**Mixed-fish commercial categories as a strategy for reducing discards from the
small-scale fleet**

**Maria del Mar Gil^{a,b,*}, Miquel Palmer^b, Rosario Rosselló^b, Josep Alós^b, Miguel
Cabanellas-Reboredo^{b,c}, Antoni Maria Grau^d, Beatriz Morales-Nin^b**

^a LIMIA, Laboratori d'Investigacions Marines i Aqüicultura (Balearic Government).

C/ Eng. Gabriel Roca 69, 07157 Port d'Andratx, Balearic Islands, Spain

^b IMEDEA, Instituto Mediterráneo de Estudios Avanzados (CSIC-UIB),

Department of Ecology and Marine Resources, Ichthyology Group. C/ Miquel

Marquès 21, 07190 Esporles, Balearic Islands, Spain

^c IEO, Instituto Español de Oceanografía (Centro Oceanográfico de Baleares).

Muelle de Poniente s/n, 07015 Palma de Mallorca, Spain

^d DGPM, Direcció General de Pesca i Medi Marí (Balearic Government). C/

Foners 10, 07006 Palma, Balearic Islands, Spain

* Corresponding author at:

Maria del Mar Gil

e-mail: mmgil@dgpesca.caib.es

Laboratori d'Investigacions Marines i Aqüicultura, LIMIA (Balearic Government)

C/ Eng. Gabriel Roca 69

07157 Port d'Andratx, Islas Baleares, Spain

Phone: + 00 34 971 67 23 35

Fax: + 00 34 971 67 42 40

ABSTRACT

Mediterranean small-scale fleets catch a substantial amount of untargeted fish that are sold at a low market price. Most of these catches are pooled into mixed-fish boxes (MFBoxes), which are usually labeled and sold as mixed-fish commercial categories (MFCategories). In this paper, we describe the MFBoxes and the MFCategories from the small-scale fleet of Mallorca Island in terms of species composition, size distribution and economic value. We used (i) daily sales records of MFCategories between 2004 and 2015 and (ii) a sample of 141 photographs of MFBoxes, collected over one year (2009-2010). MFCategories represent a non-negligible fraction of the landings, between 18 and 51 tons/year which represents 100-300 K€/year. Some of the sampled MFBoxes were sold as one of the three identified MFCategories, which differ in species composition, size and average price (3.9 €/kg for the category LARGE MORRALLA, 2.2 €/kg for SMALL MORRALLA and 7.0 €/kg for VARIAT). However, more than half (52%) of the sampled MFBoxes were actually labeled and sold not as MFCategories but as one of the most abundant species in the box. This strategy might seem unprofitable because the market price is lower for MFBoxes sold as non-mixed categories than for non-mixed boxes of the same category. However, we observed that the label itself does not affect the selling price, but species composition does. Therefore, when sorting fish into boxes, fishers may be trying to optimize the tradeoff between not selling some low-priced fish and mixing them with other more valued fish. This alternative marketing strategy should be explored in depth and properly assessed, not only to maximize profits but also to promote a zero-discard European policy.

Keywords: European discard ban, landing, mixed-fish commercial category, small-scale fishery, Western Mediterranean

1. Introduction

Small-scale fleets are considered more ecosystem-friendly than large-scale fleets (Pauly and MacLean, 2003). Small-scale fleets typically target a wide diversity of species, not only because some gears used are relatively unspecific (Merino et al., 2008; Palmer et al., 2017) but also because they shift among diverse gears, fishing techniques and fishing grounds in order to maximize the catch and profit (Matić-Skoko et al., 2011).

Small-scale fleets are composed of small boats (boats less than 12 m long using static gears according to the Council Regulation EC No 1198/2006 of 27 July 2006) and exploit fishing grounds usually located on the continental shelf within a few hours of the port where the boat is based (Forcada et al., 2010; Morales-Nin et al., 2010). Nevertheless, small-scale fisheries provide over half of the fish for human consumption (FAO, 2003; Stergiou et al., 2006). In the Mediterranean, the small-scale fleet plays an important socio-economic role and has a long-standing tradition (Morales-Nin et al., 2010; Stergiou et al., 2006). This fleet represents 79% (27,900 boats) of the EU Mediterranean fishing vessels and contributes 12% of the EU Mediterranean weight of landings (STECF, 2017). Mediterranean small-scale fisheries provide approximately 42,800 jobs and represent 60.4% of the EU Mediterranean fishing sector employment (STECF, 2017).

In the Balearic Islands, up to 318 small-scale boats were recorded in 2016 (official data from the Regional Fisheries Administration, *Direcció General de Pesca i Medi*

Marí, DGPM), but this number is continuously decreasing (Merino et al., 2008). This decrease has been attributed to new EU enforcement rules (e.g., effort reduction measures) and to the retirement of old fishers (Maynou et al., 2013). Recruitment of young fishers is scarce due to the limited profits because fish prices have stagnated or even deflated in the past few years (Maynou et al., 2013), although the appreciation of fresh fish of quality by consumers is increasing (Morales-Nin et al., 2013). Moreover, small-sized, low-priced species captured by the small-scale fleet have experienced a loss of market share in the recent years (*DGPM* unpublished data).

Given that the profitability of small-scale fishing may often be close to the economic sustainability limit (Maynou et al., 2013), fishers must optimize their selling strategy. The landings are usually sorted into separate boxes, and their average price at first sale depends significantly on species and body size (Maynou et al., 2013; Reglero and Morales-Nin, 2008). In some Mediterranean fisheries, the boxes are labeled with the species name, which allows species-specific records of landings, which in turn have been used for stock assessment of target species (Guillen and Maynou, 2015; Merino et al., 2008; Reglero and Morales-Nin, 2008). However, in addition to target species, the small-scale fisheries catch a substantial amount of untargeted captures with a relatively low market price. This fraction may represent a non-negligible contribution to the total income (Forcada et al., 2010). However, in several worldwide fisheries, this fraction of miscellaneous captures is usually pooled into mixed-fish boxes (MFBoxes) and sold as mixed-fish commercial categories (MFCategories; Baisre, 2000; García-Rodríguez et al., 2006; Samy-Kamal et al., 2014). The composition and labeling strategies of the MFBoxes remain unknown, and these uncertainties are not included in the landings statistics, which may have some impact on fisheries assessment. Moreover, these captures might be discarded if not sold mixed, which is against the EU strategy

(Regulation EU No 1380/2013 of the Common Fisheries Policy) of minimizing discards. In fact, the implementation of this new strategy should induce an increase in the categories that are usually sold at low prices.

Here, our objective was to describe, for the first time in the Mediterranean, the fraction of low-priced fish that is distributed by the fishers in MFBoxes and sold as MFCategories. Specifically, the case study selected was the small-scale fishery in the Balearic Islands. Our specific goals were (i) to analyze the long-term temporal patterns of MFCategories in terms of landings and market price; (ii) to identify and characterize the species composition and size distribution of the MFCategories; (iii) to evaluate the effects of métier and the season on MFCategories; and (iv) to understand the price formation of MFBoxes. An understanding of how these MFCategories are devised might contribute to a better management of the small-scale fisheries, which are relevant worldwide and experiencing a general decline.

