Spanish otter trawl fisheries in the Cantabrian Sea

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A non-hierarchical classification technique (clustering large applications, CLARA) was used to identify four fishing tactics of Spanish otter trawlers in the Cantabrian Sea (ICES Division VIIIc) from 1983 to 2004: mixed fishing, blue whiting fishing, horse mackerel fishing, and mackerel fishing. There were no significant differences in the fishing tactics employed by two trawl fleets identified using a non-hierarchical classification technique (partition around medoids). There was, however, a decline in the use of the blue whiting fishing tactic from 2000 on, perhaps as a result of competition with pairtrawls, a gear whose main target species is blue whiting. There was an increase in the number of trips using the mackerel fishing tactic from 1996, a change possibly caused by improved market conditions. Between 2000 and 2004, the fleets had two distinct behaviour patterns, identified depending on the area in which they operated. The study area could therefore be subdivided into two areas based on the prevalence of the fishing tactic followed. The horse mackerel fishing tactic was more commonly used in the west, and the mixed fishing tactic in the east.

Keywords: Cantabrian Sea, métier, otter trawl, segmentation.

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Introduction

The Spanish otter trawl fishery of the Cantabrian Sea is a typical mixed one (Lema *et al.*, 2006), with a broad range of target species of widely varying biological, ecological, and behavioural characteristics. The fleet is made up of vessels of differing technical characteristics and has the capacity to explore a wide area. Historically, the only otter trawl fleet that has operated in the area is the Spanish fleet, and it has always been considered a single fishery. Its management and administration have been based on this criterion, and no consideration has been given to whether the target species were always the same or whether they varied among trips or vessels.

The fishery targets the main southern demersal and pelagic stocks in the Northeast Atlantic that are subject to assessment by ICES Working Groups. Many of the stocks have been exploited historically to such an extent that they are now either outside biologically safe limits or the state of the stock is unknown (ICES, 2006a, b, c). Recovery plans are now in place for the southern stock of hake (*Merluccius merluccius*) and the Cantabrian Sea stock of Norway lobster [*Nephrops norvegicus*; Council Regulation (EC) No. 2166/2005]. In addition, the otter trawl fishery is now subject to several types of regulation [Council Regulation (EC) No. 850/98 and BOE Real Decreto 1441/1999], these being that the mesh size used must be ≥55 mm. The minimum working depth is 100 m, and some areas are closed to fishing (Rodríguez-Cabello *et al.*, 2008).

One of the most commonly used terms in the description and management of fisheries is the métier. The structure of a métier is drawn up based on gear, vessel type, area, time, and the combination of species or target species. There are many reasons behind the need to identify each of these métiers: the estimation of specific effort and abundance indices (e.g. catch per unit effort, cpue); the analysis of what is exploited and what is accessible to a certain gear in the different ecosystems, under the concept of the ecosystem approach; the improvement of sampling designs and estimates of discard volumes (Allen *et al.*, 2002); and increasing management efficiency through the application of appropriate measures aimed specifically at the fishing activity exploiting the resource. Many terms have been used to define each of the components, and a summary of these can be found in Ulrich and Andersen (2004) and Campos *et al.* (2007). The terminology used in the present study is that defined in ICES (2003) and used by Marchal *et al.* (2006): fleet, a group of vessels with similar characteristics; fishing tactic, trips made aimed at the same species/stock or a combination of these using similar gear in the same period of the year and in the same area. Hence, a métier is the combination of these two components. The only previous studies of the stratification of otter trawl activity in the area are those described by Lema *et al.* (2006). The fishing activity is classified into Vertical High Opening (VHO) or Classical according to the type of otter trawl gear used.

The present identification of métiers covering the fishing activities of Spanish otter trawlers operating in the Cantabrian Sea, together with those made by Jiménez *et al.* (2004) for the Gulf of Cádiz (ICES Subdivision IXa South) and Campos *et al.* (2007) for Portuguese waters (ICES Subdivision IXa Central), completes the description of these fisheries for all Atlantic waters of the Iberian Peninsula [except for the small area of ICES Subdivision IXa North which, as Punzón *et al.* (2008) described in their analysis of the effects of the “Prestige” oil catastrophe on the fisheries of VIIIc and IXa North, is similar in structure to that described in this work for the Cantabrian Sea]. The aim of this study was to identify fishing tactics, fleet types, and métiers in use in the Cantabrian Sea from 1983 to 2004. In addition, the main changes in otter trawl fishing tactics or métiers over the past two decades are described.

Material and methods

The data from the otter trawl fishery in the Cantabrian Sea (Figure 1) were compiled on a trip basis for the years 1983–2004. The trip data are derived from sampling the landings at markets and from trip censuses (sales slips). The information collected by trip was fishing area, gear, landing date, vessel name, landing by species, and landing harbour. The economic data by species were not taken into account because they were not available for the entire time-series. Discards were not included in the analysis matrix because no estimates were made for the whole sampling period nor for all species under study.

In total, 111 402 trips were taken into account in the final matrix (Table 1), and 2.5% were omitted (data errors and incomplete data). Given that the level of species identification in landings was highly variable throughout the time-series and among harbours, which happens mainly in the species with the lowest or most sporadic landings and in those of low economic value, the criteria for the selection of species to be included in the final data matrix were: (i) presence of the species in all years and ports considered; (ii) frequency of occurrence (number of trips in which each of the species appeared by total of trips landed) must be either constant or have a clear trend without abrupt changes that could not be attributed to fishing activity; (iii) those species for which there were doubts concerning their identification were grouped in the analyses at a higher taxonomic level.

Of the 54 original taxonomic units, only 11 were taken into account: *M. merluccius* (hake), *Lophius* spp. (monkfish), *Lepidorhombus* spp. (megrim), *N. norvegicus* (Norway lobster), *Micromesistius poutassou* (blue whiting), *Conger conger* (conger), *Trisopterus luscus* (bib), *Scomber scombrus* (mackerel), *Scyliorhinus caniculus* (small-spotted catshark), *Trachurus trachurus* (horse mackerel), and Octopodidae (*Eledone cirrhosa* and *Octopus vulgaris*). The remaining species, and those that appeared in the fishing statistics as "various" or "unidentified", were grouped under the denomination "Others" and were included in the final matrix as one more group.

To standardize the information, the specific composition by trip was expressed as a percentage of the total trip landings weight (Lewy and Vinther, 1994; Jiménez *et al*., 2004; Campos *et al*., 2007). In terms of A Coruña, the reduction in the number of trips in 1999, 2000, and 2004 was attributed to the fact that the information was obtained by trip sampling at the market, unlike the remaining years, in which data were derived from censuses taken at the harbour. Although the information collected by scientists is better, with respect to the number of species collected, the previously described criteria were applied in such a way that the whole time-series could be compared.

