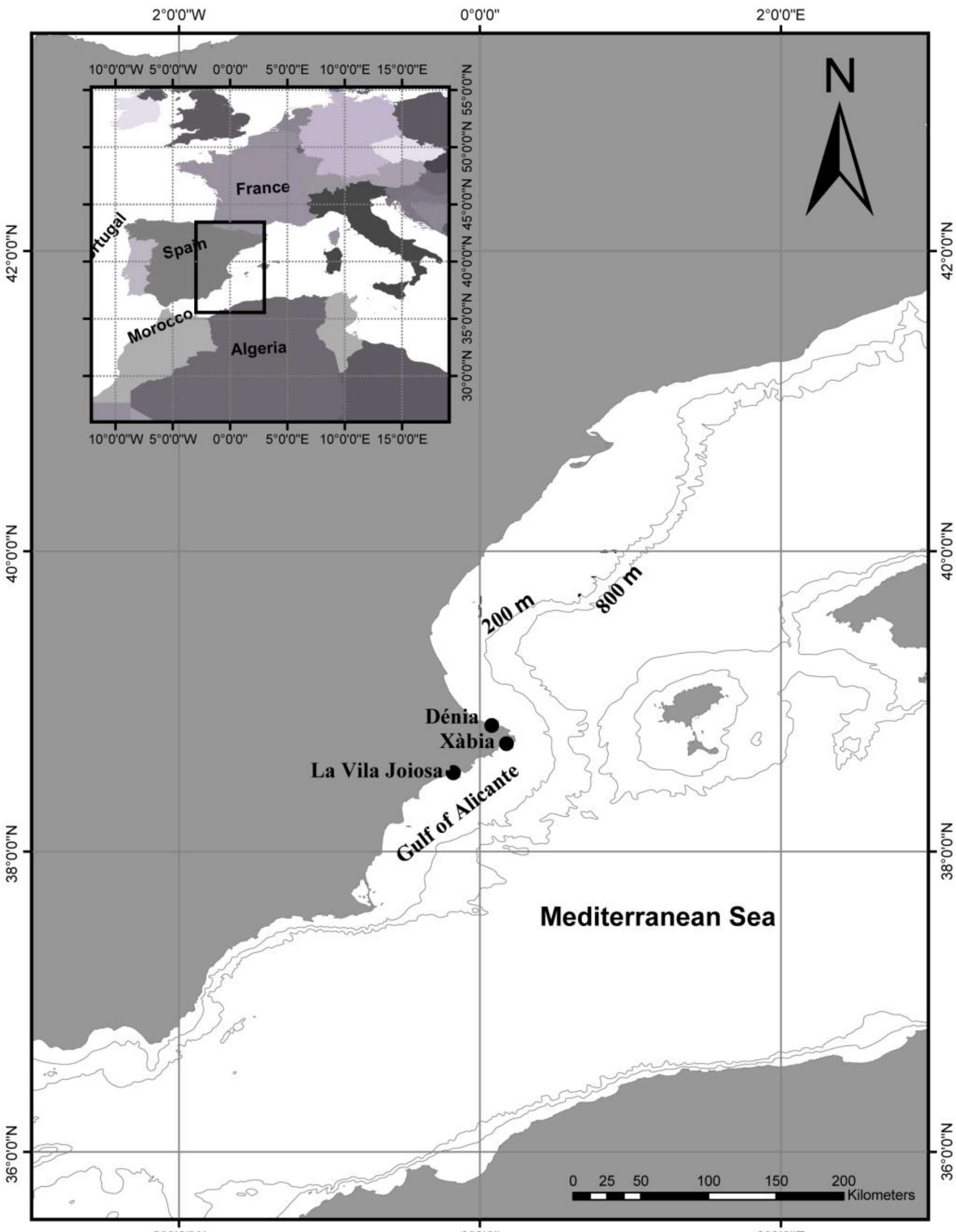


Figure 1: Map of the study area (SW Mediterranean) showing the location of the three trawling ports La Vila Joiosa, Xàbia and Dénia (Spain).

