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Trammel net catch species composition, catch rates and métiers in southern European waters: A multivariate approach

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Abstract

We identified and quantified the effect of season, depth, and inner and outer panel mesh size on the trammel net catch species composition and catch rates in four southern European areas (Northeast Atlantic: Basque Country, Spain; Algarve, Portugal; Gulf of Cádiz, Spain; Mediterranean: Cyclades, Greece), all of which are characterised by important trammel net fisheries. In each area, we conducted, in 1999–2000, seasonal, experimental fishing trials at various depths with trammel nets of six different inner/outer panel mesh combinations (i.e., two large outer panel meshes and three small inner panel meshes). Overall, our study covered some of the most commonly used inner panel mesh sizes, ranging from 40 to 140 mm (stretched). We analysed the species composition and catch rates of the different inner/outer panel combinations with regression, multivariate analysis (cluster analysis and multidimensional scaling) and other 'community' techniques (number of species, dominance curves). All our analyses indicated that the outer panel mesh sizes used in the present study did not significantly affect the catch characteristics in terms of number of species, catch rates and species composition. Multivariate analyses and seasonal dominance plots indicated that in Basque, Algarve and Cyclades waters, where sampling covered wide depth ranges, both season and depth strongly affected catch species compositions. For the Gulf of Cádiz, where sampling was restricted to depths 10–30 m, season was the only factor affecting catch species composition and thus group formation. In contrast, the inner panel mesh size did not generally affect multidimensional group formation in all areas but affected the dominance of the species caught in the Algarve and the Gulf of Cádiz. Multivariate analyses also revealed 11 different métiers (i.e., season–depth–species–inner panel mesh size combinations) in the four areas. This clearly indicated the existence of trammel net 'hot spots', which represent essential habitats (e.g., spawning, nursery or wintering grounds) of the life history of the targeted and associated species. The number of specimens caught declined significantly with inner panel mesh size in all areas. We attributed this to the exponential decline in abundance with size, both within- and between-species. In contrast, the number of species caught in each area was not related to the inner mesh size. This was unexpected and might be a consequence of the wide size-selective range of trammel nets.

Keywords: Trammel net fisheries; Small-scale fisheries; Atlantic; Mediterranean; Species composition; Catches; Dominance; Métiers; Multivariate analysis

1. Introduction

Small-scale fisheries generally contribute about half to the amount of fish consumed directly by humans (FAO, 2003). They are highly heterogeneous in terms of the fate of their

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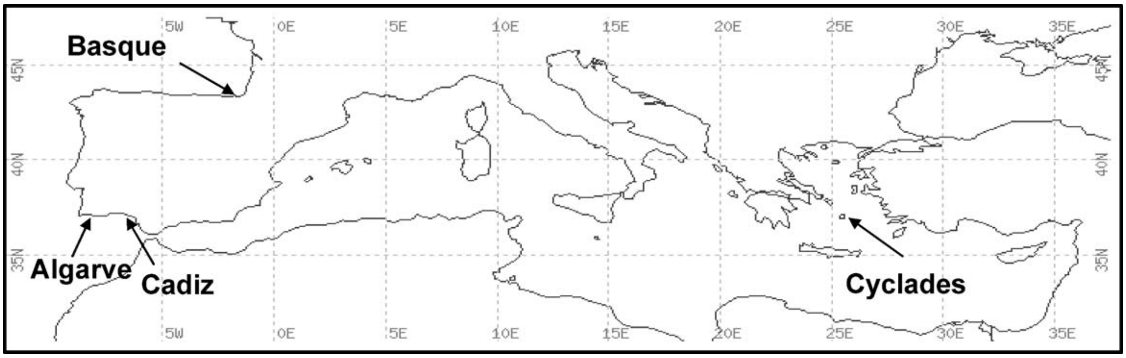

Fig. 1. Map showing the four study areas (coastline extracted from http://www.oas.ngdc.noaa.gov/mgg/plsql/extractor.mapit).

landings, their activity, their organizational level of operation (FAO, 2003, 2004), and fishing gears, fishing strategies and métiers (i.e., the combination of a particular fishing gear, fishing area, season, target species and operational process: Laurec et al., 1991; Ulrich et al., 2001; Salas and Gaertner, 2004). In the 2nd Session of the Working Party on small-scale fisheries, organised by FAO in Bangkok (Thailand, 18–21 November, 2003), it was stressed that the vision for small-scale fisheries "... is one in which their contribution to sustainable development is fully realised. It is a vision where they are not marginalized and their contribution to national economies and food security is recognized, valued and enhanced ..." (FAO, 2004).

About 75% of some 100,000 boats making up the European Union fishing fleet, operating in European Union waters as well as in other countries' waters and international waters, are smaller than 12 m in length (OCEANA, 2004). The majority of these small boats are engaged in small-scale fishing, operating a vast array of fishing gears, such as gill nets, trammel nets, longlines, traps, pots, dredges, etc. (OCEANA, 2004). For southern European countries such as Spain, Portugal, France, Italy and Greece, small-scale fishing, having a long tradition going back many centuries, is of high socio-economic importance (Stergiou et al., 1997; COPEMED, 2003; OCEANA, 2004).

Following the global trend in fisheries resources (e.g., Pauly et al., 2002, 2003; Myers and Worm, 2003), the majority of the fish stocks, especially the demersal ones, in European waters, including the Mediterranean Sea, are overexploited and 'outside safe biological limits' (Stergiou et al., 1997; Lleonart, 1999; ICES, 2003; Lleonart and Maynou, 2003; OCEANA, 2004). 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, in order for this to be realised, the level of information availability for small-scale fisheries should at least be as high as that of their industrial counterparts. Yet, it is widely accepted that there is a strong lack of information on many aspects of small-scale fisheries when compared to industrial ones (FAO, 2003, 2004). Thus, the need to improve our knowledge of small-scale fisheries is urgent. This will allow us to further develop operational schemes, including the ecosystem-based one (Pitcher, 2000; Stergiou, 2002; Garcia et al., 2003; Browman and Stergiou, 2004), within which the potential and management of small-scale fisheries can be evaluated and realised.

Elsewhere (Erzini et al., 2006) we present the selectivity of trammel nets in southern European waters. In this report, we applied regression, multivariate analysis and other 'community' techniques on the species composition of the catches of trammel nets of nine inner panel mesh sizes, ranging from 40 to 140 mm (stretched), resulted from seasonal fishing trials at depths ranging from 10 to 100 m in four southern European areas (Northeast Atlantic: Basque Country, Spain; Algarve, Portugal; Gulf of Cádiz, Spain; Mediterranean: Cyclades, Greece) (Fig. 1), all of which are characterised by important trammel net fisheries (Anon., 2001). Our analysis attempts to answer the following questions: (a) what is the relative importance of depth, inner and outer panel mesh size and season in determining species composition and catches of trammel nets and (b) whether different métiers can be identified based on multivariate analysis.

2. Material and methods

Seasonal experimental fishing trials with trammel nets of different inner/outer mesh size combinations took place in Basque waters, Algarve waters, the Gulf of Cádiz and Cyclades, at depths ranging from 10 to 100 m during 1999–2000 (Table 1). A thorough description of the gears used and of the experimental design is presented in Erzini et al. (2006). In all areas, sampling took place using commercial fishing boats and all fishing operations were carried out by professional fishers. The fishers selected the fishing grounds in traditional areas in order to ensure the highest possible catches and that fishing was as similar as possible to the traditional fishing activities employed in each area.

In all areas, we recorded the number of individuals of all species caught. We also recorded the weight of all species caught in all areas with the exception of Basque waters. From the number and weight per species caught for each fishing trial we firstly estimated the number of species and num-

Table 1
Inner and outer panel mesh sizes of the trammel nets used, number of experimental trials and sampling depths in the four areas

Characteristic	Area			
	Basque	Algarve	Cádiz	Cyclades
Inner mesh size	90, 100, 110	100, 120, 140	80, 90, 100	40, 48, 56
Outer mesh size	500, 600	600, 800	300, 400	220/240, 240/260, 280/300
Sampling frequency	Seasonal	Seasonal	Autumn, spring	Seasonal
Number of trials per inner–outer mesh size combination	48	40	60	41
Sampling depth	20–80	15–100	10–30	10–80

Mesh sizes in mm (stretched), depths in m (for a detailed description see Erzini et al., 2006).

ber and weight of specimens per species for each inner/outer panel mesh size combination of trammel nets used in each region. We compared the means between different inner/outer panel mesh size combinations, and seasons using *t*-test and one way analysis of variance (ANOVA), according to the case, and Fisher's least significance difference (LSD) test (Zar, 1999). We explored the relationships between inner mesh size and number of species and individuals caught using linear regression.

Secondly, we plotted cumulative dominance curves, which show the percentage cumulative numerical abundance against log species rank (Clarke and Warwick, 1994), based on catch numbers per 1000 m of net for: (a) all mesh sizes combined per season/area, (b) all inner panel mesh sizes combined per outer panel mesh size used in each area, and (c) all outer panel mesh sizes combined per inner panel mesh size used in each area.