Identification and characterization of fishing tactics

To identify otter trawl fishing tactics, ordination and classification techniques were applied. The ordination technique was used to evaluate the different associations among variables (species) characterizing the trips (each trip is one observation), and affinities among trips (Gordon, 1999). The results also contribute to interpretation of the final result obtained using the classification technique, which assigns each trip to a fishing tactic. Moreover, in those cases in which the classification technique provides only a weak structure, it contributes by adding support to the final configuration (Struyf *et al*., 1996). In addition, this allows fishing tactics to be explained depending on the ordination distribution of the variables (species) used (García *et al*., 2006). A detrended correspondence analysis (DCA; Hill and Gauch, 1980) was used to determine whether the response of the observations (trips) to the species (variables) was linear, in which case a principal component analysis (PCA) would be more appropriate, or unimodal, in which case the CA would be more appropriate (Jongman *et al*., 1987; Ter Braak and Prentice, 1988; Leps and Smilauer, 1999).

To classify trips, the non-hierarchical cluster technique CLARA (clustering large applications) was used. It is a technique specifically designed to handle large matrices (Kaufman and Rousseeuw, 1986) based on a partition around medoids (PAM). The Silhouette width (Rousseeuw, 1987; Pollard and van der Laan, 2005) was used to select the number of groups. According to Kaufman and Rousseeuw (1986), there are four levels of the overall Silhouette coefficient (OSW): 0.71–1, consistent pattern; 0.51–0.70, reasonable pattern; 0.26–0.50, weak pattern; <0.26, no pattern. Moreover, for each of the groups identified, a partial Silhouette coefficient (PSW) was obtained, indicating the homogeneity of the cluster internally and how heterogeneous it was with respect to those nearest to it, according to the same levels expressed for OSW.

To characterize each of the fishing tactics identified, the percentage by weight (%W) was used. In addition, and given that pelagic

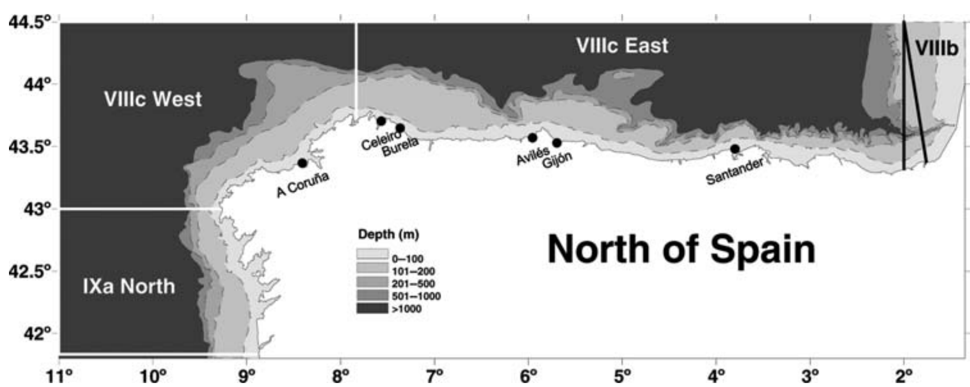

Figure 1. Study area and landing ports of the otter-trawl fleet in ICES Division VIIIc.

Table 1. Number of trips used in the final matrix for identifying the types of fisheries.

Year	A Coruña	Avilés	Burela	Celeiro	Gijón	Santander	Total
1983	–	2 698	–	–	–	–	2 698
1984	–	2 331	–	–	–	–	2 331
1985	–	2 195	–	–	–	–	2 195
1986	4 446	2 390	–	–	–	–	6 836
1987	4 010	1 858	–	–	–	–	5 868
1988	4 873	2 069	–	–	–	–	6 942
1989	5 295	–	–	–	–	–	5 295
1990	5 542	1 992	–	–	–	–	7 534
1991	5 089	1 786	–	–	–	–	6 875
1992	5 055	1 107	–	–	–	–	6 162
1993	5 694	1 070	–	–	–	–	6 764
1994	5 169	–	–	–	–	–	5 169
1995	5 470	144[a]	–	–	–	–	5 614
1996	4 858	–	–	–	–	–	4 858
1997	4 789	–	–	–	–	–	4 789
1998	3 494	110[a]	–	–	223	549	4 376
1999	263[a]	427[a]	–	–	204	522	1 416
2000	504[a]	378[a]	1 434	744	295	529	3 884
2001	3 532	246[a]	1 427	501	360	277	6 343
2002	3 211	314[a]	1 395	388	556	262	6 126
2003	2 690	269[a]	1 380	332	410	247	5 328
2004	489[a]	374[a]	1 822	359	711	244	3 999
Total	74 473	21 758	7 458	2 324	2 759	2 630	111 402

[a]Data from market sampling.

species can often yield large landings in otter trawl gear, the percentage frequency of occurrence (%FO) was also used. To make a combined analysis of the effects of the two measures, the feeding index (FI; Lauzanne, 1975) was applied. This is a combined index typically used in marine biology for the analysis of stomach contents (Rosecchi and Nouaze, 1985; Velasco, 2007):

$$\mathrm{FI} = \frac{\mathrm{FO} \times \%W}{100}.$$

The species landed by a fishing tactic can be classified (Rosecchi and Nouaze 1985) into low importance (FI < 10), secondary importance ($10 < \mathrm{FI} < 25$), essential ($25 < \mathrm{FI} < 50$), and dominant (FI > 50).

To analyse the extent to which exploitation tactics overlap (an exploitation tactic being the specific composition of landings of each of the fishing tactics identified), the niche or diet overlap index of Horn (1966) was used:

$$R_0 = \frac{\sum\left[(p_{ij} + p_{ik}) \times \log(p_{ij} + p_{ik})\right] - \sum\left[(p_{ij} \times \log(p_{ij}))\right] - \sum\left[p_{ik} \times \log(p_{ik})\right]}{2 \times \log(2)},$$

where R_0 is the Horn index between fishing tactics j and k, and p_{ij} and p_{ik} represent the proportion of species i among the total species landed by trips j and k ($i = 1, 2, 3, \ldots, n$), where n is the total number of species landed by the two fishing tactics. Following the criterion of Wallace (1981), the overlap is significant when the value is >0.6. As described in Velasco (2007), the bootstrap confidence intervals with bias correction were obtained from Horn's index, resampling the original trips and performing 1000 repeat samplings to reach the estimate with 95% confidence intervals.

