MINOUW

SFS-09-2014

RIA •634495

Science, Technology, and Society Initiative to Minimize Unwanted Catches in European Fisheries

WP1. Ecological, socioeconomic and technical characteristics of discarding fisheries.

Deliverable 1.6 Analysis of fisher's socio-economic behavior and practices

Responsible beneficiary: 1 - CSIC

Contractual due date: month 18

Dissemination level: PUBLIC

Report Status: FINAL

Actual submission date: 13 September 2016 (month 19)

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Co-funded by the Horizon 2020 Framework Programme of the European Union

European Commission RESEARCH & INNOVATION

ID•634495

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Analysis of fisher's socio-economic behavior and practices

Abstract

Most fisheries are not homogeneous but consist of a variety of vessels and activities that differs greatly in terms of, among many other factors, vessel size, gears used, technology employed, fishing grounds reached, and degree of expertise of the fishers. All these factors are also highly dependent on the market characteristics the fishery delivers to, and on a range of social aspects such as local culture and the availability of investment capital. Therefore, to assess the relative importance of each fishing practice it is relevant to define and characterize homogeneous units. The **métier** concept is specifically aimed to define a homogeneous subdivision depending either by vessel type or a fleet by type of fishing trip. Once the métiers are defined it is feasible to estimate the catch and discards, as well as the effort for the métier and therefore to upscale the discards to the entire fleet. Therefore as a first step we studied the métiers.

In the following study areas Mallorca Island, Catalan coast, Tuscany and Algarve coast (GSA05, GSA6, GSA09, ICES IXa) a detailed study of the métier practiced by a given boat was undertaken analyzing the corresponding sale records from the fishing Wharfs and landings, to provide an accurate, quantitative description of each métier. Information on the gear/fishing tactic, the main species exploited, plus background on the métier-specific temporal trends in catch, effort, gross revenues, as well as between-métier interactions are provided.

Two main approaches were followed: i) a development of a new classifier using the sales registers and interviews with the fishermen; and ii) multivariate analysis. The first approach was developed for daily registers of Mallorca small-scale fleet data. The Algarve and Catalan coasts (monthly aggregated data) as well as the landings in Tuscany were analyzed applying multivariate methods. The sales registers showed some quality problems in Algarve. In GSA09 (Tuscany, Italy), it was preferred to opt for using an approach based on interviews and questionnaires to fishermen because sales registers do not record adequate information on gear type, especially for those small scale fisheries vessels which can use a wide range of gears in relation to the target species and the season.

Accordingly with the key role of fishermen intention, we propose a new métier definition: <u>the unit that fisherman can consistently recognize. Similarly, the optimal number of métiers in which a fleet could be divided is those that fisherman can consistently recognize.</u>

A scientific publication describing the new developed method has been submitted to Fisheries Research Journal and several will be prepared in the next future. All this information will be analyzed together with the effort estimates in WP3 to quantify the importance of discards in the case study areas.

1. Introduction

Conventional fisheries data collection, advice, and management usually target single-stocks. At this basis, assessing fishing mortality throughout the relationship between catch and effort may be affordable for homogeneous, monospecific fleets. However, this approach has long been recognized as inadequate when applied to heterogeneous fisheries, which are subjected to interactions between subsets of fishing units, and across species (Marchal, 2008). Several steps have been undertaken in the past to explicitly incorporate the heterogeneity of the fishing activities within the cycle of observing, assessing, forecasting, and managing fisheries. A common sense solution is to identify units that are as homogeneous as possible. ICES (the International Council for the Exploration of the Sea) consider three types of fishing unit: the fleet, the fishery, and the métier (ICES, 2003):

- ✓ A fleet is a group of vessels sharing similar characteristics in terms of technical features and main activity.
- ✓ A fishery is a group of fishing trips targeting the same assemblage of species/stocks, using similar gear, during the same period of the year and within the same area. Nevertheless, fleet and fishery are often too heterogeneous from the managing perspective.
- ✓ Conversely, the métier concept is specifically aimed to define a homogeneous subdivision of, either a fishery by vessel type or a fleet by type of fishing trip.

Specifically, a métier is characterized by the use of a single gear targeting a specific group of species, operating in a given area during a given season, within which each boat exerts a similar exploitation pattern; i.e., the species composition and size distribution in catches taken by any vessel working in a particular métier will be approximately the same (Mesnil and Shepherd, 1990; Alarcón, 2001, Deporte et al., 2012). <u>Provided that métiers can share several target stocks, the total effort and catches upon a stock can be only properly estimated after combining all the involved métiers targeting this stock</u>. From fisher perspective, the key feature to be considered is that métiers should reflect the fishing intention, e.g. the species targeted, the area visited, and the fishing tactic used, but unfortunately, fishing intention cannot usually be observed directly.

A peculiarity of most small scale fisheries (SSF) is that some boats may use several fishing systems, which are lively alternated during the year according to the availability of resources, market demand, and other factors, such as local environmental characteristics and interaction with other fishing gears (Salas and Gaertner, 2004; Maynou et al., 2011). Therefore, SSF not only constitutes a relevant fraction of the fishing activity in some areas but also is particularly heterogeneous and, thus, challenging from the managing perspective.

Despite its importance worldwide, SSF practices have been generally subject to little attention by the scientific community and managers when compared to the industrial fishing sector. Therefore, there is an objective need for delineating métiers in such fisheries. However, this is in practice a more challenging goal than expected. The approaches used in the past to identify métiers make use of existing records of the technical features of fishing trips, which may be available in fishers' logbooks, e.g. gear and mesh size used, fishing grounds visited, season (Ulrich et al., 2001; Marchal et al., 2006), build based on interviews with stakeholders (Neis et al., 1999; Christensen and Raakjer, 2006), or are intended to infer the métiers used by retrospectively examining the catch profiles resulting from fishing trips (Marchal, 2008, Deporte et al., 2012).

The four case studies analyzed in the W Mediterranean and Algarve coasts are summarized below. The available data characteristics allowed to the use of two main analytical approaches:

Area	Data origin and periodicity	Analytical method	Period analyzed	Number métiers identified
Catalan coast	Monthly aggregated daily sales registers	Classification algorithms	2012-2015	Trawlers: 4 SSF: 12
Mallorca Island	Daily sales registers	Expert knowledge & classification algorithms	2004-2015	SSF: 11
Tuscany	CPUE obtained from interviews	Classification algorithms	2011	SSF: 11
Algarve	Monthly aggregated sales registers	Classification algorithms	1989-2009	SSF: 1-6

2. Mallorcan small scale fleet: description of "*métiers*" and development of a new classification tool (GSA05)

2.1. Introduction

The small-scale fleet in Mallorca is conducted by vessels less than 12 m long, with 1-3 hand decks, and operating close to the base harbor. Less than 1-day outings are compulsory and some combinations of fishing gears in the same fishing trip are not permitted. More details on the fishery management are provided elsewhere (Morales-

Nin et al., 2010). In Mallorca the commercialization of all the landings (i.e., SSF, trawlers and seiners) is made through a single central Fishing Warf (*OPMallorcaMar*), which is a cooperative of all the fishing boats in the island. The landings are arranged in standard boxes by the fishers and daily auctioned in decreasing prices. An automatic selling procedure, implemented from 2004, registers for each box, among other data, the commercial category, the weight in kilos, the price and the name of the boat. Any personal data is under a confidentiality agreement.

The time series (2004-2015) resulting from the daily sale records, provides a valuable information on the fishing activities, and how they change at different time scales (e.g., seasonal and decadal). However, some potentially confounding factors hinder the usefulness of such data base for fishing management. For example, some species might be sold as more than one commercial category (i.e., small, medium and large hake); boxes with mixed catches can correspond to different commercial categories depending on the vim of the auctioneer; and boats could have changed their name (and owner) along the time series of data. Nevertheless, one of the major drawbacks is that the métier used for obtaining the catch is not provided.

2.2. Developed approach

We propose to use fishermen knowledge in order to infer the métier for any fishing trip. The proposed strategy (Figure 1) started with selecting a representative sample of the fishing trips. The list of catches (i.e., the list of the daily sales of a given boat) of those sampled fishing trips were then presented to a number of experts (fishermen), who were asked to label them with the métier/s (from a closed list) that most plausibly had been used to get such a combination of catches. This sample of labeled records was then used for selecting, parametrizing and testing the success of a range of classification algorithms. Finally, the best algorithm was used for up-scaling métier's predictions from the sample to the entire time series (2004-2015) of sales daily boat records.

The specific details of the full data mining and analysis are summarized in Figure 1. The steps were:

1) The information for a given day was received as an ACCES archive that is structured by fish box (each row contents the data from a single box). These files were automatically read using the *RODBC* library (Ripley and Lapsley, 2015) from R (https://www.r-project.org/) and stored.

2) In general, several of the fish boxes above correspond to the same boat and they must be restructured to summarize the fishing activity of one boat in a day (i.e., one fishing trip). Therefore, the box data were restructured into a matrix composed by rows consisting in all the fish sold by a boat in a day, and the commercial categories in columns. Two separate matrices were produced for fish weight (kg per fishing trip) and gross revenues (Euros per fishing trip). Provided that both, the fishing trip and the auction have a compulsory daily basis, any row in the restructured matrix corresponds to all the catches landed by a boat in a single fishing trip (day). The data were cleaned of negative sales, which represent errors in the purchase or devolutions.

3) The matrix of daily boat records above included trawlers and large seiners that must be filtered out. Provided that boat category (namely, small-scale, trawler or large seiner) was available for all the active boats in 2012, an auxiliary classification algorithm were implemented using a random forest, as implemented in the *random Forest* library (Liaw and Wiener, 2002) of the R package. The performance of such algorithm was tested by cross validation and used to predict the boat category of all the fleet (2004 to 2015).

4) The result of the filtering step above were two matrices (either for weight or gross revenues) of rows consisting in the sales daily boat records for the SSF only, and covering from 2004 to 2015. The columns were the commercial categories considered after removing very uncommon categories.

5) 1,550 daily boat records were sampled from the weight matrix in step 4. The weight matrix was preferred instead the gross revenues matrix because seasonal trends of average fish price would confound landings trends. Provided that métier prevalence seems to be largely unbalanced, an ad-hoc sampling strategy was adopted to avoid underrepresentation of the less frequent métiers. The weight matrix were submitted to a principal component analysis, the first 10 axis were divided into 10 segments and, finally, a number of samples proportional to the variance explained by each of those 10 axes were then randomly selected from each of the corresponding segments.

6) Independently of the landing data (steps 1 to 5), a preliminary list of the main métiers currently used in Mallorca (12) were draw up after combining bibliographic data (Table 1), legal normative (Regulation of Artisanal Fisheries in Balearic inland waters, Decree 17/2003, Balearic Official Bulletin 28, 01/03/2003) and face-to-face, unstructured interviews to five retired (very experienced) fishers.

7) A new panel of 15 expert fishermen was then selected. Each one of this 15 fisherman was asked to label a random (but se step 8) subsample of 150 daily boat records selected from the 1,550 daily boat records described in step 5. Each sales daily boat record must be labeled with one or more of the 12 métier in step 6 (i.e., from a closed list). The information available to the fishermen was the species list, the weight per species and the date. Experts last less than 15 minutes in completing the questionnaire.

8) To test the between expert coherence when labeling daily boat records with métier/s, 50 of the 150 records in step 7 were the same for all experts. Provided the nature of the response matrix (0/1 of 12 métiers), a canonical correspondence analysis (CCA), implemented using the *cca* function of the *vegan* library (Oksanen et al., 2014) from R, allowed to test between-experts differences (Borcard et al., 2011). The initial 15 experts were submitted to an expert-by-expert sequential elimination protocol that continued until the remaining experts' set showed non-significant differences between them. Differences were tested using bootstrapping. Specifically, experts were randomly permuted while the order of the daily boat records was kept fixed (i.e., constrained bootstrapping as implemented in the *vegan* library).