Thirdly, we used multivariate analysis (cluster and multidimensional scaling, MDS) in order to quantify the overlap in terms of species between the different inner/outer panel mesh size combinations. In that end, we constructed matrices comprising the numbers and weights of each species from each inner/outer mesh combination for each season, after averaging all trials per season for each area [i.e., (all species) × (six inner/outer mesh combinations) × (four seasons in three areas, two seasons in Cádiz)]. We expressed numbers and weights (the latter were not available for Basque waters) per 1000 m of trammel nets. We transformed the matrices into triangular matrices of similarities between all pairs of inner/outer mesh combinations using the Bray–Curtis coefficient (Bray and Curtis, 1957). The latter was applied on transformed data using the double square root transformation in order to reduce the weighting of abundant species (Field et al., 1982). Consequently, we subjected the numerical and weight matrices to cluster (employing group-average clustering) and MDS. In the latter case, the adequacy of a two-dimensional representation of combinations is captured by the "stress coefficient" (Field et al., 1982), with stress values <0.2 implying good representation (Carr, 1997). We accepted groupings based on the agreement between the results of cluster and MDS analysis (Field et al., 1982).

Finally, we identified the contribution of each species to the average Bray–Curtis dissimilarity between the various groups of combinations as well as to similarity within a group of combinations using Simper analysis (Clarke and Warwick, 1994; Carr, 1997). The latter uses the standard deviation of the Bray–Curtis dissimilarity, attributed to a species, for all pairs and compares that with the average contribution of a species to the dissimilarity (Carr, 1997). For dominance curves and multivariate analyses we used PRIMER for Windows (Carr, 1997).

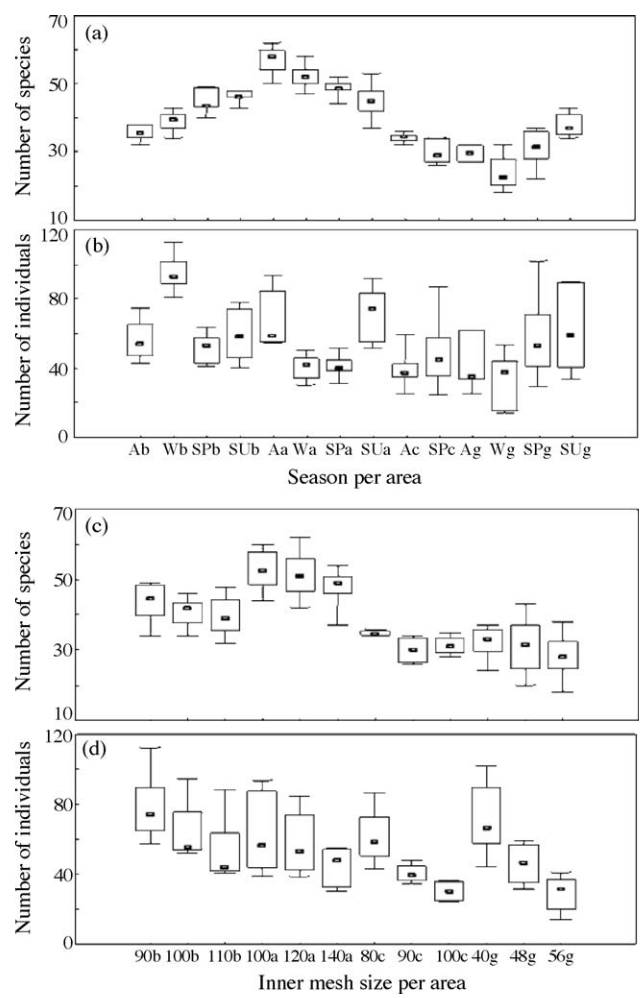

Fig. 2. Box-Whisker plots of the (a) number of species and (b) number of individuals caught with trammel nets per season (A: autumn, W: winter, SP: spring, SU: summer) and area (b: Basque, a: Algarve, c: Cádiz, g: Cyclades); and (c) number of species and (d) number of individuals, per inner panel mesh size per area. The central box covers 50% of the values, the whiskers indicate the range and the small square within the box the mean.

3. Results

3.1. Number of species and individuals

In all areas, the mean number of species and individuals caught did not differ significantly (Basque: for both cases, $t < 0.47$, $P > 0.05$; Algarve: for both cases, $t < 0.40$, $P > 0.05$; Cádiz: for both cases, $t < 1.21$, $P > 0.05$; Cyclades: for both cases, $t < 0.34$, $P > 0.05$) between the two outer panel mesh sizes used. The number of species caught per gear/mesh size/season/area combination ranged considerably both between- and within-areas (Fig. 2a and c). Thus for Basque waters, it varied between 32 and 49, for Algarve waters between 37 and 62, for the Gulf of Cádiz between 26 and 36, and, finally, in Cyclades between 18 and 43 (Fig. 2a and c).

The mean number of species caught differed significantly with season in all areas (ANOVA; Basque: $F = 17.5$, $P < 0.05$; Algarve: $F = 8.7$, $P < 0.05$; Cádiz: $F = 7.8$, $P < 0.05$; Cyclades: $F = 9.3$, $P < 0.05$), with minima and maxima differing depending on the area (Fig. 2a). In contrast, the mean number of individuals caught (Fig. 2b) differed significantly with season only in two areas, Basque and Algarve (ANOVA; Basque: $F = 12.2$, $P < 0.05$; Algarve: $F = 12.5$, $P < 0.05$; Cádiz: $F = 0.7$, $P > 0.05$; Cyclades: $F = 2.8$, $P > 0.05$). The mean number of species caught did not differ significantly with inner panel mesh size in all areas (ANOVA; Basque: $F = 1.1$, $P > 0.05$; Algarve: $F = 1.4$, $P > 0.05$; Cádiz: $F = 2.6$, $P > 0.05$; Cyclades: $F = 0.8$, $P > 0.05$) (Fig. 2c), whereas the mean number of individuals caught (Fig. 2d) differed significantly with inner panel mesh size in all areas (ANOVA; Basque: $F = 4.6$, $P < 0.05$; Cádiz: $F = 9.7$, $P < 0.05$; Cyclades: $F = 16.2$, $P < 0.05$) except in Algarve waters (ANOVA, $F = 2.4$, $P = 0.12$), with larger mesh sizes catching fewer specimens.

No relationship was found between the number of species caught and inner mesh size in each area (for all cases $P > 0.10$) (Fig. 3a). In contrast, in all areas the number of individuals caught declined significantly ($P < 0.05$) with inner mesh size (Fig. 3b). The slope of the regression was highest for Cyclades

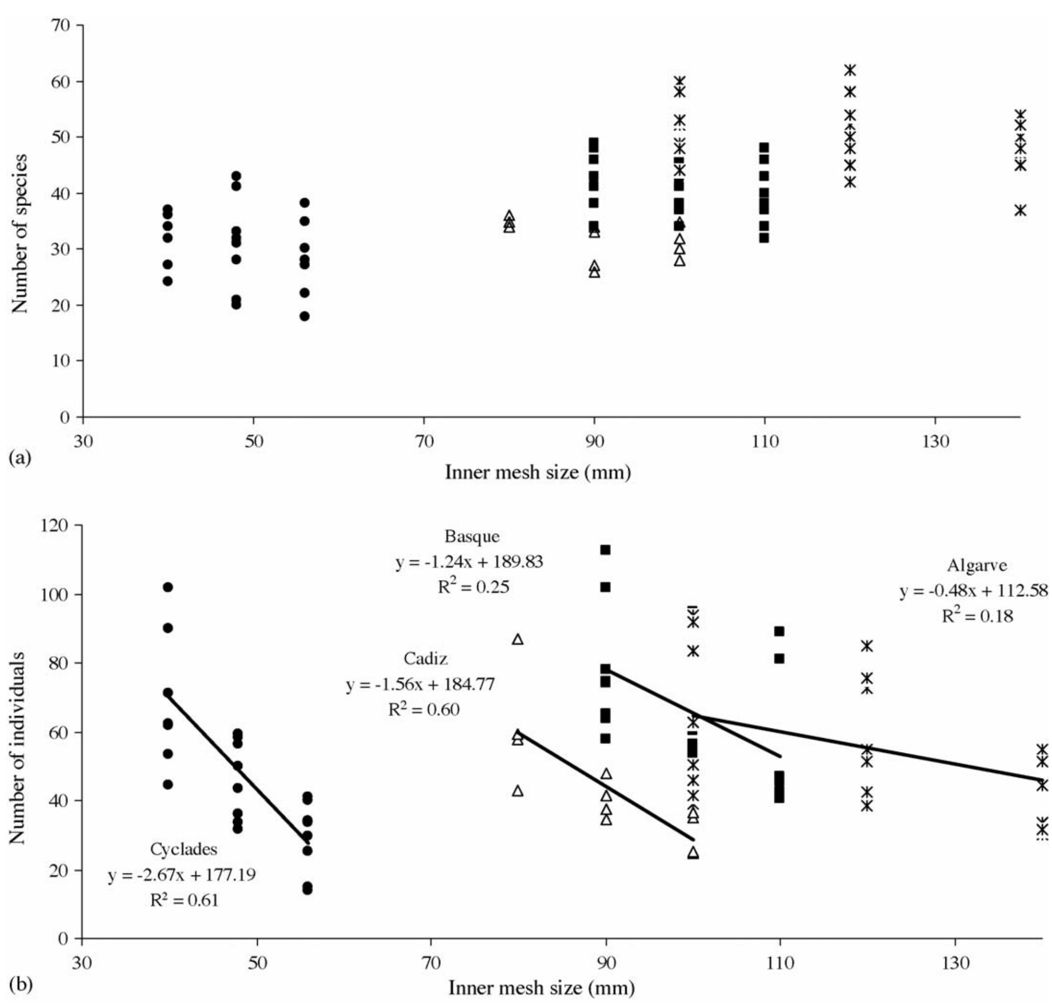

Fig. 3. Relationship between the (a) number of species and (b) number of individuals with inner mesh size for trammel nets in the four study areas. (Black circle) Cyclades; (open triangle) Cadiz; (black rectangular) Basque; (star) Algarve.

and lowest for Algarve waters, whereas the slopes did not differ significantly from each other (ANCOVA, $P > 0.05$) for Cádiz and Basque waters.