Affinity among harbours

Otter trawl fishing trips in the Cantabrian Sea typically last 1 or 2 days, so the fishing grounds are near the landing harbour (Figure 1). Hence, by analysing the type of fishing tactics by harbour, it is possible to determine whether specific vessels behaved differently depending on the working area or the landing harbour. For this purpose, we used the matrix of percentages of trips of each fishing tactic landed at each port in the last 5 years of the study period (2000–2004) for which information was available for all harbours. First, an ordination analysis (PCA or CA, depending on the criteria described previously) was conducted, before building a hierarchical cluster using the Euclidean distance as a coefficient of dissimilarity for the construction of the entrance matrix. To choose an optimum value of k (cluster number), the standardized version of the fusion coefficients, Mojena's dissimilarity, was used (Mojena, 1977).

Fleet identification

Only those vessels for which all technical characteristics were known were selected for the final matrix. Given that the time-series covered was $>$20 years, the technical characteristics of some of the vessels registered in the database could not be recovered, so of the 240 vessels for which landings by trip were available, information on 212 (88%) was used. The variables used for the analysis were the year of construction, gross registered tonnage (grt), horse power (hp), and length (m).

As before, an ordination analysis (PCA or CA) was performed before the classification analysis, which allowed us to establish the relationships between the variability of the technical characteristics of the fleet and the relationship or affinity among vessels. To prevent deviations in the results attributable to the difference in the magnitude of each of the variables, univariate standardization was performed. After carrying out the ordination analysis and identifying affinities among vessels, a PAM was used to identify and classify the vessels into homogeneous groups (Punzón *et al.*, 2004). As a criterion for selecting the number of clusters, the OSW was used.

To identify whether there was any relationship between fleets and fishing tactics, a Fisher exact test was conducted on the matrix of proportions of number of trips made by each of the types of fleet.

Results

Identification and characterization of fishing tactics

Different final configurations of 2–10 groups were tested, and the optimum number of groups was 4, according to the OSW, which gave a value of 0.41 (silhouette coefficients for the different final configurations, from 2 to 10: 0.34, 0.32, 0.41, 0.32, 0.33, 0.27, 0.26, 0.28, 0.28), indicating a weak structure according to Struyf *et al.* (1996). The value of the PSW for the first three groups was $<$0.5 (0.28, 0.43, and 0.49), and for group 4, it was 0.74.

Table 2 shows the specific characterization for each cluster; 34.9% of the trips were in Group 1 (PSW = 0.28), a cluster that does not contain any notable species in terms of percentage by weight. The most important species was that denoted "Others" (31.9%), followed by monkfish (13%), horse mackerel (11%), and blue whiting (9%). In terms of the FO, hake, monkfish, and megrim were landed in ~90% of trips. However, despite its percentage by weight of just 3.4%, Norway lobster was landed in

Table 2. Species composition by fishing tactic in terms of percentage by weight, frequency of occurrence, and feeding index.

Taxon	Percentage in weight				Frequency of occurrence				Feeding index			
	1 (T_MIX)	2 (T_WHB)	3 (T_HOM)	4 (T_MAC)	1 (T_MIX)	2 (T_WHB)	3 (T_HOM)	4 (T_MAC)	1 (T_MIX)	2 (T_WHB)	3 (T_HOM)	4 (T_MAC)
Trisopterus luscus (BIB)	3.8	1.5	1.4	0.3	50.9	36.2	54.3	41.6	1.9	0.5	0.8	0.1
Conger conger (COE)	0.9	0.5	0.2	0.1	52.5	48.0	36.7	20.4	0.5	0.2	0.1	0.0
Merluccius merluccius (HKE)	7.6	3.9	3.5	1.3	92.1	87.4	87.6	76.5	7.0	3.4	3.1	1.0
Trachurus trachurus (HOM)	11.3	10.4	63.4	15.3	63.2	69.5	100.0	81.6	7.2	7.2	63.4	12.4
Lepidorhombus spp. (LEZ)	7.9	2.9	2.2	0.7	91.5	80.8	77.8	70.4	7.2	2.3	1.7	0.5
Scomber scombrus (MAC)	3.8	3.4	9.4	75.8	32.1	37.4	66.5	100.0	1.2	1.3	6.3	75.8
Lophius spp. (MNZ)	13.3	5.6	3.0	1.3	95.0	89.5	82.8	74.7	12.7	5.0	2.5	1.0
Nephrops norvegicus (NEP)	3.4	2.1	0.7	0.1	62.1	69.1	41.0	19.7	2.1	1.5	0.3	0.0
Octopodidae (OCT)	5.0	2.7	2.4	0.8	78.0	77.5	77.6	67.6	3.9	2.1	1.8	0.5
Scyliorhinus caniculus (SYC)	1.2	0.5	0.4	0.1	43.7	33.2	41.9	27.5	0.5	0.2	0.2	0.0
Micromesistius poutassou (WHB)	9.9	62.0	9.1	3.0	72.4	100.0	75.5	54.0	7.2	62.0	6.8	1.6
Others (XXX)	31.9	4.6	4.3	1.1	94.0	81.4	84.1	76.7	30.0	3.8	3.6	0.9

62% of the trips. None of the species could be considered essential or dominant according to the FI.

Group 2 consisted of 29.2% of the trips (PSW = 0.43), and 62% of the landings by weight were blue whiting, and 10% were horse mackerel. In terms of FO, blue whiting was landed in 100% of the trips in this group and was the only species that could be considered dominant according to the FI. The balance of species taken can be considered as secondary ones.

Group 3 contained 31.5% of the trips (PSW = 0.49), and the main species by weight, FO, and FI was horse mackerel, which was landed in all trips and made up 60% of the landings weight in the trips sampled. The FI of horse mackerel was >50, so it can be considered a dominant species, and the balance of species caught can be considered secondary.

In the trips classified as Group 4 (4.3% of trips, and PSW = 0.74), mackerel was landed in all trips and was the dominant species by weight in 75% of the landings. Also, according to the FI, mackerel can be considered the dominant species. The second most important species in terms of percentage by weight was horse mackerel, which contributed 15% of the landings and was landed in >80% of the trips sampled.

As an OSW <0.5 was obtained, an ordination technique was performed to corroborate the final configuration. The value of the length of the slope of the first axis was >4, so a CA (Figure 2) was carried out. The eigenvalues were I = 0.49, II = 0.37, III = 0.35, and IV = 0.26, and the cumulative explained variance of the first four axes was 70% (I = 23.6%, II = 18%, III = 17%, IV = 11.43%).

In a combined reading of the first two axes (Figure 2), the structure as a function of target species was similar to that described by the non-hierarchical cluster analysis. There was high correlation between variables and each of the axes (Table 3), in both cases negative, of axis I with mackerel ($r = -0.75$) and horse mackerel ($r = -0.65$). For blue whiting, there was a high negative correlation with axis II ($r = -0.79$). Axis III had a similar pattern to axis I, but with a lower correlation coefficient, with horse mackerel and mackerel ($r = 0.66$ and $r = -0.53$, respectively). Axis IV only showed a positive correlation with the "Others" group ($r = 0.64$), and more moderately and negatively with Norway lobster ($r = -0.55$).

