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SEGMENTATION OF THE PORTUGUESE BOTTOM-TRAWL AND PURSE-SEINE FLEETS BASED ON THE ANALYSIS OF LANDINGS COMPOSITION BY TRIP

Cristina Silva, Alberto G. Murta e Fátima Cardador

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SEGMENTATION OF THE PORTUGUESE BOTTOM-TRAWL AND PURSE-SEINE FLEETS BASED ON THE ANALYSIS OF LANDINGS COMPOSITION BY TRIP

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ABSTRACT

A classification of the fishing activities based on the trips landing profiles was carried out using a method of non-hierarchical clustering, Partition Around Medoids. Two Portuguese fleets were investigated, the bottom-trawl and the purse-seine fleets, operating off the Portuguese continental coast in the period 2003-2005. In the bottom trawl group, two fleet components were analysed, one targeting finfish and the other directed at crustaceans. Finfish trawl trips produced three groups in 2003 and 2004, one directed at horse mackerel (*Trachurus trachurus*), a second one targeting octopus and squids and a third one directed at a mixture of species. In 2005 a new group of trips was detected targeting blue whiting (*Micromesistius poutassou*). In the case of the crustacean trawl trips, in 2004-2005, two trip types were identified, one group targeting deepwater rose shrimp (*Parapenaeus longirostris*) and another directed at Norway lobster (*Nephrops norvegicus*). In 2003, two groups were also detected, one directed at deepwater rose shrimp and the other at a mixture of the two main crustacean species. The crustacean trips' grouping reflects the interannual variation of the abundance of these two species. The analysis of the purse-seine trips produced four fishing activities that remained consistent over the period. Around 72 % of the trips were classified as targeting sardine (*Sardina pilchardus*). The other clusters were directed towards horse mackerel, Spanish mackerel (*Scomber colias*) and a mixture of small pelagic species.

Keywords: multispecies fisheries, fleet segmentation, cluster analysis, Portugal, bottom trawl, purse-seine

RESUMO

A classificação das actividades pesqueiras foi realizada com base em perfis de desembarques por viagem de pesca e segundo um método de agregação não-hierárquico ("Partition Around Medoids"). Foram analisadas a frota de arrasto de fundo e a de cerco, operando em águas de Portugal continental, de 2003 a 2005. No grupo do arrasto de fundo foram analisadas duas componentes, uma tendo como espécie-alvo os crustáceos e a outra os peixes. Os resultados indicaram que as viagens da pesca de arrasto dirigido a peixes se agrupam em três grupos em 2003 e 2004, um dirigido ao carapau (*Trachurus trachurus*), outro aos cefalópodes e um terceiro dirigido a uma mistura de espécies. Em 2005 um novo grupo de viagens de pesca foi identificado, tendo como espécie-alvo o verdinho (*Micromesistius poutassou*). Da análise da frota de arrasto de crustáceos detectou-se dois tipos de viagens em 2004 e 2005, um dirigido à gamba (*Parapenaeus longirostris)* e outro ao lagostim (*Nephrops norvegicus*). Em 2003, foram também identificados dois grupos, um dirigido à gamba e outro a uma mistura de gamba e lagostim. A existência destes grupos reflecte a variação interanual da abundância das duas espécies. Da análise das viagens de pesca da frota de cerco resultaram quatro grupos, que se mantiveram consistentes durante os três anos. Cerca de 72 % das viagens foram classificadas como dirigidas à sardinha (*Sardina pilchardus*). Nos outros grupos agruparam-se as viagens dirigidas ao carapau, à cavala (*Scomber colias*) e a uma mistura de pequenos pelágicos.

Palavras chave: pescarias multiespecíficas, segmentação da frota, análise de clusters, Portugal, arrasto de fundo, cerco.

REFERÊNCIA BIBLIOGRÁFICA

SILVA, C.; MURTA, A.; CARDADOR, F., 2009. Segmentation of the Portuguese bottom-trawl and purse-seine fleets based on the analysis of landings composition by trip. *Relat. Cient. Téc. IPIMAR, Série digital* (http://inrb.pt/ipimar) nº 51, 20pp

INTRODUCTION

Fisheries management advice for the North-east Atlantic waters has always been made on a single stock basis. This approach is considered problematic because it does not take into account the interactions that exist when there are several fleets exploiting different stocks at the same time. It is, therefore, necessary to develop multi-fleet and multi-fishery approaches, in order to be able to give a realistic and compliable advice, and the identification of fishing activities is a crucial step in the development of those approaches. At present, the European sampling programme has been defined as a “fleet-fishery based sampling” meaning that biological, technical and socio-economic data collection will be based on agreed regional fishing types and fleet segments, which will be referred here as fishing activities.

Therefore, the term fishing activity is here defined as a category of fishing trips with similar fishing features in terms of gear, target species, period of the year and geographical area. This term was used by Mahévas and Pelletier (2004) but other terms with the same meaning have been referred in the literature, as “métiers” (Biseau and Gondeaux, 1988; Marchal, 2008), “directed fisheries” (Lewy and Vinther, 1994), “fleet components” (Campos *et al.*, 2007), “fishing strategies” (He *et al*., 1997; Holley and Marchal, 2004) and “fishing tactics” (Pelletier and Ferraris, 2000).

The fishing activities off the Portuguese continental coast (Fig. 1), excluding vessels less than 12 m in length, are carried out by three fleets: bottom trawl, purse-seine and polyvalent or multi-gear fleet. In 2005, the total landings from these fleets were 130000 t (INE, 2006), of which 42 % were landed by purse-seiners, 41 % by the polyvalent fleet and 17 % by bottom trawlers. In terms of economic value they corresponded to 214 million Euro (value in the auction sales), being 67 %, 17 % and 16 % from polyvalent, trawl and purse seine, respectively. The characteristics of the polyvalent or multi-gear fleet and its fishing activities were extensively analysed and discussed by Duarte *et al*. (2009). The present study covers the bottom-trawl and the purse seine fleets.