3.2. Dominance

The area-specific dominance curves are shown in Figs. 4–7. For all areas, dominance did not differ between trammel nets of different outer panel mesh sizes (Figs. 4a–7a). With respect to the inner panel mesh sizes, dominance was about the same for the different mesh sizes used in Basque waters (Fig. 4b) and the Cyclades (Fig. 7b) whereas it increased with mesh size in Algarve waters (Fig. 5b) and decreased with mesh size in the Gulf of Cádiz (Fig. 6b). In contrast, there was a clear area-specific difference in species dominance among seasons (Figs. 4c–7c). Thus, dominance was lower in spring–summer when compared to autumn–winter in Basque (Fig. 4c) and Algarve waters (Fig. 5c), higher in spring than in autumn in the Gulf of Cádiz (Fig. 6c) and higher in autumn and lower in spring in Cyclades (Fig. 7c).

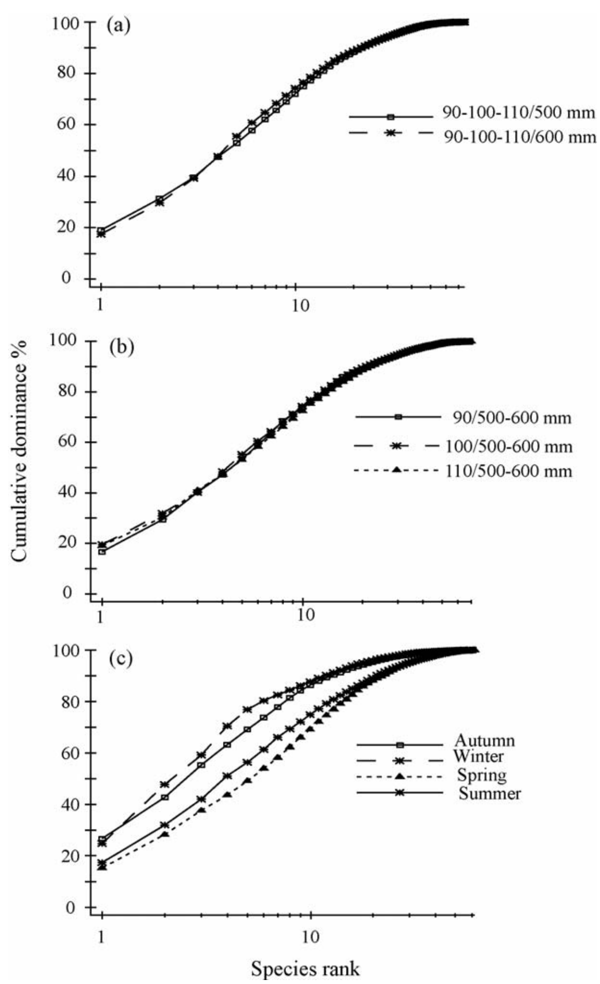

Fig. 4. Basque Country. K-dominance curves based on catch numbers (per 1000 m of net) for all species caught for six combinations of inner/outer panel mesh sizes (mm): (a and b) for all seasons combined and (c) all mesh sizes combined by season.

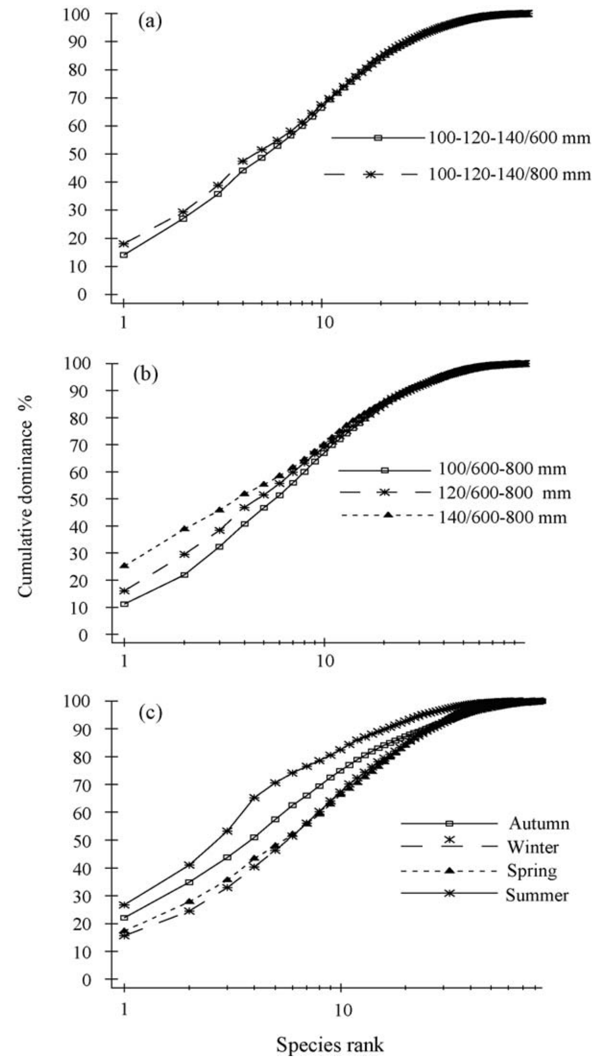

Fig. 5. Algarve. K-dominance curves based on catch numbers (per 1000 m of net) for all species caught for six combinations of inner/outer panel mesh sizes (mm): (a and b) for all seasons combined and (c) all mesh sizes combined by season.

3.3. Multivariate analyses

The results of the multivariate analyses are shown in Figs. 8–12 and Tables 2 and 3. In general, multivariate analyses indicated the formation of two to four groups of combinations, depending on the geographic area. Thus for Basque (Fig. 8) and Algarve waters (Fig. 9) both cluster and MDS applied on the numerical matrices revealed four main groups of mesh size combinations, one for each sampling season. The same was also true of the Gulf of Cádiz (Fig. 10) where sampling was limited to two seasons only (autumn and spring). For Cyclades, cluster analysis revealed two main groups (Fig. 11a); one, Group I, composed of all mesh size

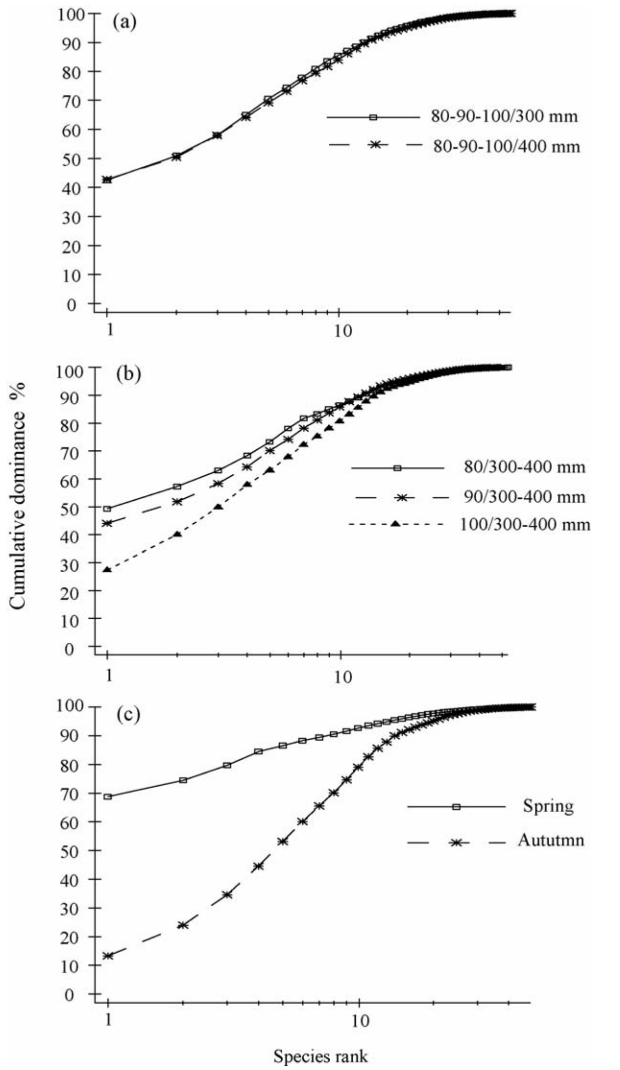

Fig. 6. Cádiz. K-dominance curves based on catch numbers (per 1000 m of net) for all species caught for six combinations of inner/outer panel mesh sizes (mm): (a and b) for all seasons combined and (c) all mesh sizes combined by season.