Figure 2 is a bi-plot of the CA, and trips are represented by the type of trip to which they were assigned. The results and the descriptions obtained by both methodologies were similar. The trips assigned to Group 1, for which the lowest silhouette coefficient was obtained, overlapped with the remaining trip types on the bi-plot. In the other three types of trip, this overlap was lower and all were defined by the species described previously per type, trip type 2 by blue whiting, type 3 by horse mackerel, and type 4 by mackerel.

In summary, the tactics defined were: T_MIX (cluster 1), mixed fishing tactic; T_WHB (cluster 2), blue whiting fishing tactic; T_HOM (cluster 3), horse mackerel fishing tactic; and T_MAC (cluster 4), mackerel fishing tactic. Table 4 lists the values of Horn's diet overlap index among the four fishing tactics identified. According to the criterion of Wallace (1981), from which values >0.6 are taken to indicate overlapping, the only fishing tactic that does not overlap with any of the others (except T_HOM) is the one targeting mackerel (T_MAC). This fishing tactic has the highest PSW and is therefore the best defined. The overlap was significant among the rest of the fishing tactics, T_MIX, T_WHB, and T_HOM.

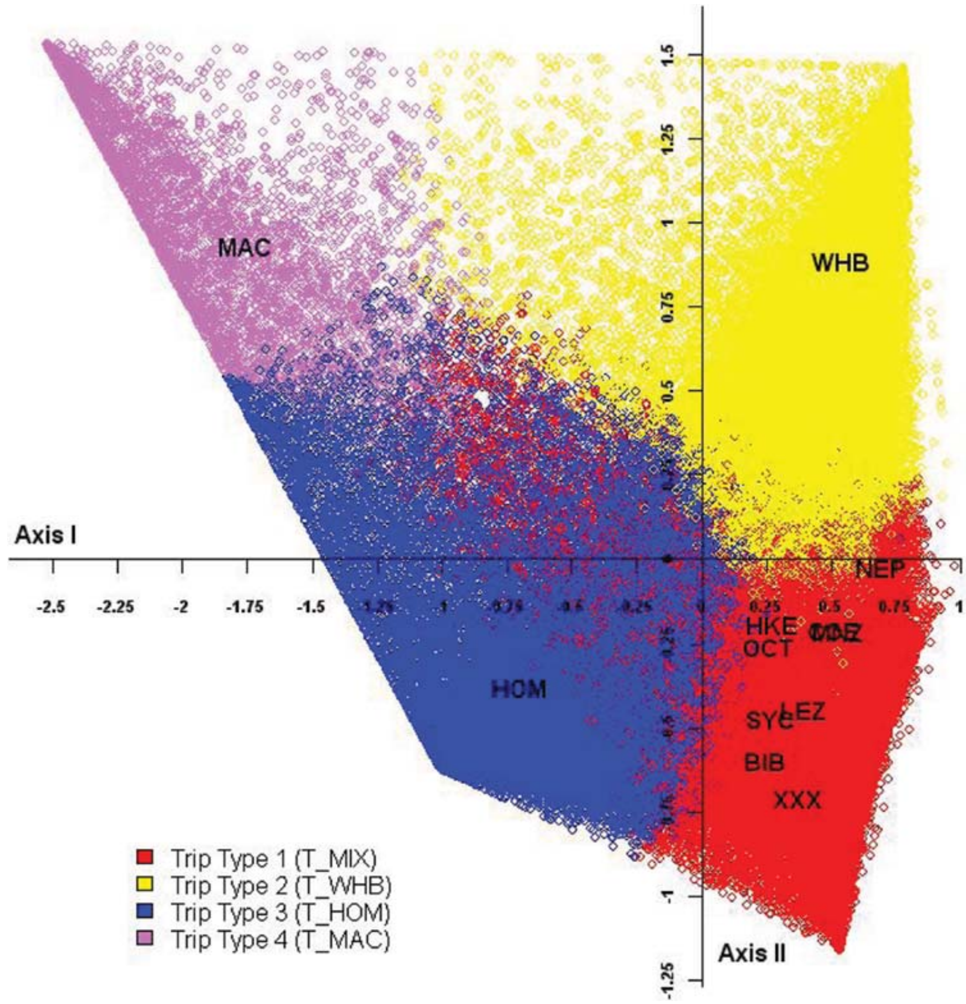

Figure 2. CA with the trips identified according to the cluster or fishing tactic to which they were assigned (explained variance: I = 23.6% and II = 18%). Species codes are listed in Table 2.

Table 3. Correlation between variables (species in landings) and the first four axes of the CA.

Taxon	Axis I	Axis II	Axis III	Axis IV
BIB	0.11	0.26	−0.12	0.27
COE	0.24	0.1	−0.16	−0.2
HKE	0.21	0.14	−0.22	−0.36
HOM	−0.65	0.35	0.66	−0.09
LEZ	0.28	0.32	−0.33	−0.07
MAC	−0.75	−0.4	−0.53	0.04
MNZ	0.39	0.16	−0.37	−0.6
NEP	0.33	0.01	−0.19	−0.55
OCT	0.17	0.17	−0.16	−0.14
SYC	0.1	0.17	−0.1	0.15
WHB	0.48	−0.79	0.33	0.19
XXX	0.27	0.51	−0.35	0.64

Codes for the species are listed in Table 2.

Evolution of fishing tactics over time and season

The percentage of trips by port and fishing tactic was calculated with the aim of identifying changes in the pattern of fishing tactics by port and the total over time (Table 5). From 1998, a large decline was observed in the relative importance of the fishing tactic targeting blue whiting (T_WHB), from 20–45% in 1998 to less than 7% in 2004. Despite the unavailability of data from the same time-series for all ports, which might have led to an impoverished final image of their extent of specialization, the trend was the same in the two ports for which the longest series is available (Avilés and A Coruña), and it is also noticeable in most of the ports for which the series is short. For the fishing tactic targeting mackerel (T_MAC), there was an increase in the relative importance of this species from 1999.

Table 4. Horn's diet overlap index and the confidence limits for each of the combinations of fishing tactics.

Tactic	Horn's index	Confidence interval
T_MIX–T_WHB	0.728	0.725–0.732
T_MIX–T_HOM	0.698	0.694–0.701
T_MIX–T_MAC	0.445	0.437–0.451
T_WHB–T_HOM	0.671	0.668–0.674
T_WHB–T_MAC	0.421	0.415–0.427
T_HOM–T_MAC	0.651	0.644–0.657

Horn's index >0.6 overlapping between fishing tactics.

In trips for which the dominant species was horse mackerel (T_HOM), there was no trend in the series considered (from 25

Table 5. Percentage of each fishing tactic by year and port, and the total.