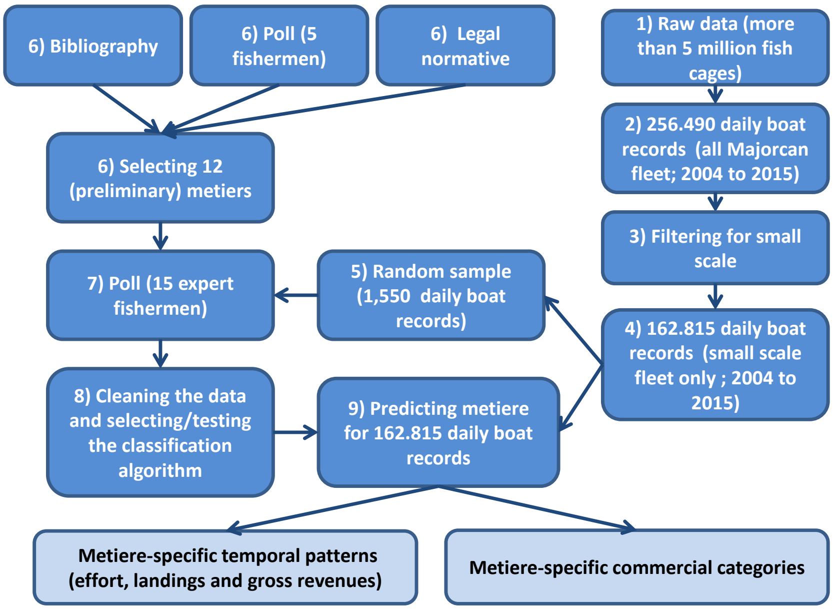

Figure 1. Procedure developed to identify métier.

The remaining date set after removing non-consistent experts were used to select and test a classification algorithm. Quality control of the prediction success of the classification algorithms was assessed by cross validated. Specifically, some of the initial 12 métiers were found either uncommon or experts were unable to successfully discriminate between some pairs of similar métiers. The outcome was that success classification rate of these métiers were low. Therefore, some of the initial 12 métiers were collapsed or deleted, which results in a final list of métiers. The resulting data set (i.e., coherent experts and finally retained métiers) were used for parameterizing and re-testing the classification algorithm finally selected.

9) This final algorithm was used to up-scale métier's predictions to the full time series of daily boat records covering from 2004 to 2015, which allowed us to describe the seasonal trends of effort, landings and gross revenues. The commercial categories of landings that best characterize the métiers finally considered was assessed using simper analysis (Clarke, 1993), as implemented in the *simper* function of the *vegan* library from R.

2.3. Predicting métier from the daily sales record

Classification problems in which an object can be classified into more than one category are known as multilabel classification problems (Tsoumakas and Katakis, 2007). Conventional classification methods, either parametric (e.g., discriminant analysis) or non-parametric (e.g., random forest) assume that categories are mutually exclusive (Jones et al., 2016). Two approaches for adapting the conventional methods to multilabel problems have been proposed. *Label powerset* considers that a mixed category (e.g., when a fisherman uses two métiers during the same fishing trip) then the daily boat record will be assigned to two categories, but this mixed category is considered a new category. *Binary relevance* consists, for a given métier, in splitting the data into two categories: the daily boat records assigned versus non-assigned to the métier considered. Therefore, the problem is transformed in a number (as many as métiers) of binary classification problems.

Conventional classification methods can be applied in both cases after adapting the input data. After preliminary inspection of the data structure, *binary relevance* was selected because the success of *label powerset* depends on the assumption that any mixed categories must be well represented, which is not the case in our data. Preliminary inspection and data recoding were completed using the *mldr* library (Charte and Charte, 2015) from the R package.

Recoded data were evaluated using all the suitable methods implemented in WEKA (http://www.cs.waikato.ac.nz/ml/weka/). WEKA (Witten and Frank, 2005) implements an exhaustive collection of machine learning algorithms within which there are 17 binary classification algorithms. The algorithm selected was which showed the largest cross-validated predictive capability as measured using kappa index (Jones et al, 2016). This process was fully automatized using the *Rweka* library (Hornik et al., 2009) from R.

2.4. Cleaning the input data matrix

The huge raw data, consisting in more than 5 million fish box entries, were successfully reorganized in two (weight and gross revenues) large matrices. In those matrices, the landings of a given boat in a given day (i.e., daily boat record) were placed at a given row. The columns were all the commercial categories (170). The total (i.e., including small scale, trawlers and big seiners) number of daily boat records from 2004 to 2015 was 256,490. The matrices were successfully filtered out for daily boat records from trawlers and seiners using the broad categories (namely, small-scale, trawlers and seiners) available for 2012. A random forest classification tool was successfully implemented with such a 2012 subset of data. As cross-validated success of predictions was excellent (Table 2; kappa index = 0.99), this tool was used to predict the broad category for the full time series (2004-2015). The total number of small-scale daily boat records for the 2004-2015 were 162,815 (or 63%). After removing trawl- and seine-specific commercial categories, plus a few commercial categories with very low prevalence for SSF, a total of 75 commercial categories were retained.

The (weight, kg per fishing trip) SSF matrix of daily boat records was used for selecting 1,550 daily boat records, which were labeled by 15 fishermen into the 12 métiers listed in Table 1. Between-expert differences were tested (CCA using constrained bootstrapping) using 50 daily boat records that have been classified by all the experts. When experts were found to differ, multivariate scores were plotted and the expert showing the most disparate pattern of métier predictions was deleted. As an example, the initial step (15 experts: $F = 2.04$, $df = (14,735)$, Prob. < 0.001) is shown in Figure 2. This loop was repeated until no between-expert differences were found, which allowed to successfully detect four outlier experts (i.e., 11 out of 15 experts were retained; $F = 0.34$, $df = (10,539)$, Prob. $= 0.111$).

After removing those experts, a reliable métier prediction is assumed for the remaining 1,100 daily boat records. However, the cross-validated classification success of up to 17 algorithms leaved room for improvement in 5 out the 12 métiers initially considered. In most of the cases, these métiers are old-fashioned and underrepresented, thus machine learning algorithms seem not able to build a reliable model. Therefore they were merged or deleted. The case of *Sipia* and *Peix* deserves particular attention because they are two trammel nets that differ by legal normative in mesh size and in seasonality (Regulation of Artisanal Fisheries in Balearic inland waters, Decree 17/2003, Balearic Official Bulletin 28, 01/03/2003). However, expert fishermen were not able to efficiently discriminate between them, suggesting that catches may be quite similar, at least for some time of the year. Therefore, these two métiers have been merged in a single category.

Table 1: Main characteristics of the 12 métiers initially identified. Expert fishermen were asked to label a sample of daily boat records with one or more of these 12 métiers. The 7 métiers finally selected were denoted in bold. Note that an additional category was considered for trawling because a few daily boat records from trawlers were erroneously included within the small scale data base.

MÉTIER	**Gear group**	**Target assemblage**	**Mesh size/gear characteristics**	**Target species**	**Activity period**
Sipia/Peix	Bottom trammel net	Benthic assemblages	67 mm/ max. 4.500 m per vessel	Cuttlefish, fishes	Winter
Llagosta	Bottom trammel net	Benthic assemblages	130 mm/ max. 4.500 m `per vessel	Spiny lobster	Spring-Summer
Moll	Bottom trammel net	Benthic assemblages	50 mm/ max. 4.500 m per vessel	Red mullet	Summer-Autumn
Palangre	Bottom long-lines	Benthic assemblages	Hooks min. 9 mm wide /max. 1.000 hooks per vessel	Red porgy, red scorpionfish,	All year
Jonquillera	Special pelagic surrounding net	Pelagic fishes	- / max. 100 m	Crystal goby	Winter
Llampuguera	FADS and special surrounding net	Epipelagic fishes	- / max. 200 m	Dolphinfish	Autumn
Trawl	Bottom trawl	Benthic assemblages	40 mm square mesh/ -	Red shrimp, Norway lobster, hake, red mullet	All year
Fluixa	Hand line	Pelagic fishes	Hooks min. 9 mm wide	Mediterranean bonito, great amberjack	All year
Potera	Hand line	Squid	Hooks min. 9 mm wide	Squid	All year
Volantí	Hand line	Demersal fishes	Hooks min. 9 mm wide	Red porgy, scorpionfish, comber, razorfish	All year
Solta	Fishing trap	Coastal fishes	80 mm/ max. 300 m	Mediterranean bonito, great amberjack	All year
Moruna	Fishing trap	Coastal fishes	50 mm/ max. 500 m	Great amberjack	Spring-summer
Almadraba	Fishing trap	Coastal fishes	200 mm/ max. 500 m	Great amberjack	Winter

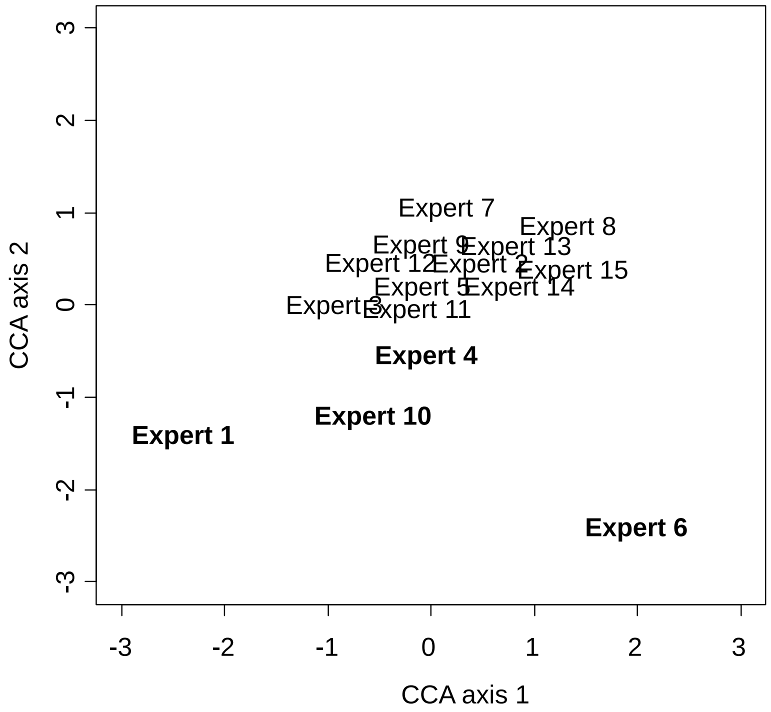

Figure 2: Result of multivariate analysis (CCA) for checking between-expert coherence. According to the expert-by-expert sequential elimination protocol *Classification algorithm*

The cleaned data set consisted in 1,100 daily boat records, for which a reliable métier prediction is available among a closed list of 7 possible métiers (*Sipia, Jonquillera, Llampuguera, Potera, Llagosta, Moll* and *Palangró*; Table 1), were re-tested using the same 17 WEKA classification algorithms. The algorithm showing the best performance (after cross validation) was *IBk*. This algorithm implements a k-nearest neighbor classifier (Fix and Hodges, 1951). Membership prediction of a new object depends on the membership the majority of their k-nearest neighbors. The confusion matrices for each one of the 7 métiers considered are shown in Table 3. Remember than *binary relevance* consists, for a given métier, in splitting the data into two categories (those labeled with the métier *versus* those labeled with any other métier). Therefore a separate confusion matrix is provided for each one of the 7 métiers. In four cases (*Jonquillera*, *Llampuguera*, *Potera* and *Palangró*), the percentage of correct predictions was perfect (100%) and for the remaining three métiers the number of failures was negligible.

Provided that the cross-validated predictions of the classification algorithm were excellent, it was used for predicting the métier that most plausibly had been used in each one of the 162,815 fishing trips carried out for the Majorcan SSF between 2004 and 2015. The relative importance of the 7 main métiers both in effort, landings and gross revenues are summarized in Table 4. Note that the total effort may be higher than the number of daily boat records due to the simultaneous use of more than one métier per day by some boats. The largest effort was invested in *Sepia-Peix* (mean ±

sd; 4,960.3 ± 600.1 fishing trips/year; n=12 years). The main contributors to the landings were *Sepia-Peix* (133.7 ± 19.1 tons/year; n=12 years) and *Llampuga* (Dolphinfish; 113.0 ± 33.7 tons/year; n=12 years), albeit the main income corresponds to *Llagosta* (the trammel net for lobster; 1.06 ± 0.1 MEuros/year; n=12 years) due to its higher price, followed by *Sepia-Peix* (1.02 ± 0.1 MEuros/year; n=12 years) and *Palangró* (0.8 ± 0.1 MEuros/year; n=12 years). Note also the disproportionately lesser effort invested in *Llampuga* (8%) in front of *Sepia-Peix* (33%), which is related with the seasonal pattern of resource exploitation.