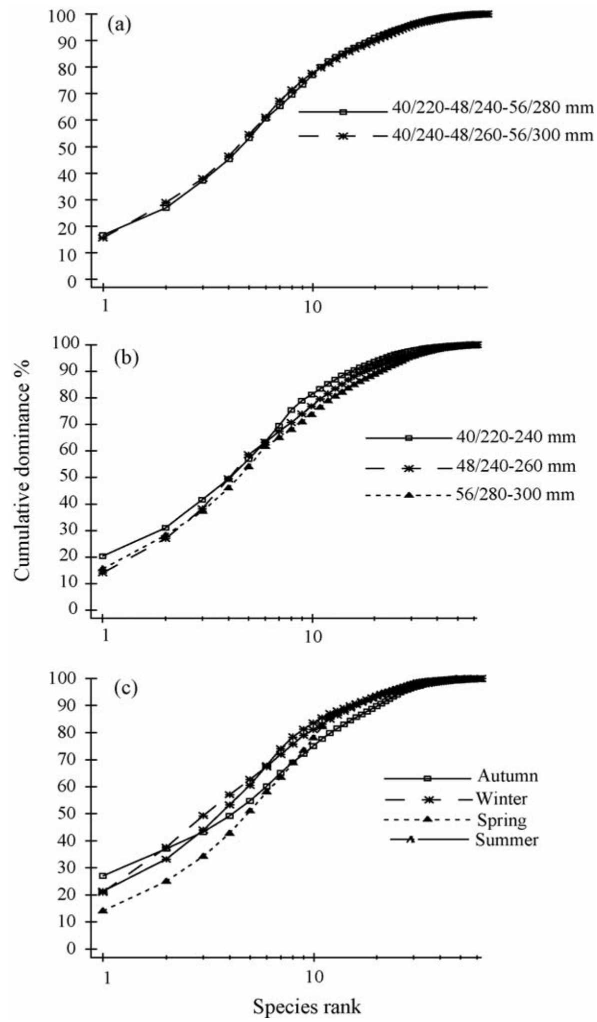

Fig. 7. Cyclades. K-dominance curves based on catch numbers (per 1000 m of net) for all species caught for six combinations of inner/outer panel mesh sizes (mm): (a and b) for all seasons combined and (c) all mesh sizes combined by season.

combinations in winter and autumn, with the exception of the 40/220 and 40/240 mm ones that were grouped with the second group (Group II), which included all inner/outer panel mesh size combinations for spring and summer. From the two-dimensional plot (Fig. 11b) it was evident that the 40/220 and 40/240 mm trammel nets in winter and autumn made up a subgroup by themselves, within Group II, which for the purposes of the present analysis we considered as a separate group, Group III. It is worth noting that for all areas, the two different combinations per inner mesh size not only belonged to the same group but also were often very close to each other within each grouping (Figs. 8–11). The similarity levels at which the different groups were indicated by cluster analysis ranged between 60 and 70% whereas for all two-dimensional plots the stress values were low, ranging from 0.01 to 0.16, depending on the area (Figs. 8–11).

Fig. 12 shows the two-dimensional plots for Basque, Algarve and Cyclades, shown in Figs. 8b, 9b and 11b respectively, with superimposed symbols the sizes of which correspond to the mean depth for each gear/mesh size/season combination in each area. From this figure, it becomes apparent that grouping formation in these three areas reflected the combined effect of season and depth. Only in the case of the Gulf of Cádiz (graph not shown), where sampling depths did not vary considerably between the two seasons, ranging between 10 and 30 m, grouping was only a function of season.

For all areas, the groups identified from multivariate analyses applied on the weight matrices were exactly the same with those resulting from the analysis of the numerical data (graphs not shown here). In this case, groups were formed at 54–68% similarity levels for cluster analysis and stress values for the two-dimensional plots ranged between 0.06 and 0.18, depending on the area.

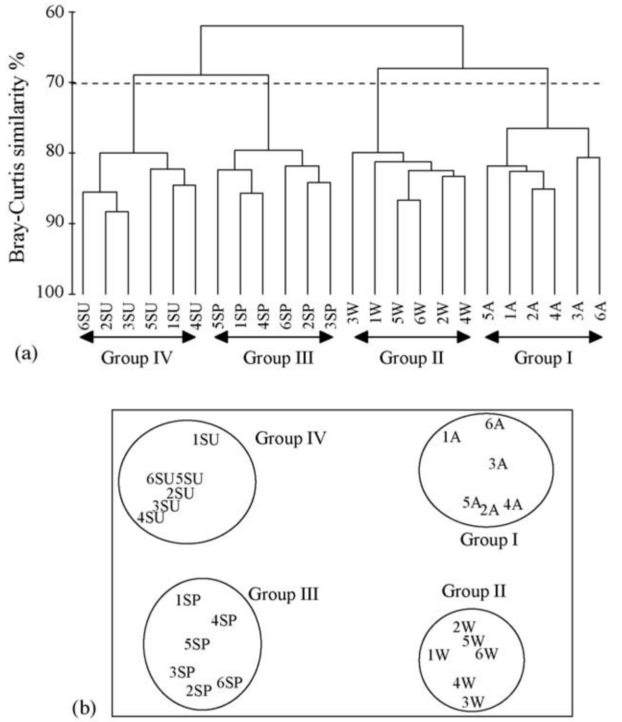

Fig. 8. Basque. (a) Dendrogram for group-average clustering and (b) multidimensional scaling ordination (stress = 0.12), based on Bray–Curtis similarities between mean catch numbers per 1000 m of net (double square root transformation) for all species caught for six combinations of inner/outer mesh sizes (stretched, mm; 1 = 90/500, 2 = 100/500, 3 = 110/500, 4 = 90/600, 5 = 100/600 and 6 = 110/600) per season (A: autumn, W: winter, SP: spring and SU: summer).

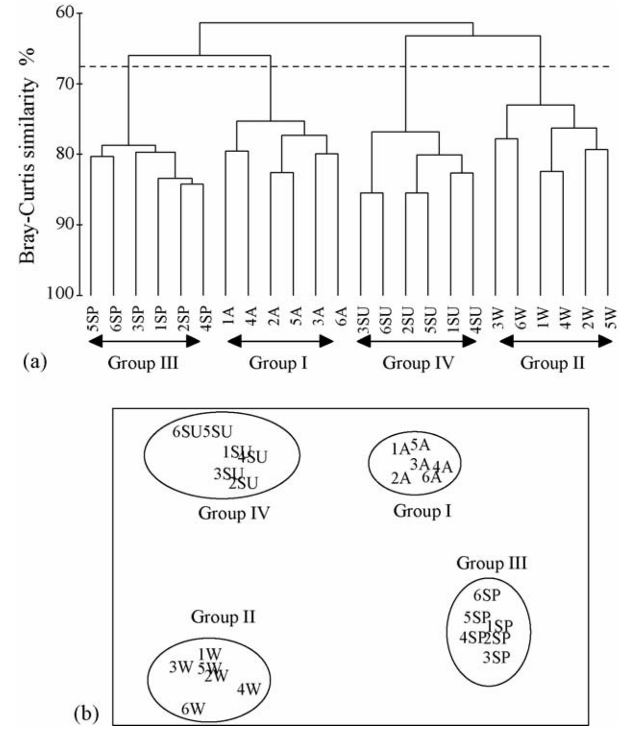

Fig. 9. Algarve. (a) Dendrogram for group-average clustering and (b) multidimensional scaling ordination (stress = 0.13), based on Bray–Curtis similarities between mean catch numbers per 1000 m of net (double square root transformation) for all species caught for six combinations of inner/outer mesh sizes (stretched, mm; 1 = 100/600, 2 = 120/600, 3 = 140/600, 4 = 100/800, 5 = 120/800 and 6 = 140/800) per season (A: autumn, W: winter, SP: spring and SU: summer).

The species that cumulatively contributed about 40% to the average Bray–Curtis similarity within the different groups identified in each region are shown in Table 2. These species generally differed between the four areas (Table 2). In contrast, differences between the within-area groups mainly referred to the relative rank of the species (Table 2). The most important species contributing to the dissimilarities between the different groups per area are shown in Table 3.

