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Objective methods for defining mixed-species trawl fisheries in Spanish waters of the Gulf of Cádiz

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Abstract

This paper presents the results obtained from applying an objective classification method to the daily commercial landings data of the Spanish bottom-trawl fishery off the Gulf of Cádiz for defining mixed-species fisheries or fishing trip types. Definition of these operational fisheries was based on the relatively unique and homogeneous species composition of the landings and technical characteristics of the vessels. The method was based on cluster (CA) and linear discriminant (DA) analysis techniques. The application of CA techniques to the 1993 data matrix of daily catch per unit of effort per species and active vessel resulted in the identification of 22 types of fishing trips, which were defined by the relative importance of their target and accessory species. Subsequently, different linear discriminant functions were derived for each FTT in order to classify new records. Five different fleet types were also identified through CA techniques according to the vessel's length, GTR and HP. The distribution of active vessels by fleet type in each landing port showed a great local and regional heterogeneity of the fleets exploiting the multispecies fishery. A correspondance analysis between types of fleets and fishing trips showed a high correlation, indicating the existence of a direct relationship between the capacity of vessel mobility and the bathymetric situation of the fisheries.

Keywords: Bottom-trawl fleet; Fishing trips; Multivariate analysis; Gulf of Cádiz (SW Spain)

1. Introduction

Preliminary descriptive studies of the trawl fishery of Gulf of Cádiz identified not only a diversity in the types of vessels comprising the fleet, but also several mixed-species fisheries showing different degrees of directionality in the effort exerted on the main target species (Sobrino et al., 1994). Consequently, if the former simplistic framework is maintained, the resulting species-specific CPUE estimates, as obtained from overall effort measures, could lead to misinterpretations about the relative abundance of their stocks. Therefore, it is necessary to define new species-specific effort measures taking into account the different constituents of the otter-trawl fishery. An essential prerequisite for obtaining this goal is the identification and definition of these fishery management units so that landings (or catches) with a specific type of fishing gear exhibit relatively unique, homogeneous and persistent multispecies groups. The understanding of fisheries typology would facilitate the estimation procedures of species-specific efforts and more real fishery-based abundance indices (CPUEs). Multivariate approaches for defining these operational fisheries

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(also termed as mixed-species fisheries or sub-fisheries or fishing tactics) within a multispecies fishery have been developed by Murawski et al. (1983), Rocha et al. (1991) and Pelletier and Ferraris (2000).

Following this research field since 1993 and thanks to the development of different UE Cooperative Projects, an important database on the Spanish trawl fishery off the Gulf of Cádiz has been generated. The compiled information originates from the control of the daily fishing trips carried out by the fleet during the previous years, including detailed information on the technical characteristics of vessels, the nominal fishing effort exerted by them and the species composition of their landings. Making use of this bulk of information, a two-stage method for defining mixed-species fisheries and species-specific efforts within the Gulf of Cádiz trawl fishery was developed recently. The first stage involves the definition of the fisheries typology by examining, through cluster analysis (CA) techniques, the presence and persistence in time of multispecies groups that are exploited by otter-trawlers. The analytical treatment for fisheries definition was very similar to that followed by Murawski et al. (1983), although the Gulf of Cádiz trawl fisheries were defined on the basis of species composition in the 1993 daily landings. Hence the resulting groupings were denominated fishing trip types (FTTs), in accordance to the usual duration of the fishing trips carried out by the fleet under study. The novelty of the Sobrino and coworkers' approach is focused on their second stage of the method, which incorporates a classification system of daily landings and their associated fishing effort into the mixed-species fisheries previously defined. In the present work, we summarize the development and application of this method and the implications on the fisheries management.

The demersal fisheries in the Spanish waters off the Gulf of Cádiz (Fig. 1) have long been characterized