2. Materials and methods

The case study analyzed here is the small-scale fleet from Mallorca, the largest of the Balearic Islands (western Mediterranean, Spain). The fleet consisted of 178 vessels smaller than 10 gross tons (Decree 17/2003 of February 21) and was based in 15 harbors. The catches were sorted by fishers in standard boxes with a capacity of approximately 7.5 kg (see Fig. 1). Each of these boxes is sold in a downward daily auction that occurs at the Palma Fishing Wharf (Reglero and Morales-Nin, 2008). The auction is managed by a producers' cooperative (*OPMallorcaMar*) that includes all fishers from the island. Provided that the enforced maximum fishing journey for all

vessels in the small-scale fleet from the Balearic Islands is kept to one day, the daily sales from a boat correspond to a single fishing journey.

2.1. Long-term temporal data analysis of MFCategories

The way the fish are distributed in boxes for the auction is decided by the fisher, but the commercial category to which each box belongs is decided by the auctioneer. The strategy adopted by the fisher has a capital relevance in the context of this paper because fishes of different species can either be pooled or not in a single box. The number of common commercial categories in the Majorcan auctions is 170. Three of them (“MORRALLA GR.”, “MORRALLA PT.” and “VARIAT”) correspond to the mixtures of different species that are the objective of this study. “MORRALLA PT.” (thereafter named SMALL MORRALLA) and “MORRALLA GR.” (thereafter named LARGE MORRALLA) are traditionally composed of low valued fishes of small and larger size, respectively, while “VARIAT” is composed of mixed fishes with variable value.

During the auction, when a box is bought, the weight (kg) and price (Euro/kg) are automatically recorded along with the fisher’s data (e.g., boat name), date and commercial category (i.e., each record corresponds to a box). These data are transferred daily to the IMEDEA (*Instituto Mediterráneo de Estudios Avanzados*, CSIC-UIB), where the identity of the fisher is encrypted in accordance with the terms of a confidentiality agreement.

At the IMEDEA, the available data covers from 2004 to the present, but this long-term temporal pattern study refers to 2004-2015. The data received from the producers’ cooperative were reorganized by pooling raw records (i.e., boxes) into a large matrix,

the rows of which were all the landings of a given boat on a given day (i.e., by fishing trip) and each column was one of the 170 commercial categories. Two separate matrices were produced for either weight (kg) or gross revenues (Euros). The records corresponding to the small-scale fleet were filtered using the algorithm described in Palmer et al. (2017). The size of each filtered matrix was 162,815 rows (boat-day) by 170 columns (commercial categories).

The filtered matrix was used here (i) to describe the temporal (on the year scale) patterns of the landings weight (kg) and the gross revenues (Euros) of sales corresponding to the MFCategories, (ii) to describe the temporal (on the year scale) trends of the price (Euros/kg) of the three MFCategories, and (iii) to test the existence of price differences among the three MFCategories using a generalized linear model (GLM) that included the average price of all the landed fish in the day (Euros/kg) and its interaction with the MFCategories as covariables for proper between-category comparison. The statistical model, fitted with the *glm* function of the R package (<http://www.rproject.org/>), was:

$$\log(Prize_j) = MFCategory_j + MeanPrize_j + MFCategory_j * MeanPrize_j + \varepsilon_j$$

where $Prize_j$ is the prize (Euros/kg) of the j box, $MFCategory_j$ is one of the three considered categories, $MeanPrize_j$ is the averaged prize of all the landed fish in the day, and ε_j is a normally distributed term with zero mean and a given standard distribution.

2.2. Sampling MFBoxes

MFBoxes were sampled just before the auction during 2009 and 2010. A total of 33 sampling days were selected. The number of sampling days per month ranged from 1 to

4, but most of the time MFBoxes were sampled twice a month to cover a whole one-year period (Table 1). Data from 49 boats and 141 boxes were finally collected.

All boxes containing mixed fish were photographed prior to the auction. The images were identified using a panel with the name of the boat and an identification code. In addition, a calibrated ruler was added to the box to allow proper length scaling (Fig. 1).

All fish in a box were identified at the species level using the images. Note that when the boxes were full and the fish were small, only the fish placed on the upper layer could be identified. Thus, data for species composition are intended to be not an exhaustive list but a representative sample. A potential bias could be presented if fishers distributed higher valued species at the upper layer of the boxes searching for major sale price. However, fish in 83.8% of the studied boxes was distributed in a single layer (i.e., almost 100% of the fish could be identified in those boxes), and fish in the remaining multi-layers boxes were apparently not sorted. This was apparent because some low valued fishes appear at the upper layer, and some valued fishes appear partially masked at lower layers.

The total length of the specimens was also estimated from the images, using the software TPSDig2 (<http://life.bio.sunysb.edu/morph/>). Linear measurements from tail to mouth were obtained for all fish that appear in an image. The linear measurements in pixels were scaled to the ruler. The boat name and date allowed cross-referencing of the sales data set transferred to the IMEDEA and the images. Therefore, the commercial category, weight and market price were known for all the sampled boxes.

Note that MFBoxes do not necessarily have to be classified by the auctioneer into one of the three MFCategories. Instead, a number of MFBoxes (see below) are labeled in any of the 167 non-mixed commercial categories, usually as the most abundant species in the box. The composition and the length of the specimens from the MFBoxes

that were labeled as MFCategories (66 boxes) were used to characterize each of the three MFCategories. The existence of differences in species composition between the three MFCategories was tested using a Redundancy Analysis (RDA; Borcard et al., 2011) of the statistical model:

$$Abundance_{i,j} = MFCategory_j + \varepsilon_{i,j}$$

where $Abundance_{i,j}$ is the number of specimens of each species in the commercial category i and in the box j (i.e, $Abundance$ is a rectangular matrix of i columns and j rows), $MFCategory_j$ is one of the three categories considered and $\varepsilon_{i,j}$ is a residual matrix of the same dimensions than $Abundance$. The patterns of between-box similarity explained by MFCategory and how they are related to species composition were depicted by a biplot (Oksanen et al., 2014). This multivariate analysis was completed using the *rda* function of the *vegan* library (Oksanen et al., 2014) of the R package on the Hellinger-transformed data (Borcard et al., 2011; *decostand* function of the *vegan* library). Between-category differences were assessed using the permutation procedure implemented in the *anova* function.

2.3. Effects of métier and season on MFCategories

The relationship between the MFCategories abundance (measured as weight in kg) and two potentially explanatory variables (métier and season) is explored in this section. The métier is characterized by the use of a fishing gear targeting a specific group of species in a fishing area during a specific season (Biseau, 1998; Mesnil and Shepherd, 1990).