4. Discussion

In this work, we used regression analysis, multivariate analysis, and other 'community measures', such as number of species and dominance curves, in order to identify and quantify the effect of season, depth, and inner and outer panel mesh size on the trammel net catch species composition and catch rates in four southern European areas (Northeast Atlantic: Basque Country, Spain; Algarve, Portugal; Gulf of Cádiz, Spain; Mediterranean: Cyclades, Greece). Multivariate analysis, widely used in community studies (e.g., Field et al., 1982; Clarke, 1993; Clarke and Warwick, 1994), has been also successfully used in identifying commercial and discarded fisheries assemblages, fishing métiers and fishing strategies, using both experimental and commercial catches, in various areas of the world ocean (e.g., Greek commercial fisheries: Stergiou, 1988, 1989; Stergiou et al., 1997; Greek small-scale fisheries: Stergiou et al., 1996, 2002; Tunisian small-scale fisheries: Jabeur et al., 2000; Spanish small-scale fisheries: Silva et al., 2002; Spanish crustacean fisheries: Maynou et al., 2003; Spanish trawl fisheries: Jiménez et al., 2004; Mediterranean fisheries landings: Kaschner et al., 2004; NE Mediterranean trawl discards: Machias et al., 2001; discards for different Portuguese fisheries: Erzini et al., 2002; USA trawl fisheries: Murawski et al., 1983; Hawaii logline fishery: He et al., 1997; Australian commercial fisheries: Pease, 1999; Cray and Kennelly, 2003).

Trammel nets are of primary importance to all four areas considered in this study (Anon., 2001). Thus, in Basque waters approximately 40% of the small-scale vessels use trammel nets during part of the year, while in the Algarve trammel net licences account for about 18% of all small-scale licences, with only longline licenses being more important. In the Gulf of Cádiz, about 48% of the total number of fishing vessels use trammel nets whereas in Cyclades about 20% of the registered fishing vessels use trammel and gill nets as main gear and 75% as a secondary gear (Anon., 2001). Our study included a wide range of inner panel mesh sizes, from 40 to 140 mm, representing some of the most important ones used in southern European waters and especially

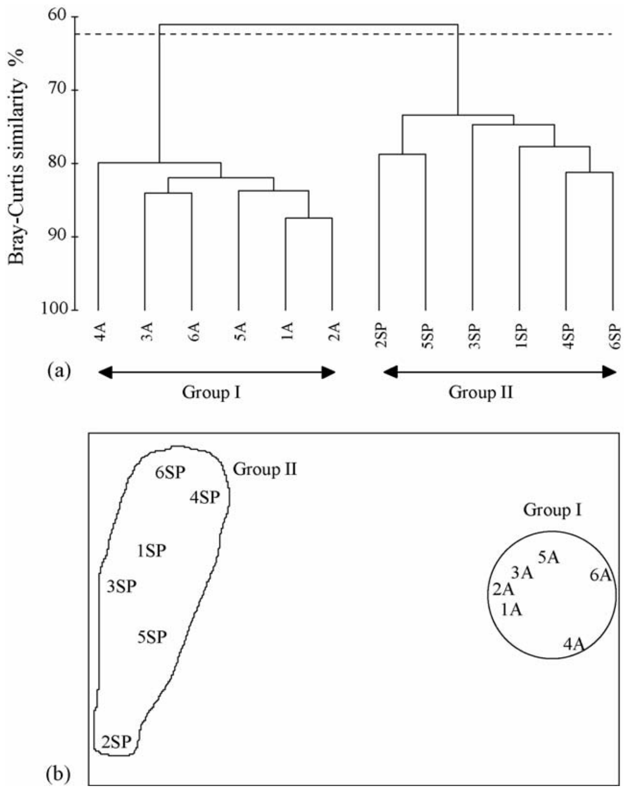

Fig. 10. Cádiz. (a) Dendrogram for group-average clustering and (b) multidimensional scaling ordination (stress = 0.01), based on Bray–Curtis similarities between mean catch numbers per 1000 m of net (double square root transformation) for all species caught for six combinations of inner/outer mesh sizes (stretched, mm; 1 = 80/300, 2 = 90/300, 3 = 100/300, 4 = 80/400, 5 = 90/400 and 6 = 100/400) per season (A: autumn, and SP: spring).

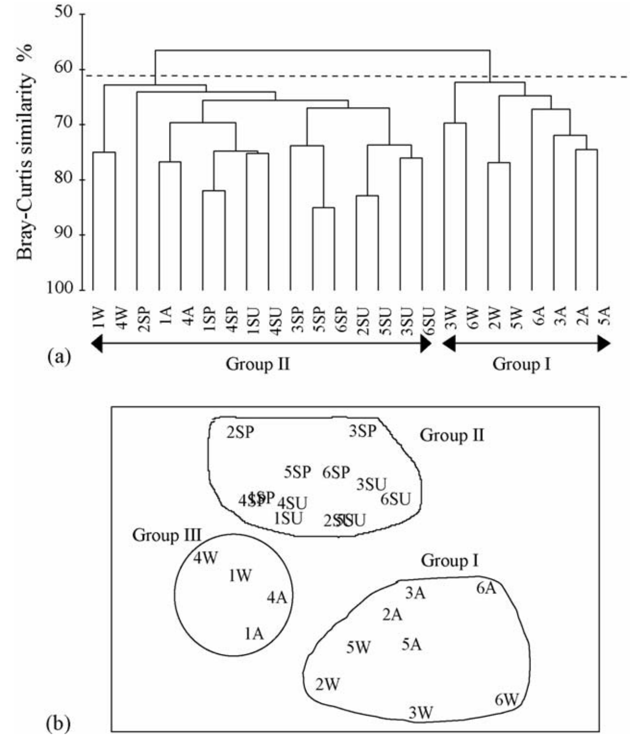

Fig. 11. Cyclades. (a) Dendrogram for group-average clustering and (b) multidimensional scaling ordination (stress = 0.16), based on Bray–Curtis similarities between mean catch numbers per 1000 m of net (double square root transformation) for all species caught for six combinations of inner/outer mesh sizes (stretched, mm; 1 = 40/220, 2 = 48/240, 3 = 56/280, 4 = 40/240, 5 = 48/260 and 6 = 56/300) per season (A: autumn, W: winter, SP: spring and SU: summer).

in the four study areas, and two outer panel mesh sizes per area.

The number of specimens caught declined significantly with mesh size in all areas. This can be attributed to the well known fact that abundance generally declines exponentially with size both within- and between-species (e.g., Jennings et al., 2001). Consequently, the rate of decline is steeper at small size ranges than at higher ones. This was reflected in the rate of decline of the number of individuals with mesh size being steeper for Cyclades intermediate for Basque and Cadiz waters and least steep for the Algarve. In contrast, the number of species caught in each area was not related to inner mesh size, which was unexpected, and might be a consequence of the wide size-selective range of trammel nets (see Erzini et al., 2006).

All our analyses indicated that the outer panel mesh sizes used in the present study did not significantly affect the catch characteristics in terms of number of species, catch rates and species composition. In addition, the outer panel mesh size did not affect the size selectivity of the trammel nets (see Erzini et al., 2006). Multivariate analyses and seasonal dominance plots indicated that in Basque, Algarve and Cyclades waters, where sampling covered wide depth ranges, both season and depth strongly affect catch species compositions and thus group formations. For the Gulf of Cádiz, where sampling was restricted to depths 10–30 m, season was the only factor affecting grouping formation. In contrast, the inner panel mesh size did not affect group formation in all areas except in Cyclades in the case of the 40 mm net in autumn and winter. Yet, inner panel mesh size affected the dominance of the species caught in the Algarve and the Gulf of Cádiz but not in the other two areas.

Multivariate analyses also revealed that seasonality was less evident in the case of Cyclades. Thus in this area multivariate analysis indicated two main groups, one for the colder part of the year, autumn–winter, and another one for the warm part, spring–summer. This might suggest that seasonal changes in the inshore fish communities, and thus seasonality in fisheries, are not as pronounced in the eastern Mediterranean when compared to the Northeast Atlantic. This agrees, to a large extent, with the fact that seasonal fluctuations in many oceanographic parameters, such as temperature, are less strong in the Mediterranean when compared to the Atlantic Ocean whereas the opposite is true for river runoff and rainfall (J. Lloret, unpublished data).

In general, the species contributing mostly to the catches and similarities differed with area. In three of the four areas, soles were among the most important species in terms of