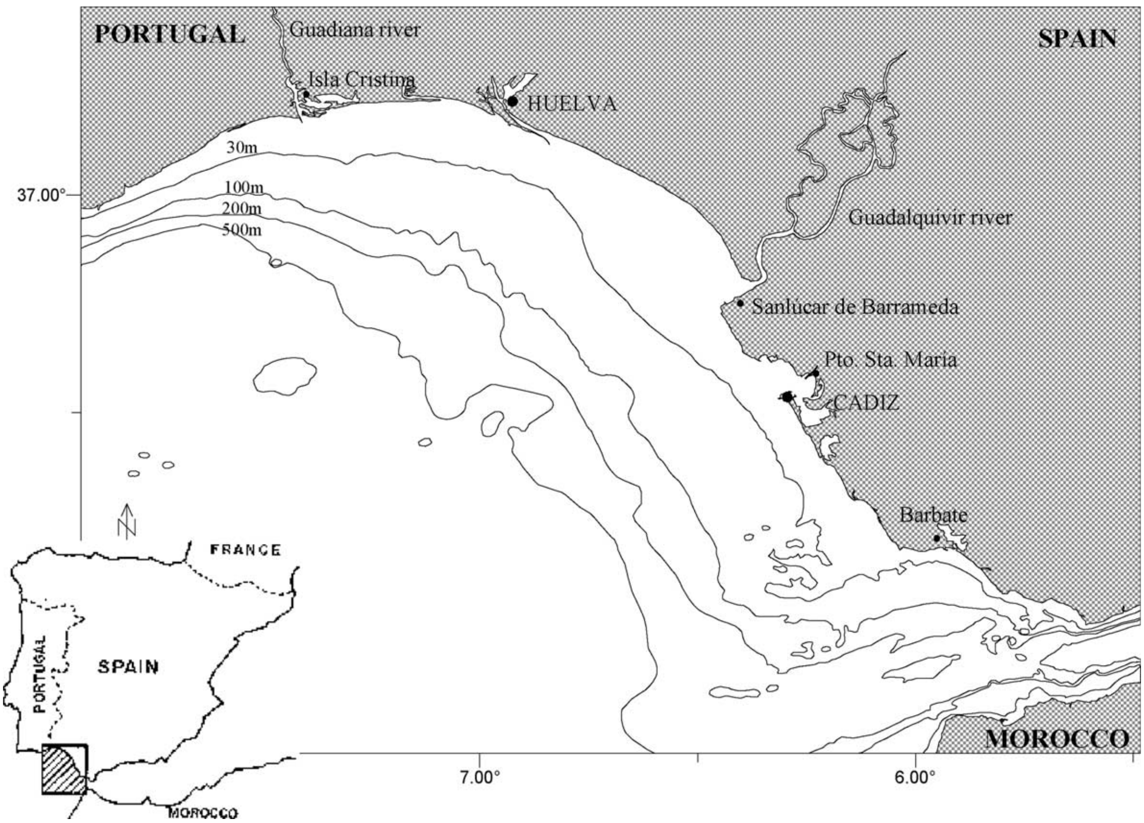

Fig. 1. Gulf of Cádiz: main landing ports of Spanish South Atlantic bottom-trawl fleet.

by their great diversity, not only in exploited species (fish, crustaceans and molluscs), but also in the fishing gears utilized (Anonymous, 1994; Sobrino et al., 1994). Such characteristics, which are closely related to the biotic and environmental particularities of its continental shelf and slope, have determined the development of multi-gear and multispecies fisheries with diverse modes of competing for the same resources, which are exploited by very different fleet–gear combinations.

Within these demersal fisheries, the otter-trawl fishery with a great social importance in some coastal localities, has been usually typified so far as a single "métier" for assessment and management purposes. On the other hand, the trawl fleet has also been defined in previous reports (Sobrino et al., 1994) as a single entity by considering only their average technical characteristics (GTR, HP and length) as descriptors, in a similar way to the criteria used to define more industrialized fleets. However, the aforementioned approach is inappropriate when dealing with heterogeneous inshore fishing fleets like those operating in the region, whose vessels are distributed over a range of different home ports and whose characteristics are influenced by their respective fishing traditions and the own historic evolution of each local fishing sector. This situation, typical of artisanal fisheries, also seems to be the case in the bottom-trawl fishery off the Gulf of Cádiz.

2. Material and methods

2.1. Definition of FTTs

The global database of landings was composed of 16,576 records (fishing trips of year 1993) and 48 different landed species and groups of species (fish, crustaceans and molluscs). After checking ambiguous records (typing errors, anomalous landings, vessels with other gears or foreign fishing grounds, etc.) through exploratory analyses, the database was reduced to 15,327 records (92.5% of the total) and 32 species. The information included in the database was as follows: vessel code, landing port, landing date (day and month), number of fishing days, catches (kg) by landed species and species CPUE per fishing trip (kg/fishing day). This information was arranged in an annual matrix including the vessels as cases (rows), and the different species landed as variables (columns). Values of the matrix cells corresponded to the percent of each of the species CPUE per fishing trip and vessel with respect to the total CPUE of the vessel in that trip. At the same time, from the annual matrix, 12 other data matrices (one per month, but without losing the daily detail) were designed to allow a monthly CA (Fig. 2).

The starting point of CA is a similarity or dissimilarity matrix between the individuals. As measures of similarity/dissimilarity, different indices have been developed, depending, generally, on the characteristics of the data. Among these measures, the distances are the most commonly used group of (dissimilarity) indices. Despite some conceptual divergences based on the mathematical properties of the *distances* (Pielou, 1984; Everitt, 1993), most authors apply the concept of *distances* simply to a group of methods which establish dissimilarities between individuals. This last concept was adopted in this study.

In the present work, the Euclidean metric distance, ED (Sokal and Rohlf, 1962) was chosen as dissimilarity measure and corresponds to the usual geometric distance between points of co-ordinates $(x_{i1}, \dots, x_{ip})$ and $(x_{j1}, \dots, x_{jp})$, which is given by

$$\mathrm{ED} = \sqrt{\sum_{k=1}^{p} (x_{ik} - x_{jk})^2} \quad (1)$$

where p is the number of variables, and i and j are observations (i.e., rows) of the data matrix.

The clustering algorithm used was the unweighted paired-group mean average, UPGMA (Sokal and Michener, 1958; Sneath and Sokal, 1973).

The resulting clusters were considered representative of the different FTTs and defined from the original data matrix. For each of the clusters, the following was estimated: relative importance in number and volume of the landings; relative importance (percentage of the total landed) of the species that define each group; mean CPUE (and percentage of the total mean CPUE) of each species that defined each group and main landing ports. Each of the individual cases in the 1993 landings matrix was then coded with the corresponding FTT code as resulted in the CA stage (coded matrix).