From the data set of the time series 2004-2015 mentioned in section 4.1 (i.e., the filtered matrix of 162,815 records by 170 commercial categories), the métiers possibly

used by the fisher were inferred using the algorithm developed by Palmer et al. (2017). Then, the métiers used to capture the boxes sold as each MFCategory were analyzed. The métiers considered here were Cuttlefish/Fish (trammel net targeting mainly cuttlefish, *Sepia officinalis*, and mixed fishes), Red mullet (gill net targeting striped red mullet, *Mullus surmuletus*), Spiny lobster (trammel net targeting lobster, *Palinurus elephas*), and Longline (small bottom longline). The other métiers used by the small-scale fishery in the Balearic Islands are not mentioned here because they are very species-specific, and the by-catch fraction is nearly zero (Palmer et al., 2017).

The seasonal pattern was analyzed with the landing data of each of the three MFCategories during the period 2004-2015. Total landings (kg) were grouped by month and subsequently averaged.

2.4. Descriptors of MFBoxes prices

The sale price (Euros/kg) of each of the 141 sampled MFBoxes was identified, using the data set transferred to the IMEDEA. In a preliminary descriptive analysis, a PCA (using the *rda* function of the *vegan* library) of the Hellinger-transformed (using the *decostand* function of the *vegan* library) species abundance data was completed, and sale prices were interpolated over the resulting biplot (using the *ordisurf* function of the *vegan* library). In a second step, a GLM was completed with the (log-transformed) sale price (as response variable) against (i) the abundance of the six top influential species (inferred from the PCA above) and (ii) the commercial category assigned by the auctioneer. The statistical model considered was:

$$\log(\text{Price}_j) = sp1_j + sp2_j + sp3_j + sp4_j + sp5_j + sp6_j + MFCategory_j + \varepsilon_j$$

where $Prize_j$ is the prize (Euros/kg) of the j box, $sp1_j$ to $sp6_j$ are the abundance of the six most influential species (number of specimens in the box j), $MFCategory_j$ is one of the three considered categories, and ε_j is a normally distributed term with zero mean and a given standard distribution.

Finally, and focusing only on the MFBoxes that were assigned to a non-mixed commercial category, the sale price was compared with the average sale price of all boxes of the same category sold on the same day. This analysis was performed with 70 of the 74 mixed boxes sold as non-mixed categories (4 boxes were excluded because no boxes of the same commercial category were sold on these days). The aim of this analysis was to test the effects on price when catches were mixed in the same box (which is a fisher choice) but the box was sold as any given non-mixed commercial category (which is an auctioneer choice). The existence of differences was tested using a paired t-test.

3. Results

3.1. Long-term temporal pattern of landings and gross revenues of MFCategories

The temporal pattern of landings (in weight) corresponding to MFCategories between 2004 and 2015 is shown in Fig. 2. The total annual landings ranged from 18,825 kg to 51,245 kg and suggest a clear decline from 2006 to 2008. The between-year variability before and after this decline was relatively small. The percentage of landings of MFCategories in respect to the total landings during the same year ranged from 4.8% to 11.6% (Fig. 2), showing a similar pattern to that of total landings, i.e., the

same marked decrease in 2006-2008 and a posterior stabilization. Therefore, this decline cannot be attributed to any pattern of the total landings of the entire fleet.

The temporal pattern of the gross revenues from the sale of MFCategories landings (Fig. 3) showed a trend similar to that of the total landings. Annual gross revenues oscillated between 292,425 Euros in 2006 and 94,262 Euros in 2012, which coincides with the maximum and minimum total landings of MFCategories (Fig. 2). The percentage of the gross revenues of MFCategories in relation to the gross revenues of the entire fleet landings showed a similar pattern. However, in the case of gross revenues, the difference between before and after 2008 was smaller (between 2.6% and 6.9%; Fig. 3). This result indicates that the gross revenues depend on the landings of MFCategories but also on price oscillations.

The sale price (Euros/kg) variations of the three MFCategories during the period 2004-2015 are shown in Fig. 4a. The category SMALL MORRALLA showed the lowest price, with annual averaged values ranging between 1.7 and 3.4 Euros/kg. The annual averaged prices of the category LARGE MORRALLA varied between 3.2 and 5.2 Euros/kg. The annual averaged prices of VARIAT, which showed the highest market price, varied between 5.5 and 8.1 Euros/kg. Furthermore, the prices of the three MFCategories increased when the average price of all the fleet landings in the same day was augmented (Fig. 4b), but mainly for the category VARIAT. Therefore, the sale prices of the MFCategories depended significantly on the MFCategory (i.e., there are between-category differences), on the average price of all the fish landed, and on their interaction (i.e., the larger the average price of the day, the larger the differences between MFCategories; Table 2). The predictions of MFCategory prices for a given average price (i.e., all the fish landed on a given day) of 6.5 Euros/kg were 3.9 Euros/kg (95% CI: 1.8 to 8.2) for the category LARGE MORRALLA, 2.2 Euros/kg (95% CI: 1.0

to 4.7) for SMALL MORRALLA and 7.0 Euros/kg (95% CI: 3.3 to 14.8) for VARIAT.

Therefore, in spite of the fact that the prices for the first two categories are below average, the price of VARIAT may be above the average price of all the fish marketed on a given day by the small-scale fleet.

3.2. Characterization of MFCategories

A total of 2,437 specimens were unequivocally identified in the 141 sampled MFBoxes. These specimens belonged to 59 different species (57 species of fishes and 2 species of cephalopods) and 27 families. The most abundant family was Sparidae (48.2%), followed by the family Scorpaenidae (21.5%). Each of the other families accounted for less than 10% of the total (Table 3).

The commercial category assigned to these 141 MFBoxes was identified using the data set transferred to the IMEDEA. Surprisingly, more than half of those MFBoxes (52.5%) were not sold as any MFCategory. Of the rest, 28.4% of the MFBoxes were sold as category VARIAT, 11.3% as LARGE MORRALLA and the remaining 7.8% as SMALL MORRALLA.

The species composition of the MFCategories is detailed in Fig. 5. The category LARGE MORRALLA was made up mainly of Scorpaenidae, mostly *Scorpaena porcus*, and Sparidae, mostly *Diplodus vulgaris* (Fig. 5a). The category SMALL MORRALLA was composed mostly of *Diplodus annularis* but also of other species, such as *Scorpaena porcus* and *Pagellus erythrinus* (Fig. 5b). The category VARIAT was characterized by higher diversity and by the occurrence of specific species, such as *Sciaena umbra*, *Solea vulgaris*, *Dentex dentex* or *Zeus faber* (Fig. 5c). These species-specific patterns are evidenced by the RDA's biplot (Fig. 6). In addition, differences in

species composition between MFCategories were found to be statistically significant (RDA permutation-based test: $F_{2, 63} = 2.91$, $p < 0.05$).