Table 2: Cross-validated confusion matrix for the classification algorithm intended to filter out trawlers and seiners. Successful predictions are at the main diagonal (in bold).

	Trawlers	Small-scale	Seiners
Trawlers	**218**	0	0
Small-scale	0	**176**	0
Seiners	0	3	**195**

Table 3: Cross-validated confusion matrix for the classification algorithm intended to predict métier from the daily boat record of landings. Note that in that case a binary classification was completed for each one of the métiers considered. Successful predictions are at the main diagonal (in bold).

Sipia			*Jonquillera*		*Llampuguera*		*Potera*		*Llagosta*		*Moll*		*Palangró*	
	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
NO	**683**	0	**1045**	0	**1000**	0	**1044**	0	**867**	0	**1017**	0	**857**	0
YES	5	**412**	0	**55**	0	**100**	0	**56**	2	**231**	1	**82**	0	**412**

2.5. Temporal and seasonal trends

Based on the values estimated after fitting the annual data (12 years; 2004 to 2015) to a linear trend, landings of the entire fleet (Table 4) have decreased in 23%, from 526 tons in 2004 (95%CI: 407 to 645) to 401 tons in 2015 (282 to 520). The decreasing trend for effort (number of fishing trips of the entire fleet; Figure 3b) was 20%, from 16,280 fishing trips in 2004 (95%CI: 14,708 to 17,850) to 13,044 fishing trips in 2015 (11,473to 14,616). Finally, the decreasing of gross revenues was 18%, from 4.5 MEuros in 2004 (95%CI: 4.2 to 4.9) to 3.7 MEuros in 2015 (3.3 to 4.1). Note, however, that the latter figures have not been deflated by any consumer price index; therefore the actual decrease in gross revenues will be larger than 18%. Contrasting with those decreasing trends, CPUE (kg landed per fishing trip) seems to be stationary (slope of a linear trend of annual averaged CPUE was not significantly different from zero; Prob = 0.57; mean ± sd; 31.5 ± 2.3 kg per fishing trip; n = 12 years). Gross revenues per fishing trip seem stationary too (slope of a linear trend of annual averaged data was not significantly different from zero; Prob = 0.59; mean ± sd; 283 ± 12 euros per fishing trip; n = 12 years). In the same period the number of boats has been reduce in more than 25%. Therefore, it is possible that the effort, ladings and gross revenues per boat either have changed at different rate (e.g., decrease at lower rate or even increase) than the rates referred above for the entire fleet. Alternatively, it is also possible that the boats that have quit are those with the smallest efficiency.

The periodicity at the métier level was precisely regular across years, for effort, landings and gross revenues. Concerning effort, when the predictions were polled by month across the 12 years considered (Figure 3), the resulting pattern supports the hypothesis that some métiers are seasonally rotated. The canonical cycle was already described (Iglesias et al. 1995) but here a more precise delineation of the métier-specific periodicity is provided. The cycle starts with *Jonquillo* in winter, followed by *Sepia-Peix* (but see below) in spring, *Llagosta* in summer and *Llampuga* in autumn. The other métiers did not show a so clear seasonal pattern or were carried out with similar intensity along the year (e.g., *Palangró*). As noted above, the experts have not been able to discriminate between *Sepia* and *Peix*. The outcome of this misperception is the extended exploitation patter predicted for *Sepia-Peix* from August to December (Figure 3).

Table 4: Métier-specific estimates of effort (days), landings (kg) and gross revenues (euros) of the small scale fleet from Mallorca between 2004 and 2015.

	TOTAL	*Sipia*	*Jonquillera*	*Llampuguera*	*Potera*	*Llagosta*	*Moll*	*Palangró*
Effort (days)	175,828	59,571 (33.9%)	7,890 (4.5%)	14,504 (8.2)	10,981 (6.2%)	38,450 (21.9%)	16,230 (9.2%)	28,202 (16.0%)
Landings (kg)	5,074,070	1,475,893 (29.1%)	190,495 (3.8%)	1,313,345 (25.9%)	145,063 (2.9%)	700,323 (13.8%)	394,332 (7.8%)	854,615 (16.8%)
Gross revenues (€)	46,720,555	1,1514,927 (24.6%)	3,293,985 (7.1%)	6,054,470 (13.0%)	2,435,400 (5.2%)	11,996,098 (25.7%)	2,798,047 (6.0%)	8,627,627 (18.5%)

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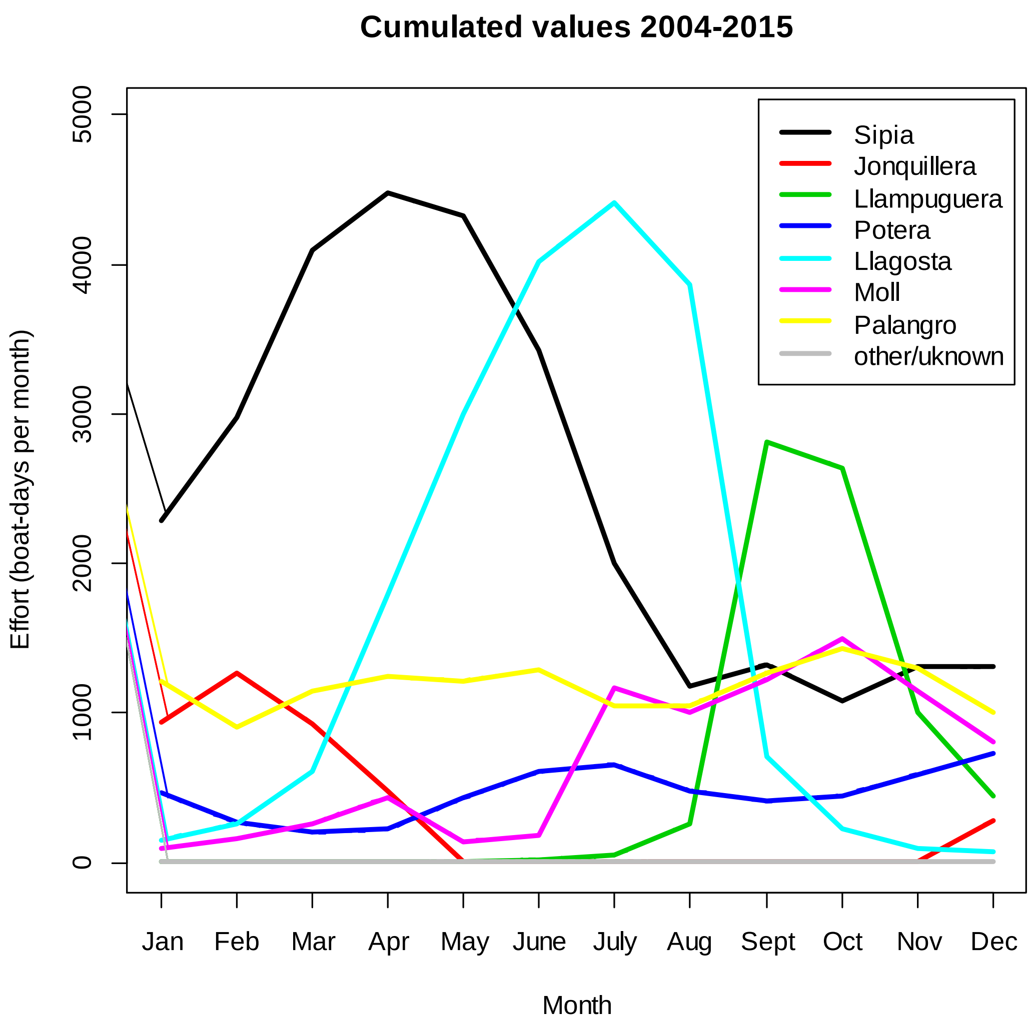

Figure 3: Effort by métiers seasonal temporal trends (fishing trips of the same month are poled across the 12 years considered).

Finally, simper analysis was used to identify the commercial categories that better characterizes (in terms of weight landed by category) each one of the 7 métiers. In three cases (*Jonquillera, Llampuguera* and *Potera*), landings are characterized by the target species only (*Aphia minuta, Coryphaena hippurus* and *Loligo vulgaris*, respectively), plus a very few secondary categories of commercialized by-catch. The case of *Potera* is noticeable because this métier may be secondary activity: fishermen would spend the waiting time when fishing with another static métier (e.g., trammel nets or long-lines) by targeting squid. In this case, the squid gear used (hand line) is very selective and renders few but high quality and high valued product. The same squid species reaches a lower price when captured with other gears (i.e., trawling).

Conversely, *Sipia/peix, Llagosta* and *Moll* are trammel nets characterized by a long list of by-catch in addition to the main target species, which are *Sepia vulgaris*, *Palinurus elephas* and *Mullus surmuletus*, respectively. However, such a by-catch is not only a relevant fraction of the landings but also of the gross revenues, especially in the case of *Llagosta*. Finally, the landings of *Palangró* (small longline) are largely unspecific, being large sparids and serranids (e.g., *Epinephelus marginatus*) the most valued of the target species.

2.6. Toward a pragmatic métier concept

The framework proposed here allows defining métiers in a more pragmatic way, and describing them comprehensibly for management purposes. We suggest a full sequence to predict métier for any fishing trip from historical time series of landings data. Briefly, métier prediction for the entire fleet is made possible after training a classifier with a sample of landings records that has been classified into métiers by expert fishermen. This strategy points more directly to fishermen intention and, to our knowledge, this is the first time that fishermen knowledge is combined with a sale register of landings in such a way. An obvious limitation of the method is that a landings register per fishing trip must already exist, but its implementation is promoted from EU.

The conventional approach for inferring métier from landing records has been to cluster fishing trips according to their similarity in landing composition. The rationale behind is that the clusters obtained include the fishing trips in which the same métier was used (Alemany and Alvarez, 2003; García Rodríguez, 2003; Tzanatos et al., 2006). This approach has two practical drawbacks (Palmer et al, 2009): (i) to determine the optimal number of clusters and (ii) to unequivocally define a métier for a given cluster, which is carried out *a posteriori*. That is, the most common species in the landings profiles from a cluster are assumed to characterize the (single) métier used for all the fishing trips in that cluster. In addition, the unit of the landing records should be the fishing trip because when pooling units together (Alemany and Alvarez, 2003; García-Rodrıguez, 2003), any subjacent variability will be confounded.

Accordingly with the key role of fishermen intention, we propose a new métier definition: <u>the unit that fisherman can consistently recognize. Similarly, the optimal number of métiers in which a fleet could be divided is those that fisherman can consistently recognize.</u>

3. Algarve (southern Portugal) "*métiers*" - classification based on monthly landings data

3.1. Introduction

In Portugal, all landings must be sold at auction, where they are recorded. The monthly aggregated landings by species or taxonomic group per vessel for "polivalente" (multi-gear or multi-species) vessels registered in Algarve ports for the period from 1989 to 2009 were obtained from DGRM (Direção Geral de Recursos Naturais, Segurança e Serviços Marítimos). The multi-species, or multi-gear fleet accounts for approximately 92% of all the fishing vessels in Portugal, consisting largely of "local" category vessels less than 7 m in total length (85.9%) that can operate up to 6 miles from the port and "coastal" category vessels greater than 7m (6.1%) that can operate beyond the 6 mile limit (Leitão et al. 2004). These vessels usually have licenses for a variety of different static gears, including longlines, gill nets, trammel nets, octopus pots, traps for cuttlefish and for fish, jigs and dredges.

Given the fact that the official landings statistics do not identify the métier (or even the gear used), the objective of this study was to use multivariate statistical analysis techniques to group landings and then use the species associated with each cluster to identify the métier based on expert knowledge.