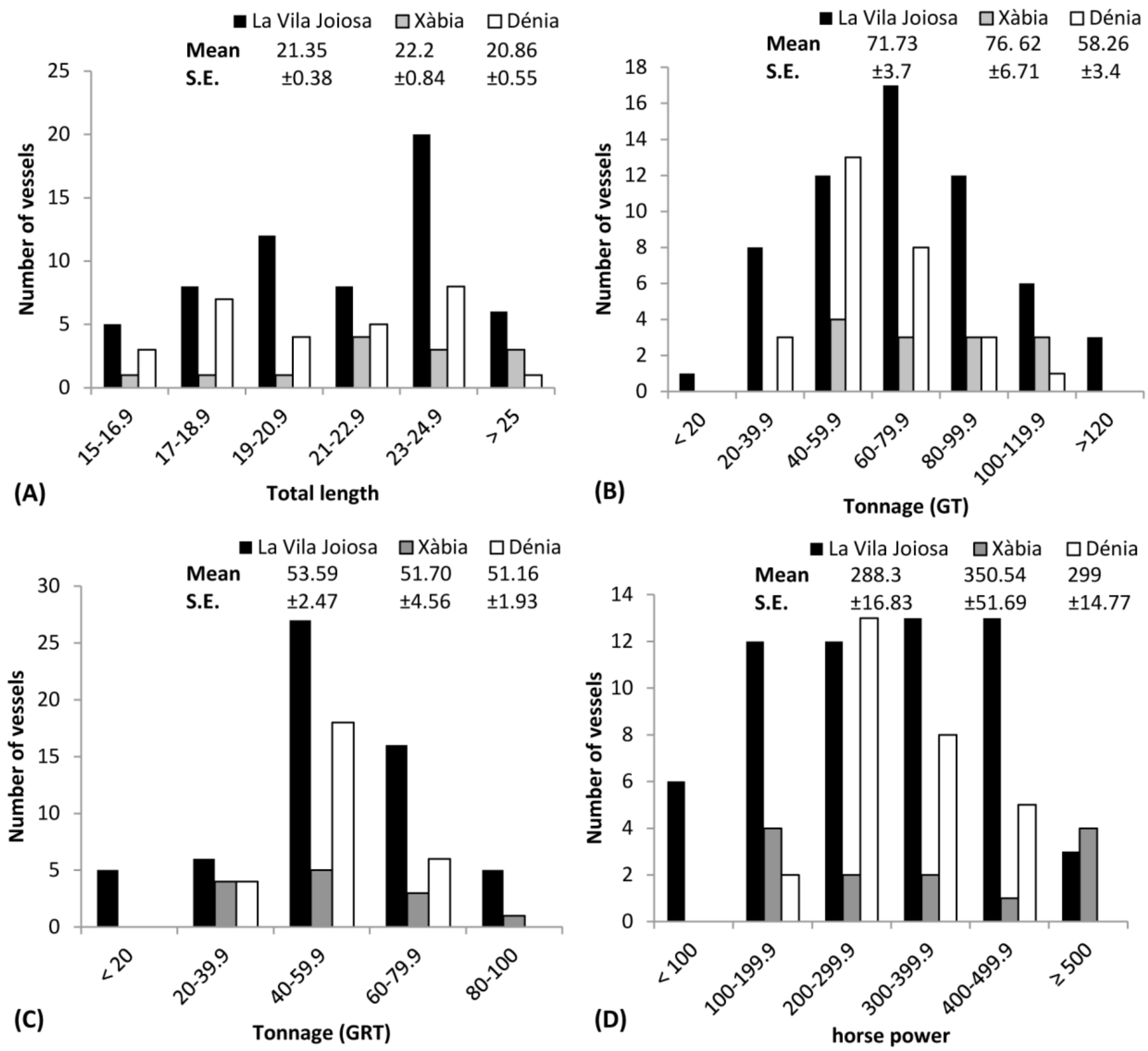


Figure 2: Structure of the trawling fleets of La Vila Joiosa, Xàbia and Dénia by (a) vessel length, (b) gross tonnage (c) relative gross tonnage and (d) horse power. Mean characteristics and standard errorare shown under the legend.

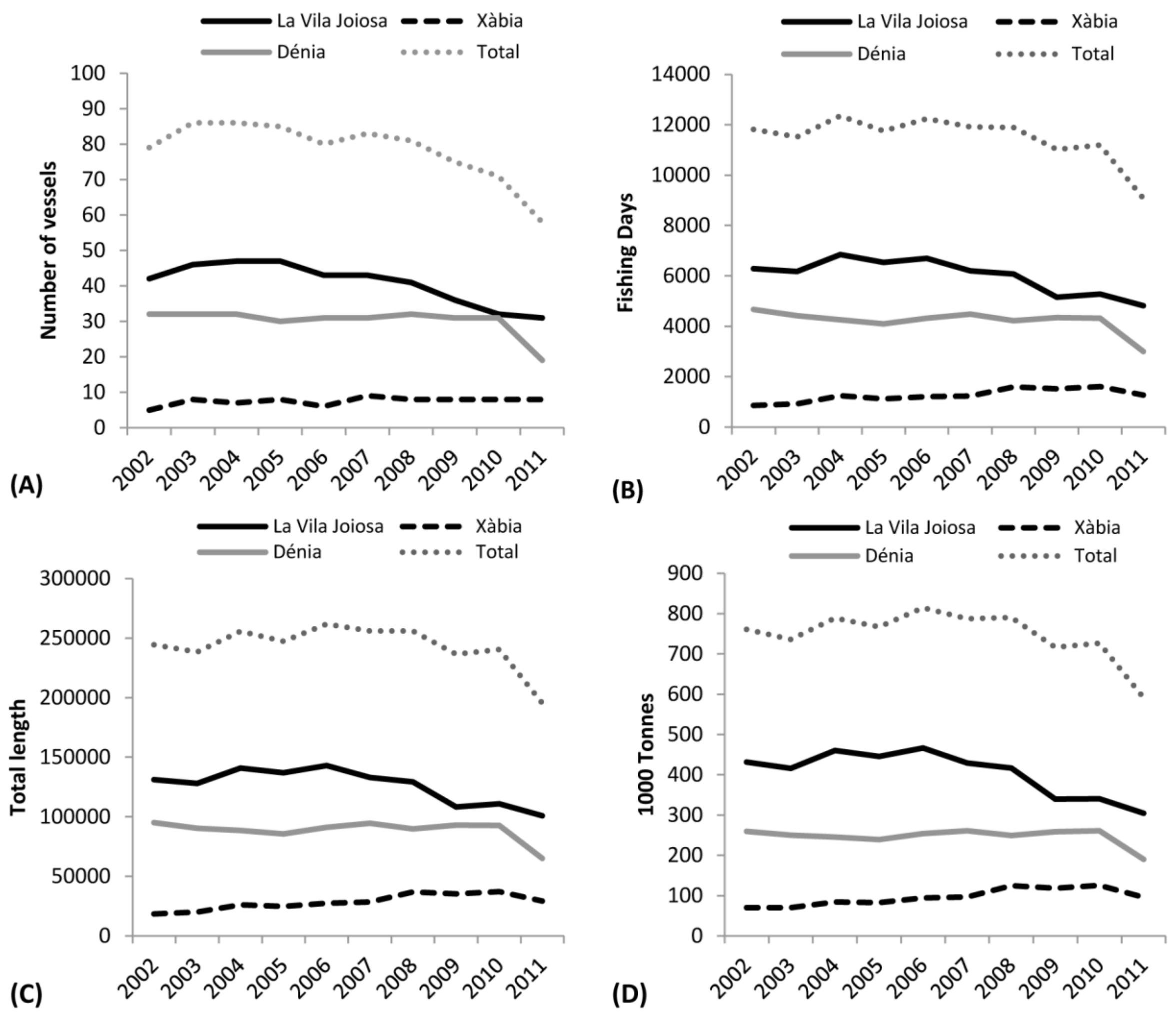


Figure 3: Temporal evolution of the fishing effort of the trawling fleets in La Vila Joiosa, Xàbia and Dénia over the period of study expressed as: (a) number of vessels, (b) total fishing days (fishing days per vessel), (c) total length of vessels and (d) total gross tonnage.

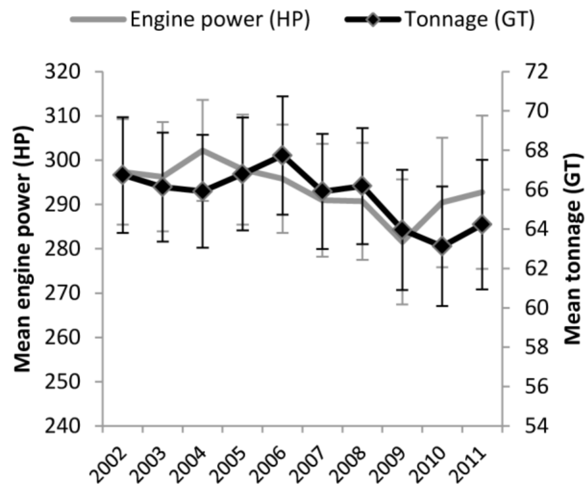


Figure 4: For the total fleet annual change in both (GT) and (HP) means over 10 years of study (2002-2011). Error bars show the standard error.

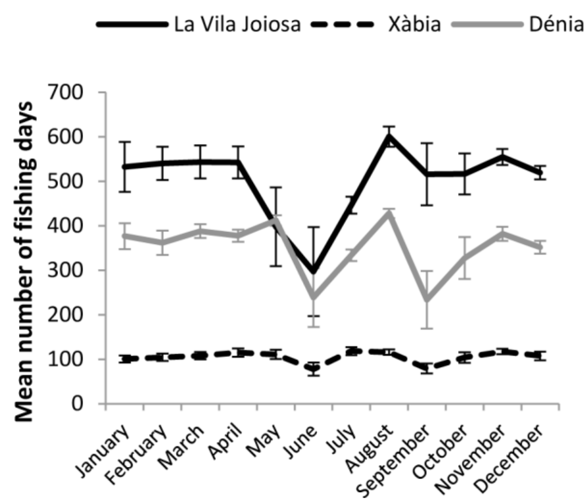


Figure 5: Monthly trend of mean fishing days (fishing day per vessel) of the trawling fleets of La Vila Joiosa, Xàbia and Dénia over 10 years of study (2002-2011). Error bars show the standard error.