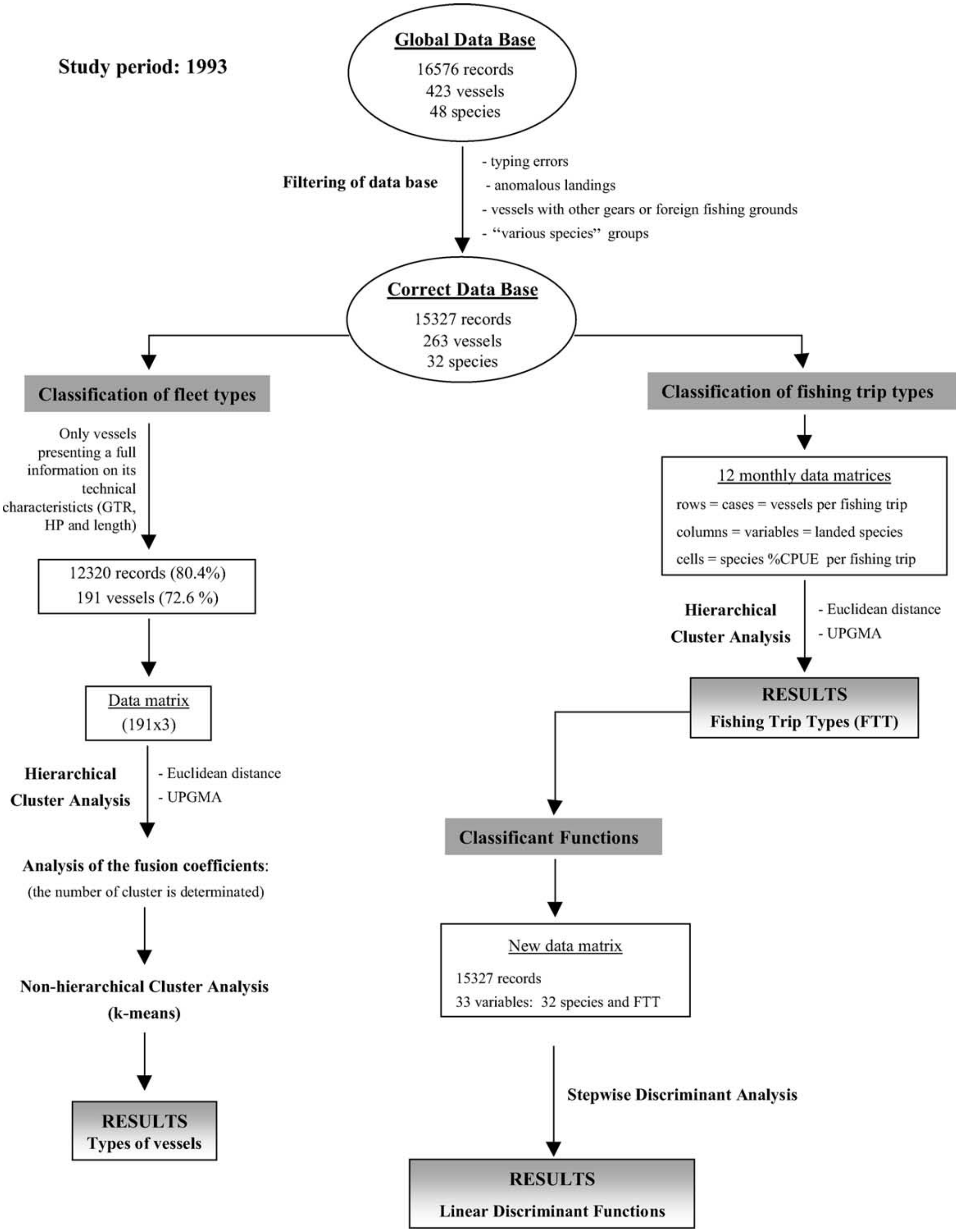

Fig. 2. Material and methods: explanatory graphic.

2.2. Stepwise discriminant analysis (DA)

One of the utilities of the DA is the obtaining of classification functions, called discriminant functions to classification (or Fisher lineal functions). A stepwise linear DA was applied to the coded matrix using different combinations of discriminating variables (species) to generate a series of functions. These allow us to classify the landings in the different trip types defined previously by means of AC. The functions obtained for each FTT in the classification rule were of the following form:

$$\mathrm{FTT}_i = k_i + (a_{i1}\,\mathrm{sp}_1) + \cdots + (a_{ij}\,\mathrm{sp}_j) \qquad (2)$$

where FTT_i is the ith fishing trip type; k_i the constant for the ith FTT; a_{ij} the species-specific coefficient for jth species in the ith FTT; and sp_j the daily CPUE for the jth species (in kg/fishing days).

As many equations as trip types exist are calculated for each landing. Then this landing will be assigned to that trip type which obtained a higher result.