	Santander				Avilés				Gijón				Burela			
Year	**T_MIX**	**T_WHB**	**T_HOM**	**T_MAC**	**T_MIX**	**T_WHB**	**T_HOM**	**T_MAC**	**T_MIX**	**T_WHB**	**T_HOM**	**T_MAC**	**T_MIX**	**T_WHB**	**T_HOM**	**T_MAC**
1983	–	–	–	–	36.1	27.7	35.1	1.1	–	–	–	–	–	–	–	–
1984	–	–	–	–	37.5	19.9	41.3	1.2	–	–	–	–	–	–	–	–
1985	–	–	–	–	26.2	37.6	35.9	0.4	–	–	–	–	–	–	–	–
1986	–	–	–	–	43.6	26.6	26.8	3	–	–	–	–	–	–	–	–
1987	–	–	–	–	40.9	30.1	28.6	0.4	–	–	–	–	–	–	–	–
1988	–	–	–	–	38.9	38.9	21.1	1.2	–	–	–	–	–	–	–	–
1989																
1990	–	–	–	–	39.2	24.3	30	6.5	–	–	–	–	–	–	–	–
1991	–	–	–	–	46.7	23.7	24.6	4.9	–	–	–	–	–	–	–	–
1992	–	–	–	–	55.4	12.8	28.8	3	–	–	–	–	–	–	–	–
1993	–	–	–	–	60.1	1.3	37.3	1.3	–	–	–	–	–	–	–	–
1994																
1995	–	–	–	–	59	5.6	29.2	6.2	–	–	–	–	–	–	–	–
1996																
1997																
1998	92.3	7.5	0.2	0	87.3	0.9	6.4	5.5	34.2	21.2	42.8	1.8	–	–	–	–
1999	95.4	4	0.6	0	72.8	1.4	15.2	10.5	39.7	15.7	39.2	5.4	–	–	–	–
2000	93.4	6.2	0.4	0	55.6	4.5	11.1	28.8	56.3	9.2	27.5	7.1	45.7	5.6	35.8	12.9
2001	85.2	8.7	6.1	0	58.1	1.2	22	18.7	36.9	9.4	48.1	5.6	21.9	8.4	57.4	12.2
2002	91.2	6.5	2.3	0	66.6	0.3	8	25.2	60.6	4.3	27.7	7.4	30.1	2.9	51.3	15.7
2003	94.7	0.4	1.6	3.2	82.3	1.1	3.8	12.8	73.7	6.3	12.4	7.6	46.5	1.5	33.3	18.6
2004	98	0	0.8	1.2	86.1	0.3	4.6	9	66.1	14.1	17.6	2.3	47.5	2	34.4	16.1

	Celeiro				A Coruña				Total			
Year	**T_MIX**	**T_WHB**	**T_HOM**	**T_MAC**	**T_MIX**	**T_WHB**	**T_HOM**	**T_MAC**	**T_MIX**	**T_WHB**	**T_HOM**	**T_MAC**
1983	–	–	–	–	–	–	–	–	36.1	27.7	35.1	1.1
1984	–	–	–	–	–	–	–	–	37.5	19.9	41.3	1.2
1985	–	–	–	–	–	–	–	–	26.2	37.6	35.9	0.4
1986	–	–	–	–	16.9	56.8	25.2	1.1	26.3	46.3	25.7	1.8
1987	–	–	–	–	39.6	26.6	31.5	2.2	40	27.7	30.6	1.6
1988	–	–	–	–	27.4	48.5	22.5	1.6	30.8	45.6	22.1	1.5
1989	–	–	–	–	27.3	42.1	29	1.6	27.3	42.1	29	1.6
1990	–	–	–	–	20.4	52.4	24.1	3.2	25.4	45	25.6	4
1991	–	–	–	–	23.5	42.1	31.1	3.3	29.5	37.4	29.4	3.7
1992	–	–	–	–	26.4	39.5	33.6	0.5	31.6	34.7	32.7	1
1993	–	–	–	–	17	40.8	41.6	0.6	23.8	34.5	41	0.7
1994	–	–	–	–	22.8	35.7	36.9	4.6	22.8	35.7	36.9	4.6
1995	–	–	–	–	32.3	30.5	33.8	3.5	33	29.8	33.7	3.5
1996	–	–	–	–	30.9	29.8	36.5	2.8	30.9	29.8	36.5	2.8
1997	–	–	–	–	34.7	38.2	24.1	3	34.7	38.2	24.1	3
1998	–	–	–	–	26.8	31.8	35.3	6	37	27.5	30.5	5
1999	–	–	–	–	29	33.2	33.6	4.2	68.3	10.3	16.7	4.7
2000	38.4	3	45.4	13.2	33.5	35.1	22.8	8.6	51	9.1	28.1	11.7
2001	41.9	7.4	47.2	3.5	36.7	11.8	41.9	9.6	36.6	10	43.9	9.5
2002	21.3	2.2	49.6	26.9	47.9	8.1	34.4	9.7	46	5.6	36	12.4
2003	38.8	2.9	57.1	1.3	53.8	8.1	32.7	5.5	55.9	5.2	29.9	9
2004	53.3	0.6	41.8	4.3	54.8	7.2	31.8	6.2	58.8	4.4	27	9.8

to 44%). For Avilés, a decrease in the relative importance of this trip type was observed from 1998 on, although no information is available for 1996 and 1997. Despite the importance of this decrease, the final image of stability may be because from 2000, information from the ports of Burela and Celeiro was made available, ports at which landings of this type of fishing tactic are considerable (Burela supplied the final matrix with a large number of trips; Table 1).

For the mixed fishing tactic (T_MIX), there was an increase in relative importance both when considering all series together and when treating them individually by port. At the end of the series, they contributed >50% of the trips in the final matrix.

To analyse the seasonality of each fishing tactic, the percentages of trips by month were computed (Figure 3). Additionally, to detect whether there had been changes throughout the series, the number of trips made each year, monthly by fishing tactic, were also computed (Figure 3). The fishing tactic targeting mackerel (T_MAC) showed marked seasonality, which was not so evident in the other types of trip analysed. In terms of the fishing tactic targeting horse mackerel (T_HOM), the values were highest during the first half of the year. As for the fishing tactic targeting blue whiting (T_WHB), values were highest in January and February. There was no clear seasonality in the mixed fishing tactic (T_MIX).

Relationships among fleets and fishing tactics

To identify affinities among vessels depending on their technical characteristics, a CA was carried out (length of the slope of the first axis >4; Figure 4). The eigenvalues were I = 0.01 and II = 0.002, and the accumulated explained variance of the first two axes was 99% (I = 85% and II = 14.72%).