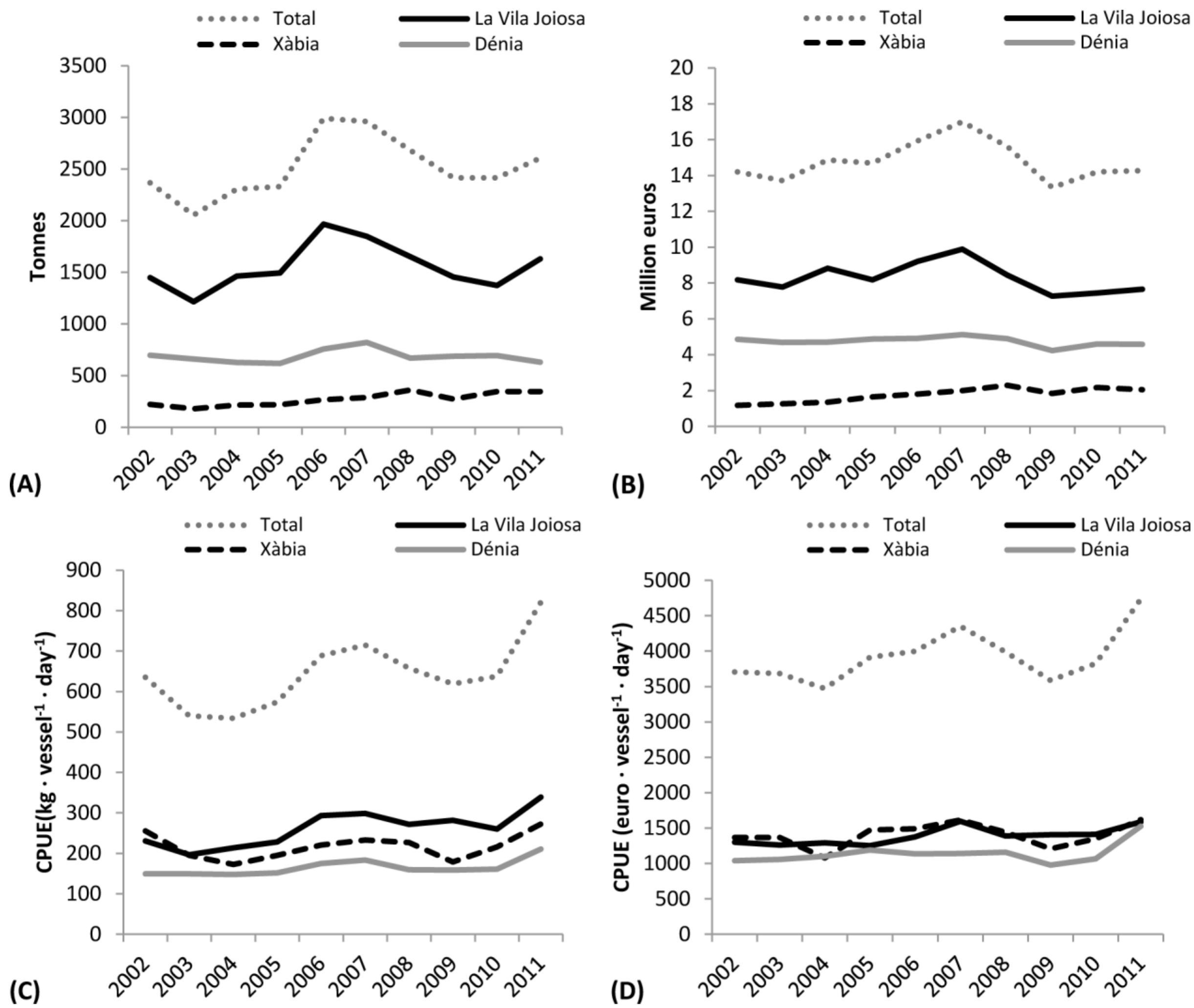


Figure 6: Temporal evolution of (a) total annual landings (ton), (b) total annual income (euros), (c) annual CPUE (kg·vessel^{-1}·day^{-1}) and (d) annual income €PUE (euros·vessel^{-1}·day^{-1}) for the trawling fleets of La Vila Joiosa, Xàbia and Dénia over 10 years of study (2002-2011).