The fish length distribution of the most prevalent species measured from the MFBoxes that were sold as MFCategories is shown in Fig. 7. The category LARGE MORRALLA presented mainly specimens of medium size (Fig. 7a), although in some cases, small specimens were detected, such as specimens of *Spondyliosoma cantharus*. Conversely, specimens recorded in boxes sold as SMALL MORRALLA either belonged to small species, such as *Diplodus annularis*, or were small specimens of larger, high-valued species, such as *Scorpaena notata* (Fig. 7b), although large specimens of low-valued species as *Symphodus tinca* were relatively common too. The category VARIAT was composed of larger specimens (Fig. 7c), although some small specimens were included from otherwise high-valued species, such as *Dentex dentex*, *Scorpaena scrofa*, *Solea vulgaris* or *Zeus faber*.

3.3. Effects of métier and season on MFCategories

The métiers used by fisher to capture all the MFBoxes sold during the time series 2004-2015 as MFCategories (i.e., LARGE MORRALLA, SMALL MORRALLA or VARIAT) are detailed in Table 4. The métier Cuttlefish/Fish captures most of the fish sold as any of the three MFCategories. Almost half of the captures of SMALL MORRALLA were fished using the métier Red mullet. A remaining, small fraction of LARGE MORRALLA and VARIAT were fished using the métiers Spiny lobster, Red mullet and Longline (Table 4).

Concerning the seasonal pattern (Fig. 8), the among-years pooled data showed a clear increment of landings of MFCategories in spring and summer. The landings of the

categories LARGE MORRALLA and VARIAT peaked in May and June, while the landings of SMALL MORRALLA reached their highest value in August. Note, however, that the variables *métier* and *season* are not independent because the fishers are adopting a rotation cycle of métiers over the course of a year (Palmer et al., 2017); thus, the seasonal pattern in the landings of MFCategories may result from the seasonal distribution of fishing effort by métier.

3.4. Economic descriptors of MFBoxes

The species that have more influence on the sale prices of the MFBoxes are shown in Fig. 9. The GLM analysis showed that *Diplodus annularis*, *Diplodus vulgaris* and *Symphodus tinca* significantly and negatively affected the sale price (Table 5). In contrast, the species that significantly and positively influenced the sale price were *Scorpaena scrofa*, *Uranoscopus scaber* and *Zeus faber* (Table 5). It is noteworthy that the MFCategory actually assigned to an MFBox by the auctioneer did not show any significant effect on the price (Table 5). Therefore, the sale price of the MFBoxes depends on the species composition and not on the commercial category assigned.

Consistently, the sale prices of the 70 MFBoxes that were assigned to a non-mixed commercial category were significantly lower than the average sale price of all boxes of the same category sold in the same day (Paired t-test: $t = 2.0862$, $df = 69$, $p < 0.05$). For example, a mixed box sold as the DENTOL category (i.e., *Dentex dentex*) had an average price of 15.0 Euros/kg, while a non-mixed box sold as the same category in the same day had an average price of 22.2 Euros/kg. Therefore, mixing several species in the same box has a negative effect on the sale price, and it seems that including species with a low price decreased the final price (Euros/kg) of the box.

4. Discussion

The small-scale fishery in the Balearic Islands, as in other areas, is highly heterogeneous in terms of fishing gears, fishing strategies (métiers), fishing areas, seasons, target species, etc. (Stergiou et al., 2006). Much of the fishing effort of this fishery is focused on set nets corresponding to trammel nets and gill nets (Palmer et al., 2017), which are characterized by a non-negligible fraction of by-catch (Erzini et al., 2006; Fabi et al., 2002). The long list of by-catch species from the trammel nets and gill nets of the Mallorcan small-scale fleet has been reported elsewhere (Palmer et al., 2017). Most of these untargeted species are pooled together in MFBoxes by fishers and are sold as MFCategories. These categories represent between 4.8% and 11.6% of the landings of the small-scale fleet (between 18 and 51 tons/year). The average landings (32 tons/year) of MFCategories are similar to those of, for example, cuttlefish (Merino et al., 2008). They are clearly even larger than those of other well-recognized target species of the fleet, such as red mullet or red scorpionfish (Merino et al., 2008). The Balearic case is not an exception; for example, MFCategories (specifically, *morralla*) make up the predominant landings of the trammel nets from Alicante Gulf (García-Rodríguez et al., 2006). Moreover, in Mallorca, more than half of the MFBoxes are not sold as MFCategories; thus, the fraction of low-valued fish may be even higher. Therefore, the strategy of sorting fish in MFBoxes may imply several outcomes at different scales.

4.1. Why fishers mix fish

Mixing several species in the same box has a negative effect on the sale price. The data reported here support the conclusion that including low-market-price species (such as *Diplodus annularis*, *Diplodus vulgaris* and *Symphodus tinca*) or small specimens of larger, high-priced species decreases the final price (Euros/kg) of the box. There is a significant relationship between the average length composition of the box and the sale price (Reglero and Morales-Nin, 2008); therefore, there must be some incentive for mixing fish. We propose that this strategy is used to optimize the tradeoff between not selling some low-priced fish and mixing them with other, more valued fish. Thus, although the benefit of these MFCategories is reduced when compared with the price of the targeted fish, the fishers ensure the sale of a larger rate of the captured fish and get at least some profit from a low-valued by-catch. This point may have great relevance because the fleet described here seems to be at the economic sustainability limit. In fact, the low abundance of target species and the high by-catch of low-priced species make this fishery unprofitable in comparison with other fisheries in the same area, such as those of the dolphin fish, *Coryphaena hippurus*, and the transparent goby, *Aphia minuta* (Maynou et al., 2013). In addition to the low abundance of target species, the stagnation or even the deflation of fish prices supports the suggestion that most fishers may be at or near the economic sustainability level (Maynou et al., 2013), which in turn would explain the trend of the continuous regression of small-scale fishers in the last decades. This decrease seems not to be limited to Mallorca, as the relevance of the small-scale fishery is also decreasing in other parts of the world (Alió et al., 1999) and is undergoing a serious crisis in Europe (Maynou et al., 2013). Therefore, the commercialization of low-value species, which are less exploited yet more abundant available resources, could improve the profits. This idea was also proposed by Battaglia et al. (2010) given the gradual decrease of target catches over the past 20 years in the

study area. In addition, a study on a tropical bottom trawling found that the commercialization of bycatch (which was traditionally discarded) was increasingly marketable and helped to avoid the economic extinction of the fishery (Lobo et al., 2010).