Axis I had a high positive correlation with horse power (r = 0.99), whereas the variables that contributed most to axis II were grt and length (r = 0.86 and r = 0.76, respectively). The year of construction did not correlate with either of the axes. Although the fleet was distributed mainly over axis I, in which horse power was the variable that contributed most, affinities between vessels could not be determined so as to be able to estimate the number of types of vessel there were in the series considered. The variables used for the classification analysis as a result of their being the most discriminatory in the ordination analysis were power, grt, and length.

The optimum number of groups with PAM was 2, with an OSW of 0.5, so the structure may be considered reasonable (Struyf *et al.*, 1996). Group 1 consisted of smaller vessels with a mean horse power of 434, a length of 26.7 m, and a gross registered tonnage of 134 (Figure 5), and Group 2 had the largest vessels, with mean characteristics of 547 hp, 32 m length, and 193 grt. The differences between the two groups in terms of length, grt, and hp were significant. Although the year of construction was not included in the analysis, because it had no weight in the affinity between vessels, we included it in the descriptive analysis of both types of fleet, and significant differences were found between the mean year of construction of Group 1 and Group 2 vessels (1980 and 1973, respectively).

Table 6 shows the proportions of number of trips made by each type of fleet by each type of trip. There were no significant differences between the proportions of trips made by each fleet for each type of fishing tactic (p = 0.97).

Affinities among ports

To identify the affinities among ports and years, a PCA was performed (length of the slope of the first axis <3; Figure 6). The eigenvalues were I = 2.1 and II = 1.2, and the accumulated explained variance of the first two axes was 83% (I = 52.6% and II = 30.4%). Axis I was highly negatively correlated with T_MIX (r = −1) trips, and positively with T_HOM (r = 0.91) trips. For axis 2, there was a positive correlation with the trip type T_WHB (r = 0.85).

Axis I discriminated the ports and years whose trips targeted horse mackerel (r = 0.9) from those in which T_MIX trips (r = −1) were more important. Among ports and years on the positive side of this first axis were all years and ports located west of the Cantabrian shelf (Burela, Celeiro, and A Coruña) and on the negative side were those trips in which horse mackerel was of little importance, which corresponded to trips to the eastern Cantabrian shelf (every year from Santander and most years from Gijón and Avilés). Axis II discriminated between the landings of the fishing tactic targeting blue whiting (positive) and those targeting mackerel (negative; Table 7, Figure 6).

Using Mojena's dissimilarity, the mean fusion coefficient was 14.58 and the typical deviation was 11.7. The optimal cutting point was obtained with a k-value of 3.2, for two clusters. The structure was similar to that described previously (Figure 7). To the left of the dendrogram are the ports and years with few trips of type T_HOM and those in which the mixed fishing tactic (T_MIX) was important. To the right, mainly, were the trips targeting horse mackerel. The main difference from the structure put forward by the PCA lay in years 2000, 2001, and 2002 in Avilés, because all years for that port grouped in the cluster characterized by a great importance of the T_MIX trips, whereas in the ordination analysis, they were not well-defined.

Discussion

The definition of the target species of a fishery is normally determined by the combination of the volume of landings and its economic value (Goñi *et al.*, 1999; Stergiou *et al.*, 2003; Ulrich and Andersen, 2004). In the absence of economic information, determination of target species is achieved by establishing limits to the percentage composition of landings (Murawski *et al.*, 1983; Jiménez *et al.*, 2004). The FI used in this study is closely related to that suggested by Biseau (1998) and more recently used by Campos *et al.* (2007). It corrects deviations that arise when considering solely the proportion of landings, especially when dealing with pelagic species, which might be very abundant in certain landings even if the number of trips in which they appear is low.

In the Cantabrian Sea, traditionally just one trawl fishing tactic was operative in an area, but in reality, as shown by this study, there were four types of fishing tactic: aimed at mixed (T_MIX), blue whiting (T_WHB), horse mackerel (T_HOM), and mackerel (T_MAC). The fishing tactic that we refer to as mixed (T_MIX) does not have a target species according to the criterion established by the FI and is also the one with the lowest silhouette coefficient of the four identified. This might place it as an internally heterogeneous group, with little differentiation from the nearest fisheries. The most important "species" in its landings is the group "Others", and this mixture of species occurs for several reasons. On the one hand, the continental shelf where the activity takes place is narrow, between 10 and 60 km from the coast (Sanchez and Olaso, 2004), so a vessel can trawl the whole area of the