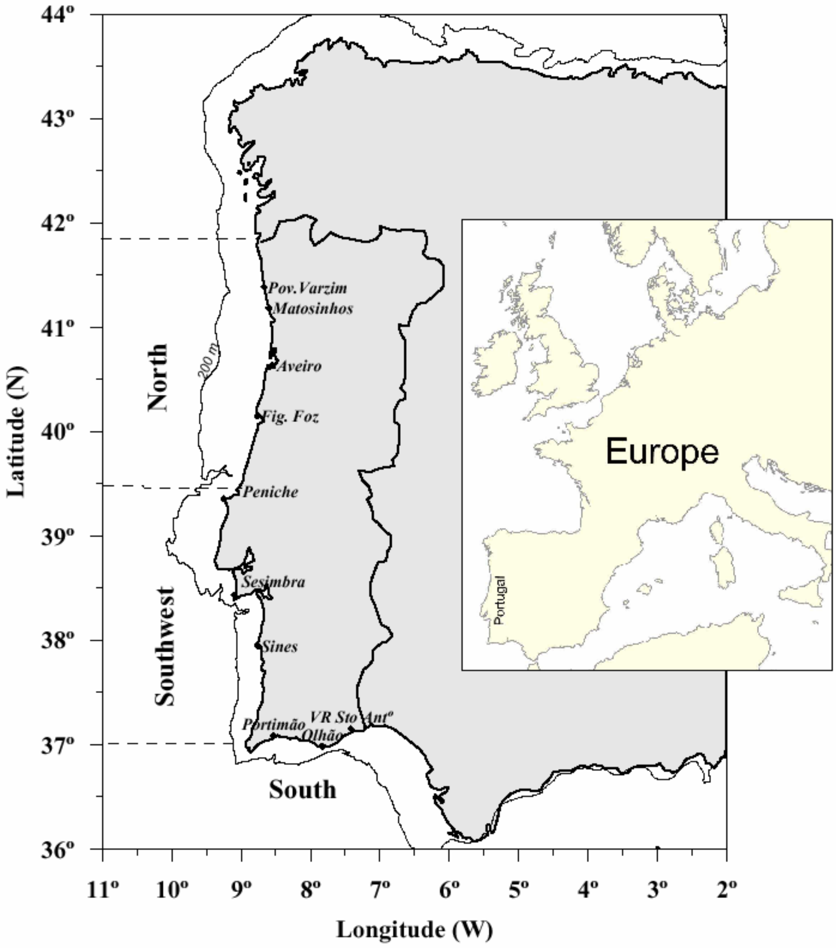

Figure 1 - Main fishing areas and landing harbours of the Portuguese mainland coast.

The Portuguese bottom-trawl fleet comprises two components, one for finfish and another for crustaceans. The trawl fleet fishing for finfish operates off the entire Portuguese continental coast in waters shallower than 500 m, while the trawl fleet targeting crustaceans operates mainly in deep waters (200 – 800 m) in the Southwest and South coasts, where these species are more abundant. The fish trawlers are licensed to use a cod-end mesh size of 65 mm or greater, while the crustacean trawlers are licensed for two different mesh sizes, 55 mm for catching shrimps and 70 mm or greater for Norway lobster (*Nephrops norvegicus*). The landings of the crustacean trawlers in 2005 were mostly composed by blue whiting (*Micromesistius poutassou*, 36 %) and Norway lobster (24 %), while the landings from the finfish trawlers were dominated by horse mackerel (*Trachurus trachurus*, 41 %) and blue whiting (17 %).

According to the national regulation (Portaria no. 1102-G/2000), the purse-seine fleet is allowed to target only 7 species: sardine (*Sardina pilchardus*), horse mackerel, jack mackerel (*Trachurus picturatus*), mackerel (*Scomber scombrus*), Spanish mackerel (*Scomber colias*), bogue (*Boops boops*) and anchovy (*Engraulis encrasicolus*). Other species can be taken at most as 20 % by-catch in weight by trip. Purse-seine landings in 2005 were mostly composed of sardine (81 %), Spanish mackerel (13 %) and horse mackerel (4 %).

In 2005, the finfish trawl fleet was composed of 69 units, with averages of 27.6 metres (CV = 20 %) in overall length (LOA), 188.7 gross tons (GT) (CV = 36 %) and engine power of 535.7 kilowatts (kW) (CV = 38 %). The average age of these vessels was 19 years (CV = 78 %). The crustacean trawl fleet, more homogeneous, was composed of 30 units averaging 11 years old (CV = 84 %), 24.6 m LOA (CV = 5 %), 173.0 GT (CV = 20 %) and 418.2 kW (CV = 13 %) of engine power. The purse-seine fleet in operation in 2005 comprised a total of 174 vessels, being on average 23 years old (CV = 79 %), 17.9 m LOA (CV = 31 %), 40.2 GT (CV = 65 %) and 205.2 kW (CV = 54 %).

The present work was developed within the project IBERMIX, an EU-funded study, where the main objective was the identification of the fishing activities operating in the Atlantic Iberian waters during 2003-2005 to be adopted in the sampling programme and in the fisheries advice and management (Abad *et al.*, 2007).

MATERIAL AND METHODS

The data analysed in this study, provided by the Portuguese Fisheries Administration (DGPA), comprised the information on the characteristics of the vessels, license type and species composition of landings, in weight and in value, per vessel and per day, sold in the auction markets, in all ports in Portugal mainland (Fig. 1). Given that fishing is highly driven by the market value of the product, it was assumed that the revenue obtained with the catch would be the best descriptor for the activity of the fishing fleets (ICES, 2003). However, for sardine, which is the dominant species in the landings of the purse-seine fleet, a special subsidy is given to fishermen that fail to sell their sardine catches in the fish auction above a minimum price. This exception creates a bias in the revenue of the purse-seine fleet; therefore, the analyses were performed on the landings value (in Euro) for the trawl fleets, and on the landings weight for the purse-seine fleet. It was also assumed that the landings made on a given day corresponded to one fishing trip. The total number of trips and vessels, by year and fleet, analysed in this work are shown in Table 1.

Table 1 – Number of vessels and trips covered by the study, by fleet type.

	Trawl fleet		Purse-seine fleet	
Year	No. of Vessels	No. of Trips	No. of Vessels	No. of Trips
2003	101	12868	182	18043
2004	106	12149	176	16242
2005	99	12129	174	18392

The data matrix with the daily landings per vessel, in value or weight, had originally 200 species for both trawl fleets (finfish and crustacean) and 117 for the purse-seine fleet. For practical purposes the number of species was reduced, for the trawl fleets, to the 23 most important species or groups of species, each of them representing more than 0.5 % of the total annual value. For the purse-seine fleet, the data set was reduced to the 7 target species defined in the legislation. All the remaining species were aggregated into a group called "Others" that accounted in each year, for about 7 % of total trawl landings in value and for less than 1 % of the total purse-seine landings in weight. A total number of 37146 trawl trips and 50879 purse-seine trips were analysed for the period 2003-2005.