4.2. *Economic implications of mixing strategy*

The existence of an economic driver that explains the mixing fish strategy is based on several of the results presented here: (i) More than half of the actual MFBoxes were labeled non-mixed categories (i.e., the most common species in the box is used for the label). (ii) The price of those boxes is always lower than that of their non-mixed counterparts. (iii) The price is a function not of the label but of the species composition and fish size, which nevertheless differed significantly among MFCategories. The lowest-valued MFCategory (SMALL MORRALLA) is characterized by the presence of small-sized, low-valued species (e.g., *Diplodus annularis*). The highest-valued MFCategory (VARIAT) is characterized by the presence of a high diversity of small specimens of larger-sized, higher-valued species (e.g., *Scorpaena scrofa* or *Zeus faber*). (iv) MFCategories are low valued. For the three MFCategories described here, we found an average value of 2.2 Euros/kg for SMALL MORRALLA, 3.9 Euros/kg for LARGE MORRALLA and 7.0 Euros/kg for VARIAT. The price of most of the conventional target species of the fleet is much higher (Merino et al., 2008), and even the average price of the landings of all the Mallorcan fisheries has a high value (around 10.35 Euros/Kg; Maynou et al., 2013). (v) The decrease of MFCategories landings between 2006 and 2008 seems to be related to a change in the labeling strategy rather than a decrease in the total landings, given that the decrease observed in the total annual

landings of MFCategories was also observed in the percentage of MFCategories landings with regard to the total landings. Therefore, this decline is due solely to MFCategories and not to the total landings of the small-scale fleet.

Although fishers mostly intend to maximize the economic benefit, the number of discards or unwanted catches is reduced with the sale of the by-catch, which is a primary objective for the EU. Many discarding practices are imposed by legal constraints (such as over-quota or undersized specimens), but others are voluntarily conducted to maximize profitability, for example highgrading, the practice of discarding low value species, etc. (Veiga et al., 2016). However, unwanted catches and discards constitute a substantial waste of natural resources that negatively affects the sustainable exploitation of marine ecosystems and the financial viability of fisheries (Kelleher, 2005; Viana et al., 2013); therefore, the European Commission has proposed a new plan to enforce the reduction of discards (Regulation EU No 1380/2013 of the European Parliament and the Council on the Common Fisheries Policy). Landing obligation has been included in this new plan (Article 15 of EU Reg. 1380/2013) affecting all commercial species subject to catch limits or minimum landing sizes. It is expected that obligation will encourage fishers to use more selective fishing gears and practices (Salomon, 2009; Veiga et al., 2016). In most cases, some of the target species captured by the studied small-scale fleet will be affected by the landing obligation, which will inevitably result in an increased logistic and economic burden to fishers (Sardà et al., 2015; Villasante et al., 2016). Taking into account that this fishery, as other small-scale fisheries, is characterized by low economic revenue (Maynou et al., 2013), the changes enforced by the new discard regulation may render the activity economically unsustainable (Veiga et al., 2016). However, the by-catch captured by this small-scale fleet would be less affected by the landing obligation because no species are subject to

catch limits or TACs (Total available catches) and few of them are captured under the legal size (i.e. although most of the captures in MFCategories have a small size, just a few species have a legal minimum size and only in rare cases they are captured under that size). So, the strategy followed by the Mallorcan fishers reduces the amount of discards that, not being affected by the landing obligation, would be returned to the sea. Therefore, in sustainably exploited resources, the revaluation of low value species through different strategies such as the sale of MFCategories should be extended to other small-scale fisheries, which usually produce some by-catch, in order to reduce discards and to improve the profitability of fishing.

In some areas, such as the Mediterranean, studies on discarding practices are poor and cover only a small proportion of the total fishing activity (Tsagarakis et al., 2014). These studies are especially scarce in small-scale fisheries, probably because discard rates are generally low (Veiga et al., 2016). However, the uncertainty associated with unaccounted fishing mortality due to discards hinders the reliability of stock assessments (Kelleher, 2005). Therefore, an specific on-board sampling program within an European funded project (MINOUW Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries; EU H2020 RIA SFS-634495) is currently in progress for estimating of discards of the small-scale fishery in Mallorca. The results of this program will allow monitoring the discards of the fleet considered and propose measures to reduce that discards.

4.3. Outcomes of mixing for species-specific fisheries assessment

The assessment and management of fisheries are usually based on information from long-term studies of fisheries resources. These studies use landings statistics for

estimating catch-per-unit-effort and ultimately the fishing mortality of target species. However, landings statistics do not include the small-sized individuals of target species sold as MFCategories. The data reported here show that for target species such as red mullet, red scorpion fish or black scorpion fish, small specimens may possibly be sold also as mixed categories (Reglero and Morales-Nin, 2008). Therefore, the data of the captures of target species and their fishing mortality are underestimated. This bias may be relevant because the trammel net fisheries for red and black scorpion fish, red mullet and cuttlefish are claimed to be near the maximum sustainable yield (Merino et al., 2008; Morales-Nin et al., 2010).

Conversely, we reported that more than half of the actual MFBoxes are labeled as non-mixed categories, i.e., as one of the common species in a given box. Therefore, blindly including these landings leads to overestimating the real catches and the fishing mortality of the species concerned. These inaccuracies could affect biomass estimations in the studies based on landings statistics and, consequently, on the stock assessment.

4.4. Ecological outcomes

The size distribution of the species sold as MFCategories showed that MFBoxes tend to be composed of small specimens. The outcomes of the mortality of this low-aged fraction on population dynamics are not fully known, especially in cases when the size of the specimens in the MFBoxes is below the maturation size. One example may be the case of *Scorpaena scrofa*. The reported female length at first sexual maturity for this species is 29.0 cm (Matić-Skoko et al., 2015), but all the specimens measured in the MFBoxes were under this size. Exploiting an species before it reaches the length of first reproduction could produce recruitment overfishing (Cushing, 1996; Lleonart and

Maynou, 2003). Thus, the risk of a stock collapse is increasing and could lead to important changes in the whole ecosystem (Leonart and Maynou, 2003). Therefore, these small specimens, for which a low benefit is reported and which in some cases are captured alive (Gray, 2002; Purbayanto et al., 2001), could be returned to the sea. A high post-capture survival rate has been proved for some species (Bell and Lyle, 2016; Smith and Scharf, 2011). Therefore, they might be able to grow and reach sexual maturity in order to provide new recruits and contribute to the maintenance of the population. However, releasing practices will be banned under EU landing obligation for some species, although this regulation allows the possibility of exemption for species for which *scientific evidence demonstrates high survival rates*. However, the survival rate is highly variable (Bell and Lyle, 2016; Davis, 2002) and specific studies are needed as those conducted in Mallorca as part of the MINOUW project (<http://minouw-project.eu/>).

4.5. Toward alternatives

Despite the limited profit from the sale of MFCategories and their implications for the sustainable exploitation of the resources, the critical situation of this fleet makes us propose a more comprehensive management approach underpinned by two pillars. First, there is a need to develop new tools to produce more precise and cost-effective fishing statistics. The current methods, usually based on sampling a small sample of the landings, are expensive and imprecise. However, the Balearic government is currently implementing an interesting initiative. All the ports of Mallorca will be provided with weighing stations where all boxes will be registered and identified with a label that will

allow traceability to the final consumer. Automatic sampling of species composition and size distribution is expected to be implemented at the same weighing stations.