The species were sequentially included in the analysis following a stepwise procedure. Selection criteria for the inclusion or rejection of variables were based on the partial multivariate *F*-statistics (*F*-to-enter and *F*-to-remove). *F*-to-enter must be higher than *F*-to-remove and both values must be positive values (3.84 and 2.71, respectively). Thus, a species was included in the model if its *F*-value was higher than *F*-to-enter and removed if its value was lower than *F*-to-remove. Additionally, those cases which were suspected to be misclassified based on Mahalanobis D^2 statistics (Huberty, 1994; McLachlan, 1992) were corrected. The percentage of cases correctly classified and cross-validation techniques were used to test the validity of the resulting classification rule. A goal of 65% or better overall correct classification of landings into FTT was set as the best compromise.

2.3. Definition of fleet types

Data on the technical characteristics of the vessels comprising the Spanish South Atlantic bottom-trawl fleets have been compiled since 1993 and stored in the fleet file of the Gulf of Cádiz fisheries database. The fleet file includes, for each vessel, the following records and variables: vessel's code number; vessel's name; home port; gross ton register (GTR, in t); motor power (in HP); vessel length (in m); year of construction and fishing gear.

Vessels belonging to fleets fishing in foreign grounds were not considered in the study. Among the 263 trawl vessels that showed some activity during 1993, a large number of them had information gaps for all or some records in the file. These were filled from consultations with *fishing and ship owner* associations of the region and through the revision of the official census of the fleet. The final data filtering resulted in 191 vessels (72.6%) presenting full information on their technical characteristics, which accounted for 80.4% of the whole of the sampled fishing trips (12,320 cases) (Fig. 2).

The first statistical tool applied was a hierarchical classification technique, particularly the CA, using the Euclidean metric distance as an index of similarity or distance measurement between cases (vessels), and the UPGMA method as hierarchical aggregation algorithm. Three continuous variables were selected for the analysis, namely, GTR, HP and vessel length. In a first test, an initial data matrix of 191×3 was designed.

Subsequently, a non-hierarchical classification analysis was applied. In this method, the number (k) of the clusters is determined, forcing previously the resulting number of clusters. In our case, k was equal to the number of resulting clusters in the hierarchical classification, and its value graphically tested by the analysis of the fusion coefficients. The reassignment of all the cases to the k clusters is carried out through an iterative process (grouping for k-means). Each vessel of the fleet file was subsequently coded with an identification number indicating the vessel or fleet type (VFT) to which it belonged.

Finally, the relationship between types of fisheries (FTT) and fleets (VFT) was tested through correspondence analysis. A frequency matrix of 12,320 coded fishing trips × five fleet types was built for 1993 data.

3. Results

3.1. Definition of "FTTs"

As a result of the CA applied to the 1993 database fishing trip by fishing trip, 22 types of fishing trips or mixed-species fisheries were defined. These fisheries are described in Table 1 with indication of their

Table 1
Description of the FTTs: relative importance in numbers and weight, and the main species that define each trip

FTT	Species in percentual decreasing importance of the total of the FTT										*N* of landings	%*N* of landings	Weight of the catch (kg)	Percentage of the total annual catch
	First species	Second species	Third species	Fourth species	Fifth species	% (first)	% (second)	% (third)	% (fourth)	% (fifth)				
G2	*P. longirostris*	*T. trachurus*	*M. merluccius*	*L. budegassa*	*S. elegans*	33.1	20.4	11.1	6.6	6.1	1,063	6.94	241,245	5.58
M1	*O. vulgaris*	*D. cuneata*	*S. mantis*	*M. merluccius*	*T. trachurus*	19.7	10.7	9.3	9.0	8.9	3,411	22.25	1,053,724	24.35
M2	*O. vulgaris*	*T. trachurus*	*L. mormyrus*	*S. officinalis*	*P. erythrinus*	36.1	9.1	8.9	8.7	5.5	655	4.27	173,345	4.01
LAN	*P. kerathurus*	*S. officinalis*	*S. mantis*	*O. vulgaris*	*Solea* spp.	39.3	15.3	13.7	7.1	6.1	95	0.62	16,642	0.38
ACE	*D. cuneata*	*S. officinalis*	*S. mantis*	*Solea* spp.	*O. vulgaris*	46.9	10.4	9.4	7.9	5.8	68	0.44	8,249	0.19
LEG	*Solea* spp.	*S. officinalis*	*O. vulgaris*	*P. acarne*	*Batoideos*	40.8	16.9	15.7	5.1	5.1	169	1.10	43,877	1.01
EPR	*L. budegassa*	*O. vulgaris*	*M. merluccius*	*P. longirostris*	*S. elegans*	47.1	13.6	7.5	7.5	5.5	47	0.31	22,774	0.53
ESP	*L. mormyrus*	*O. vulgaris*	*S. officinalis*	*T. trachurus*		50.7	11.4	8.8	7.3		306	2.00	75,708	1.75
CGA	*N. norvegicus*	*P. longirostris*	*M. merluccius*	*L. budegassa*		33.6	27.0	15.4	5.2		93	0.61	16,969	0.39
GI	*P. longirostris*	*M. merluccius*	*T. trachurus*	*S. elegans*		61.4	12.2	6.7	6.2		952	6.21	112,867	2.61
JBQ	*T. trachurus*	*E. encrasicholus*	*M. merluccius*	*S. officinalis*		33.6	32.3	9.0	5.5		194	1.27	114,454	2.65
JPU	*T. trachurus*	*O. vulgaris*	*S. officinalis*	*L. vulgaris*		33.6	28.9	7.9	6.1		380	2.48	118,021	2.73
MER	*M. merluccius*	*T. trachurus*	*P. longirostris*	*O. vulgaris*		42.4	11.7	10.7	8.2		398	2.60	84,642	1.96
LCH	*S. officinalis*	*Solea* spp.	*O. vulgaris*			36.8	33.7	8.7			66	0.43	14,288	0.33
CHO	*S. officinalis*	*O. vulgaris*	*L. vulgaris*			59.9	14.9	5.0			994	6.49	150,148	3.47
EPB	*M. poutassou*	*L. budegassa*	*O. vulgaris*			63.9	7.8	6.2			55	0.36	61,924	1.43
CIG	*N. norvegicus*	Elasmobranquios	*M. merluccius*			71.5	9.8	6.6			526	3.43	221,016	5.11
BOQ	*E. encrasicholus*	*T. trachurus*				66.3	16.1				714	4.66	285,284	6.59
PCH	*S. officinalis*	*O. vulgaris*				38.6	35.6				430	2.81	86,491	2.00
PUL	*O. vulgaris*	*S. officinalis*				69.6	10.2				2,268	14.80	648,229	14.98
JUR	*T. trachurus*	*E. encrasicholus*				71.4	5.0				1,925	12.56	686,796	15.87
MGA	*M. merluccius*	*P. longirostris*				35.9	34.8				518	3.38	89,975	2.08
Total											15,327		4,326,668	