3.2. Material and Methods

Due to privacy laws, data was provided with codes instead of vessel names and no information on the type of gear used for each landing was provided. The raw data consisted of 320 species for a total of 1.4 x 106 landings, from 3,357 different vessels. Prior to analysis, the data set was examined in order to exclude species that were clearly not caught in Portuguese waters and very rare species. Vessels landing a total of less than 500 kg were also excluded. The resulting data matrix consisted of 237,414 landings and 153 species.

The CLARA (Clustering for Large Applications) algorithm implemented in R was used to cluster the large number of landings. CLARA can handle very large data sets by clustering a sample from the data set and then assigning all the landings to the clusters. After optimal differentiation of groups and assignment of each landing to a group, pair-wise comparison after SIMPER analysis and analysis of the species composition of landings of each group were used to attribute a métier to each group based on expert knowledge and experience of the CCMAR group with the local Algarve fisheries.

3.3. Results

While the results of the analysis suggest that the optimal number of groups is 6 (Figure 1), there is little improvement from 2 to the maximum of 6 clusters and the difference between the optimal value of 6 and a greater number of clusters is not very significant.

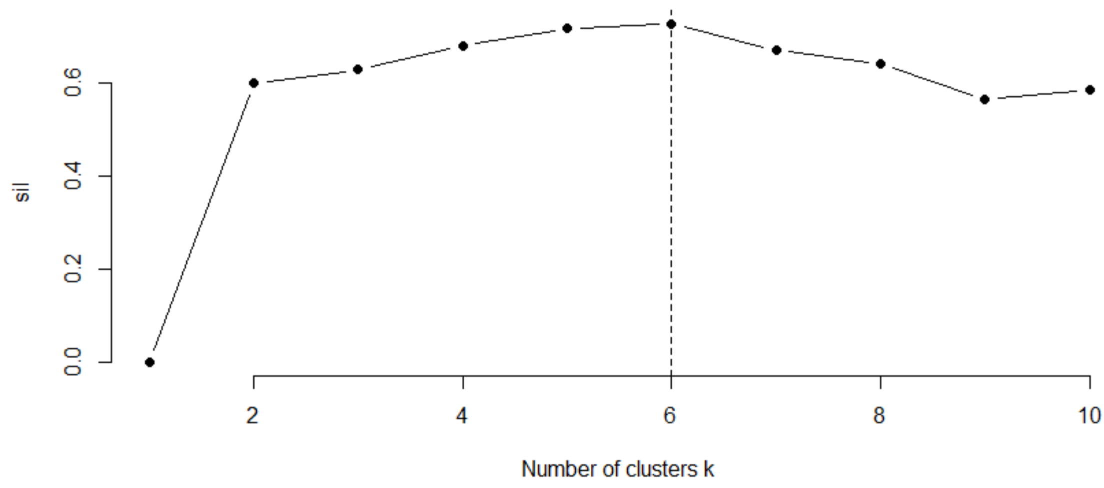

Figure 1. Results of the CLARA analysis for the Algarve data.

The cross-validated confusion matrix for the classification algorithm intended to predict métier from the daily boat record of landings is given in Table 1. As can be seen, the cross-validated success of predictions was excellent only for group 6.

Table 1. The cross-validated confusion matrix for the classification algorithm intended to predict métier from the daily boat record of landings.

	1	2	3	4	5	6
1	99	1	0	0	0	0
2	0	97	1	2	1	0
3	1	0	99	0	0	0
4	0	1	0	98	0	0
5	0	1	0	0	99	0
6	0	0	0	0	0	100

Based on pair-wise comparison after SIMPER analysis and analysis of the species composition of landings of each group, it was only possible to clearly identify one métier with some degree of confidence: group 6, is clearly the octopus pot métier as the landings are almost exclusively octopus (Table 2). Group 3 probably corresponds to the octopus trap métier as this species dominates the landings but other species known to be by-catch in octopus traps are also landed by theses vessels (Table 2). Based on the species composition in Table 2, it is clear that the remaining groups are not single métiers but mixtures of métiers. For most of the groups the species composition of the landings suggests a combination of gillnet/trammel net/ longline/purse seine.

3.4. Discussion

It was not possible to successfully identify Algarve métiers based on a very large data set of aggregated monthly landings per vessel. The official landings data provided by the authorities had a number of problems. Landings by vessels that had fished in waters far from the Algarve are not identified. However, a preliminary analysis of the initial list in the data set showed that a considerable number were not native to continental Portuguese waters and some were not even saltwater species. These were eliminated in a first step.

Other problems in the data remained, such as significant landings of small pelagics, especially sardine (*Sardina pilchardus*), even though the data corresponds to the "polivalente" or multi-gear or multi-species fisheries that are licensed to fish with static geat (gill nets, trammel nets, longline, pots, traps, dredges and jigs). The appearance of sardine (and other small pelagics) in the data could be due to the following:

1) Landings by small vessel purse seiners known as "rapa" that may be classified as "polivalente". These small purse seiners use purse seines of approximately 200m length mainly to target schools of high value sea breams and sea bass in relatively shallow water. However, at certain times of the year when sardine prices are high or when it is difficult to catch the demersal species because they are not schooling, they switch to target sardines and other small pelagics.

2) To renew their license, fishers must present proof of a minimum number of annual sales at auction. It is known that small-scale fishers often get large quantities of small pelagics from purse seiners at no cost or for a small amount and present these "catches" at the auction for sale, thereby reaching their goal for license renewal.

3) Small pelagics, namely sardine and chub mackerel (*Scomber japonicus*) are caught in gill nets and trammel nets. In fact they may constitute the most important by-catch in these fisheries in the Algarve (Erzini et al. 2006, Stergiou et al. 2006).

Other factors contributing to the poor classification are the following:

1) Most small-scale commercial fishers in the Algarve have licenses for more than one gear. In fact many may have up to 5 or 6. Although most fishers work with one main gear, they may switch gears during the year or from year to year. They may also use more than one gear at the same time. Therefore landings on the same day for a particular vessel may be composed of for example caches from trammel nets and longlines.

2) The same gear may be used in different métiers during the year. For example, one of the main trammel net métiers is that for cuttlefish (*Sepia officinalis*). This takes place mainly in the Autumn when cuttlefish dominate the catches. However, during the rest of the year, the same nets may be used to target flatfish and a mixture of other finfish, which is an entirely different métier.

3) Species composition changes may occur over time as abundances of different species varies, resulting in variable landings and inconsistent métier profiles.

4) Some métiers may disappear over time. For example, certain small hook longline métiers targeting sea breams have largely disappeared, at least in some parts of the Algarve, over the past 20 years largely because this is a very labor intensive gear, requiring the fisher to harvest invertebrates for bait and to prepare and bait the longline on land.

5) Technological changes and fisher behavior may confound the landings data. For example, gear modification or new techniques may appear, causing changes in the landings profiles.

For a more successful classification, data analysis should be based on a shorter period, ideally only for one year at a time or even by season in order to avoid the problem caused by seasonality. Only data from the most recent years should be used as the taxonomic resolution has been improving over the years. However, there are still problems of grouping of species in taxonomic groups such as *Diplodus* spp. This practice varies from auction to auction. Furthermore, the analysis should be based on daily, not monthly aggregated landings. This will greatly improve results. Finally, expertise of fishers should be used to help identify métiers from a sub-sample of the landings, as in the approach successfully applied above for Mallorca Island.

Table 2. Mean landings in kg for all landings in each group. Only mean landings of at least 5 kg are included.

Species	Group 1
Sepia officinalis	161
Trachurus trachurus	17
Pagellus acarne	13
Mugil spp	13
Spondyliosoma cantharus	8
Trachurus picturatus	8
Pagellus erythrinus	7
Mullus surmuletus	6
Solea solea	5
Sardina pilchardus	5
Species	**Group 2**
Sardina pilchardus	194
Scomber japonicus	87
Pharus legumen	30
Pagellus acarne	26
Trachurus trachurus	26
Spondyliosoma cantharus	24
Merluccius merluccius	14
Scomber scombrus	14
Mugil spp	13
Pagellus erythrinus	11
Centroscymnus coelolepis	11
Trachurus picturatus	10
Raja spp	9
Sarpa salpa	9
Scyliorhinus spp	8
Sparus aurata	7
Argyrosomus spp	7
Isurus oxyrinchus	6
Species	**Group 3**
Octopus spp	268
Sepia officinalis	9
Murex spp	7
Spondyliosoma cantharus	6
Trachurus trachurus	5
Species	**Group 4**
Solea spp	78
Sepia officinalis	31
Octopus spp	14
Raja spp	11
Torpedo spp	10
Spondyliosoma cantharus	6
Species	**Group 5**
Loligo spp	36
Argyrosomus spp	26
Scomber japonicus	24
Trachurus trachurus	20
Sepia officinalis	14
Sardina pilchardus	12
Species	**Group 6**
Octopus vulgaris	509

4. Identification of the main "*métiers*" of the small scale fisheries of the Tuscany (NW Mediterranean, GSA9)

4.1. Introduction

According to recent estimates (EU fleet Register 2013), the fishing fleet in GSA 9 consists of 1,750 boats, approximately 13% of the total number of Italian fishing vessels. In 2013, the annual landings in GSA 9 for all fishing gears amounted to around 17,500 tonnes, slightly less than 10% of the national totals.

The fishing fleet operating in GSA 9 is characterised by a high proportion of small-scale vessels, which accounts for about three quarters of the boats. The small scale fleet of GSA 9 comprises about 1,300 boats with a total tonnage of 2,650 GT. The vessels have a typical overall length of less than 12 metres, employing passive gears. An important fraction of the small scale fisheries is located in Tuscany, which heterogeneous environment (e.g. different habitats, 7 Islands of the Tuscan Archipelago) has the proper characteristics for establishing of diversified artisanal fleets.

According to recent data (IREPA-MIPAAF, 2014), the small scale fisheries in Tuscany accounts for 415 vessels, representing about 75% of the fleet registered in the Region and engages 60% of the personnel devoted to fishing activity. In spite of this, the knowledge on this fleet segment is still scattered. A peculiarity of these fisheries is the use of several fishing systems, which are alternated during the year according to the availability of resources, market demand, and other factors, such as local environmental characteristics and interaction with other fishing gears.

The small scale fisheries of Tuscany have been object of study since several decades, in order to provide useful information for their proper management.

Recently (year 2011) a detailed study was developed, in order to identify the main "métiers" practiced by the Tuscan small scale fisheries, and to gather information on the gears utilized, fishing patterns, fishing effort, as well as on the composition of the catches.

From July to September 2011 a wide monitoring program was carried out in all the harbours and mooring sites hosting small scale fisheries, covering all the Tuscany coastline (Fig. 1). Data were collected in two different phases:

- a pre-survey, in which fishermen were interviewed in 22 harbours, in order to verify the existing informations about the fishing boats and to obtain a first picture of the fishing activity, in terms of seasonality of fishing grounds, gears used and target species.
- a survey, in which 1814 observations were collected in 12 Tuscan ports by mean of interviews. According to a standardized protocol, interviews were realized with fishermen belonging to the small scale fishery in order to collect information on their fishing activity. The interviews were targeted to collect information on the fishing areas, on the types of gear used, target species and on species composition of the catch, including *by-catch* and discard. Catch data were standardised as CPUE, e.g. catches per unit of effort expressed as weight

(kg) per fishing day; the whole data were merged as average catch per boat/gear/quarter.