To aggregate trips into homogeneous groups, each trip was treated as a multivariate observation of the proportions (in value or weight) of the species in the trip landings. The data matrices were analysed separately by year, using a non-hierarchical cluster analysis to classify the landing profiles. The "Partitioning Around Medoids" method (Kaufman and Rousseeuw, 1990; Rousseeuw, 1987) takes as input a dissimilarity matrix, which in our case was the matrix of Euclidean distances between trips.

The clustering procedure yields clusters that may be more or less well-defined. The quality of a given cluster can be assessed by its average silhouette coefficient (for details see Kaufman and Rousseeuw, 1990). According to Struyf *et al.* (1997), silhouette coefficients smaller than 0.26 indicate that no substantial structure has been found, between 0.26 and 0.50 indicates that the structure is weak or can be artificial, between 0.51 and 0.70 a reasonable structure and finally between 0.71 and 1.00 indicates a strong structure.

All data analyses were made with the R language for statistical computing (R Development Core Team, 2007). The cluster analysis was made with the R package "cluster" (Maechler *et al.*, 2005[1]), which implements the methods described by Kaufman and Rousseeuw (1990).

[1] Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., 2005. Cluster Analysis Basics and Extensions. Unpublished.

RESULTS

Bottom-trawl

The bottom-trawl data were initially split in two data sets, one targeting finfish and the other targeting crustaceans, which were based on the vessels license and on the target species of the trips.

Regarding the finfish trips (Table 2), some of the clusters are reasonably defined (average s_i>0.5) and clearly directed at one species or a species group, while others (with a low s_i) include trips targeting a mixture of different species (Fig. 2).

Table 2 – Silhouette coefficient (s_i) and number of trips of the finfish trawl group by cluster and year.

	2003			2004			2005			
Cluster	HOM	CEPH	MIXF	HOM	CEPH	MIXF	HOM	CEPH	MIXF	WHB
s_i coefficient	0.46	0.35	0.08	0.53	0.49	0.05	0.56	0.25	0.06	0.57
Number of Trips	3137	1700	5104	3729	1682	4229	3268	1425	4529	442

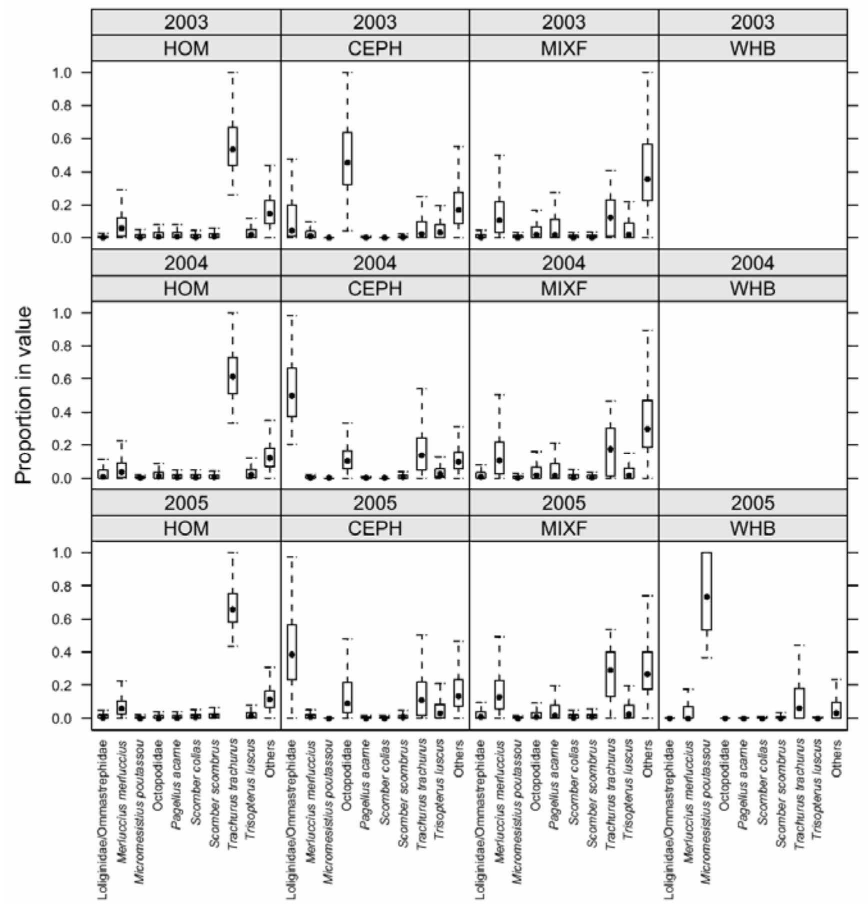

Figure 2 – Boxplots showing the distribution of species proportions by trip and year in each cluster, for the finfish trawl fishery (point: median; box: interquartile range; whisker: most extreme value within 1.5 times the interquartile range).

Three main clusters can be considered for the three years analysed: trips targeting horse mackerel (HOM), trips targeting cephalopods (CEPH), primarily octopus and squid, and trips targeting a mixture of fish species (MIXF) such as horse mackerel, hake, Norway pout (*Trisopterus luscus*) and axillary sea bream (*Pagellus acarne*). The importance of blue whiting in the landings increased over the period resulting in a new cluster directed at blue whiting (WHB) in 2005 (Fig. 2).

The MIXF group is the most important representing on average 47 % of all fish trips, followed by HOM (35 %) (Table 3). Although horse mackerel is present in all groups (Table 4), the cluster HOM contributes with approximately 70 % of the total landings (in value) of this species by year.

Table 3 – Distribution of finfish trawl trips, landed value and landed weight by cluster and year.

		Number of Trips (%)			**Landed value (%)**			**Landed weight (%)**		
	Cluster	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Demersal Fish Trips	**HOM**	32	39	34	34	42	36	43	47	38
	CEPH	17	17	15	14	15	12	8	10	7
	MIXF	51	44	47	53	43	47	49	44	43
	WHB	-	-	5	-	-	5	-	-	12

The cluster CEPH has 15 % to 17 % of the trips, with octopus as the most important species, in value, in 2003 and squids in 2004 and 2005 (Table 4). There are clear seasonal patterns in the finfish bottom-trawl fishing activities (Fig. 3), with cluster HOM showing a higher number of trips in the first half of the year, whereas the cluster CEPH is more important in the second half. The trips of the cluster MIXF are evenly distributed throughout the year.