relative importance in terms of landed weight and the number of fishing trips, as well as the species defining each of them. The FTT M1 was the most important both in number and weight of landings, accounting for 22.3 and 24.4%, respectively, of the total of fishing trips carried out in 1993. It is followed by order of importance by the fishing trips PUL (14.8 and 15.0% in number and weight, respectively) and JUR (12.6 and 15.9%). Of the remaining fishing trips, none attained 10%, only being remarkable in order of importance the types G2, CHO, G1 and BOQ.

The common octopus (*Octopus vulgaris*), the horse-mackerel (*Trachurus trachurus*) and the cuttlefish (*Sepia officinalis*) are the species showing the highest landings, each one being the main target species in three different types of fishing trips. FTTs can be additionally classified in three groups depending on the number of species dominating their landings. Those in which the fishing effort seems to be clearly directed to a single target species and considered as single-species FTTs are: JUR (*T. trachurus*, 71.4% ± 19.5), CIG (*Nephrops norvegicus*, 71.5% ± 18.8), PUL (*O. vulgaris*, 69.6% ± 17.3), BOQ (*Engraulis encrasicholus*, 66.3% ± 20.5), EPB (*Micromessistius poutassou*, 63.9% ± 20.1), G1 (*Parapenaeus longirostris*, 61.4% ± 17.1), CHO (*S. officinalis*, 59.9% ± 18), ESP (*Lithognatus mormyrus*, 50.7% ± 18), EPR (*Lophius budegassa*, 47.1% ± 16.6), ACE (*Dicologoglossa cuneata*, 46.9% ± 20.2), LEG (*Solea* spp., 40.8% ± 23.2), MER (*Merluccius merluccius*, 42.4% ± 21.6), and LAN (*Penaeus kerathurus*, 39.3% ± 20.2). Species from these single-species trip types present small variation coefficients which oscillate among 0.247 in the octopus (trip type PUL) and 0.546 in the sole (trip type LEG). The group comprising those trip types mainly catching two species is composed by the types CGA (*N. norvegicus–P. longirostris*), MGA (*M. merluccius–P. longirostris*), LCH (*Solea* spp.–*S. officinalis*), PCH (*O. vulgaris–S. officinalis*), JBQ (*T. trachurus–E. encrasicholus*), and JPU (*T. trachurus–O. vulgaris*). In these trip types the CPUE mean percentage of these species oscillates between 30 and 40, approximately for each one of them, S.D. between ±10 and ±12.4 and coefficients of variation between 0.272 and 0.391. Finally, the trip types which have not been able to break down in trips with one or two target species. These continue having the character of multispecific due to the high number of species that define them. This is the case for the trip types M1 and M2 where the catched species present lower CPUE mean percentages and higher variation coefficients.

With regard to the fisheries seasonality, in the first place we make reference to those trip types that are mainly carried out along the spring–summer (RAP, MER, MGA, CIG and in a minor level CGA). A second group of trip types is those that present a summer seasonality (BAC, ESP, GAM-2 and, also less marked LEG). Then fisheries like M2, CHO, PCH, ACE, BOQ, GAM-1 and PUL with a fall–winter seasonality. In the case of ACE, this seasonality coincides with the certain spawning time of the wedge sole in the study area (Jiménez et al., 1998). In the case of the PUL, also coincides with the recruitment time (Sobrino et al., 2002). The trip type LAN presents a very marked seasonality, being carried out mainly in spring at the same the time of the caramote prawn spawning and in second place and smaller proportion during the third trimester coinciding with the recruitment (Rodríguez, 1981).