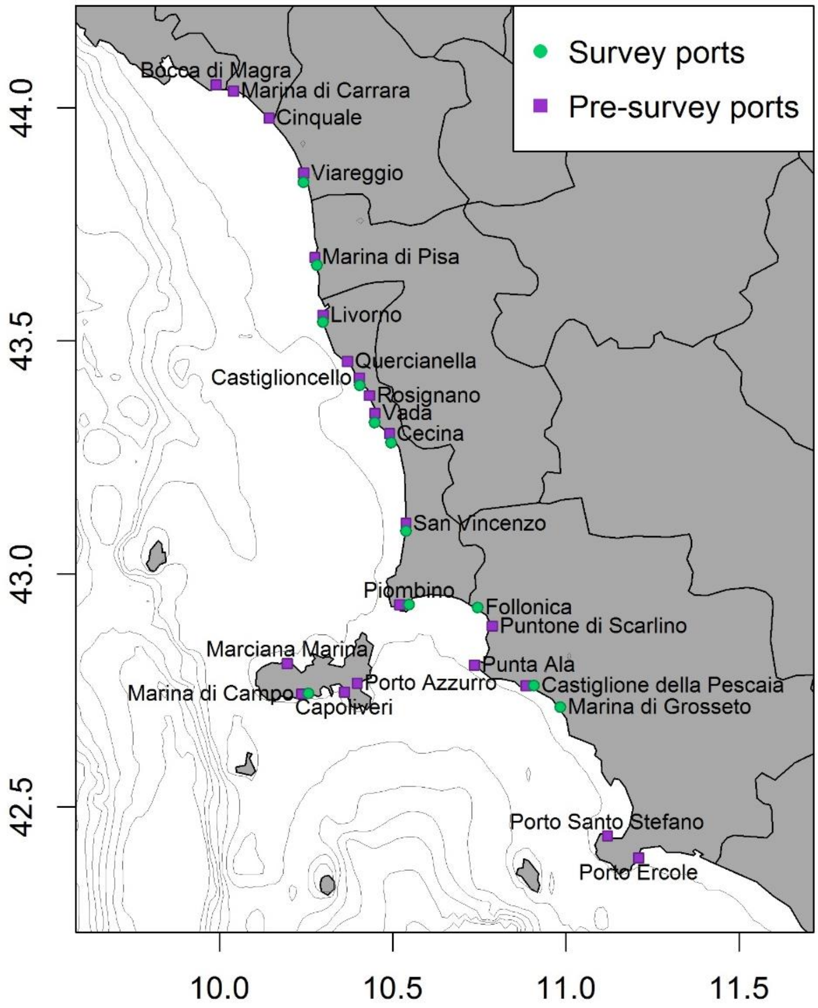

Figure 1. Map showing the fishing harbours investigated.

To identify peculiar fishing typologies (e.g. potential "*métiers*", according to the indications provided by the EU Reg. 199/2008), the whole matrix of CPUE data (species per boat/gear/quarter) was analysed by means of a hierarchical cluster analysis, using the Bray-Curtis similarity index, after angular transformation of data.

In order to identify the main species characterizing each *métier* in terms of biomass, the similarity percentage analysis (SIMPER) was applied to the species per boat/gear/quarter matrix. Thus, it was highlighted the percentage contribution of each species to the diversity between *métiers*.

Below the main results of the study are summarised.

It was found that about one third (the 34%) of the fishermen are used to employ 3 different kinds of fishing gear throughout the year, alternating them, depending on the season and the target species; another third of fishermen (32%) used 2 gears along the years. Only the 15% of the interviewed used only 1 typology of fishing gear throughout the year (Fig. 2).

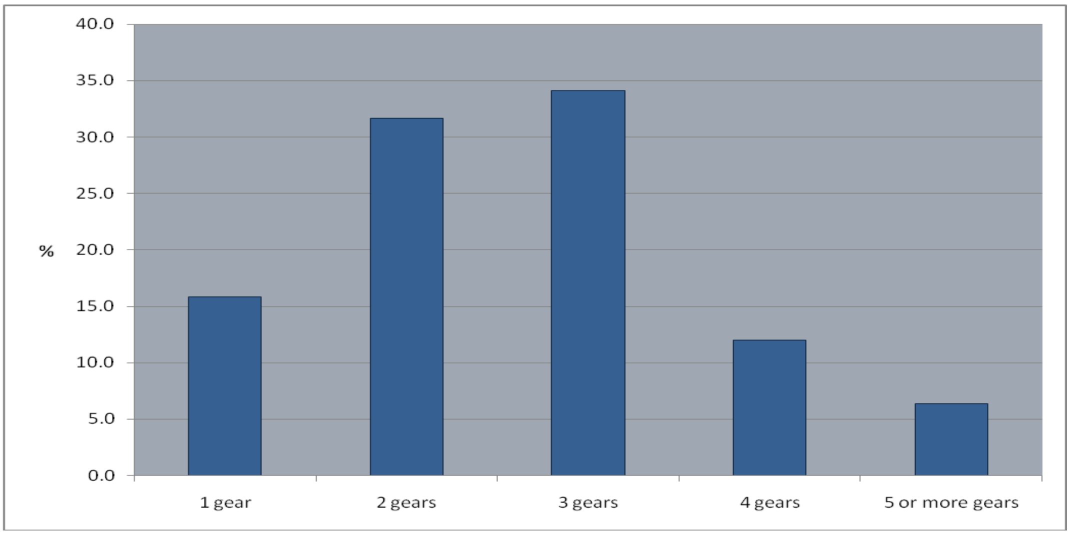

Figure 2. Number of gears used yearly by each fishermen (percentage values) in the small scale fisheries of Tuscany.

Fig. 3 shows the dendrogram of classification of catch data (CPUE by vessel/gear/quarter). The results of the cluster analysis allowed identifying at least 12 main homogeneous groups; they can be associated different *métiers* and are arranged according to 5 main gear typologies: trammel nets, gillnets, pots, longlines and boat seines.

According to the results of the routine SIMPER, the pie charts of Fig. 4 show the most abundant species (in terms of CPUE) for each *métier*. Every *métier* identified is characterised by its own characteristics in terms of species composition and relative abundance.

The Tab. 1 reports information on the characteristics of the gear, fishing grounds and composition of discards for each *métier* identified, while Tab. 2 shows the seasonal succession in the use of the different *métiers*.

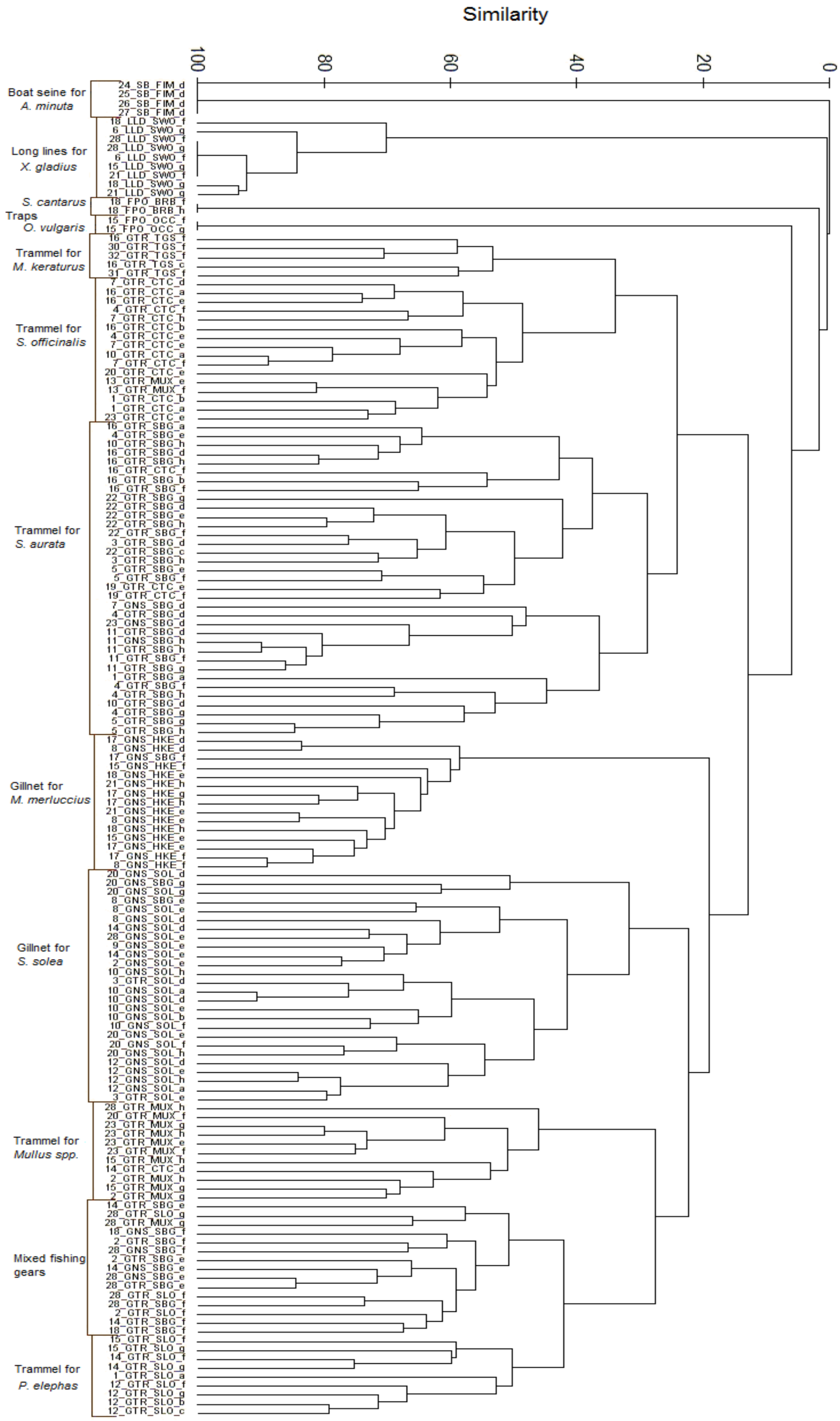

Figure 3. Dendrogram showing the classification of catch data (CPUE by vessel/gear/quarter).

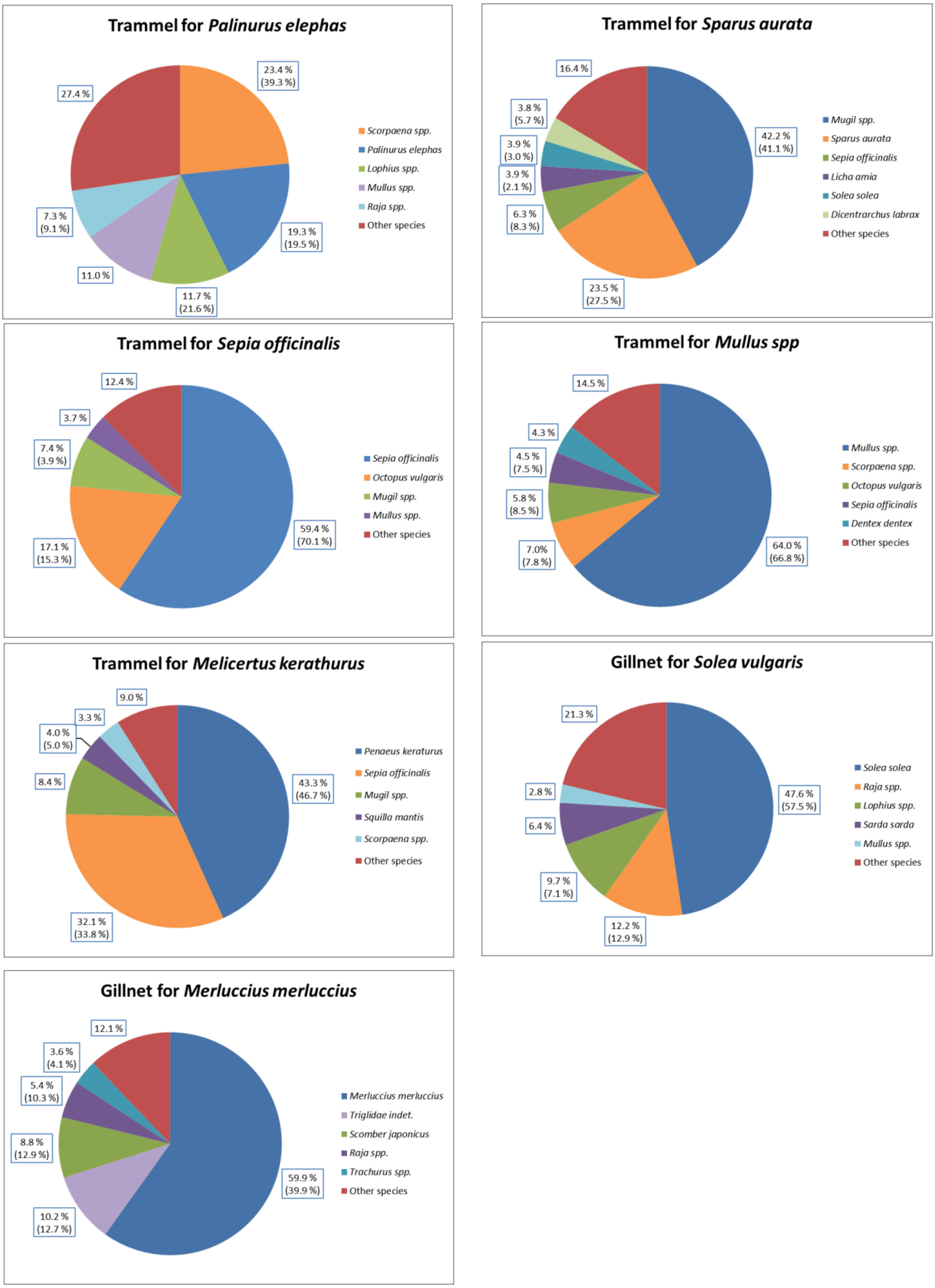

Figure 4. Composition of the catch of each *mètier*. The main species contributing to the landings are reported (with percentage contribution to the total CPUE and percentage of similarity contribution, in

parenthesis).