The second pillar is to promote fishers' involvement in management. Co-management is defined as the collaborative and participatory process of regulatory decision making among representatives of user groups, government agencies, and research institutions (Jentoft et al., 1998). This method is particularly advantageous for small-scale fisheries. However, its success depends on the stability of an already established policy and on regional and national governmental support for the communities' initiatives. In the Mediterranean, this strategy has been suggested as promising because fishers may be prone to adopt it (Lleonart et al., 2014; Morales-Nin et al., 2017). In the context of co-management, after the scientific assessment of the resources is completed, the expected effects of management measures (such as closer monitoring and vigilance or spatially rotating closures) on profits could be considered by the fishers themselves, since these measures were suggested by them. Similarly, objective economic data should be produced to compare the current exploitation model with possible alternative models.

In summary, mixed fish should not be neglected, because they constitute a non-negligible fraction of landings and imply ecological and economic outcomes. However, the proper management of this fraction will be challenging. Pauly and MacLean (2003) claim that transferring fishing effort from industrial fisheries to small-scale fisheries will have benefits for the socio-economy of the fisheries sector as well as for the ecosystems supporting the fisheries. However, quantitative data on Mediterranean small-scale fisheries are scarce (Colloca et al., 2004). Therefore, new technological tools and new conceptual approaches for local and more inclusive management alternatives are urgently needed.

Acknowledgments

This study is a result of the Associated Unit LIMIA-IMEDEA. This research received funding from the European Commission's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 634495 for the project Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries (MINOUW). *OPMallorcaMar* and the *Federació Balear de Confraries de Pescadors* are thanked for their support and collaboration. J.A. and M. C-R were supported through Juan de la Cierva post-doc grants (grants no. FJCI-2014-21239 and FJCI-2014-20374, respectively) funded by the Spanish Ministry of Economy and Competitiveness.

References

- Baisre, J.A., 2000. Crónica de la pesca marítima en Cuba (1935–1995): análisis de tendencias y del potencial pesquero, FAO, Documento Tecnico de Pesca (Vol. 394), FAO.
- Battaglia, P., Romeo, T., Consoli, P., Scotti, G., Andaloro, F., 2010. Characterization of the artisanal fishery and its socio-economic aspects in the central Mediterranean Sea (Aeolian Islands, Italy). Fish. Res. 102, 87-97, <http://dx.doi.org/10.1016/j.fishres.2009.10.013>.
- Bell, J.D., Lyle, J.M., 2016. Post-capture survival and implications for by-catch in a multi-species coastal gillnet fishery. PLoS ONE 11, e0166632, <http://dx.doi.org/10.1371/journal.pone.0166632>.
- 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, [http://dx.doi.org/10.1016/S0990-7440\(98\)80109-5](http://dx.doi.org/10.1016/S0990-7440(98)80109-5).
- Borcard, D., Gillet, F., Legendre, P., 2011. Numerical Ecology with R, Springer New York, USA.
- Colloca, F., Crespi, V., Cerasi, S., Coppola, S.R., 2004. Structure and evolution of the artisanal fishery in a southern Italian coastal area. Fish. Res. 69, 359-369, <http://dx.doi.org/10.1016/j.fishres.2004.06.014>.
- Cushing, D.H., 1996. Towards a science of recruitment in fish populations, Ecology Institute, Germany.
- Davis, M.W., 2002. Key principles for understanding fish bycatch discard mortality. Can. J. Fish. Aquat. Sci. 59, 1834-1843, <http://dx.doi.org/10.1139/f02-139>.

608 Erzini, K., Gonçalves, J.M.S., Bentes, L., Moutopoulos, D.K., Casal, J.A.H., Soriguer,
 609 M.C., Puente, E., Errazkin, L.A., Stergiou, K.I., 2006. Size selectivity of
 610 trammel nets in southern European small-scale fisheries. *Fish. Res.* 79, 183-201,
 611 <http://dx.doi.org/10.1016/j.fishres.2006.03.004>.
 612 Fabi, G., Sbrana, M., Biagi, F., Grati, F., Leonori, I., Sartor, P., 2002. Trammel net and
 613 gill net selectivity for *Lithognathus mormyrus* (L., 1758), *Diplodus annularis*
 614 (L., 1758) and *Mullus barbatus* (L., 1758) in the Adriatic and Ligurian seas.
 615 *Fish. Res.* 54, 375-388, [http://dx.doi.org/10.1016/S0165-7836\(01\)00270-3](http://dx.doi.org/10.1016/S0165-7836(01)00270-3).
 616 FAO. Strategies for increasing the sustainable contribution of small-scale fisheries to
 617 food security and poverty alleviation. Report of the twenty-fifth session of the
 618 Committee on Fisheries. Italy: FAO; 2003
 619 Forcada, A., Valle, C., Sánchez-Lizaso, J.L., Bayle-Sempere, J.T., Corsi, F., 2010.
 620 Structure and spatio-temporal dynamics of artisanal fisheries around a
 621 Mediterranean marine protected area. *ICES J. Mar. Sci.* 67, 191-203,
 622 <http://dx.doi.org/10.1093/icesjms/fsp234>.
 623 García-Rodríguez, M., Fernández, Á.M., Esteban, A., 2006. Characterisation, analysis
 624 and catch rates of the small-scale fisheries of the Alicante Gulf (SE Spain) over
 625 a 10 years time series. *Fish. Res.* 77, 226-238,
 626 <http://dx.doi.org/10.1016/j.fishres.2005.09.002>.
 627 Gray, C.A., 2002. Management implications of discarding in an estuarine multi-species
 628 gill net fishery. *Fish. Res.* 56, 177-192, [http://dx.doi.org/10.1016/S0165-](http://dx.doi.org/10.1016/S0165-7836(01)00319-8)
 629 [7836\(01\)00319-8](http://dx.doi.org/10.1016/S0165-7836(01)00319-8).
 630 Guillen, J., Maynou, F., 2015. Characterisation of fish species based on ex-vessel prices
 631 and its management implications: An application to the Spanish Mediterranean.
 632 *Fish. Res.* 167, 22-29, <http://dx.doi.org/10.1016/j.fishres.2015.01.011>.

633 Jentoft, S., McCay, B.J., Wilson, D.C., 1998. Social theory and fisheries co-
634 management. Mar. Policy 22, 423-436, [http://dx.doi.org/10.1016/S0308-](http://dx.doi.org/10.1016/S0308-597X(97)00040-7)
635 [597X\(97\)00040-7](http://dx.doi.org/10.1016/S0308-597X(97)00040-7).

636 Kelleher, K., 2005. Discards in the world's marine fisheries. An update, FAO, Italy.

637 Lobo, A.S., Balmford, A., Arthur, R., Manica, A., 2010. Commercializing bycatch can
638 push a fishery beyond economic extinction. Conservation Letters 3, 277-285,
639 <http://dx.doi.org/10.1111/j.1755-263X.2010.00117.x>.