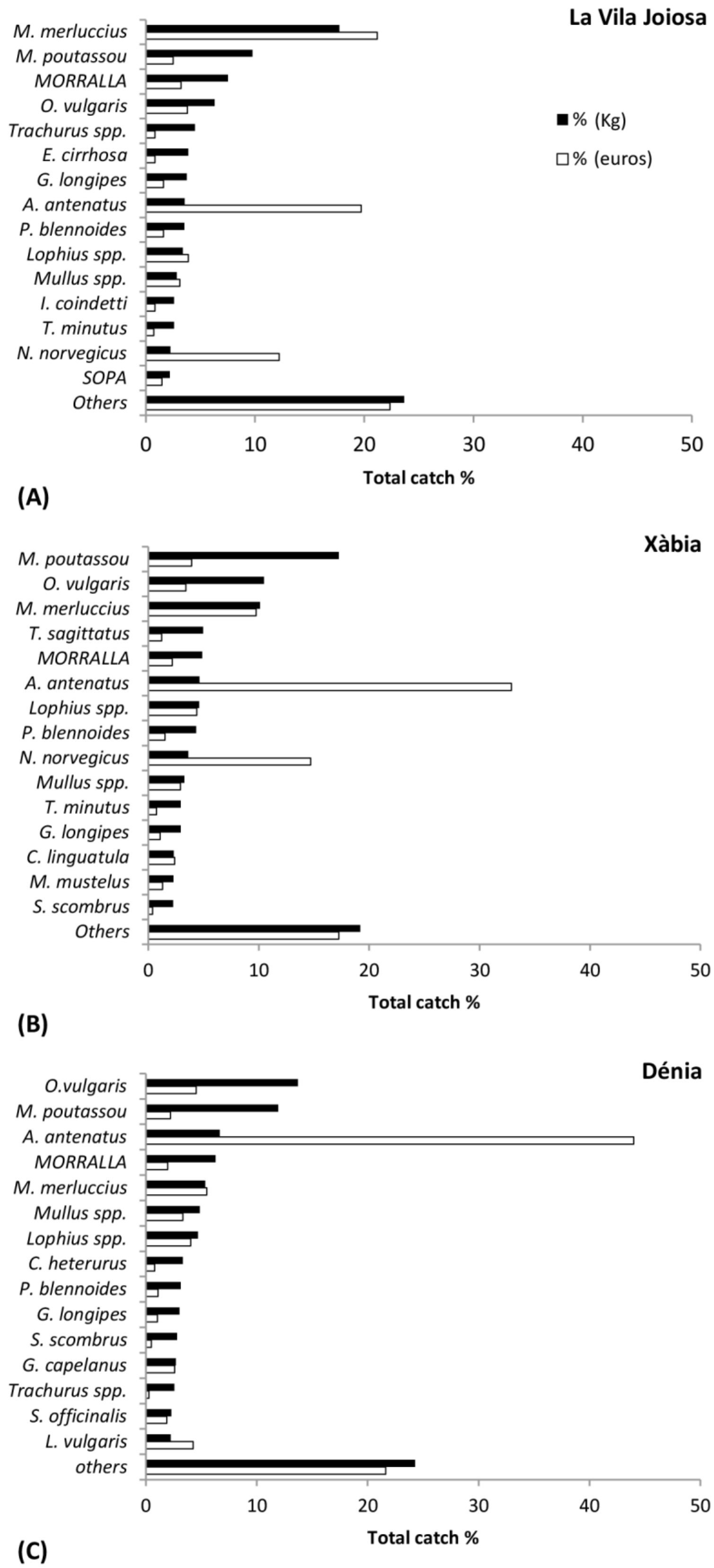

La Vila Joiosa
M. merluccius
M. poutassou
MORRALLA
O. vulgaris
Trachurus spp.
E. cirrhosa
G. longipes
A. antenatus
P. blennoides
Lophius spp.
Mullus spp.
I. coindetti
T. minutus
N. norvegicus
SOPA
Others
% (Kg)
% (euros)
0
10
20
30
40
50
Total catch %
(A)
Xàbia
M. poutassou
O. vulgaris
M. merluccius
T. sagittatus
MORRALLA
A. antenatus
Lophius spp.
P. blennoides
N. norvegicus
Mullus spp.
T. minutus
G. longipes
C. linguatula
M. mustelus
S. scombrus
Others
0
10
20
30
40
50
Total catch %
(B)
Dénia
O.vulgaris
M. poutassou
A. antenatus
MORRALLA
M. merluccius
Mullus spp.
Lophius spp.
C. heterurus
P. blennoides
G. longipes
S. scombrus
G. capelanus
Trachurus spp.
S. officinalis
L. vulgaris
others
0
10
20
30
40
50
Total catch %
(C)

Figure 7: Mean catch composition for the ports (a) La Vila Joiosa, (b) Xàbia and (c) Dénia, showing the mean proportion (in biomass and income) of the 15 most important species in the total catch.

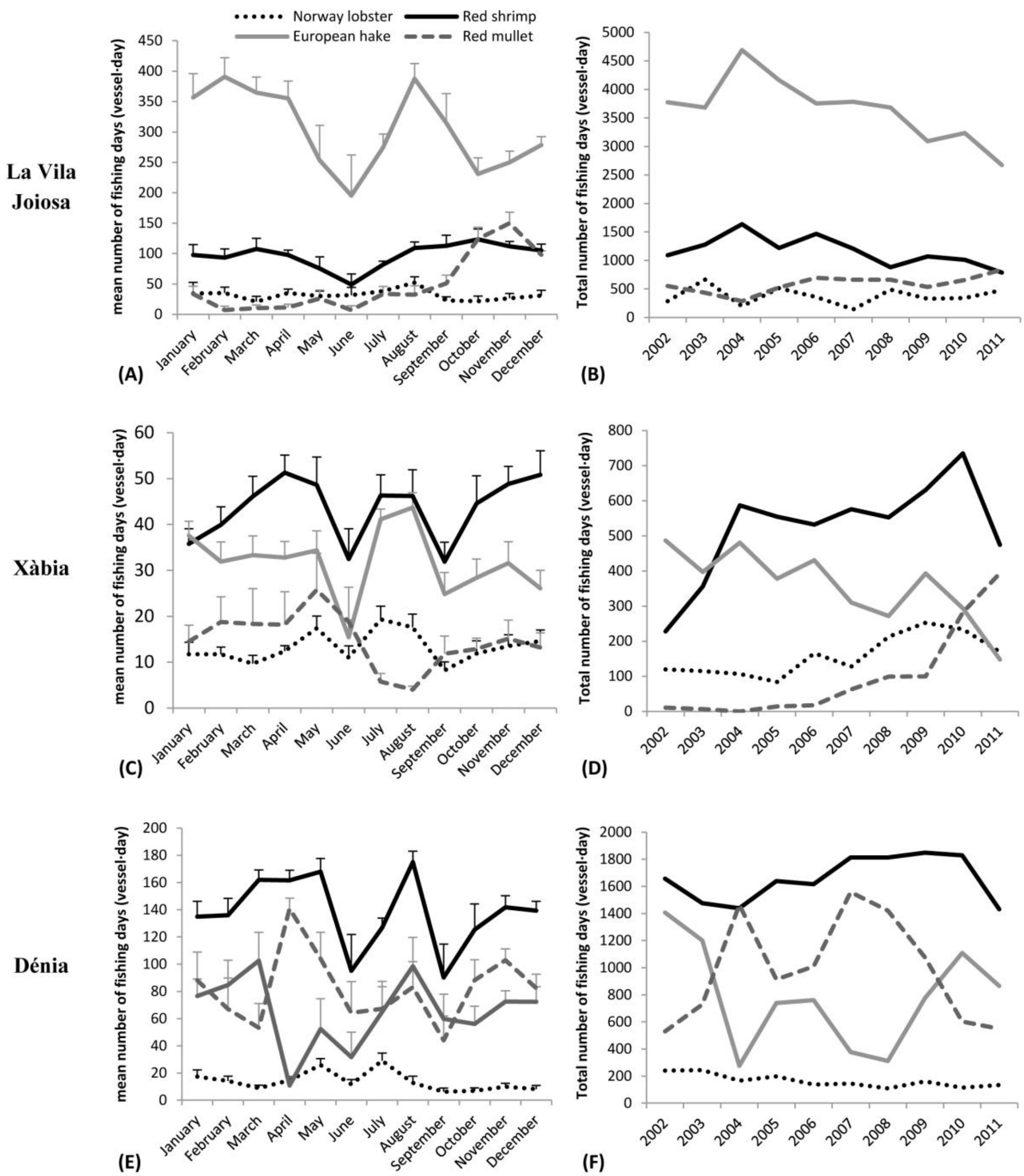
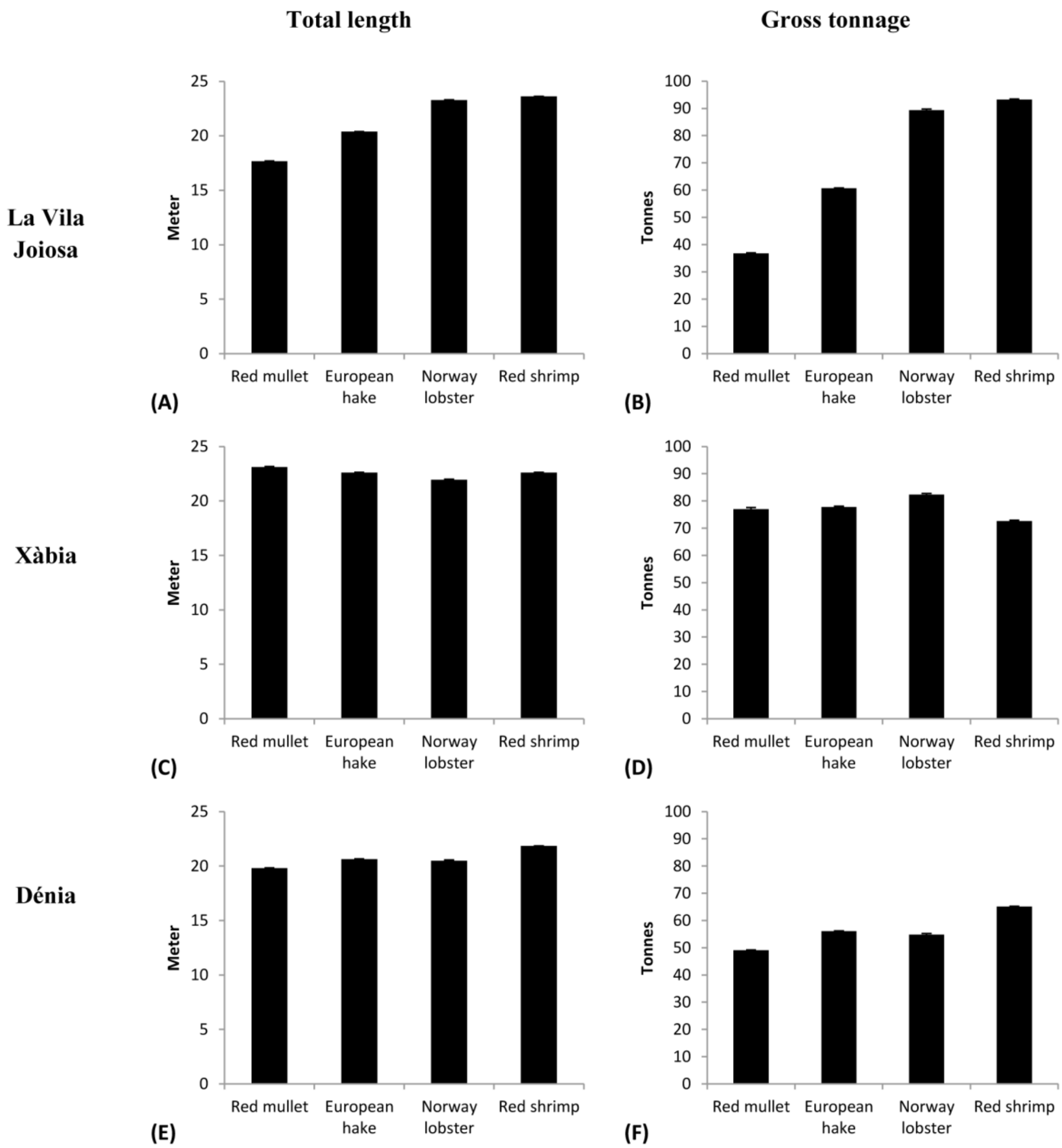