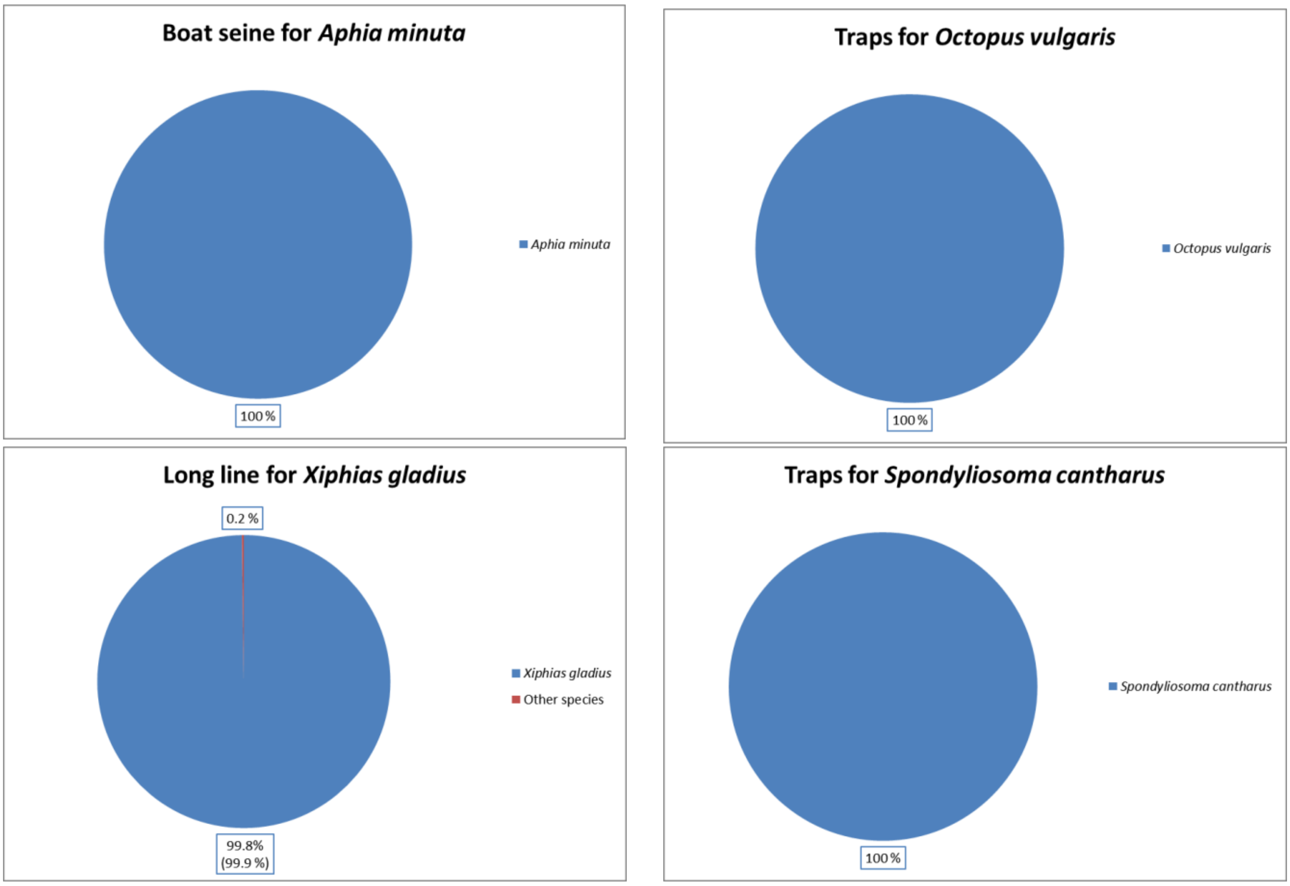

Figure 4 (continued).

Table 1. Target species, characteristics of the gears, fishing grounds and information on discards for each *métier* identified.

Gear/METIER	Depth (m)	Fishing time (h)	Mesh size (mm)/ hook size (n°)	Discard (more significative species)
Trammel net				
Palinurus elephas (Fabricius, 1787)	30-80	24-72	90-120	*Conger conger, Muraena helena,* Damaged specimes
Melicertus kerathurus (Forsskål, 1775)	5-15	6-10	44-50	Brachiurans *Diplodus annularis, Engraulis encrasicolus*
Sparus aurata Linnaeus, 1758	5-50	8-12	80-100	Damaged or undersized specimes, *D. annularis, Trachurus* spp.
Sepia officinalis Linnaeus, 1758	5-20	10-12	70-80	Damaged specimes, *D. annularis, Trachurus* spp., Labridae indet.
Mullus spp.	5-30	3-6	44-52	*D. annularis, Trachurus* spp., Labridae indet.
Pots				
Octopus vulgaris Cuvier,1797	3-40	36-72		*D. annularis* , Brachiurans, Labridae indet.
Spondyliosoma cantharus (Linnaeus, 1758)	30-70	12		*Trachurus* spp., *Spicara* spp.
Gillnet				
Merluccius merluccius (Linnaeus, 1758)	100-300	4-10	80-120	Small *T. trachurus*
Sparidae indet.	5-90	8-12	70-120	*Trachurus* spp., Damaged specimes
Solea solea (Linnaeus, 1758)	5-80	10-12	70-90	Brachiurans, Damaged or undersized specimes, *Trachurus* spp.
Longline				
Xiphias gladius Linnaeus, 1758	50-100	8-12	1-3	Damaged specimes, Dasyatidae indet.
Boat seine				
Aphia minuta (Risso, 1810)	5-20	0.3	9	Labridae indet., *D. annularis*

Table 2. Seasonality of the use of each *métier*

Gear/metièr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trammel net												
Palinurus elephas (Fabricius, 1787)				■	■	■	■	■	■			
Melicertus kerathurus (Forsskål, 1775)				■	■	■	■	■				
Sparus aurata Linnaeus, 1758	■	■	■	■	■	■	■	■	■	■	■	■
Sepia officinalis Linnaeus, 1758	■	■	■	■	■	■				■	■	■
Mullus spp.					■	■	■	■	■			
Pots												
Octopus vulgaris Cuvier,1797	■	■	■	■	■	■						
Spondyliosoma cantharus (Linnaeus, 1758)		■	■	■	■	■						
Gillnet												
Merluccius merluccius (Linnaeus, 1758)	■	■	■	■	■					■	■	■
Solea solea (Linnaeus, 1758)	■	■	■	■					■	■	■	■
Longline												
Xiphias gladius Linnaeus, 1758						■	■	■	■			
Boat seine												
Aphia minuta (Risso, 1810)	■	■	■								■	■

Below there is a brief description of each *métier*.

4.2. Trammel nets

4.2.1. Trammel net for red mullets

A specific trammel net, the so-called "Tramaglino" was a widely used gear until a few years ago, to catch red mullet and striped red mullet (*M. barbatus and M. surmuletus*); currently, the use of this gear is limited. This gear is used mainly from mid-spring to all summer, on sandy-muddy rocky bottoms. The nets are usually deployed at sea during the night for a limited period, between 3 and 6 hours, to avoid excessive by-catch.

Because of the small mesh size, 22 to 25 mm in the inner panel, the trammel net for red mullets presents a low selectivity. The target species, the red mullet and the striped red mullet, constitute on average the 30% of the biomass caught; the by catch belongs mainly to a medium-low commercial value species: *Serranus scriba, S. cabrilla, S. hepatus*, small scorpionfish (e.g. *Scorpaena porcus*), *Diplodus annularis* and *Coris julis*. Discard is an important component of the catch and it is represented mainly by benthic invertebrates such as Holoturoids, Gastropods *(Bolinus brandaris*, *Hexaplex trunculus*), crabs and damaged fish.

4.2.2. Trammel net for spiny lobster

The use of trammel nets for spiny lobster (*Palinurus elephas*) is restricted during late spring and summer. The nets employed range between 1800 and 4000 m and have large meshes, between 50 and 80 mm side (inner pannel). Fishing for spiny lobster is closed from January and April every year, as well to land specimens with eggs is prohibited.

The nets are deployed on rocky bottoms near the coast, within a depth range from 20 to 50 m. The permanence of the gear at sea generally ranges from two to three days.

The target species constitutes about 15% of the total biomass caught. Among the by-catches, important species with commercial value are the crab *Maja squinado*) the Scorpeaenid *Scorpena scrofa*) and the striped red mullet*, M. surmuletus*.

4.2.3. Trammel net for “whitefish”

This gear is widely used by the small scale fishery of Tuscany. The target species consists in a group of species commonly called "white fish", specifically, the gilt-head sea bream (*Sparus aurata*), other sea bream (*Diplodus* spp.), the striped sea bream (*Lithognathus mormyrus*) and the sea bass (*Dicentrarchus labrax*).

This gear is used throughout the year, more in autumn and winter, on various types of seabed and depths, but not exceeding 50 m. Generally, the trammel net has a mean length of 2300 m, with the inner panel having a mesh size of about 40 mm. The permanence in the water of the gear is between 8 and 12 hours.

The gilt head sea bream is the most abundant target species and accounts for about 35% of the catch in biomass. The by catch it is often a major fraction, reaching over 50% of the biomass captured: cuttlefish (*Sepia officinalis*), common pandora (*Pagellus erythrinus*), axillary sea bream (*Pagellus acarne*) and the common octopus (*Octopus vulgaris*) are the most important species belonging to this category.

Discards represent a significant fraction of the catch; the specific composition varies depending on the type of bottom and consists largely of damaged fish, undersized or of no commercial value, crabs and Phanerogams (*Caulerpa racemosa*, fragments of *Posidonia oceanica*).

4.2.4. Trammel net for cuttlefish

This type of gear is among the most used in Tuscany. It is employed all year round with the exception of the summer months; the net length ranges between 1500 and 3000 m; the gear is mainly deployed on sandy bottoms at few meters depth (maximum 20 m). The inner panel of net presents a mesh size between 35 to 40 mm. The nets are deployed at sea at sunset and retrieved at sunrise, for a fishing time of about 12 hours.

It is a selective fishing: more than 50% of the biomass caught consists of cuttlefish. The by catch is predominantly made up by the common octopus (*O. vulgaris*) and mullets (*Liza* and *Mugil* spp.). It is not uncommon to catch species of high commercial value, such as sea bass (*D. labrax*), gilt head sea bream (*S. aurata*) and shi drum (*Umbrina cirrhosa*).

Discards can be abundant and consist mainly of benthic invertebrates such as gastropods and crustaceans (crabs, *Medorippe lanata* and *Liocarcinus spp*.).

4.2.5. Trammel net for caramote prawn

The caramote prawn (*Melicertus keraturus*) fishery, is historically performed several places of Tuscany, mainly in front of Viareggio (S Ligurian Sea) and Castiglione della Pescaia (N Tyrrhenian Sea). It is a seasonal (spring-early-summer) fishery, highly specialised and valuable, which provides up to 50% of the yearly incomes to the involved fishermen).