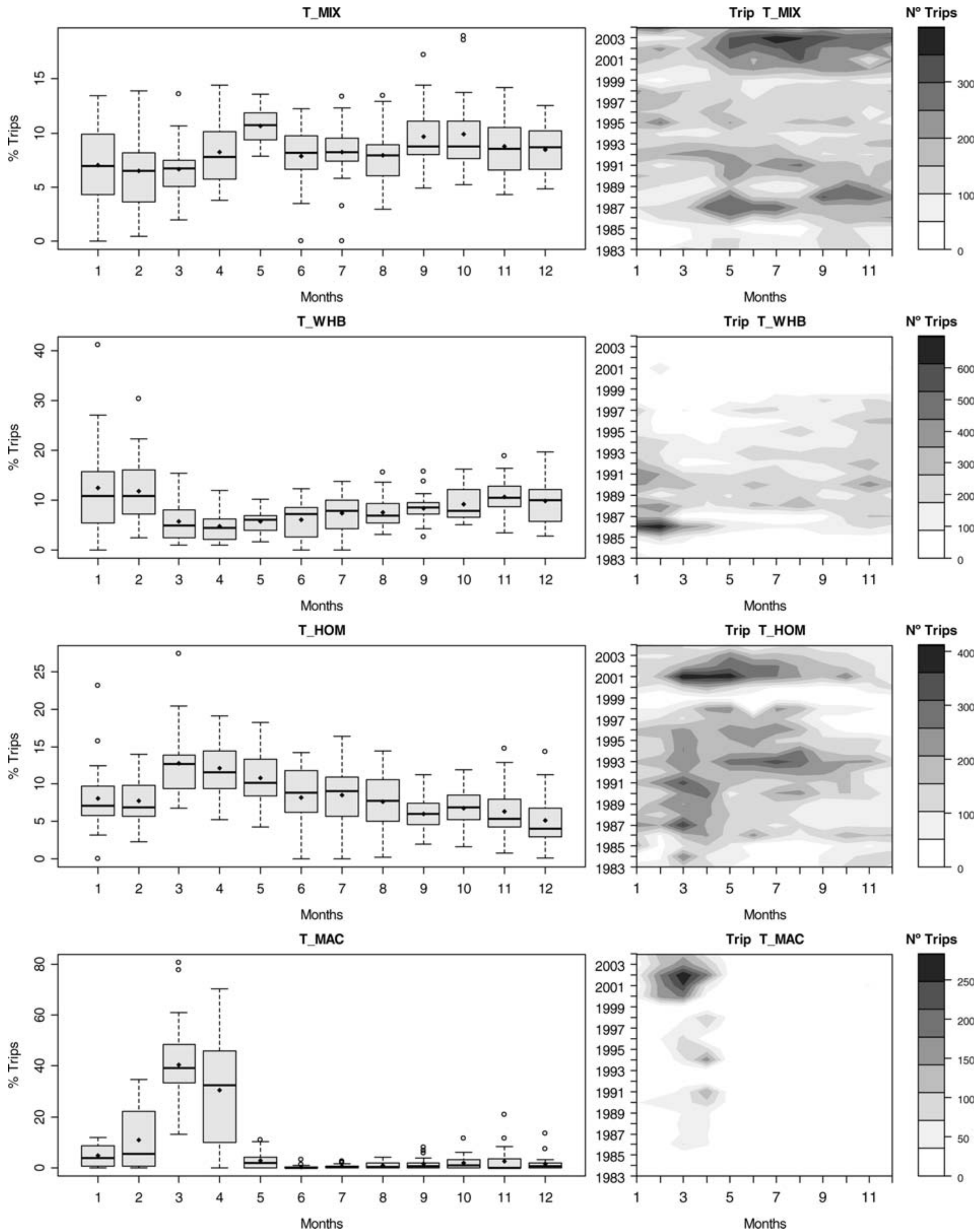

Figure 3. Interannual variation in the number of trips (percentage) by fishing tactic and month (dots indicate mean values and the open circles are outliers).

continental shelf, the slope, and along the coast on the same day or during the same trip. Moreover, many of the species characteristic of the study area and caught by otter trawl have a wide depth distribution which, given the extensive slope of the continental shelf in the Cantabrian Sea, results in notable overlap of niches and species (Olaso, 1989; Sánchez, 1990). On the other hand, it is possible for the gear to be changed during a trip, from the traditional otter trawl to one operating a very high vertical opening (VHVO) trawl (Lema *et al.*, 2006). The target species of otter and VHVO trawls are different, the former targeting hake, megrim, blue

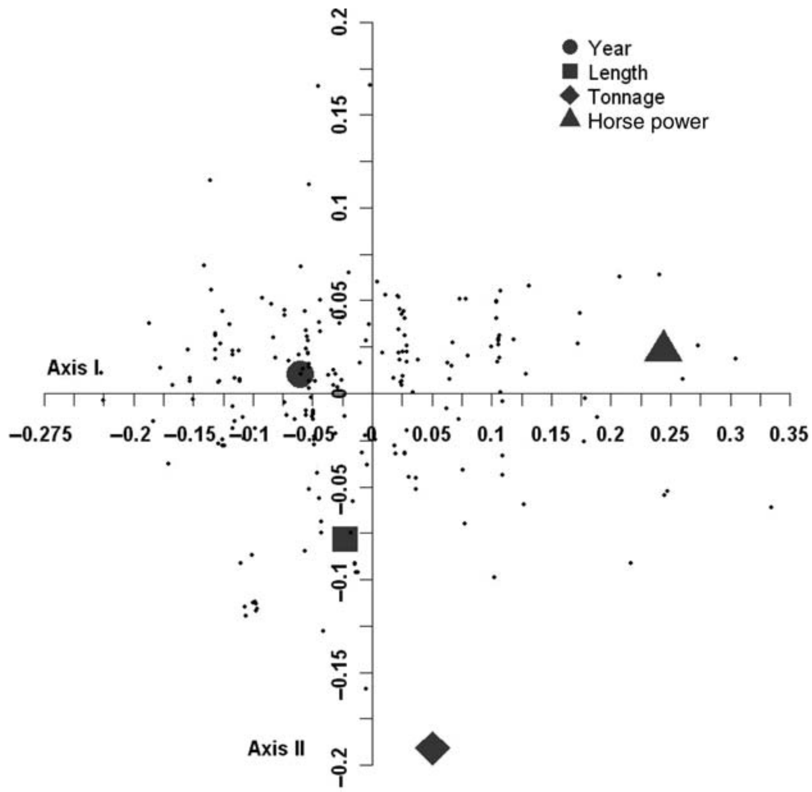

Figure 4. CA of the fleet (explained variance: I = 85% and II = 14.72%).

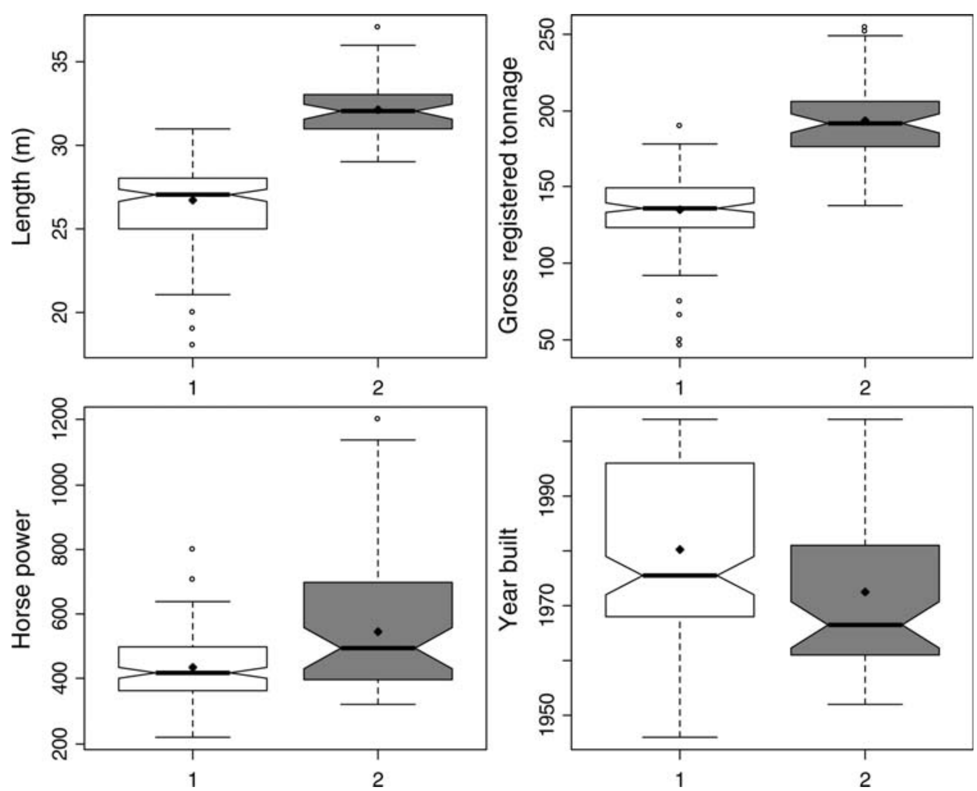

Figure 5. Box diagrams for the two types of fleet identified using the technique of non-hierarchical classification (the notches give an indication of the statistical differences between two batches).

whiting, and horse mackerel, and the latter targeting horse mackerel, blue whiting, and mackerel. This could explain too why in trips in which both types of gear have been used, combinations of species of the types described are caught.