Table 4 – Percentage of value and weight landed for the main species or species group by cluster and year for the finfish trawl trips.

	LANDED VALUE (%)										LANDED WEIGHT (%)									
	2003			2004			2005				2003			2004			2005			
SPECIES	HOM	CEPH	MIXF	HOM	CEPH	MIXF	HOM	CEPH	MIXF	WHB	HOM	CEPH	MIXF	HOM	CEPH	MIXF	HOM	CEPH	MIXF	WHB
Merluccius merluccius	8	3	13	6	1	13	7	2	15	5	3	2	6	2	1	5	3	1	7	1
Micromesistius poutassou	3	0	4	2	0	9	3	0	2	73	11	2	16	9	1	25	7	1	8	85
Trachurus trachurus	58	7	14	64	17	19	68	14	28	11	58	11	22	60	25	21	63	27	33	6
Trisopterus luscus	3	6	5	4	4	4	2	7	5	0	3	15	6	4	11	5	2	10	5	0
Pagellus acarne	3	1	9	2	1	8	2	1	7	1	1	1	5	1	0	3	1	1	3	0
Scomber colias	1	0	2	2	1	2	2	1	2	1	6	1	11	8	4	11	9	7	12	2
Scomber scombrus	3	1	1	2	1	1	2	2	3	2	6	5	5	4	8	5	6	6	8	2
Octopodidae	2	49	4	2	12	5	1	15	3	0	1	32	1	1	6	2	0	10	1	0
Squids (*)	3	13	3	4	51	3	2	39	3	0	1	6	1	1	27	1	1	16	1	0
Others	16	20	45	13	12	36	12	20	33	7	11	24	26	11	15	22	10	20	21	4

(*) Squids include species from the families Loliginidae and Ommastrephidae

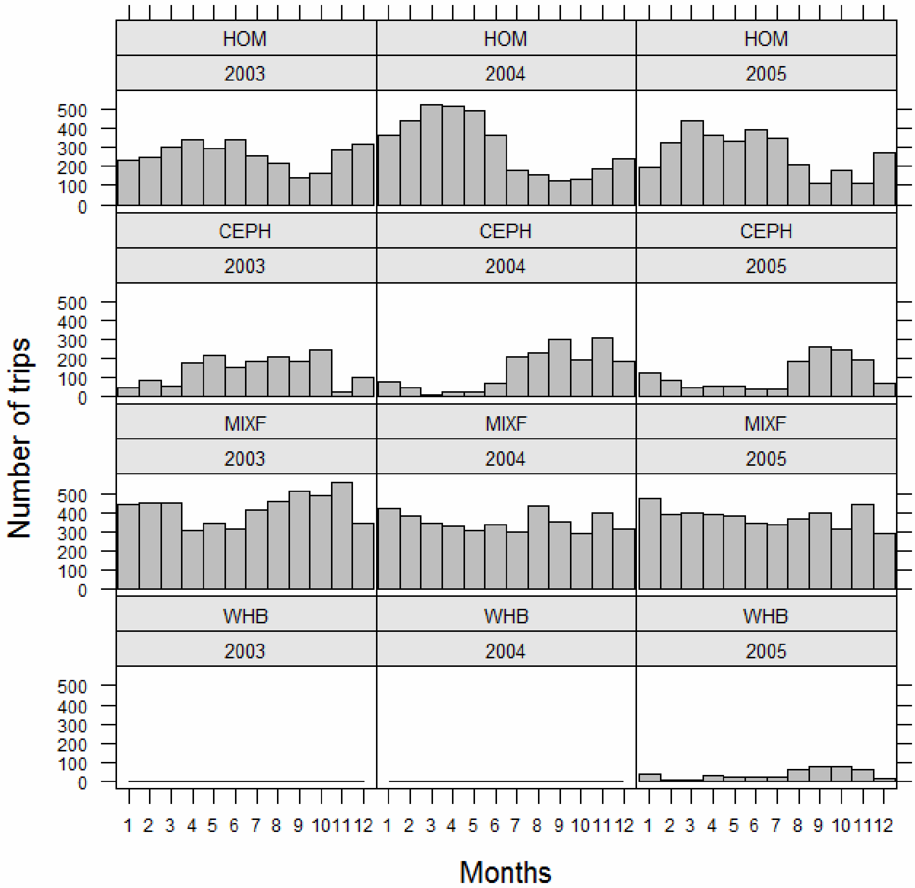

Figure 3 – Monthly distribution of fishing trips by year and cluster, for the finfish trawl fishery group.

The cluster analysis for the trips targeting crustaceans indicated two clusters for each year (Table 5). In 2003, one of the clusters, directed at rose shrimp (DPS), accounted for 58 % of the trips (Fig. 4 and Table 6).

Table 5 – Silhouette coefficient (s_i) and number of trips of the crustacean trawl group by cluster and year.

	2003		2004		2005	
Cluster	DPS	MIXC	DPS	NEP	DPS	NEP
s_i coefficient	0.67	0.38	0.59	0.44	0.59	0.67
Number of Trips	1686	1241	1122	1387	1066	1399

Table 6 – Distribution of crustacean trawl trips, landed value and landed weight by cluster and year.

		Number of Trips (%)			Landed value (%)			Landed weight (%)		
	Cluster	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Crustacean Trips	**DPS**	58	45	43	52	44	42	59	31	34
	NEP	-	55	57	-	56	58	-	69	66
	MIXC	42	-	-	48	-	-	41	-	-

The other was a mixed cluster (MIXC) targeting two species (rose shrimp and Norway lobster) with similar percentages (Fig. 4). In 2004 and 2005, the percentage of rose shrimp fell in both clusters although continuing to dominate in the first, the previous mixed cluster became dominated by trips targeting Norway lobster (being renamed NEP) (Fig. 4 and Table 7).