Figure 8: Mean number of fishing days of each métier by month (left), and total number of fishing days of each métier by year (right), for the trawling fleets of (a,b) La Vila Joiosa, (c,d) Xàbia and (e,f) Dénia over 10 years of study (2002-2011). Error bars show the standard error.



Total length
Gross tonnage
La Vila Joiosa
Xàbia
Dénia
Meter
Tonnes
25
20
15
10
5
0
100
90
80
70
60
50
40
30
20
10
Red mullet
European hake
Norway lobster
Red shrimp
(A)
(B)
(C)
(D)
(E)
(F)

Figure 9: Mean characteristics and standard error calculated for (left a,c,e) Mean TL and (right b,d,f) mean GT, of each métier for the ports (a,b) La Vila Joiosa, (c,d) Xàbia and (e,f) Dénia over 10 years of study (2002-2011).

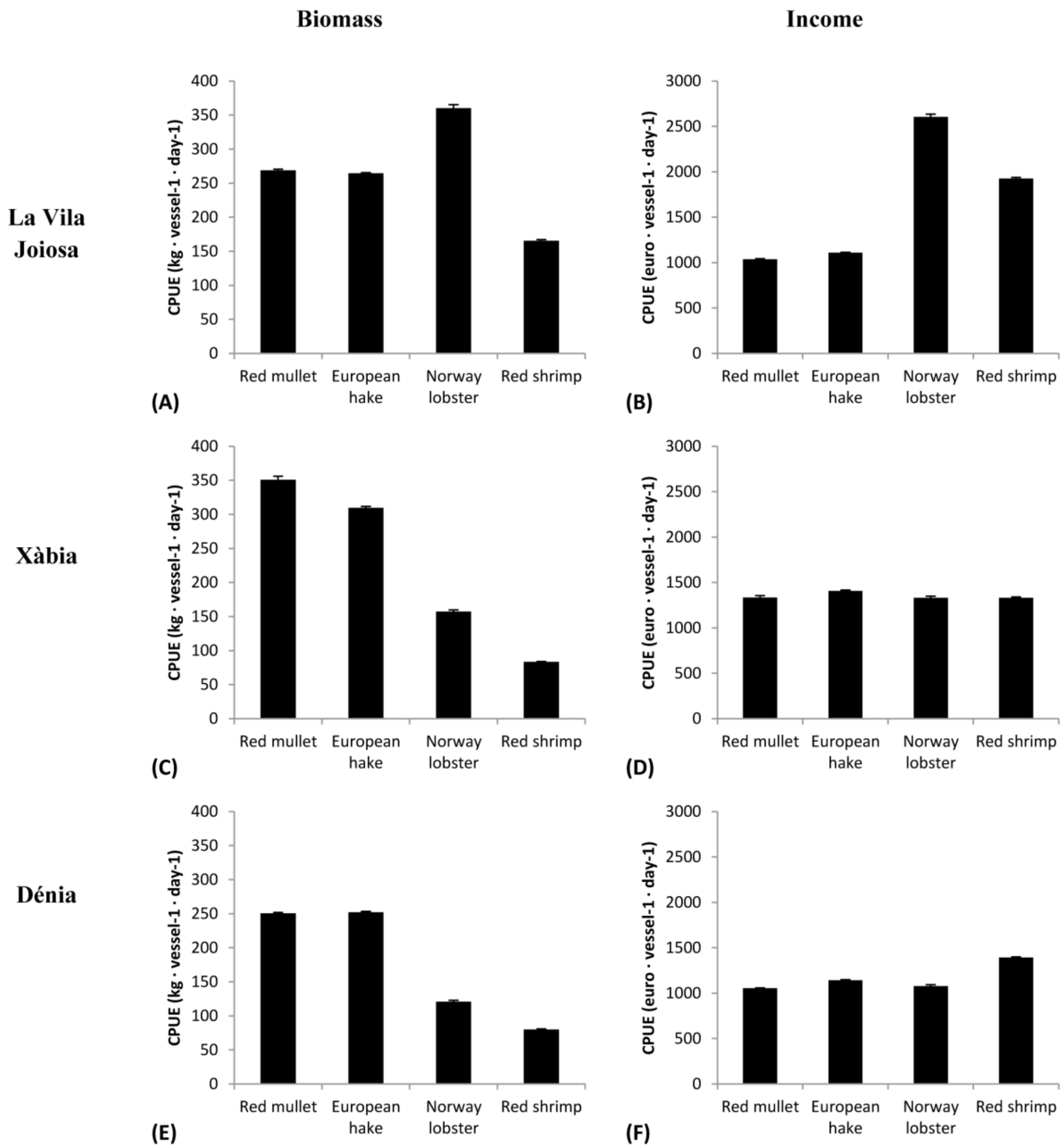

Biomass
Income
La Vila Joiosa
Xàbia
Dénia
CPUE (kg · vessel-1 · day-1)
CPUE (euro · vessel-1 · day-1)
Red mullet
European hake
Norway lobster
Red shrimp
(A)
(B)
(C)
(D)
(E)
(F)

Figure 10: Mean CPUE and standard error of the total catch, calculated as (left a,c,e) biomass and (right b,d,f) income, of each métier for the ports (a,b) La Vila Joiosa, (c,d) Xàbia and (e,f) Dénia over 10 years of study (2002-2011).

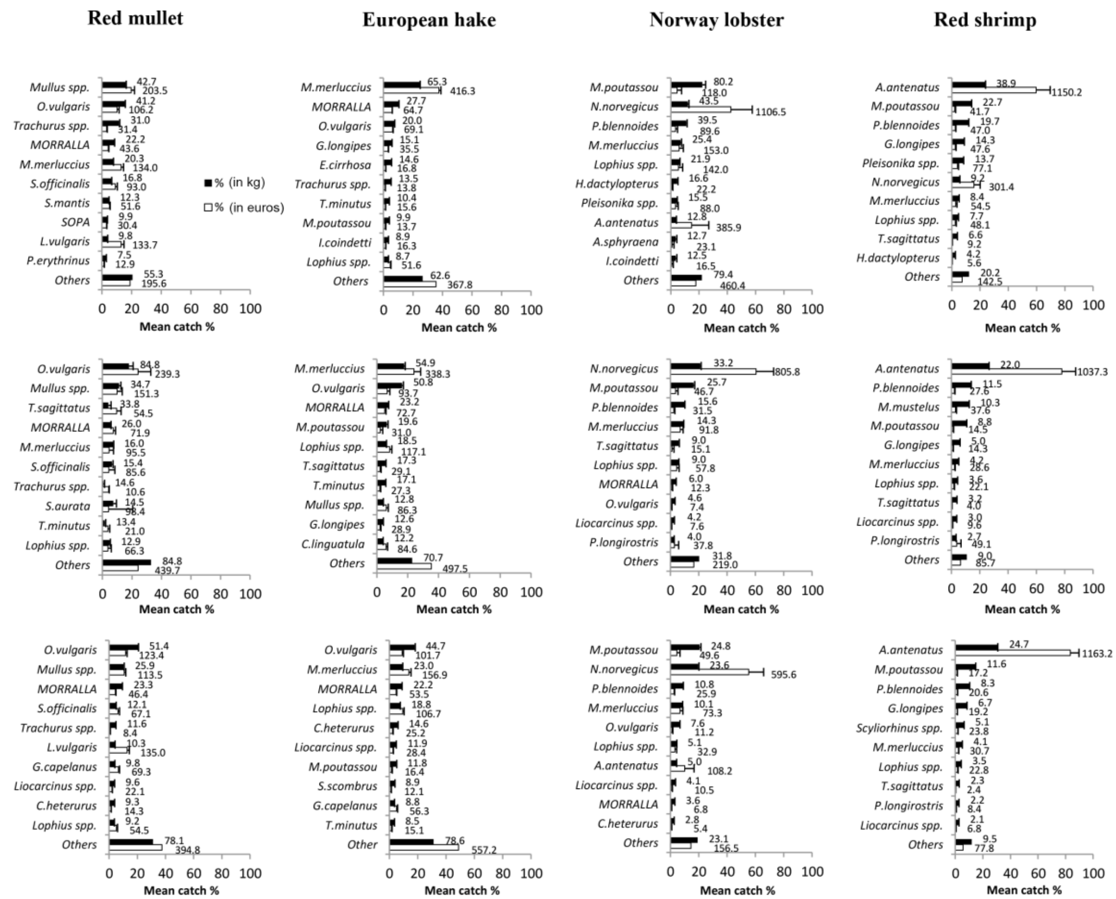
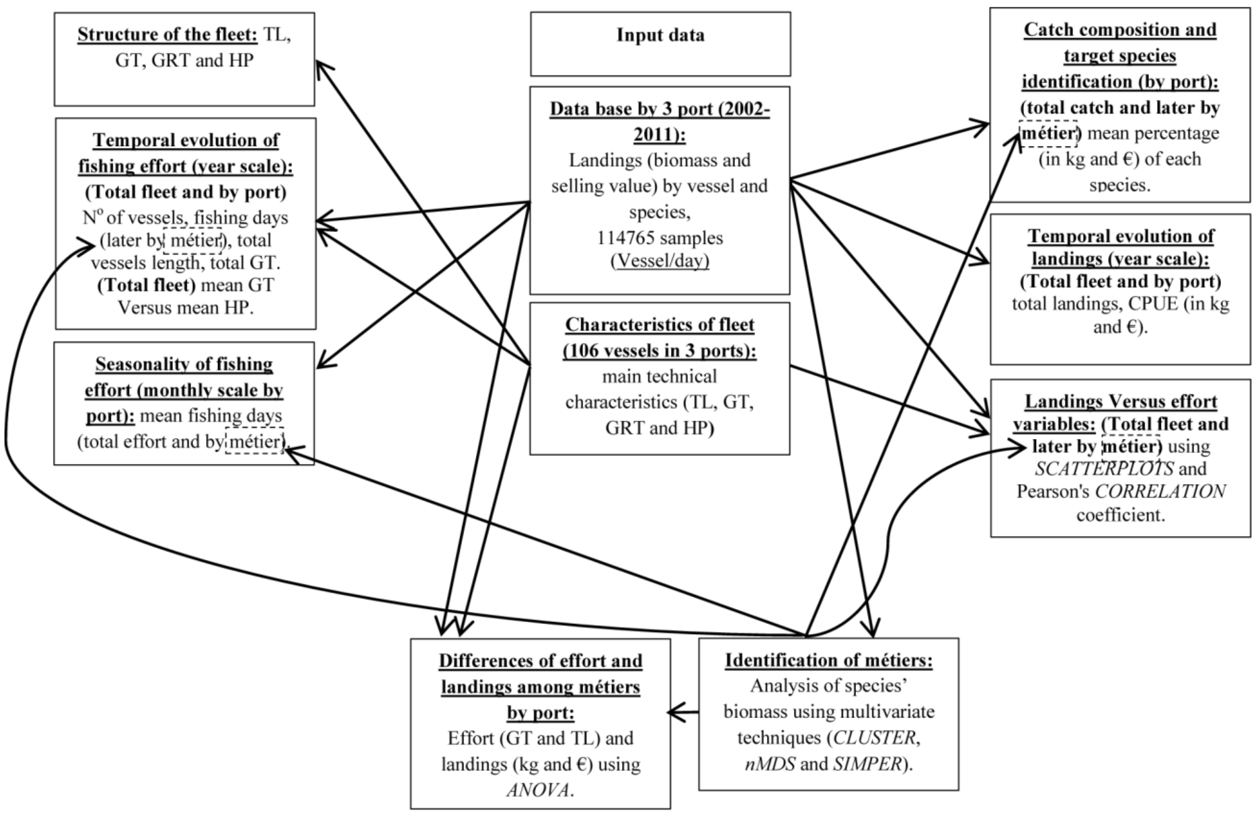
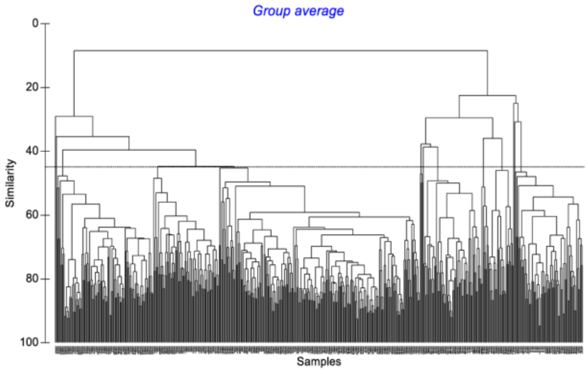