640 Lleonart, J., Demestre, M., Martín, P., Rodón, J., Sainz-Trápaga, S., Sánchez, P.,
641 Segarra, I., Tudela, S., 2014. The co-management of the sand eel fishery of
642 Catalonia (NW Mediterranean): the story of a process. Sci. Mar. 78, 87-93,
643 <http://dx.doi.org/10.3989/scimar.04027.25A>.

644 Lleonart, J., Maynou, F., 2003. Fish stock assessments in the Mediterranean: state of the
645 art. Sci. Mar. 67, 37-49, <http://dx.doi.org/10.3989/scimar.2003.67s137>.

646 Matić-Skoko, S., Stagličić, N., Kraljević, M., Pallaoro, A., Dulčić, J., 2015. The
647 biological traits of the large red scorpionfish, *Scorpaena scrofa*: Temporal and
648 ontogenetic dynamics. Estuar. Coast. Shelf Sci. 152, 91-99,
649 <http://dx.doi.org/10.1016/j.ecss.2014.11.019>.

650 Matić-Skoko, S., Stagličić, N., Pallaoro, A., Kraljević, M., Dulčić, J., Tutman, P.,
651 Dragičević, B., 2011. Effectiveness of conventional management in
652 Mediterranean type artisanal fisheries. Estuar. Coast. Shelf Sci. 91, 314-324,
653 <http://dx.doi.org/10.1016/j.ecss.2010.10.029>.

654 Maynou, F., Morales-Nin, B., Cabanellas-Reboredo, M., Palmer, M., García, E., Grau,
655 A.M., 2013. Small-scale fishery in the Balearic Islands (W Mediterranean): A
656 socio-economic approach. Fish. Res. 139, 11-17,
657 <http://dx.doi.org/10.1016/j.fishres.2012.11.006>.

658 Merino, G., Morales-Nin, B., Maynou, F., Grau, A.M., 2008. Assessment and
 659 bioeconomic analysis of the Majorca (NW Mediterranean) trammel net fishery.
 660 Aquat. Living Resour. 21, 99-107, <http://dx.doi.org/10.1051/alr:2008027>.
 661 Mesnil, B., Shepherd, J.G., 1990. A hybrid age- and length-structured model for
 662 assessing regulatory measures in multiple-species, multiple-fleet fisheries. ICES
 663 J. Mar. Sci. 47, 115-132, <http://dx.doi.org/10.1093/icesjms/47.2.115>.
 664 Morales-Nin, B., Cardona-Pons, F., Grau, A.M., García, E., Alvarez, I., Pérez-Mayol,
 665 S., 2013. Does angling activity influence consumer choices of fresh fish? Br.
 666 Food J. 115, 1054-1066, <http://dx.doi.org/10.1108/BFJ-04-2011-0096>.
 667 Morales-Nin, B., Grau, A.M., Aguilar, J.S., Gil, M.M., Pastor, E., 2017. Balearic
 668 Islands boat seine fisheries: the transparent goby fishery an example of co-
 669 management. ICES J. Mar. Sci., <http://dx.doi.org/10.1093/icesjms/fsw227>.
 670 Morales-Nin, B., Grau, A.M., Palmer, M., 2010. Managing coastal zone fisheries: A
 671 Mediterranean case study. Ocean Coast. Manage. 53, 99-106,
 672 <http://dx.doi.org/10.1016/j.ocecoaman.2010.01.003>.
 673 Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O'Hara, R.B.,
 674 Simpson, G.L., Solymos, P., Stevens, M.H.H., Wagner, H., 2014. vegan:
 675 Community Ecology Package, R package version 2.2-0.
 676 Palmer, M., Tolosa, B., Grau, A.M., Gil, M.M., Obregón, C., Morales-Nin, B., 2017.
 677 Combining sale records of landings and fishers knowledge for predicting métiers
 678 in a small-scale, multi-gear, multispecies fishery. Fish. Res. 195, 59-70,
 679 <http://dx.doi.org/10.1016/j.fishres.2017.07.001>.
 680 Pauly, D., MacLean, J., 2003. In a Perfect Ocean—The State of Fisheries and
 681 Ecosystems in the North Atlantic Ocean, Island Press, USA.

682 Purbayanto, A., Tsunoda, A., Akiyama, S., Arimoto, T., Tokai, T., 2001. Survival of
 683 Japanese whiting *Sillago japonica* and by-catch species captured by a sweeping
 684 trammel net. Fish. Sci. 67, 21-29, [http://dx.doi.org/10.1044-
 685 2906.2001.00194.x](http://dx.doi.org/10.1046/j.1444-2906.2001.00194.x).
 686 Reglero, P., Morales-Nin, B., 2008. Relationship between first sale price, body size and
 687 total catch of trammelnet target species in Majorca (NW Mediterranean). Fish.
 688 Res. 92, 102-106, <http://dx.doi.org/10.1016/j.fishres.2008.01.010>.
 689 Salomon, M., 2009. Recent European initiatives in marine protection policy: towards
 690 lasting protection for Europe's seas? Environ. Sci. Policy 12, 359-366,
 691 <http://dx.doi.org/10.1016/j.envsci.2008.12.008>.
 692 Samy-Kamal, M., Forcada, A., Sánchez-Lizaso, J.L., 2014. Trawling fishery of the
 693 western Mediterranean Sea: Métiers identification, effort characteristics,
 694 landings and income profiles. Ocean Coast. Manage. 102, 269-284,
 695 <http://dx.doi.org/10.1016/j.ocecoaman.2014.10.005>.
 696 Sardà, F., Coll, M., Heymans, J.J., Stergiou, K.I., 2015. Overlooked impacts and
 697 challenges of the new European discard ban. Fish Fish. 16, 175-180,
 698 <http://dx.doi.org/10.1111/faf.12060>.
 699 Smith, W.E., Scharf, F.S., 2011. Postrelease survival of sublegal southern flounder
 700 captured in a commercial gill-net fishery. North Am. J. Fish. Manage. 31, 445-
 701 454, <http://dx.doi.org/10.1080/02755947.2011.590116>.
 702 STECF, 2017. Scientific, Technical and Economic Committee for Fisheries (STECF) –
 703 The 2017 Annual Economic Report on the EU Fishing Fleet (STECF-17-12).
 704 ISBN 978-92-79-73426-7; <http://dx.doi.org/10.2760/36154>.
 705 Stergiou, K.I., Moutopoulos, D.K., Soriguer, M.C., Puente, E., Lino, P.G., Zabala, C.,
 706 Monteiro, P., Errazkin, L.A., Erzini, K., 2006. Trammel net catch species

composition, catch rates and métiers in southern European waters: A
multivariate approach. *Fish. Res.* 79, 170-182,
<http://dx.doi.org/10.1016/j.fishres.2006.03.003>.

Tsagarakis, K., Palialexis, A., Vassilopoulou, V., 2014. Mediterranean fishery discards:
review of the existing knowledge. *ICES J. Mar. Sci.* 71, 1219-1234,
<http://dx.doi.org/10.1093/icesjms/fst074>.