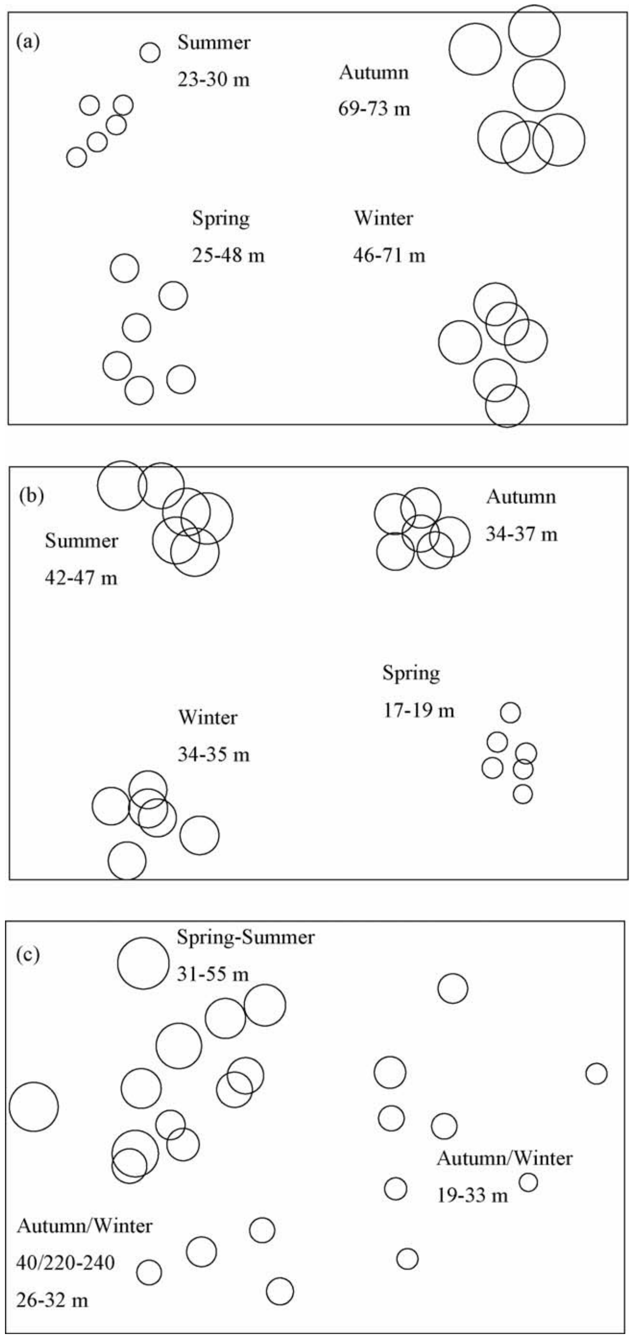

Fig. 12. The multidimensional scaling plots shown in Figs. 8b, 9b and 11b, for (a) Basque, (b) Algarve and (c) Cyclades, respectively, with superimposed symbols the diameter of which corresponds to the mean sampling depth.

numbers and weight (i.e., *Solea solea* in Basque waters, *Solea senegalensis* and *Microchirus azevia* in the Algarve, and *S. senegalensis* and *Synaptura lusitanica* in the Gulf of Cádiz) whereas *Sepia officinalis* was the most important species in numbers and weight in the Algarve and the Gulf of Cádiz. Other important species were Gadidae for Basque waters and small- and medium-sized pelagics in the Algarve and the Gulf of Cádiz. In contrast, for Cyclades, flatfishes were relatively unimportant and the catches were dominated by a variety of other small- to medium-sized demersal species.

Given that fishing operations were conducted by fishers following traditional practices in traditional fishing grounds, we considered groupings as indications of fishing strategies, i.e., combinations of depths and seasons, adopted by fishers in order to take advantage of the seasonal migrations and availability of the most important target species in each area. The best example is cuttlefish, *Sepia officinalis*, in the Gulf of Cádiz and Algarve waters. *Sepia officinalis* is a semelparous species, which spawns in late spring in coastal areas and moves offshore for wintering in deeper waters (e.g., Guerra and Castro, 1988; Denis and Robin, 2001). Hence, it is seasonally targeted by fishers and makes up the major part of the spring catch in shallow waters in the Gulf of Cádiz and in the Algarve, where it is the second most important species. At the same time, important quantities of the small pelagic *Sardina pilchardus* were also occasionally caught, and largely discarded or used for self-consumption (Anon., 2001), at larger depths in autumn and summer in the Algarve waters and at small depths in autumn in the Gulf of Cádiz, when they occur for spawning (see Froese and Pauly, 2004, www.fishbase.org). Similarly, *S. solea*, which generally occurs at depths smaller than 150 m, retreats to deeper waters in winter and moves to shallow waters for spawning between January and June, depending on the area (www.fishbase.org). Thus, in Basque waters, *S. solea* is targeted with trammel nets in deeper waters in autumn–winter and in shallower waters in spring–summer. Finally, *Mullus surmuletus* and *Pagellus erythrinus* are both characterised by a spring–summer spawning season, with spawners occurring at mid-shelf depths and young individuals on shallow, vegetated bottoms (Machias et al., 1998; Somarakis and Machias, 2002). As a result, they were both caught in spring–summer at greater depths, with *Mullus surmuletus* mainly with the 40 mm net and *Pagellus erythrinus* with the 48 and 56 mm nets (based also on the catches for each inner panel mesh size per season; not shown here). The smaller individuals of these two species were caught in shallower waters in autumn–winter, mainly with the 40 mm nets, with an important part of the catch of the two larger mesh sizes, 48 and 56 mm trammel nets, in the Cyclades being composed of *Diplodus annularis*, which is considered as by-catch.

Overall, multivariate analyses, together with the seasonal catches per inner panel mesh size (not shown here), revealed a number of different trammel net métiers in the four areas. They are listed below as area–season–depth–species combinations together with the inner panel mesh size characterised by the highest catch rate:

(1) Basque waters, summer, depths <30 m, *S. solea* with the 90 mm nets, *S. senegalensis* with the 100 mm nets.
(2) Basque waters, winter–autumn, depths >40 m, *S. solea* with the 90 mm of trammel nets.
(3) Basque waters, spring, depths 25–50 m, *S. solea* with the 100 mm nets, *S. senegalensis* with the 90 mm nets.

Table 2
Contribution of each species to the average Bray–Curtis similarity (%) within each of the groups indicated by multivariate analysis (for groups see Figs. 8–11) in each area (Basque, Algarve, Cádiz, Cyclades)

Species	Basque groups								Algarve groups								Cádiz groups				Cyclades groups					
	I		II		III		IV		I		II		III		IV		I		II		III		I		II	
	79		81		81		82		77		75		81		79		82		75		67		65		70	
	A	C%	A	C%	A	C%	A	C%	A	C%	A	C%	A	C%	A	C%	A	C%	A	C%	A	C%	A	C%	A	C%
Argyrosomus regius																	1.7	4.5								
Balistes carolinensis											0.8	2.9														
Boops boops									6.0	3.3			1.4	3.1							3.6	6.4				
Chelidonichthys lastoviza									2.3	2.6																
Chelidonichthys lucernus	4.4	5.6	2.1	3.8	1.6	3.3	2.8	3.5																		
Chelidonichthys obscurus					2.8	3.9			1.0	2.5	1.6	3.3	0.9	2.9	3.8	4.0										
Citharus linguatula													0.7	2.5												
Diplodus annularis																					4.6	6.8	3.8	8.6	5.4	6.2
Diplodus bellottii																			1.0	5.2						
Halobatrachus didactylus											1.7	3.0					2.7	4.9								
Lophius piscatorius					4.9	4.5																				
Maja squinado	2.3	4.7					1.7	3.4	1.4	2.9																
Merluccius merluccius	7.1	6.3	3.3	4.4	2.2	3.6	1.3	3.0	1.3	2.8			1.7	3.5	1.4	3.4										
Microchirus azevia									4.4	3.7	3.4	4.2	3.2	5.9	8.8	5.1										
Microchirus variegatus	2.6	4.6	6.0	4.5																						
Mullus surmuletus																					17.2	10.2	5.2	8.5	6.5	6.2
Octopus vulgaris															1.2	3.1										
Pagellus acarne									2.3	3.2			1.9	3.6											3.6	5.1
Pagellus erythrinus											1.2	3.2													10.7	7.3
Pegusa lascaris					2.5	3.5											3.4	4.7								
Phycis phycis									2.1	3.1			4.3	4.3												
Raja asterias																	1.8	4.5								
Raja undulata											1.9	3.3														
Sardina pilchardus			10.7	5.9			5.4	4.1	8.6	4.1			1.4	3.0	8.6	4.9	4.1	5.5	2.3	6.7						
Sciaena umbra							3.1	3.2																		
Scomber japonicus									14.9	5.0	2.1	3.5	7.1	4.0	10.3	5.6										
Scomber scombrus			21.8	7.2									3.2	4.0												
Scorpaena notata									3.4	2.8	2.4	3.2														
Scorpaena porcus																					2.2	5.7	2.6	7.8	5.7	6.4
Scyliorhinus canicula													0.8	2.7												
Sepia officinalis					1.6	3.4	1.6	3.3	4.9	3.8	3.0	4.0	0.8	2.9	19.2	6.6	3.9	5.0	33.7	12.2			1.3	6.5		
Serranus cabrilla																					5.9	7.9			4.6	5.4
Solea senegalensis					2.0	3.6	5.9	4.5			3.6	4.1			1.5	3.4	4.2	5.4	2.8	7.2						
Solea solea	9.0	6.8	23.5	7.3	6.7	4.8	8.6	4.9							2.5	3.7										
Spicara maena																					4.2	6.2	3.7	7.0	4.0	5.9
Spondyliosoma cantharus											0.9	3.0														
Symphodus tinca																							1.5	6.0		
Synaptura lusitanica																			2.6	6.8						
Torpedo marmorata					2.1	3.6													0.9	4.9						
Torpedo torpedo																	5.2	6.1								
Trachinus draco	3.3	5.1			7.9	4.8	10.3	5.0			6.4	4.8	1.5	3.3	1.4	3.3										
Trachurus trachurus							1.9	3.4	1.7	2.5			1.5	3.1												
Trisopterus luscus	15.0	7.5	10.9	5.9	3.1	4.0	2.9	3.6					0.6	2.5												
Zeus faber													0.8	2.6												

A: average abundance (numbers of specimens/1000 m of trammel nets); C%: percentage contribution to the Bray–Curtis similarity of the groups. The number below each group (indicated by Latin numerals) shows the overall similarity within the group.