Figure 11: Mean catch composition for the identified métiers by port, showing the mean proportion (in biomass and income) of the 10 most important species. Error bars show the standard error. Data labels show mean CPUE in biomass (kg·vessel^{-1}·day^{-1}) and income (euros·vessel^{-1}·day^{-1}). *Morralla* is a Spanish category that refers to a mix of low-valued small fishes (mainly Sparidae and Labridae); *Sopa* is a Spanish category that refers to a mix of high-valued medium-sized fishes (mainly Scorpaenidae and Serranidae).

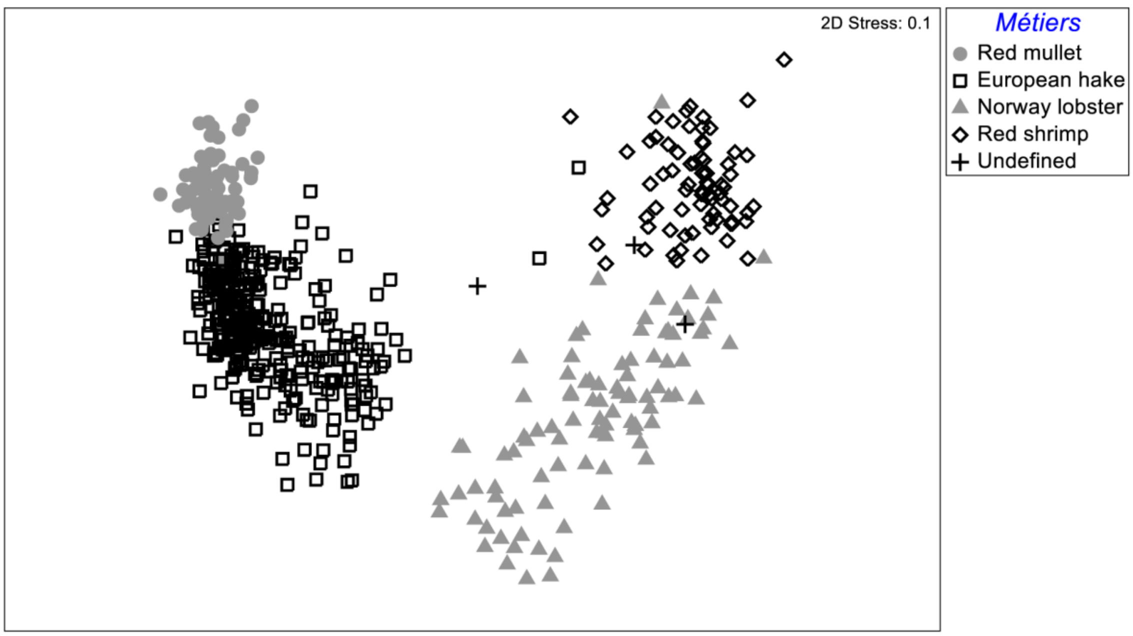
10 Appendices:



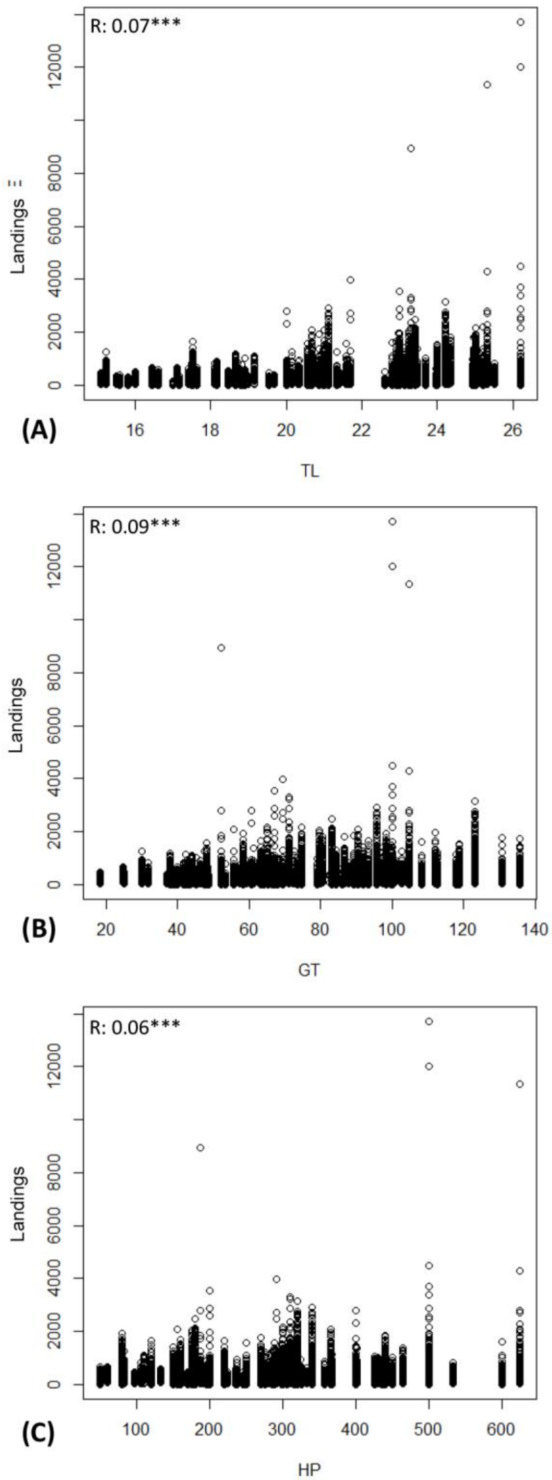
Appendix 1: Flow chart shows the data used and presents the general scheme of the analysis. Total length (TL), relative gross tonnage (GRT), gross tonnage (GT) and engine power (HP).