Mostly the net is deployed on muddy bottoms at a depth between 10 and 20 m. The mesh size of the inner panel is between 22 and 25 mm. In addition to the target species, which represent 30-50% of the daily catch, the by catch species of commercial value are the cuttlefish (*S. officinalis*), the mantis shrimp (*Squilla mantis*) and fish belonging to the local commercial category "soup"The average daily catches of the target species, around the fishing period, amounts to 2.0 kg / day. The by catch amounts on average at o 0.4 kg / day for the mantis shrimp and 1.5 kg / day for the cuttlefish.

Because of the small mesh sizet and he type of biotic communities where it is used, the trammel for caramote prawns is a low selective gear. . The presence of abundant amounts of discard, principally made by crabs, gastropods, algae, is therefore a recurrent phenomenon. The net often requires a continuous maintenance and a very long and hard work, once at port, to be cleaned.

Some fishermen, especially those of the Viareggio fleet, are using, in the last years, trammel nets provided with a gill net stripe (locally called “greca”) placed at the base of the trammel net, between the net and the leadline , to minimize the presence of discards in the catch.

4.3. Gillnet

4.3.1. Gillnet targeting common sole

Gillnet for common sole (*Solea solea*) is widely used all year except during the summer season. These fisheries reaches the maximum activity during winter and spring. This gear is built "*ad hoc*" for the capture of the sole; the mesh size ranges between 35 and 45 mm; the net is deployed from few metres depth to over 50 m. The permanence at sea is comprised between 10 and 12 hours. The target species, *S. solea* represents almost 50% of catches on average. Important by-catch species, from the economic point of view, are the skates (*Raja* spp.), monkfish (*Lophius* spp.) and Scorpenids(*Scorpaena* spp.).

Discards are mainly constituted by fish without commercial value (species or organisms without market value, damaged, or under the minimum landing size) or by benthic invertebrates, such as crabs or molluscs gastropods.

4.3.2. Gillnets targeting European hake

The gillnets targeting European hake (*Merluccius merluccius*), a gear locally called "nasellara", is a fishing system with ancient traditions. The period of maximum use of this gear is the winter time. The mesh size varies between 40 and 50 mm; the nets are deployed at sea during the early hours of the day on muddy bottoms (between 40 and 300 m depth), for a permanence time of 3-5 hours.

Hake represents more than half of the catch; other important by-catch species are gurnards, skates, mackerel and horse mackerel (*Trachurus* spp.). The last two species, due to the low commercial value, are often discarded.

4.4. Longline

Longline targeting swordfish

This gear is specifically built for targeting swordfish (*Xiphias gladius*); other important species caught are tunas and tuna like species, occasionally spiny dogfish. The longline targeting swordfish is a selective gear: the by catch is generally less than 5% of the total catch..

Fishing activity is carried out from June to September; longlines are deployed many miles away from the coast.

4.5. Pots

Pots targeting cephalopods

Pots targeting cephalopods are the most used type of pots. The target species are the common octopus (*O. vulgaris*) and cuttlefish (*S. officinalis*). The fishing period last from January to June. An average of 100 traps per fisherman is used, although there is a lot of variability. The traps are hauled in on average every two days. The catch is very selective; the by-catch is less than 5% of the total biomass captured.

4.6. Boat seine

Boat Seine targeting transparent goby

Transparent goby, *Aphia minuta*, is a small goby having a maximum size of 6 cm. In Italy it is an important resource of small-scale fishing. Transparent goby is fished along the GSA 9 with boat seine, mainly along Liguria and Tuscany coasts. This is a very rentable activity, due to the high mean price of the target species.

This is why many fishermen tend to practice this fishery in winter replacing the traditional gear commonly used for the rest of the year. The catches are made almost entirely by the target species, the presence of by catch is very scarce, almost occasional.

Since the boat seine it is considered a towed gear, this fishery is practices needs of a "special" fishing licence, including a derogation of mesh size and distance from the coast, and it is currently practiced in the context of a specific management plan.

The management plan defines a maximum number of boats a maximum level of catches and a maximum number of licenses The activity is authorized from November to March.

5. Identification of the main "*métiers*" in Catalonian demersal fisheries (CS1.4 and CS3.4)

5.1. Introduction

Catalonia is an Autonomous Community of Spain where demersal fisheries represent 41% of the total landings and 70% of the value (in 2014), while the remaining fisheries yield correspond to small pelagics captured by the purse seining fleet. Demersal fisheries are carried out mainly by fleets using bottom trawl, set nets (trammel nets and gillnets) and longlines. The bottom trawl fleet (256 units in 2014 corresponding to fleet segments OTB1218, OTB1824 and OTB2440) produces 35% of the total landings in weight and 54% of the total landings in value. As in other Mediterranean fisheries, it shows a high rate of unwanted catches, both of species under minimum size regulation and marine organisms in general, that are discarded at sea (Sánchez et al. 2004; Lleonart 2015). Small scale fisheries (SSF) in Catalonia are carried out by a large number of vessels (ca. 700 licensed units in 2015), usually in length classes 12 and 18 m (50-100 HP), operated by a crew of one or two using trammel nets, bottom longlines and other types of set gear to catch a variety of demersal resources. The fleet rotates the metiers practiced along the year, depending on the availability of main target species.

The identification of métiers in the two demersal case studies was based on multivariate statistics applied to a matrix of daily sale records by species and fishing vessels, provided by the Catalonian fisheries management agency, covering the period 2012-2015. The daily records were aggregated to a monthly level to facilitate computation.

5.2. Data sources and statistical methods

191174 monthly-aggregated daily records for 750 vessels were examined. The total number of commercial categories[1] landed was 90 for bottom trawlers and 85 for SSF. The original data matrix of fishing trips (day x vessel) and species was reduced by eliminating rare taxa (< 0.5% of total landings) and eliminating fishing trips with zero landings.

The statistical approach followed is based on the classical model by Pelletier and Ferraris (2000) for the identification of métiers (see also Tzanatos et al. 2006), consisting in the following steps:

1 A data matrix of species (columns) x trips (rows) was built.

2 Each cell of the matrix contained the daily landings (kg) per species by boat

3 Each trip was labeled with a boat code and month (factors)

[1] The majority of commercial categories sold at the auction correspond to biological species, but some taxa of species in the same genus are sold mixed, such as horse mackerels or monkfish.

4	Bottom trawlers and SSF were separately studied by multivariate technics
5	Trips with zero landings were omitted from the analysis
6	Species with zero kg caught across all trips were also omitted of analysis
7	A catch profile by trip was calculated by weighting each species by the total catch
8	Only species that reached 0.5% of total landings were retained for the multivariate analysis.
9	The resulting matrix was log-transformed log(x+1)
10	A triangular resemblance matrix was created using the resemblance measure of Bray Curtis similarity
11	A cluster analysis using group average was used for aggregating trips by métier.
12	Trips that shared a percentage of similarity equal or upper than 48% were considered as involving separate métiers
13	Métiers meeting the above criteria but involving 100 (1.2% of total number trips) or less trips were rejected
14	PCA and SIMPER analyses were performed in order to determine what species contributed to métier separation.

5.3. Results

5.3.1. Definition of métiers

The number of species retained in the matrix was 35 for bottom trawlers and 26 for SSF. The number of trips eliminated amounted to less than 10% of the total trips. The number of métiers retained for bottom trawlers was 4 and for SSF 12.

The percentage of trips in each métier, arbitrarily coded OTB Mx and SSF Mx, is shown in the following table:

Table 1. Clusters obtained in the multivariate analysis, identified as métiers, with the proportion of trips classified in each.

Bottom trawlers	% of trips
OTB M1	3.61
OTB M2	57.77
OTB M3	35.09
OTB M4	3.53
Small Scale Fishing gears	
SSF M6	4.32
SSF M7	31.10
SSF M9	3.44

SSF M11	6.03
SSF M12	2.15
SSF M15	6.36
SSF M16	11.24
SSF M18	3.46
SSF M21	21.85
SSF M25	5.19
SSF M28	1.74
SSF M29	3.11

The majority of bottom trawls fishing trips were in métiers M2 and M3 (Table 1, Fig. 1).

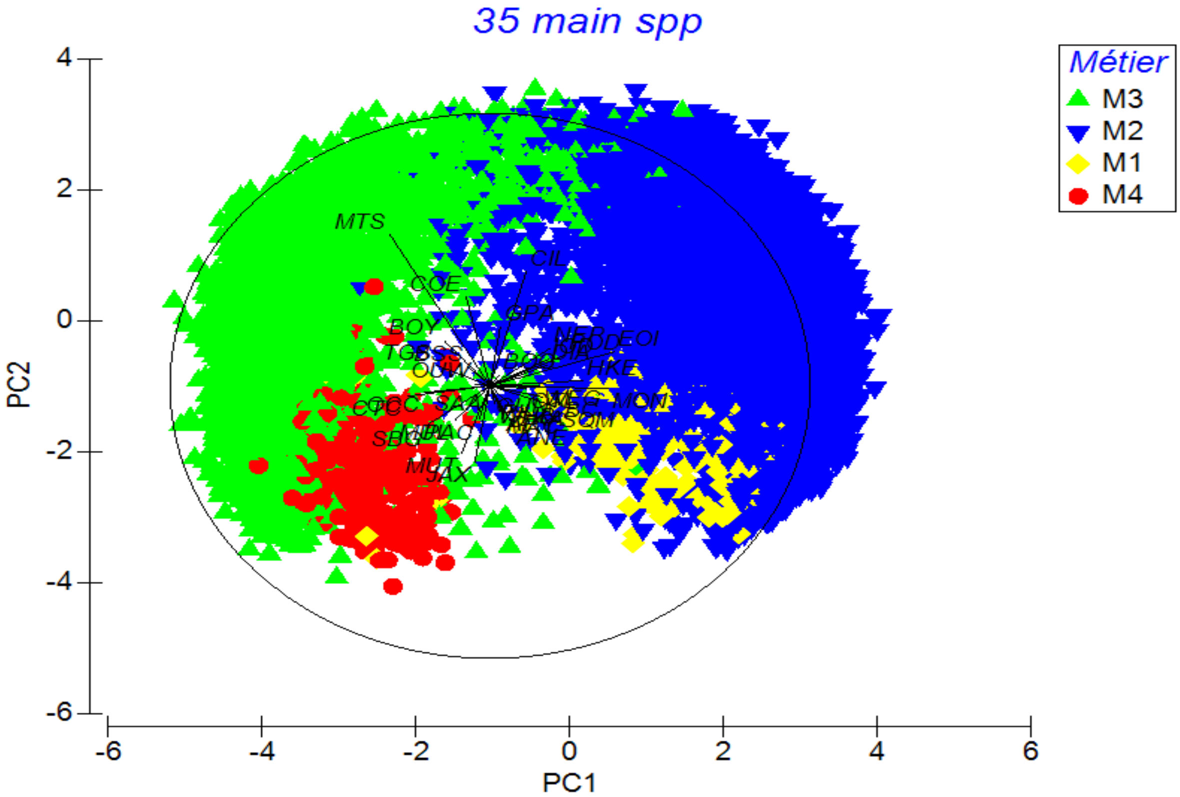

Fig. 1. Biplot of principal component analysis showing the distribution on the first two axes of the four metiers identified for bottom trawl fishing trips.

In the case of SSF, the most practiced métiers where M2, M9 and M7 (Fig. 2).