A close relationship between FTTs and the ports where the catches of these FTTs are landed was observed, in which their landings species composition is defined by the geographic located of the fleets and the depth of their traditional fishing grounds. Catches of the ACE, EPB, EPR, LAN, G2 and M1 types are mainly landed in the Sanlúcar de Barrameda port (Table 2). FTTs targeting on Nephrops and shrimp (CIG, CGA, G1 and MGA) as well as those directed to horse-mackerel and anchovy fishing (JUR, BOQ and JBQ) mostly land their catches in the westernmost ports in the study area, such as Huelva and Isla Cristina. The same was also observed for FTTs dedicated to the cephalopod fishing (CHO and PUL). On the other hand, catches of sole fishing trips (LEG and LCH) are almost exclusively landed in the easternmost ports in the region (Puerto de Sta. María and Barbate).

3.2. Discriminant functions

The application of the stepwise DA to the 1993 coded matrix resulted in a classification rule composed by 22 discriminant functions corresponding to each of the identified FTTs. The percentages of the cases correctly classified for each FTTs in relation to the

Table 2
Distribution and relative importance of the fleet types by landing port

Trip type	Huelva	Isla Cristina	Sanlúcar de Barrameda	Puerto de Sta. María	Barbate
ACE	8.3	2.7	86.1	2.9	0.0
BOQ	44.3	54.7	0.2	0.7	0.0
CGA	60.7	32.3	1.8	5.3	0.0
CHO	4.1	84.7	5.2	2.8	3.3
CIG	94.9	0.3	0.3	4.6	0.0
EPB	0.0	0.0	92.9	7.1	0.0
EPR	2.5	1.3	96.2	0.0	0.0
ESP	0.0	63.8	36.2	0.0	0.0
G1	46.1	38.3	7.0	8.6	0.0
G2	2.5	67.3	28.6	1.6	0.0
JBQ	28.0	47.6	0.3	24.1	0.0
JPU	12.9	53.4	9.9	22.3	1.5
JUR	4.1	94.7	0.7	0.4	0.0
LAN	51.3	4.3	43.6	0.9	0.0
LCH	3.6	0.6	0.0	60.1	35.7
LEG	0.9	0.9	1.5	69.8	27.0
M1	3.2	0.6	93.6	2.7	0.0
M2	1.1	29.2	21.8	47.3	0.6
MER	12.5	51.7	24.2	11.0	0.6
MGA	34.3	48.0	12.6	5.1	0.0
PCH	2.6	57.1	11.6	22.1	6.7
PUL	8.3	55.7	18.9	10.2	6.9

classification resulting from CA stage are shown in Table 3. An overall correct classification of cases in the FTTs of 75.4% was obtained.

3.3. Definition of fleet types

Five types of vessels were characterized in the CA stage after analyzing the fusion coefficients (Fig. 3). For defining each type, the number of vessels and their mean (±S.D.) GTR, HP and length were estimated. The resulting types are defined in the Table 4. The most important fleet type in number of vessels is VT_2 (40.8%), followed by the VT_3 and VT_1 types, which accounted for 27.2 and 19.9%, respectively. The larger vessels are included in VT_4 and VT_5, which represented 12.1%.

GTR showed as the best descriptor of the vessel size, the engine horse power may be a very misleading variable. The latter variable is subjected to legislation raising serious doubts about the veracity of data provided by the vessel skippers. This is the reason for the VT_5 vessels (the heaviest and largest ones)

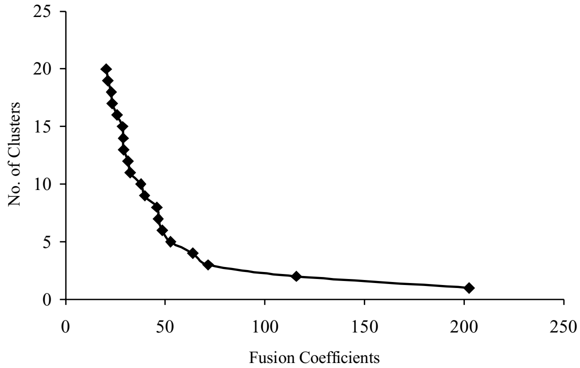

Fig. 3. Definition of fleet types by CA. Graphic mode for determining the number of clusters. A marked flattening in the graph suggests that no new information is portrayed beyond five clusters.

having a lower HP than the lighter and smaller VT_4 vessels. GTR ranged between 11.9 t in the smallest vessels (VT_1) and 48.9 t in the largest ones, suggesting a close and direct relationship between length and GTR.

3.4. Relationship between types of fleet and mixed-species fisheries

The interpretation of the results of the correspondence analysis was based on the information explained by the two first factorial axis, which explain 89.1% of the total inertia of the analysis. Table 5 shows the eigenvalue of each axis, the percentage referred to the total inertia and the accumulated percentage.