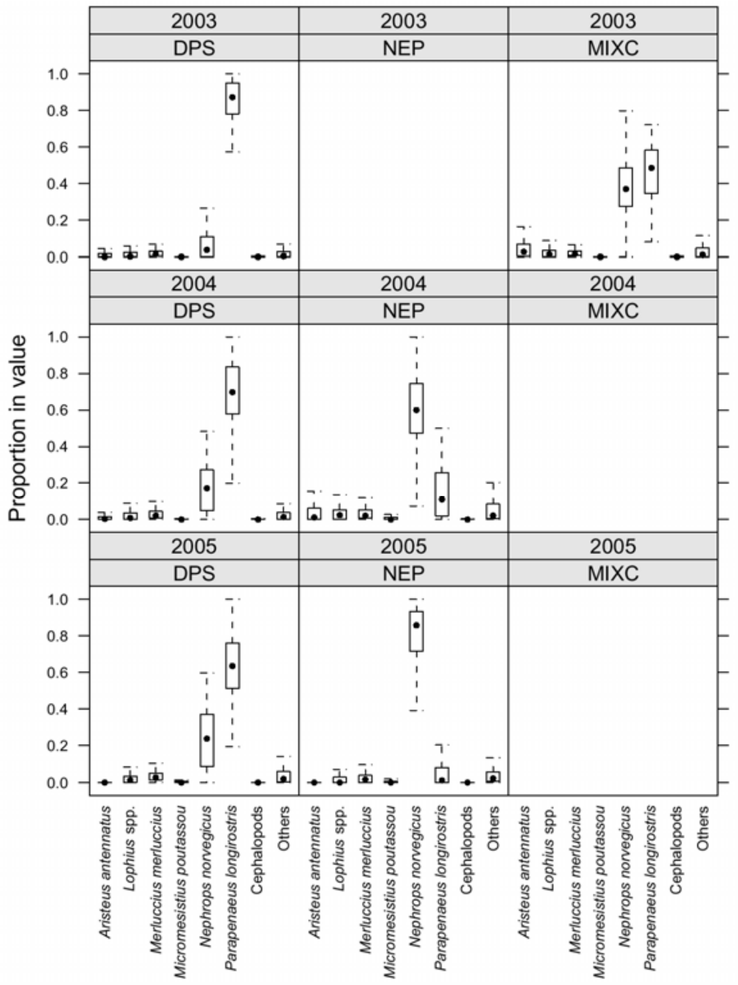

Figure 4 – Boxplots showing the distribution of species proportions by trip and year in each cluster, for the crustacean trawl (point: median; box: interquartile range; whisker: most extreme value within 1.5 times the interquartile range).

The distribution of the crustacean fishing trips of each cluster in 2004-2005 (Fig. 5) shows that the cluster dominated by rose shrimp is more important in winter and spring, while the one corresponding to Norway lobster is more important in the summer. In 2003, the higher availability of rose shrimp resulted in a large number of trips directed at this species with no clear trend.

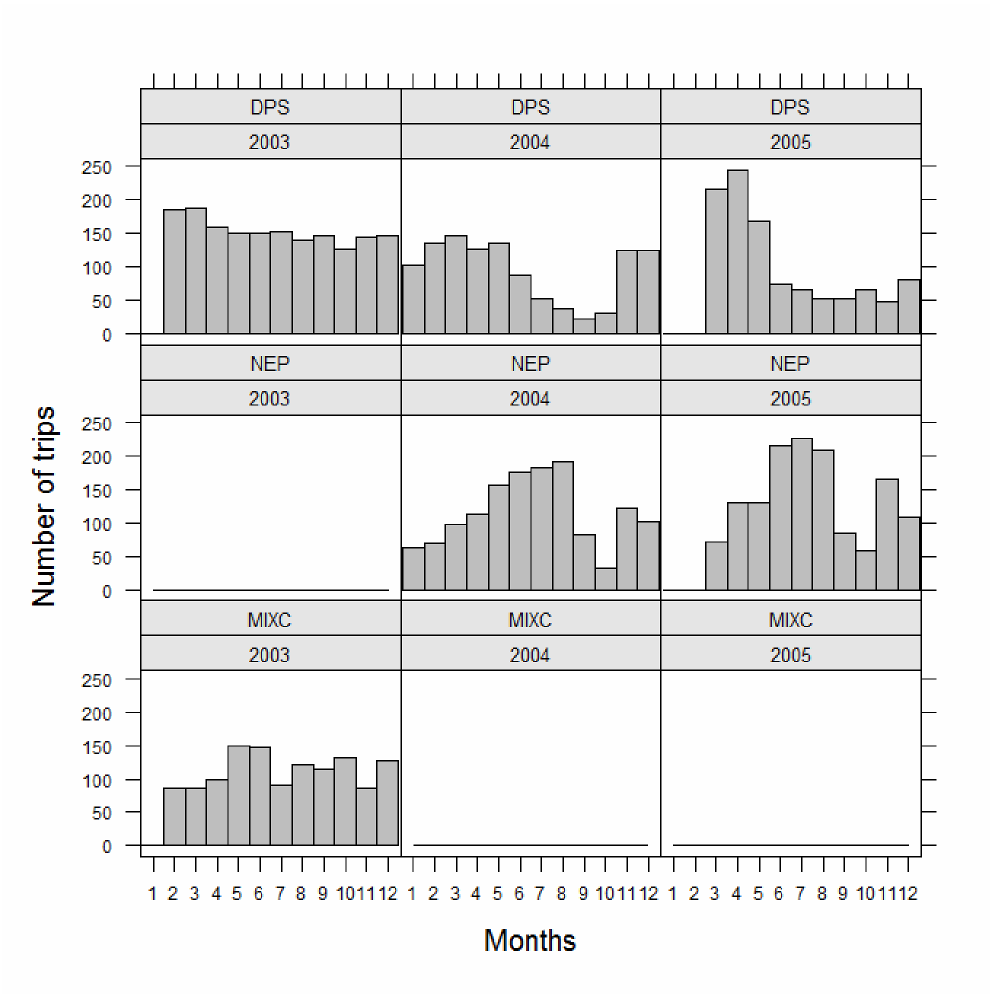

Figure 5 – Monthly distribution of fishing trips by cluster and year, for the crustacean trawl fishery group. In January 2003 and in January-February 2005, the crustacean fishery was closed.

Table 7 – Percentage of value and weight landed for the main species or species group by cluster and year for the crustacean trawl trips.