Veiga, P., Pita, C., Rangel, M., Gonçalves, J.M.S., Campos, A., Fernandes, P.G., Sala,
A., Virgili, M., Lucchetti, A., Brčić, J., Villasante, S., Ballesteros, M.A.,
Chapela, R., Santiago, J.L., Agnarsson, S., Ögmundarson, Ó., Erzini, K., 2016.
The EU landing obligation and European small-scale fisheries: What are the
odds for success? *Mar. Policy* 64, 64-71,
<http://dx.doi.org/10.1016/j.marpol.2015.11.008>.

Viana, M., McNally, L., Graham, N., Reid, D.G., Jackson, A.L., 2013. Ignoring
discards biases the assessment of fisheries' ecological fingerprint. *Biol. Lett.* 9,
20130812, <http://dx.doi.org/10.1098/rsbl.2013.0812>.

Villasante, S., Pierce, G.J., Pita, C., Guimeráns, C.P., Garcia Rodrigues, J., Antelo, M.,
Da Rocha, J.M., Cutrín, J.G., Hastie, L.C., Veiga, P., Sumaila, U.R., Coll, M.,
2016. Fishers' perceptions about the EU discards policy and its economic impact
on small-scale fisheries in Galicia (North West Spain). *Ecol. Econ.* 130, 130-
138, <http://dx.doi.org/10.1016/j.ecolecon.2016.05.008>.

Figure captions

Fig. 1. Image of a mixed box collected prior to auction during the sampling in 2009-2010. Note the presence of undersized specimens such as *Scorpaena notata*.

Fig. 2. Temporal pattern of landings (in weight) of the three mixed-fish commercial categories (MFCategories) from 2004 to 2015. Total annual landings (kg per year) are presented as bars, and percentage of landings of MFCategories with respect to total landings is presented as a solid line.

Fig. 3. Temporal pattern of gross revenues from the sale of the three mixed-fish commercial categories (MFCategories) from 2004 to 2015. Total annual gross revenues (Euros per year) are presented as bars, and percentage of gross revenues of MFCategories with respect to total gross revenues of total landings is presented as a solid line.

Fig. 4. A) Variation of the sale price (Euros/kg) of the three mixed-fish commercial categories (LARGE MORRALLA, SMALL MORRALLA and VARIAT) during the period 2004-2015. B) Predictions of the three mixed-fish commercial categories (MFCategories) prices for a given average price for all the landed fish (Euros/kg).

Fig. 5. Species composition of the three mixed-fish commercial categories: A) LARGE MORRALLA GR., B) SMALL MORRALLA and C) VARIAT. The group “Others” combines the species with fewer than 10 specimens.

Fig. 6. RDA plot of species composition in the mixed-fish commercial categories (MFCategories) showing the 75% confidence ellipses of concentration. Crosses represent minority species with low relevance to the analysis.

Fig. 7. Length distribution of the most abundant species present in the photographs of mixed-fish boxes (MFBoxes) sold as mixed-fish commercial categories (MFCategories).

Fig. 8. Monthly averaged pattern of the total landings (kg) of the three mixed-fish commercial categories (MFCategories) during the period 2004-2015.

Fig. 9. PCA plot of species abundance in mixed-fish boxes (MFBoxes; white dots). The sale prices (Euros/kg) of the MFBoxes are fitted on the PCA space and shown as isoclines. The names of the species that have more influence (positive or negative) on the price are represented by the full name, while the other species are shown as a cross.

782 Figure 1:

783

784

785

Figure 2:

786

787

788

Figure 3:

Figure 4:

Figure 5:

Figure 6:

Figure 7:

Figure 8:

Figure 9:

807
808
809
810
811
812
813
814
815
816
817
818
819

Tables

Table 1

Distribution of sampling on the Palma Fishing Wharf during the period 2009-2010 for the collection of photographs of mixed-fish boxes (MFBoxes). The number of photographed boxes and the number of boats that captured the boxes are detailed by month.

Year	Month	Num. days	Num. boats	Num. boxes
2009	April	3	12	25
	May	4	9	11
	June	2	3	6
	July	2	3	3
	August	2	4	4
	September	3	10	17
	October	3	10	15
	November	1	5	7
	December	3	5	8
2010	January	3	9	16
	February	2	8	11
	March	2	5	6
	April	1	3	4
	May	2	6	8

Table 2

Results of the GLM for the sale price effect of the mixed-fish commercial category (MFCategory) and the price of all the landed fish.

	Df	Sum Sq	Mean Sq	F value	Prob.
Price MFCategory	2	1779.0	889.5	6071.7	<0.001
Price all landed fish	1	46.1	46.1	315.1	<0.001
Interaction	2	3.9	1.9	13.4	<0.001
Residual	8299	1215.7	0.15		

Table 3

833 Composition by family (%) of the identified species in the mixed-fish boxes
834 (MFBboxes).

Family	%	Family	%
Sparidae	48,21	Sphyraenidae	0,57
Scorpaenidae	21,50	Triglidae	0,53
Labridae	8,20	Sepiidae	0,49
Uranoscopidae	3,73	Phycidae	0,28
Mullidae	3,48	Loliginidae	0,16
Zeidae	2,05	Merlucciidae	0,12
Sciaenidae	1,96	Clupeidae	0,08
Carangidae	1,72	Mugilidae	0,08
Soleidae	1,39	Lophiidae	0,04
Trachinidae	1,35	Moronidae	0,04
Haemulidae	1,18	Pomatomidae	0,04
Serranidae	1,18	Scombridae	0,04
Centracanthidae	0,73	Triakidae	0,04
Bothidae	0,69		

835

836 **Table 4**

837 Mixed-fish commercial categories (%) from the métiers Cuttlefish/Fish, Spiny lobster,
838 Red mullet and Longline for the period 2004 to 2015.

Category/Métiers	Cuttlefish/Fish	Spiny lobster	Red mullet	Longline
VARIAT	34,3%	5,9%	5,0%	4,7%
LARGE MORRALLA	21,2%	2,8%	5,6%	4,2%
SMALL MORRALLA	7,6%	0,7%	7,1%	0,7%
TOTAL	63,1%	9,4%	17,7%	9,6%

839

840 **Table 5**

841 Results of the GLM for the sale price effect of the six top influential species and the
842 assigned mixed-fish commercial category (MFCategory).

	Coeff.	Df	Sum sq	F value	p
<i>Diplodus annularis</i>	-0.27	1	12.2	22.80	<0.05
<i>Diplodus vulgaris</i>	-0.08	1	2.19	4.09	<0.05
<i>Symphodus tinca</i>	-0.47	1	13.05	24.35	<0.05
<i>Uranoscopus scaber</i>	0.22	1	6.93	12.93	<0.05
<i>Scorpaena scrofa</i>	0.32	1	2.70	5.03	<0.05
<i>Zeus faber</i>	0.33	1	8.15	15.21	<0.05

		MFCATEGORY	3	1.60	1.00	N.S.
		Residual	124	66.4		
843	N.S.: Non-significant					

844