(4) Algarve, spring, depths <20 m, a mixed-species metier, all mesh sizes.
(5) Algarve, autumn–winter, depths 30–40 m, *Sepia officinalis* with the 140 mm net, *S. senegalensis* with the 120 mm net and *M. azevia* with the 100 mm net.
(6) Algarve, summer, depths >40 m, *Sepia officinalis* with the 120 mm net, *M. azevia* with the 100 mm net.
(7) Gulf of Cádiz, spring, depth 10–30 m, *Sepia officinalis* with the 80 mm net;
(8) Gulf of Cádiz, autumn, depth 10–30 m, *Solea* spp. and *Sepia officinalis* with the 80 mm net.
(9) Cyclades, autumn–winter, depth 26–36 m, *Mullus surmuletus*, 40 mm net.
(10) Cyclades, autumn–winter, depth 19–33 m, *Mullus surmuletus* (and *Diplodus annularis* as by-catch), 48 and 56 mm nets.
(11) Cyclades, spring–summer, depth 30–55 m, *Mullus surmuletus*, with the 40 mm net, and *Pagellus erythrinus*, with the 48 mm net.

The above mentioned métiers largely agree with the results of questionnaire surveys which were conducted in the four areas (Anon., 2001). The identification of different trammel

Table 3
Contribution of each species to the average Bray–Curtis dissimilarity (Av. dissimilarity, %) between each of the groups (showed with Latin numerals) indicated by multivariate analysis (for groups see Figs. 8–11) in each area

Basque

Av. dissimilarity = 32	I	II	C%
Scomber scombrus	0.1	21.8	8.0
Sardina pilchardus	0.3	10.7	6.1
Scyliorhinus stellaris	0.9	0.0	4.2
Pleuronectes platessa	0.0	0.8	4.2
Av. dissimilarity = 37	I	III	C%
Solea senegalensis	0.0	2.0	4.1
Diplodus sargus	0.0	0.9	3.6
Pleuronectes platessa	0.0	0.9	3.5
Scyliorhinus stellaris	0.9	0.0	3.5
Av. dissimilarity = 36	II	III	C%
Scomber scombrus	21.8	0.2	7.0
Sardina pilchardus	10.7	0.1	5.4
Diplodus sargus	0.0	0.9	3.5
Triglidae spp.	1.8	0.1	3.1
Av. dissimilarity = 40	I	IV	C%
Solea senegalensis	0.0	5.9	5.1
Microchirus variegates	2.6	0.0	4.3
Sardina pilchardus	0.3	5.4	3.4
Scorpaena porcus	0.0	0.7	3.2
Av. dissimilarity = 38	II	IV	C%
Scomber scombrus	21.8	0.0	7.1
Microchirus variegates	6.0	0.0	5.1
Solea senegalensis	0.1	5.9	3.9
Trisopterus minutus	1.1	0.0	3.5
Av. dissimilarity = 31	III	IV	C%
Sardina pilchardus	0.1	5.4	4.7
Sciaena umbra	0.1	3.1	3.7
Microchirus variegates	0.8	0.0	3.7
Mola mola	0.0	0.6	3.4

Algarve

Av. dissimilarity = 39	I	II	C%
Boops boops	6.0	0.1	2.7
Solea senegalensis	0.2	3.6	2.6
Trachinus draco	0.3	6.4	2.5
Sardina pilchardus	8.6	0.5	2.5
Av. dissimilarity = 34	I	III	C%
Labrus bergylta	0.5	0.0	2.8
Scyliorhinus canicula	0.0	0.8	2.6
Sparus aurata	0.3	0.0	2.4
Solea solea	0.4	0.0	2.3
Av. dissimilarity = 42	II	III	C%
Scomber scombrus	0.1	3.2	3.1
Balistes carolinensis	0.8	0.0	2.8
Scyliorhinus canicula	0.0	0.8	2.8
Callionymus lyra	0.5	0.0	2.4
Av. dissimilarity = 35	I	IV	C%
Labrus bergylta	0.5	0.0	2.4
Sparus aurata	0.3	0.0	2.3
Raja miraletus	0.2	0.0	2.2
Solea senegalensis	0.2	1.5	2.2
Av. dissimilarity = 37	II	IV	C%
Solea solea	0.1	2.5	3.2
Sardina pilchardus	0.5	8.6	2.9
Sepia officinalis	3.0	19.2	2.6
Lithognathus mormyrus	0.3	0.0	2.5
Av. dissimilarity = 40	III	IV	C%
Solea solea	0.0	2.5	3.7
Sepia officinalis	0.8	19.2	3.7
Scyliorhinus canicula	0.8	0.0	3.0
Callionymus lyra	0.0	0.6	2.6

Cádiz

Av. dissimilarity = 39	I	II	C%
Sepia officinalis	3.9	33.7	4.8
Pegusa lascaris	3.4	0.1	4.6
Argyrosomus regius	1.7	0.1	4.2
Diplodus sargus	0.8	0.0	3.8

Cyclades

Av. dissimilarity = 42	III	I	C%
Serranus cabrilla	5.9	0.3	4.6
Spondyliosoma cantharus	0.1	1.1	3.5
Mullus barbatus	1.1	0.0	3.3
Xyrichthys novacula	0.6	0.2	3.2
Av. dissimilarity = 37	III	II	C%
Merluccius merluccius	0.0	1.5	4.5
Pagellus acarne	1.9	3.6	3.4
Pagellus erythrinus	1.2	10.7	3.3
Xyrichthys novacula	0.6	0.0	3.1
Av. dissimilarity = 44	I	II	C%
Pagellus acarne	0.1	3.6	4.3
Merluccius merluccius	0.0	1.5	4.2
Pagellus erythrinus	0.7	10.7	3.7
Serranus cabrilla	0.3	4.6	3.3

The first two columns next to species' names indicate average abundance (numbers of specimens/1000 m of nets); C%: percentage contribution to the Bray–Curtis dissimilarity of the groups.

net métiers clearly indicate the existence of trammel net 'hot spots', which represent essential habitats (Bergmann et al., 2004), such as spawning, nursery or wintering grounds, of the life history of the targeted and associated species. Given that many of the species exploited by trammel nets are often exploited by other small-scale and industrial gears (e.g., trawls, purse seines, longlines: Stergiou et al., 2004) at depths greater than 50–100 m, their essential habitats are always subjected to fishing. Mapping trammel net 'hot spots', as well as those of other gears, is of primary importance for quantifying gear overlap and managing the European demersal and inshore fisheries, which suffer from intense overexploitation (Stergiou et al., 1997; Lleonart and Maynou, 2003; ICES, 2003; OCEANA, 2004). This is especially important for the design of networks of marine protected areas (e.g., Gell and Roberts, 2003), an important tool supplementing current management schemes (e.g., Browman and Stergiou, 2004). Mapping 'hot spots' together with mapping of species' life histories (e.g., sensu Zeller and Pauly, 2001) will ensure that an important part of the different species-specific habitats are protected by the establishment of marine protected areas.

Finally, it must be stressed that despite the fact that trammel nets target specific species in different seasons and bathymetric ranges, multivariate analysis also indicated that in all cases an important part of the catch was composed of a variety of other demersal and small- and medium-sized pelagic species (by-catch), a fact showing the multispecies nature of the trammel net fisheries in southern European waters. In addition, trammel nets in the Algarve and Cyclades caught many more species than gill nets and longlines (Erzini et al., 1996a,b, 1998; Stergiou et al., 2002), as is also the case in other eastern Mediterranean areas (Kyrtatos, 1982; Papaconstantinou et al., 1988; Stergiou et al., 1996), with the number of species caught with trammel nets being often somewhat less or similar to those caught with trawlers and beach seines. We attribute this to the wide size-selection properties of trammel nets, ranging from unimodal to multimodal and logistic (see Erzini et al., 2006). As a result, trammel nets are less species- and size-selective than gillnets, resembling in many instances trawl cod-ends.

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References

Anon., 2001. Trammel net selectivity studies in the Algarve (Southern Portugal), Gulf of Cadiz (Spain), Basque Country (Spain) and Cyclades Islands (Greece). Report to the EU (DG XIV), Project 98/014. European Commission, Brussels.

Bergmann, M., Hinz, H., Blyth, R.E., Kaiser, M.J., Rogers, S.I., Armstrong, M., 2004. Using knowledge from fishers and fisheries scientists to identify possible groundfish 'Essential Fish Habitats'. Fish. Res. 66, 373–379.

Bray, J.R., Curtis, J.T., 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27, 325–349.

Browman, H.I., Stergiou, K.I. (Eds.), 2004. Perspectives on ecosystem-based approaches to the management of marine resources. Mar. Ecol. Prog. Ser. 274, 269–303.

Carr, M.R., 1997. PRIMER User Manual. Plymouth Marine Laboratory, Plymouth, UK.

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

Clarke, K.R., Warwick, R.M., 1994. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. Natural Environment Resource Council and Plymouth Marine Laboratory, Plymouth.