	LANDED VALUE (%)						LANDED WEIGHT (%)					
	2003		2004		2005		2003		2004		2005	
SPECIES	DPS	MIXC	DPS	NEP	DPS	NEP	DPS	MIXC	DPS	NEP	DPS	NEP
Aristeus antennatus	2	6	2	5	-	-	1	3	1	1	-	-
Parapenaeus longirostris	84	46	68	15	62	6	73	39	22	2	20	1
Nephrops norvegicus	7	38	19	58	24	80	4	29	12	18	15	25
Lophius spp	2	2	3	4	2	2	2	4	4	4	3	2
Merluccius merluccius	2	2	3	5	4	3	7	9	11	8	11	5
Micromesistius poutassou	0	0	1	2	1	2	3	5	24	54	31	55
Cephalopods	0	0	0	0	0	0	2	2	7	2	1	1
Others	3	5	5	10	7	7	9	10	19	10	19	11

The majority of the trawlers have more than 50 % of their trips allocated to one main cluster (Table 8). Some of these vessels direct their effort towards species different from those specified in the fishing license. In fact, a fraction of the crustacean trawlers (11 % in 2003 and 4 % in 2005) had more than half of their trips classified into the mixed fish cluster (MIXF), while 5 % of the finfish trawlers, in 2004 and 2005, had more than half of their trips classified into the Norway lobster cluster. Only 12 % of the vessels (23 % in the case of finfish trawlers in 2005) do not have 50 % of their trips classified in a single cluster.

Table 8 – Percentage of finfish and crustacean trawlers with more than 50 % of their trips in one cluster, in each year.

		Number of vessels (%) in Clusters					
	Year	HOM	CEPH	MIXF	DPS	NEP	MIXC
Demersal Fish Trawlers	2003	16	12	61	-	-	-
	2004	29	10	42	-	5	-
	2005	15	9	47	-	5	-
Crustaceans Trawlers	2003	-	-	11	44	-	33
	2004	-	-	-	37	52	-
	2005	-	-	4	44	40	-

No area-based analysis was performed for the trawl fleet because the landings could not be assigned to specific fishing harbours or areas. In order to look for the best price for each species landed, the landings from one trip can be fractioned and sold in more than one auction market. Therefore, the landings from any single trip can be recorded in different harbours, some of them far away from the fishing ground.

Purse-seine

The trips from the purse-seine fleet were clustered into four groups (Table 9) with a similar pattern.

Table 9 – Silhouette coefficient (s_i) and number of trips of the purse-seine fleet by cluster and year.

	2003				2004				2005			
Cluster	Sardine	H. Mack	S. Mack	Others	Sardine	H. Mack	S. Mack	Others	Sardine	H. Mack	S. Mack	Others
s_i coefficient	0.97	0.55	0.53	0.70	0.93	0.61	0.61	0.75	0.92	0.68	0.74	0.95
Number of Trips	13358	1557	1581	1547	12012	1277	1504	1449	12866	1515	2046	1965

A very well defined and dominant group (silhouette coefficient above 0.92) was present in all years, consisting of trips with very high sardine proportions (Fig. 6) and accounted for around 72 % of the fishing trips (Table 10).

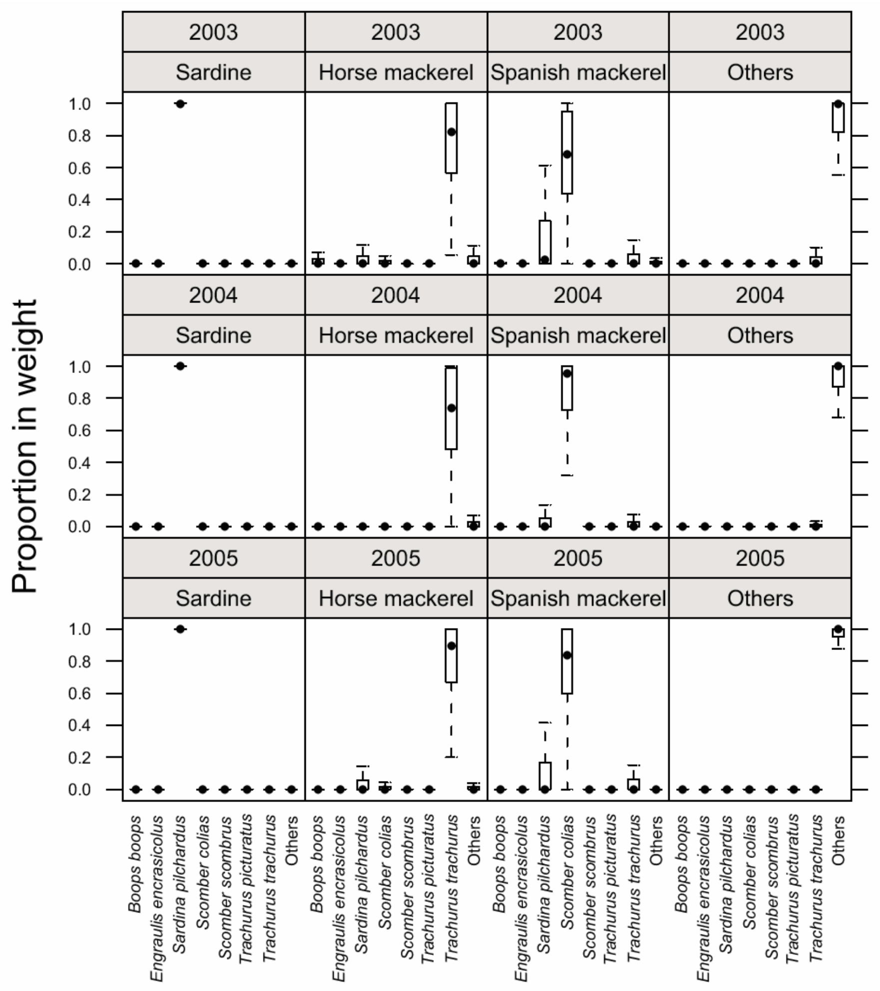

Figure 6 – Boxplots showing the distribution of species proportions by trip and year in each cluster, for the purse-seine fleet (point: median; box: interquartile range; whisker: most extreme value within 1.5 times the interquartile range).

Table 10 – Distribution of purse-seine trips, landed value and landed weight by cluster and year.

		Number of trips (%)			Landed weight (%)			Landed value (%)		
	Cluster	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Purse-seine trips	**Horse-mackerel**	9	8	8	3	3	4	10	10	7
	Others	9	9	11	1	1	1	4	4	5
	Sardine	74	74	70	88	82	82	81	80	80
	Spanish-mackerel	9	9	11	8	14	14	6	6	7

A second grouping, also resulted in a high silhouette coefficient (0.70 to 0.95), characterised by landings from the “Others” group, with sea breams (*Pagellus acarne*, *Diplodus* spp., *Spondyliosoma cantharus* and *Sarpa salpa*) as the most important species . This cluster had between 9 % and 11 % of the total number of trips in each year. The remaining two groups were characterised by large proportions of horse mackerel or Spanish mackerel in the landings (Fig. 6 and Table 11).