Fig. 4 represents the inertial axes I and II of the different vessel types and fishing trips types. The interaction between both axis causes an open V representation, producing what is called as the Guttman effect. This effect appears when the system is fundamentally unidimensional and there is some contagious effect between the variables and the samples. This effect usually is produced by the existence of a parameter with a gradient. In our case, the gradient seems to have a certain environmental feature, specifically bottom depth. In general terms, a high correlation between the technical characteristics of the vessels and the FTTs practiced can be observed. Vessels with lesser navigation autonomy and engine power (VT_1 and VT_2) are specialized in the development of coastal fisheries (ACE, ESP, LEG, LCH, PUL, M1,

Table 3
Classification matrix showing percentages of cases correctly classified for each FTT

Trip type	ACE	BOQ	CGA	CHO	CIG	ESP	G1	G2	JUR	JBQ	JPU	LEG	M1	M2	MER	MGA	PCH	PUL	EPB	LCH	EPR	LAN
ACE	94.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOQ	0.0	74.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CGA	0.0	0.0	90.3	0.0	4.3	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.1	3.2	0.0	0.0	0.0	0.0	0.0	0.0
CHO	0.0	0.0	0.0	74.8	0.0	2.2	0.0	0.1	0.5	0.1	2.5	0.0	0.8	1.2	0.0	0.0	13.8	0.0	0.0	1.3	0.0	2.6
CIG	0.0	0.0	2.5	0.0	86.9	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
ESP	0.0	0.0	0.0	0.0	0.0	86.3	0.0	0.7	0.0	0.0	0.0	0.0	0.3	11.4	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.0
G1	0.0	0.0	2.1	0.0	0.0	0.0	78.6	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.3	0.0	0.0	0.0	0.0	0.2	0.0
G2	0.2	0.0	0.6	0.0	0.0	0.2	8.8	68.0	4.1	0.5	0.0	0.0	4.9	0.4	0.6	7.8	0.1	0.1	0.0	0.0	3.7	0.0
JUR	0.0	0.0	0.1	0.0	0.0	0.2	0.0	3.4	78.9	6.8	9.7	0.0	0.4	0.3	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0
JBQ	0.0	9.5	0.0	0.0	0.0	0.0	0.0	0.0	3.0	84.5	0.6	0.0	1.2	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0
JPU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	3.3	1.0	80.7	0.0	0.8	7.6	0.0	0.0	2.0	2.8	0.0	0.0	0.0	0.3
LEG	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	53.8	1.2	3.6	0.0	0.0	3.6	1.2	0.0	34.9	0.0	0.0
M1	2.7	0.0	0.1	0.1	0.0	0.2	0.0	4.0	0.3	0.1	5.4	0.0	74.6	6.8	0.8	0.2	1.4	0.3	0.2	0.4	1.2	1.1
M2	0.0	0.0	0.1	0.0	0.0	9.6	0.0	1.4	0.0	0.3	14.8	0.3	6.3	50.1	0.7	0.0	7.9	5.2	0.1	0.4	2.5	0.1
MER	0.0	0.3	0.3	0.0	0.0	0.0	0.0	2.6	0.3	1.8	2.9	0.0	2.3	0.9	76.8	11.4	0.0	0.0	0.0	0.0	0.3	0.0
MGA	0.0	0.0	1.1	0.0	0.0	0.0	7.2	11.9	0.0	0.0	0.0	0.0	0.6	0.0	7.9	70.8	0.0	0.0	0.0	0.0	0.6	0.0
PCH	0.0	0.0	0.0	14.8	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.1	3.0	8.0	0.0	0.0	63.8	4.1	0.0	3.0	0.0	0.7
PUL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.2	0.4	8.4	0.0	0.0	9.2	80.8	0.0	0.1	0.0	0.0
EPB	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	94.4	0.0	1.9	0.0
LCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	0.0	0.0	0.0	0.0	3.1	0.0	0.0	81.5	0.0	0.0
EPR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	3.4	1.7	0.0	0.0	0.0	0.0	0.0	0.0	93.2	0.0
LAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	7.4	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.3

Table 4
Classification of the trawl fleet by means of the CA based on its technical characteristics

Vessel type	N	%	GTR		HP		Length (m)	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
VT1	38	19.9	11.9	4.8	110.4	17.6	12.3	2.2
VT2	78	40.8	20.4	5.8	177.3	17.2	13.0	2.3
VT3	52	27.2	29.9	10.5	262.8	24.6	15.1	2.8
VT4	8	4.2	43.6	12.9	420.8	15.8	17.2	2.4
VT5	15	7.9	48.9	13.2	348.7	21.8	17.5	1.0

Table 5
Results of the correspondence analysis between fishing trip and fleet types

Axis	Eigenvalue	Inertia	χ^2	Significance	Proportion of inertia	
					Explained	Cumulative
1	0.566	0.320	–	–	0.754	0.754
2	0.241	0.058	–	–	0.137	0.891
3	0.158	0.025	–	–	0.058	0.950
4	0.146	0.021	–	–	0.050	1
Total	–	0.424	5226.34	0.000	1	1

Note: d.f. = 84.

PCH, LAN, M2 and CHO fishing trips). The increase of technical characteristic values of the vessels (VT_3 and VT_4) makes possible the exploitation of deeper depths of the shelf (JPU, EPR, JUR, MER, BOQ, JBQ and EPB fishing trips). At the end of the depth gradient, the fisheries in the upper continental slope are exploited by the fleet of greatest size, VT_5 (G2, MGA, G1, CGA and CIG fishing trips).