COPEMED, 2003. Artisanal fishery communities in the Mediterranean: two case studies. Informes y Estudios 10.

Cray, C.A., Kennelly, S.J., 2003. Catch characteristics of the commercial beach-seine fisheries in two Australian barrier estuaries. Fish. Res. 63, 405–422.

Denis, V., Robin, J.P., 2001. Present status of the French Atlantic fishery for cuttlefish (*Sepia officinalis*). Fish. Res. 52, 11–22.

Erzini, K., Costa, M.E., Bentes, L., Borges, T.C., 2002. A comparative study of the species composition of discards from five fisheries from the Algarve (southern Portugal). Fish. Manag. Ecol. 9, 31–40.

Erzini, K., Gonçalves, J.M.S., Bentes, L., Lino, P.G., Cruz, J., 1996a. Species and size selectivity in a multispecies Portuguese artisanal longline fishery. ICES J. Mar. Sci. 53, 811–819.

Erzini, K., Gonçalves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., 1998. Species and size selectivity in a 'red' sea bream longline métier in the Algarve (southern Portugal). Aquat. Living Resour. 11, 1–11.

Erzini, K., Santos, M.N., Monteiro, C.C., Gonçalves, J.M.S., Bentes, L., Lino, P.G., 1996b. A comparison of monofilament gillnet and small hook longline selectivity in a multispecies artisanal fishery in the Algarve (South of Portugal). Naga (ICLARM Quarterly) 19, 29–32.

Erzini, K., Gonçalves, J.M.S., Bentes, L., Moutopoulos, D.K., Hernando Casal, J.A., Soriguer, M.C., Puente, E., Errazkin, L.A., Stergiou, K.I., 2006. Size selectivity of trammel nets in southern European small-scale fisheries. Fish. Res. 79, 183–201.

FAO, 2003. Strategies for increasing the sustainable contribution of small-scale fisheries to food security and poverty alleviation. FAO COFI/2003/9: 1–14.

FAO, 2004. Report of the Second Session of the Working Party on Small-scale Fisheries. FAO Fish. Rep. 735, pp. 1–21.

Field, J.G., Clarke, K.R., Warwick, R.M., 1982. A practical strategy for analysing multispecies distribution patterns. Mar. Ecol. Prog. Ser. 8, 37–52.

Froese, R., Pauly, D., 2004. FishBase. World Wide Web electronic publication. November 2004 (www.fishbase.org).

Garcia, S.M., Zerbi, A., Aliaume, C., Do Chi, T., Lassarre, G., 2003. The ecosystem approach to fisheries. FAO Rep., 443.

Gell, F.R., Roberts, C.M., 2003. Benefits beyond boundaries: the fishery effects of marine reserves. Trends Ecol. Evol. 18, 448–455.

Guerra, A., Castro, B.G., 1988. On the life cycle of *Sepia officinalis* (Cephalopoda, Sepioidea) in the Ria de Vigo (NW Spain). Cahiers Biol. Mar. 29, 395–405.

He, X., Bigelow, K.A., Boggs, C.H., 1997. Cluster analysis of longline sets and fishing strategies within the Hawaii-based fishery. Fish. Res. 31, 147–158.

ICES, 2003. Environmental status of the European Seas. ICES Report, 75 pp. (downloadable at www.ices.org).

Jabeur, C., Gobert, B., Missaoui, H., 2000. Typologie de la flottille de peche cotier dans le golfe de Gabes (Tunisie). Aquat. Living Resour. 13, 421–428.

Jennings, S., Kaiser, M.J., Reynolds, J.D., 2001. Marine Fisheries Ecology. Blackwell Science, London, UK.

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

Kaschner, K., Stergiou, K.I., Weingartner, G., Kumagai, S., 2004. Trophic levels of marine mammals and overlap in resource utilization between marine mammals and fisheries in the Mediterranean Sea. CIESM Workshop Monographs 23, pp. 51–58 (www.ciesm.org/publications/Venise04.pdf).

Kyrtatos, N., 1982. On the Fishery and Biology of the Most Important Fishery Resources of the Aegean Island Tinos, vol. 5. Institute of Oceanographic and Fisheries Research, Special Publication, pp. 1–88 (in Greek).

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

Lleonart, J., 1999. Precautionary approach and Mediterranean fisheries. CIESM Workshop Ser. 7, 15–23.

Lleonart, J., Maynou, F., 2003. Fish stock assessments in the Mediterranean: state of the art. Sci. Mar. 67 (Suppl. 1), 37–49.

Machias, A., Somarakis, S., Tsimenides, N., 1998. Bathymetric distribution and movements of red mullet *Mullus surmuletus*. Mar. Ecol. Prog. Ser. 166, 247–257.

Machias, A., Vassilopoulou, V., Vatsos, D., Bekas, P., Kallianiotis, A., Papaconstantinou, C., Tsimenides, N., 2001. Bottom trawl discards in the N.E. Mediterranean Sea. Fish. Res. 53, 181–195.

Maynou, F., Demestre, M., Sánchez, P., 2003. Analysis of catch per unit effort by multivariate analysis and generalised linear models for deep-water crustacean fisheries off Barcelona (NW Mediterranean). Fish. Res. 65, 257–269.

Murawski, S.A., Lange, A.M., Sissenwine, M.P., Mayo, R.K., 1983. Definition and analysis of multispecies otter–trawl fisheries off the northeast coast of the United States. J. Cons. Int. Explor. Mer. 41, 13–27.

Myers, R.A., Worm, B., 2003. Rapid worldwide depletion of predatory fish communities. Nature 423, 280–283.

OCEANA, 2004. European trawlers are destroying the oceans. 77 pp. (http://www.europe.oceana.org/downloads/european_trawlers_destroying_oceans.pdf).

Papaconstantinou, C., Caragitsou, E., Vassilopoulou, V., Petrakis, G., Stergiou, K.I., 1988. The Coastal Fisheries in Kastellorizo Area, vol. 15. National Centre for Marine Research, Athens, Greece, pp. 1–106, Spec. Publ.

Pauly, D., MacLean, J., 2003. In a Perfect Ocean—The State of Fisheries and Ecosystems in the North Atlantic Ocean. Island Press, Washington, 175 pp.

Pauly, D., Alder, J., Bennett, E., Christensen, V., Tyedmers, P., Watson, R., 2003. The future for fisheries. Science 302, 1359–1361.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R., Zeller, D., 2002. Towards sustainability in world fisheries. Nature 418, 689–695.

Pease, B.C., 1999. A spatially oriented analysis of estuaries and their associated commercial fisheries in New South Wales, Australia. Fish. Res. 42, 67–86.

Pitcher, T.J., 2000. Ecosystem goals can reinvigorate fisheries management, help dispute resolution and encourage public support. Fish Fish 1, 99–103.

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

Silva, L., Gil, J., Sobrino, I., 2002. Definition of fleet components in the Spanish artisanal fishery of the Gulf of Cádiz (SW Spain ICES division IXa). Fish. Res. 59, 117–128.

Somarakis, S., Machias, A., 2002. Age, growth and bathymetric distribution of red Pandora (*Pagellus erithrinus*) on the Cretan shelf. J. Mar. Biol. Assoc. UK 82, 149–160.

Stergiou, K.I., 1988. Multivariate analysis of the commercial fishery of the northwestern coast of Greece, 1964–1981. Acta Adriat. 29, 161–170.

Stergiou, K.I., 1989. Multivariate analysis and trends of the Greek fishery. Fishbyte (ICLARM) 7 (3), 4–7.

Stergiou, K.I., 2002. Overfishing, tropicalization of fish stocks, uncertainty and ecosystem management: resharpening Ockham's razor. Fish. Res. 55, 1–9.

Stergiou, K.I., Moutopoulos, D.K., Erzini, K., 2002. Gill net and longlines fisheries in Cyclades waters (Aegean Sea): species composition and gear competition. Fish. Res. 57, 25–38.

Stergiou, K.I., Moutopoulos, D.K., Krassas, G., 2004. Body size overlap in industrial and artisanal fisheries for five commercial fish species in the Mediterranean Sea. Sci. Mar. 68, 179–188.

Stergiou, K.I., Petrakis, G., Politou, C.-Y., 1996. Small-scale fisheries in the south Euboikos Gulf (Greece): species composition and gear competition. Fish. Res. 26, 325–336.

Stergiou, K.I., Christou, E.D., Georgopoulos, D., Zenetos, A., Souvermezoglou, C., 1997. The Hellenic Seas: physics, chemistry, biology and fisheries. Ocean. Mar. Biol. Ann. Rev. 35, 415–538.

Ulrich, C., Gascuel, D., Dunn, M.R., Le Gallic, B., Dintheer, C., 2001. Estimation of technical interactions due to the competition for resource in a mixed-species fishery, and the typology of fleets and métiers in the English Channel. Aquat. Living Resour. 14, 267–281.

Zar, J.H., 1999. Biostatistical Analysis, fourth ed. Prentice Hall, New Jersey, 663 pp.

Zeller, D., Pauly, D., 2001. Visualisation of standardized life-history patterns. Fish Fish 2, 344–355.