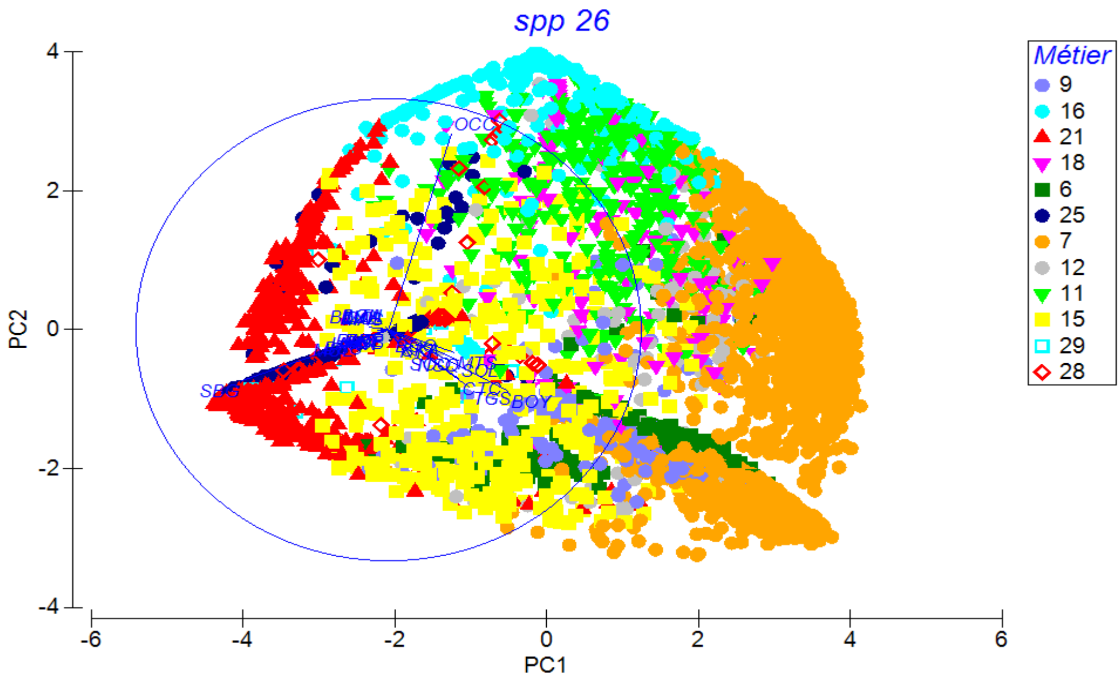

Fig.2 Biplot of principal component analysis showing the distribution on the first two axes of the 12 métiers identified for SSF fishing trips

The main species contributing to each metier are shown in the following table:

Table 2. Species contribution to métiers, derived from the multivariate *SIMPER* analysis.

Métier code	Fleet	Species 1	Contribution (%) sp 1	Species 2	Contribution (%) sp 2	Fishing gear
6	SSF	*Bolinus brandaris* (BOY)	60.36			Dredge
7	SSF	*Bolinus brandaris* (BOY)	26.67	*Penaeus kerathurus* (TGS)	20.34	Trammel net
9	SSF	*Sepia officinalis* (CTC)	68.89			Trammel net
11	SSF	*Octopus vulgaris* (OCC)	42.42	*Solea vulgaris* (SOL)	32.11	Trammel net and pots
12	SSF	*Bolinus brandaris* (BOY)	21.38	*Lithognathus mormyrus* (SSB)	20.84	Trammel net
15	SSF	*Sepia officinalis* (CTC)	22.02	*Sparus aurata* (SBG)	19.77	Trammel net
16	SSF	*Octopus vulgaris* (OCC)	98.27			Pots

18	SSF	*Nassarius mutabilis* (NSQ)	70.26			“aros”
21	SSF	*Sparus aurata* (SBG)	60.95			Trammel net
25	SSF	*Pomatomus saltatrix* (BLU)	74.35			Longline
28	SSF	*Euthynnus alletteratus* (LTA)	32.58			gillnet
29	SSF	*Donax trunculus* (DXL)	97.06			Bivalve dredge
1	OTB	*Micromesistius poutassou* (WHB)	24.00			trawl
2	OTB	*Merluccius merluccius* (HKE)	10.86	*Eledone cirrhosa* (EOI)	10.46	trawl
3	OTB	*Squilla mantis* (MTS)	22.76			trawl
4	OTB	*Trachurus* spp (JAX)	23.25			trawl

Table (2) shows that some métiers are highly mono-species, particularly the SSF métiers, with values higher than 50% for the main target species and as high as 97% of contribution of the truncate donax *Donax trunculus* in the bivalve dredge métier (SSF M29). The métiers defined for bottom trawlers (OTB) are much more multi-species, with 25% or less of contribution for the main 1-2 species and a large variety of species. For instance, the deepwater trawl métier characterized by the blue whiting *Micromesistius poutassou* (OTB M1) has a large variety of other species, particularly the very valuable deepwater crustaceans *Nephrops norvegicus* and *Aristeus antennatus*. Métiers OTB M1 to M4 are carried out over shelf bottoms, with a large variety of secondary species such as red mullets (*Mullus spp.*) and anglerfishes (*Lophius spp.)*.

The fishing gear attributed to the SSF métiers was derived from the information provided by fishers during the stakeholder processes and interviews (see Deliverables D2.1 and D1.5, respectively). Generally, a trammel net can be modified or used in different configurations during the year to target different main species. In these cases, it is appropriate to speak of prawn trammel net for SSF M7, cuttlefish trammel net for SSF M9 and M15, sole trammel net for SSF M11, striped seabream trammel net for SSF M12, and gilthead seabream trammel net for SSF M21, as recognized in the literature (for instance: Colloca et al. 2004; Stergiou et al. 2006; Tzanatos et al. 2006; Merino et al. 2008; Forcada et al. 2010; Maynou et al. 2011).

The different métiers identified for bottom trawl are practiced with essentially the same fishing gear, but on different fishing grounds along the year.

5.3.2. Seasonal distribution of métiers

The different métiers are rotated along the year, with higher frequency in specific months, according to the availability of the target species (Table 3 and Fig. 3). The dynamics of small scale fisheries is complex, with different types of trammel nets deployed sequentially along the year. For instance, from winter to spring different metiers characterized by cuttlefish and gilthead seabream are deployed (SSF M15, M9, M21). In spring cuttlefish disappears as a target species from trammel netters and gilthead seabream combines with purple-dye murex in métier SSF M12. In autumn, trammel netters target sole and octopus in a different metier (SSF M11). In spring and summer the types of fishing gear used by the small scale fishing fleet diversifies to include beam trawl targeting purple-dye murex (SSF M6), pots for octopus (SSF M16, also in autumn), longline for bluefish (SSF M25 and gillnets for little tunny (SSF M28). Two additional specific small scale fishing gear are deployed in winter “aros” targeting changeable nassa and bivalve dredges targeting truncate donax.

Table 3. Percentage of the contribution to the total catches by SSF métier by month (see Table 1.6.2 for codes). Months with more than 10% of contribution are highlighted.

Month	6	7	9	11	12	15	16	18	21	25	28	29
Jan	3.23%	16.29%	2.24%	2.00%	1.24%	12.10%	3.06%	39.91%	7.80%	0.00%	0.00%	20.78%
Feb	0.62%	6.43%	3.49%	2.12%	0.63%	14.25%	3.41%	12.15%	11.62%	0.08%	0.00%	6.75%
Mar	5.11%	8.13%	16.71%	1.66%	1.15%	23.46%	4.00%	14.13%	13.13%	0.05%	0.00%	7.60%
Apr	8.23%	12.30%	23.54%	0.17%	3.63%	18.88%	0.33%	5.57%	12.66%	5.92%	0.00%	7.89%
May	20.34%	10.54%	34.58%	0.28%	17.84%	1.71%	0.44%	3.08%	10.32%	7.19%	0.00%	28.67%
Jun	19.85%	7.87%	16.04%	0.77%	33.81%	2.29%	0.90%	0.94%	6.35%	13.12%	0.00%	14.51%
Jul	13.00%	0.98%	2.36%	7.52%	14.58%	0.26%	16.03%	0.93%	4.61%	19.37%	0.67%	2.86%
Aug	10.39%	0.28%	0.22%	2.70%	0.00%	0.03%	35.57%	0.00%	7.61%	25.41%	12.64%	1.18%
Sep	10.53%	6.27%	0.16%	16.74%	18.06%	3.22%	4.85%	0.00%	8.91%	11.13%	45.04%	2.63%
Oct	0.95%	8.25%	0.04%	43.09%	5.15%	15.63%	15.06%	0.00%	7.44%	11.80%	36.89%	1.54%
Nov	3.08%	9.67%	0.61%	15.31%	1.81%	6.32%	14.49%	0.00%	3.07%	5.85%	4.55%	1.64%
Dec	4.66%	12.99%	0.00%	7.66%	2.09%	1.84%	1.87%	23.30%	6.46%	0.09%	0.21%	3.95%

Bottom trawlers have a more consistent seasonal pattern, with the main two métiers OTB M2 and OTB M3 deployed in spring-summer and autumn-winter, respectively. Métiers OTB M1 and M4 are less often practiced and are carried out in winter-spring and end of spring respectively (Table 4)

Table 4. Percentage of the contribution to the total catches by OTB métier by month (see Table 2 for codes). Months with more than 10% of contribution are highlighted. (July and August correspond to close seasons).

Month	1	2	3	4
Jan	12.92%	9.99%	11.00%	4.33%
Feb	19.82%	8.85%	4.88%	0.00%
Mar	12.50%	11.03%	3.55%	1.83%
Apr	18.76%	10.76%	1.61%	17.17%

May	12.09%	13.30%	0.04%	40.92%
Jun	9.77%	11.93%	0.43%	30.24%
Sep	2.61%	9.78%	25.27%	5.50%
Oct	2.97%	10.40%	18.18%	0.00%
Nov	3.55%	6.39%	22.81%	0.00%
Dec	5.02%	7.58%	12.23%	0.00%

5.3.3. Activity per vessel

The number of métiers practiced by fishing vessel varied: Individual trawlers practiced 2 to 4 métiers along the year, with 3 métiers being the most common. The SSF vessels practiced from 3 to 12 métiers, with the most common values being 7 and 8 metiers (36% of the vessels), but 30% of the vessels practiced only 3 or 4.

Table 5. Number of métiers practiced by fishing vessel.

Métiers by boat	% boats
SSF	
3	15%
4	15%
5	13%
6	10%
7	18%
8	18%
9	8%
10	5%
Trawlers	
2	29%
3	44%
4	27%

5.3.4. Discarding in the métiers identified

The métiers identified statistically can be related to the métiers declared by fishers during the multi-actor approach carried out on Task 2.1 (Deliverable D2.1) and the problems of unwanted catches can be summarized as follows:

In small scale fisheries, trammel nets targeting fin fish (mainly SSF M11, M12 and M21) suffer from losses of valuable commercial fish that must be discarded because of damages due to predation by amphipods. This problem may affect all sizes of regulated species (species in Annex III of the Mediterranean regulation) and is external to the fishery. These same métiers can have by catch of unwanted, low value round sardinella or annular sea bream, but in very low amounts, typically less than 5% in weight (results of own experimental observations in MINOUW). In trammel nets targeting invertebrates, cuttlefish (SSF M9 and M15) and caramote prawn (SSF M7) the unwanted catches of crabs and low-value spottail mantis are problematic, but these species are not covered by the Landings Obligation. Unwanted catches of undersize seabreams (*Pagellus* spp.) do occur in these métiers, but in low quantities, typically less than 10% in weight (results of own experimental observations in MINOUW). Fishers claim that these unwanted catches are not discarded, but used for own consumption. The catches of undersize purple-dye murex can be high (SSF M6) in certain areas, but specimens are returned to sea with high survival rates (to be confirmed by experimental laboratory studies). The other métiers identified (e.g. SSF M16 octopus fishery using pots; SSF M18, changeable nassa fisheries using “aros”, M25 longline fishery targeting bluefish, M28 gillnet fishery targeting little tuna or M29 bivalve dredge targeting truncate donax) are very selective and have little problem if unwanted catches.

The four métiers identified in the bottom trawl fishery produce unwanted catches, particularly of undersize individuals. The deepwater métier OTB M1 is the less problematic because the most valuable species caught, the red shrimp *Aristeus antennatus*, is not included in Annex III of the Landings Obligation. The by catch of undersize specimens of a second valuable crustacean, the Norway lobster *Nephrops norvegicus*, can be problematic and experimental laboratory studies to address survival are being undertaken in the context of the MINOUW project. The three continental shelf métiers (bottom trawl mixed fisheries), targeting hake, spottail shrimp and horse mackerel are well known to produce unwanted catches of regulated species in Annex III of the Mediterranean regulation, from 1% to 18% of catch volume, depending on the season and specific fishery, as shown in several studies (see for instance Sánchez et al. 2004) and the review in Deliverable D1.1.

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Co-funded by the Horizon 2020
Framework Programme of the European Union

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