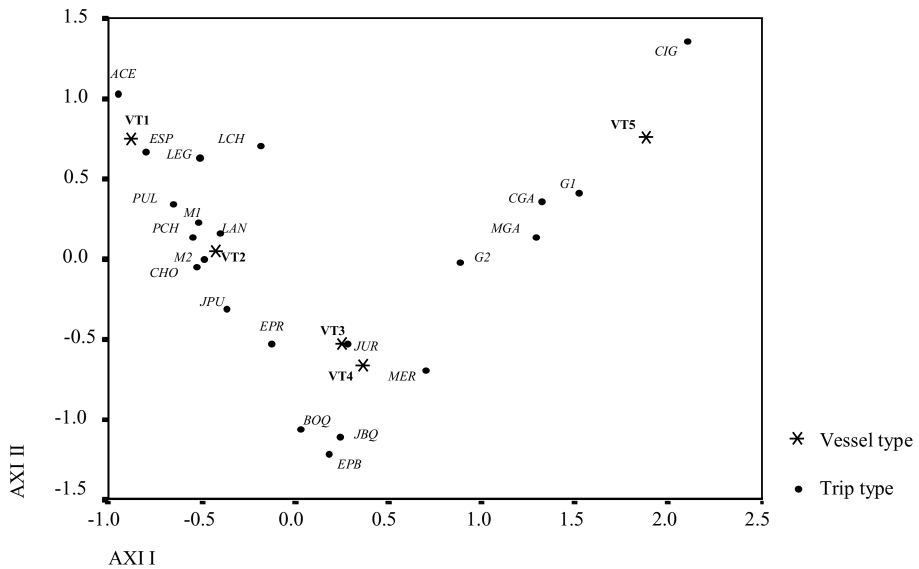

Fig. 4. Correspondence analysis: distribution of fleet types and FTTs by the two first axis.

4. Discussion

From the described fishing trips, the group M1 was seen as the most important in terms of number of fishing trips and importance of the landings. This is the type of fishing trip with the greatest number of species landed. It does not have a distinct target species. The importance of the different species depends on the season of the year and the availability of the species. Nevertheless, it always has the same specific composition (Jiménez, 2002). This type of fishing trip principally landing in catch in the port of Sanlúcar de Barrameda (93.6%). The other type of multispecific fishing trip is the M2. As in the previous fishing trip, it does not show a clear target species. However, the composition of the species differs from the M1, mainly because the exploited fishing grounds are different. The landing ports are also different, M2 reporting 47.3% of the landings in the port of Puerto de Sta. María, and the remaining ones between Isla Cristina and Sanlúcar (29.2 and 21.8%, respectively).

There are other fishing trips that have a mono-specific character, that is have one target species. Among these types of fishing trips, the G1 and G2 are mainly for shrimp. The fishing trips MER, LAN, ACE, LEG, CIG, EPR, EPB, PUL, CHO or JUR, each have one distinct target species. Another group exploits jointly two species, the fishing trips MGA, JBQ, JPU, LCH, CGA and PCH. All these fishing trips are done by vessels of very distinct technical characteristics and land in different ports either due to the vicinity of the fishing grounds being exploited, or due to higher commercial values that the landings obtain in some determined ports. For instance, catches of the ACE type are principally landed in Sanlúcar de Barrameda, related to the geographic distribution of the wedge sole, the target species for this FTT (Sobrino et al., 1996; Ramos et al., 1997). Similar situations can be described for other mono-specific trip types, such as LEG, LAN, G1, CIG, GGA and JUR. In all of these cases, a direct relationship between their landing ports and proximity of the fishing grounds of their target species was found.

A very obvious correspondence between each fleet type (defined according to their technical characteristics) and the FTTs that they carry out has also been shown. As described in Section 3.3, the smaller vessels, which also have lesser navigation capability, usually target on more coastal species. Conversely, the largest vessels target on species inhabiting in deeper depths, including those typical species from the upper slope such as Nephrops.

Another feature to be highlighted is the classification rule. The objective of these discriminant functions is to make possible the classification of fishing trips from an objective viewpoint. The classification of these fishing trips permits the utilization of these data series to assign the effort exerted on the main target species. Without a methodology as described in this paper, which automatically classifies the fishing trip by means of the discriminant function, this would not have been possible. Moreover, this classification rule can be used to classify fishing trips from previous years with adequate statistical information, and thus, aid in the process of their classification and their allocation of specific effort.

Since the allocation of effort is based on the selection of those fishing trips in which a particular species is the target species, and at the same time, to which the effort is directed, the classification of the fishing trips is essential in the process. The election of the trip types with representative abundance CPUE index of each one of the target species could be made by means of MANOVA. This analysis is based on the hypothesis that those CPUE series which present higher stability in short time periods can be considered as better indicative of the abundance because in that time did not exist big fluctuations of the abundance. The proposed model is (Jiménez, 2002):

$$\log \mathrm{CPUE}_{ij} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + E_0 \tag{3}$$

where i is the species, j the FTT, x_1 the vessel factor, x_2 the time factor, and E_0 the error.

An equation is obtained by trip type and species. These CPUE series which present smaller error will be those that present higher stability in this time period. To obtain an unique CPUE series standardized by target species could be applied to a general lineal model (GLM) as the one proposed by Hilborn and Walters (1992).

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