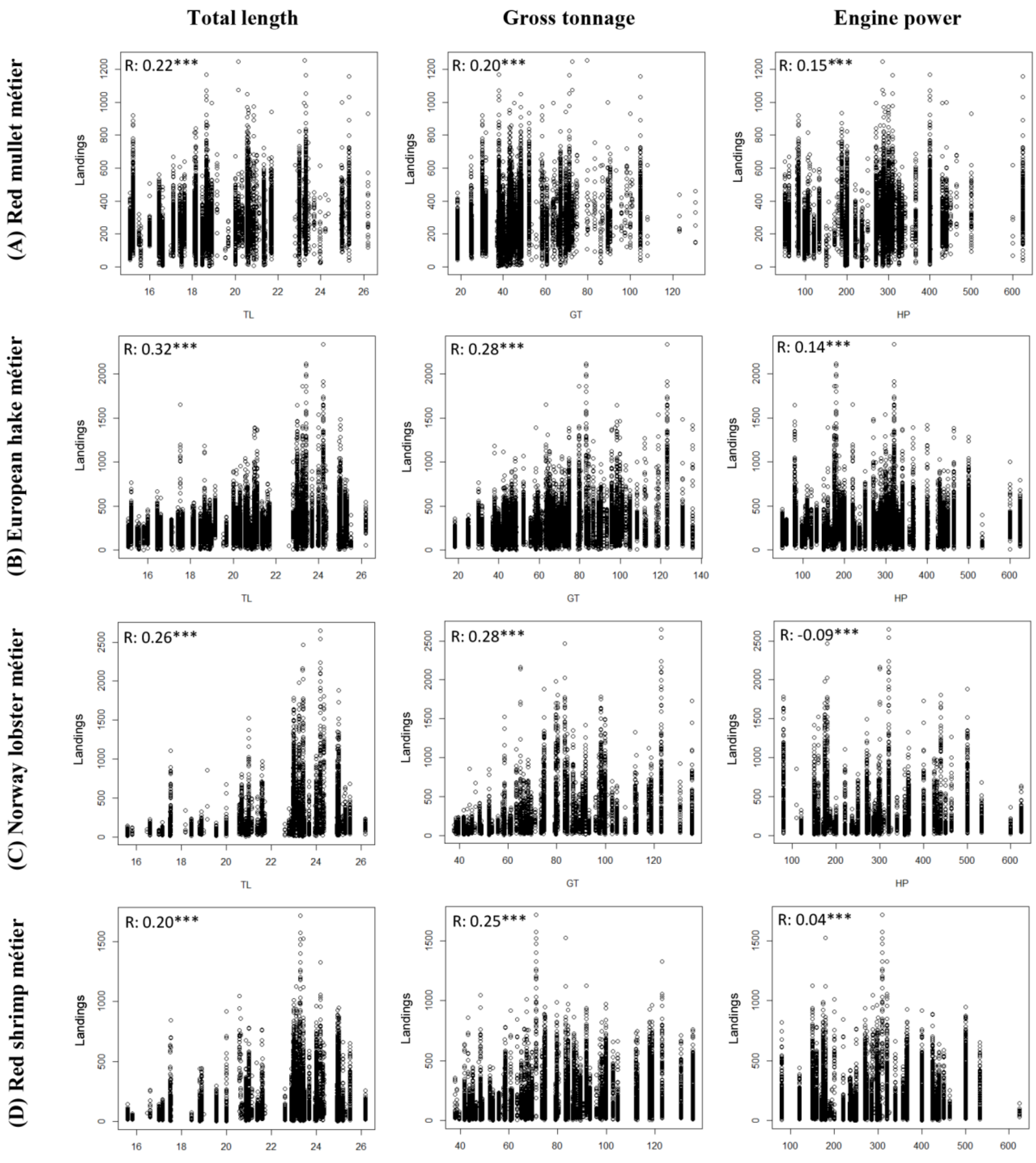
Metiér Red mullet		Metiér European hake	
Average similarity	61.46	**Average similarity**	53.62
Species	**Contrib%**	**Species**	**Contrib%**
Octopus vulgaris	39.22	*Merluccius merluccius*	27.35
Trachurus spp.	11.47	*Octopus vulgaris*	20.14
MORRALLA	9.72	*Illex coindetti*	10.98
Mullus spp.	8.8	MORRALLA	9.59
Trisopterus minutus	7.5	*Lophius* spp.	7.99
Pagellus erythrinus	6.74	*Geryon longipes*	7.25
		Trisopterus minutus	6.2
Metiér Norway lobster		**Metiér Red shrimp**	
Average similarity	43.50	**Average similarity**	57.94
Species	**Contrib%**	**Species**	**Contrib%**
Micromesistius poutassou	28.97	*Aristeus antenatus*	32.16
Eledone cirrhosa	20.07	*Eledone cirrhosa*	25.7
Phycis blennoides	19.44	*Geryon longipes*	20.92
Nephrops norvegicus	15.43	*Pleisonika* spp.	7.11



Appendix 2: Dendrogram and two dimensional nMDS ordination of samples (vessel/day) used to identify métiers. In this example (month), grouping samples were identified at similarity level of 45%, then the resulting clusters were overlaid on the nonmetric multi- dimensional scaling ordination. At this similarity level, the four métiers were identified: Red mullet (solid circles), European hake (empty squares), Norway lobster (triangles), Red shrimp (empty diamonds), and undefined samples (asterisks). Species percentage contribution (that contributed more than 5%) of dissimilarity between métiers is also provided according to a SIMPER analysis, using a similarity level of 90%. *Morralla* is a Spanish category that refers to a mix of low-valued small fishes (mainly Sparidae and Labridae).


R: 0.07***
Landings
TL
(A)
R: 0.09***
Landings
GT
(B)
R: 0.06***
Landings
HP
(C)

Appendix 3: Scatterplots and Pearson's product moment correlation coefficient (r) between landings (kg·vessel^{-1}·day^{-1}) and different fishing effort variables: (a) vessel length, (b) gross tonnage, and (c) engine power. Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001.



Appendix 4: Pair scatterplots by métier Scatterplots and Pearson's product moment correlation coefficient (r) between the landings ($kg \cdot vessel^{-1} \cdot day^{-1}$) and different fishing effort variables: total length (TL), gross tonnage (GT) and engine power (HP). Levels of significance were $*p < 0.05$, $**p < 0.01$ and $***p < 0.001$.