Table 11 – Percentage of weight and value landed for the main species or species group by cluster and year for trips within the purse-seine fleet.

	Landed weight (%)												Landed value (%)											
	2003				2004				2005				2003				2004				2005			
SPECIES	Horse mackerel	Others	Sardine	Spanish mackerel	Horse mackerel	Others	Sardine	Spanish mackerel	Horse mackerel	Others	Sardine	Spanish mackerel	Horse mackerel	Others	Sardine	Spanish mackerel	Horse mackerel	Others	Sardine	Spanish mackerel	Horse mackerel	Others	Sardine	Spanish mackerel
Boops boops	7	3	0	2	3	3	0	0	1	2	0	1	1	0	0	1	0	0	0	0	0	0	0	0
Engraulis encrasicolus	0	0	0	5	19	0	0	0	0	0	0	0	0	0	1	26	32	0	1	0	0	0	1	2
Scomber colias	3	2	1	74	5	3	2	91	4	3	2	85	1	0	1	36	1	0	1	67	1	0	1	56
Scomber scombrus	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Sardina pilchardus	6	5	98	14	6	5	97	5	8	3	97	9	2	1	96	19	3	1	96	16	6	0	96	21
Trachurus picturatus	1	0	0	1	0	0	0	0	1	0	0	1	1	0	0	2	0	0	0	1	0	0	0	2
Trachurus trachurus	80	6	0	3	64	6	0	3	83	4	1	4	92	8	2	11	61	6	2	13	87	4	2	14
Others	2	83	0	1	2	82	0	0	1	87	0	0	4	90	1	5	3	92	1	3	4	95	1	4

The horse mackerel cluster accounted for 8-9 % of the purse-seine trips, while the Spanish mackerel group varied between 9 % and 11 % of the trips (Table 10). Although the number of trips in these smaller clusters is similar, their contribution to the landed weight and estimated value is very different. The group dominated by horse mackerel is more important in value, whilst the Spanish mackerel cluster is more important in weight. There is a clear seasonality in the number of trips classified in the sardine cluster (Fig. 7), being more frequent in the summer months.

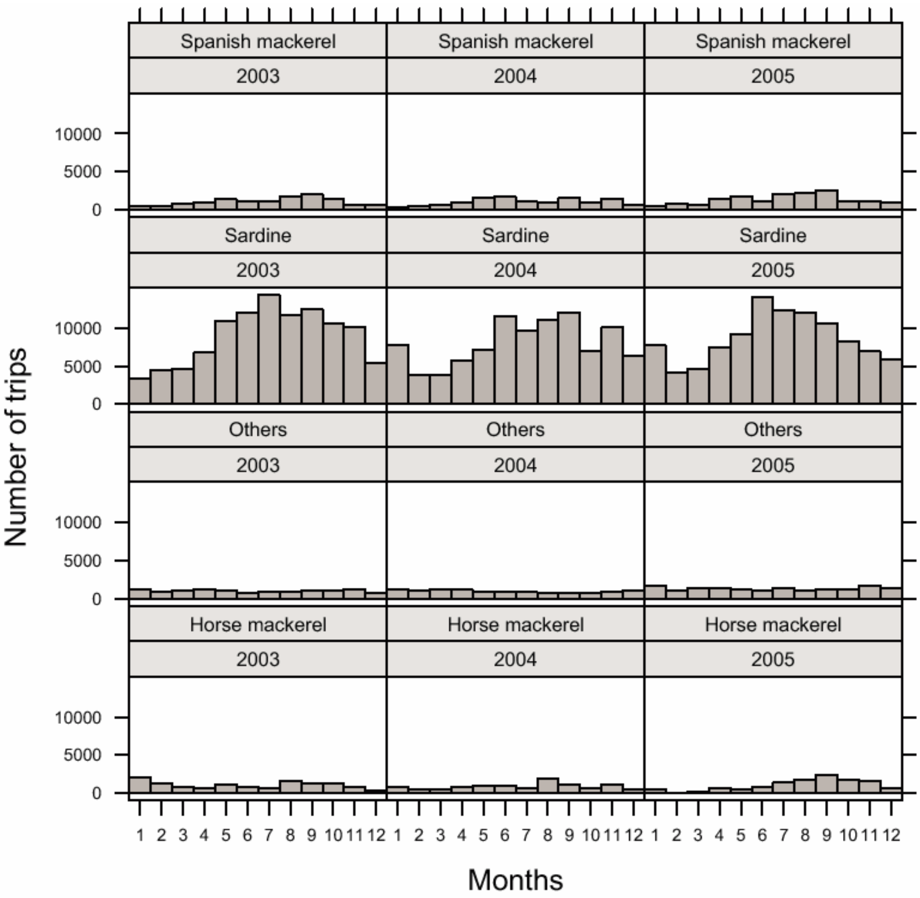

Figure 7 – Monthly distribution of fishing trips by cluster and year, for the purse-seine fleet.

Evidence of seasonality is not so pronounced for the remaining clusters. The horse mackerel group however shows a slight increase in the number of trips in the autumn, which corresponds to the recruitment season for this species off Portuguese continental waters (Borges and Gordo, 1991).

It is clear that most of the vessels participating in the sardine cluster had more than 50 % of their trips in this cluster. While the sardine fishery is a well defined fishing activity in which the majority of vessels spend most of their effort, the importance of the other clusters depends on the time of the year or on the fishing grounds. Regarding geographical variations, the cluster corresponding to other species is more important in the southern coast with at least 15 % of the vessels having more than 50 % of the trips in the southern coast, compared to lower values in the north and south-western ones (Table 12).

Table 12 – Percentage of purse-seiners with more than 50 % of their trips in one cluster, by area each year.

	Purse-seiners (%)								
	2003			2004			2005		
Clusters	N	SW	S	N	SW	S	N	SW	S
Sardine	96	84	65	98	82	74	94	85	56
Horse mack.	3	1	2	0	1	0	2	0	0
Others	1	3	14	2	4	15	3	9	21
Spanish mack.	0	0	2	0	1	2	1	0	8

DISCUSSION

This is the first time that daily landings have been used for the identification of fishing activities in the Portuguese trawl and purse-seine fleets. Campos *et al*. (2007) made a first attempt to identify clusters in the trawl fleet, analysing monthly aggregated landings in weight per vessel, from 2002 to 2004, with a hierarchical agglomerative cluster analysis. The results obtained pointed out six clusters targeting different species or species groups: horse mackerel, blue whiting, cephalopods, Norway lobster, shrimp and mixed species. Another recent study (Fonseca, *et al*., 2008) addressed the finfish trawlers, also using monthly vessel landings in weight for 2002-2004, with the objective of investigating the seasonal and spatial patterns of the landings profiles of the cephalopods, horse mackerel and blue whiting clusters. The results of the present work are in accordance with the main conclusions of both these works (Campos *et al.*, 2007; Fonseca *et al.*, 2008), however, the greater resolution of the data analysed here leads to a more precise definition of the fishing activities and makes possible a future estimation of their fishing effort.

Several studies have been published describing methodologies used to identify fishing activities (e.g. Biseau and Gondeaux, 1988; Lewy and Vinther, 1994; He *et al*., 1997; Ulrich and Andersen, 2004; Marchal, 2008). Many of these authors have applied hierarchical agglomerative cluster analysis to the catch proportions (in value or weight) of each species relative to the total catch. Also, different levels of data aggregation have been used. Considering that the same vessel may target different species in different periods of the year, the base unit chosen here for the clustering procedure was the trip species composition, rather than the vessel species composition, resulting in large quantities of data. Taking this into account, a non-hierarchical partitioning clustering was preferred to a hierarchical agglomerative method. The clusters or fishing activities identified combine a particular gear, target species and in some cases also the fishing area and season. Therefore, one fishing vessel may be involved in different fishing activities throughout the year.

The value of the catches and/or landings is expected to reflect more accurately the real intention of fishermen, particularly with regards to high-priced species, than just the weight of the catches or landings (ICES, 2003). This is the case of the crustaceans and octopus, which are the true target species for some trawlers, although they may be caught in quantities that are smaller than the so-called “by-catches”. Nevertheless, the catch in weight could be more meaningful in the case of very low-value species, as it was the case with sardine in the purse-seine fishery. Value of catches or landings, in combination with vessel and gear characteristics, has also been taken in recent years to identify the fishing activities in other areas, such as the North Sea, Baltic Sea, Eastern English Channel and Bay of Biscay (Ulrich and Andersen, 2004; Marchal, 2008). In the trawl fleet analysis, clusters were more clearly defined when the value of the species landed was used. In this particular work, the data available correspond to trawl landings and did not include discards. In these conditions, the species value is more likely to be representative of the fishing intention. However, in the case of the purse-seiners, value was an inappropriate variable due to distortion of prices introduced by official subsidies to maintain the market price at a minimum level.

Three main fishing activities were found when analysing the trips of the bottom-trawl fleet targeting finfish. One cluster is well defined, having horse mackerel as target species. Two other groups are less well defined and include trips targeting a mixture of species, one of them with dominance of octopus and squids. A fourth and very well defined fishing activity, targeting blue whiting, appeared only in 2005 and includes just a few trips. In previous years, this species was not a target species, having been included in the landings profile of the mixed species group. However, the importance of blue whiting has increased over the period, as indicated by the trend in the landings, which is a response to a greater market demand.

Regarding the crustacean fishing activities, there are two main target species: Norway lobster and deepwater rose shrimp. The rose shrimp occurs in depths from 100 to 350 metres whereas the Norway lobster is distributed from 200 to 800 metres (Figueiredo and Viriato, 1989; Sobrino *et al.*, 2005; ICES, 2008). The cluster analysis of the crustacean targeted trips resulted in two clusters for each year, varying in species composition between years as a result of changes in the abundance of the two main species. In 2003, one cluster targeted rose shrimp and the other contained a mixture of this species and Norway lobster, whilst in the following years the mixed cluster became more focused towards Norway lobster. This shift in the species composition is in line with an increase in abundance of this species during 2004 and 2005 (ICES, 2006).

Although not constituting a separate cluster, the weight of blue whiting landed from the crustacean trips increased over the period. This species is caught as by-catch in the crustacean trawl and was previously discarded. Due to a greater demand of this species at the Spanish market, this fleet increased landings of blue whiting, particularly in the period of lower catches of the crustacean target species. This is another example of changes in the practices and behaviour of a particular fleet as a result of skippers choice and market demand (Pelletier *et al*., 2000; Hilborn, 1985).

Concerning the Portuguese purse-seine component, four well-defined fishing trip types were identified: sardine, Spanish mackerel, horse mackerel and others. There are no previous studies aimed at defining fishing activities based on individual trips for this fleet. The results obtained in this study confirm previous empirical observations indicating sardine as the main target species of this fleet. Nevertheless, there are groups of trips that clearly indicate other important species, such as Spanish mackerel and horse mackerel. Regarding the spatial variation, the relative importance of the sardine cluster increases with latitude. This pattern can be seen in all years, and it may be explained by the higher availability of the other species (especially Spanish mackerel) in the southernmost regions.

The two main purposes for the definition of fishing activities are: (i) the start-up of a fishery-based sampling scheme, and (ii) the future implementation of fishery-based management plans. For these purposes, the ideal situation is to find clearly defined fishing activities, which can be easily located in space and time, are stable and include the same group of vessels from year to year. These conditions are difficult to meet for most fisheries, including the fisheries studied here. While the bottom-trawl fleets show some flexibility at switching between fishing activities, the purse-seine fleet showed the opposite, with an overwhelming importance of the cluster dominated by sardine. Movement of vessels between fishing activities within a year complicates a fishery-based sampling program in relation to allocating sampling effort *a priori*. The purse-seine targeting sardine is the only grouping identified here within which the majority of vessels spend over 50 % of their trips, and where sampling effort can be easily allocated.

The information obtained with this work can be useful for management plans in different ways. Firstly, it is important to know the flexibility of a fleet in relation to target species, thus the ability of a fleet to redirect fishing effort from a declining stock toward less depleted stocks. Secondly, it is also important to have fleet/fishery specific estimates of the fishing effort (or catch-per-unit-effort) of a given fleet on a given stock in order to be able to separate the trips targeting that stock from those in which that species was not caught or was just taken as by-catch. Therefore, the definition of fishing activities as proposed in this work will allow the estimation of target CPUE and effort for each species and the management of the fisheries taking into consideration their multi-specific nature.

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