The T_MIX fishing tactic does not show marked seasonality, and although there seem to be more trips in summer, the differences over the rest of the year are not significant. The greater number of trips using this type of fishing tactic during summer may be a consequence of the good yields of some of the target species then, notably Norway lobster (Fariña and Herraiz, 2003). Even if, according to the FI, Norway lobster is not targeted by the T_MIX fishing tactic, it can be considered a target species given its high economic value and the fact that it is now caught virtually only by trawl gear. Moreover, Norway lobster (Olaso, 1989), like spawning hake (Sánchez and Gil, 2000), are found mainly over the outer continental shelf and on the slope, so the activity of the fishery when these resources are targeted may be limited more by weather than by operations closer to shore and port.

Although information for all years from all ports is not available, a decline in the importance of the T_WHB fishing tactic appears to be evident from the late 1990s. For A Coruña, for which the series is more complete, this decline in blue whiting appears from 2001 on. The decrease, amounting to near disappearance, may be the consequence of competition from pairtrawlers, gear that targets blue whiting (Lema *et al.*, 2006) and which yields more per trip than an otter trawl (ICES, 2006a). Between 1999 and 2001, there was a drop in the effort exerted by the otter trawl fleet of some ports, among them Avilés and A Coruña (ICES, 2004), a reduction transferred to pairtrawls, i.e. vessels that previously worked with an otter trawl changed gear and paired with each other. This led to a sharp increase in the effort exerted by pairtrawlers from 2000, as described by Punzón *et al.* (2008). For this reason, the increase in the effort of a gear that is more efficient than an otter trawl in the development of a fishing tactic, such as that targeting blue whiting, may have led to the practical disappearance of the gear with the least yield.

In terms of seasonality, although the T_WHB fishing tactic is in evidence throughout the year, it is most prevalent in winter. This may be because it is complementary to the T_MIX fishing tactic, which operates mainly during summer. In fact, the decline in the importance of trips targeting blue whiting was compensated for by an increase in those targeting mixed species.

The fishing tactic targeting horse mackerel (T_HOM) was important from the beginning of the series, although it seems to have undergone changes in ports such as Avilés, where it has become less important in recent years. Most trips involving this fishing tactic take place during the second quarter of the year, followed by a notable reduction in the last 4 months of the year. This may be a result of the decreasing yields at the end of the year, as suggested by Villamor *et al.* (1997) caused by feeding migrations once the spawning season has ended (Abaunza *et al.*, 2003).

Of the four fishing tactics identified, that targeting mackerel (T_MAC) took the fewest accompanying species. It developed

Table 6. Proportion of number of trips made by each type of vessel and fishing tactic.

Tactic	Fleet 1	Fleet 2
T_MIX	36.4	33.3
T_WHB	28.6	31.0
T_HOM	31.1	31.3
T_MAC	4.0	4.4

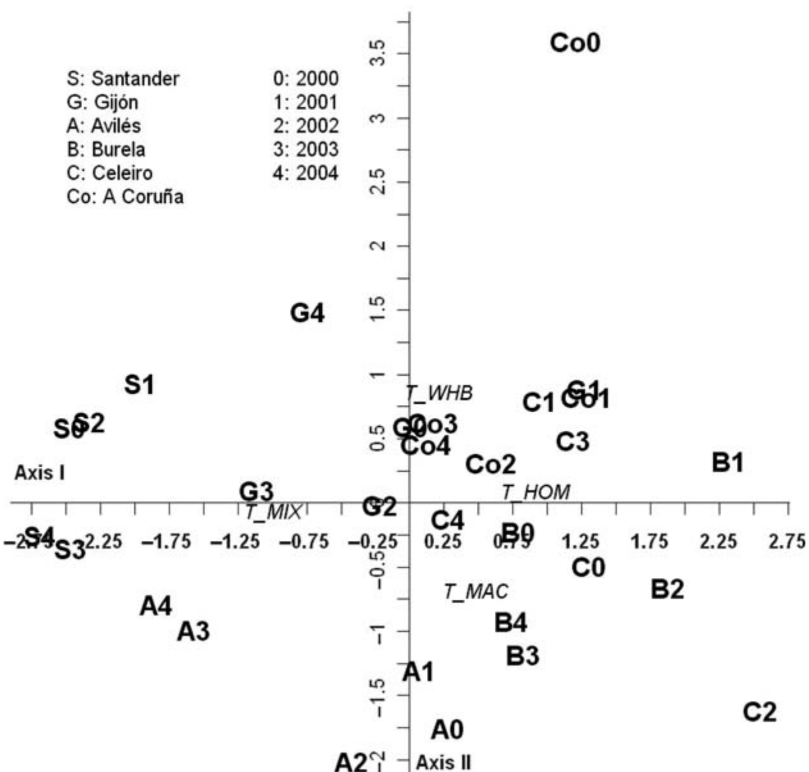

Figure 6. PCA with fishing tactics landed at each port between 2000 and 2004 (explained variance: I = 52.6% and II = 30.4%).

Table 7. Correlation between variables (fishing tactics) and the first two axes of the PCA.

Tactic	Axis I	Axis II
T_MIX	−1	−0.08
T_WHB	0.21	0.85
T_HOM	0.91	0.08
T_MAC	0.48	−0.69

mainly from 2000, perhaps in response to improved market conditions for mackerel (Punzón *et al*., 2004). It takes advantage of the spawning migration of mackerel to the north coast of Spain (Solá *et al*., 1990), as do other fisheries operating in the same areas and targeting mackerel, such as handlining (Punzón and Villamor, 2009) and purse-seining (Villamor *et al*., 1997). The T_MAC fishing tactic starts right at the beginning of the year, when mackerel appear over the eastern Cantabrian Sea continental shelf, and ends around May when the mackerel migrate from the western Cantabrian Sea to feeding areas in Norwegian waters (Villamor *et al*., 1997; Uriarte and Lucio, 2001; Uriarte *et al*., 2001).

For the period for which we have information available from all ports (2000–2004), and assuming the relationship between the proximity to the port of landing and the operating area (Punzón, 2009), there are differences in the behaviour of the fleets depending on fishing area. According to the criteria established by the classification technique, the landing ports of the fleet operating otter trawls are of two types: (i) those in the west of the area (Galician waters), at which landings of the T_HOM fishing tactic are important, and (ii) those in the east (Santander, Gijón, and Avilés), for which the T_HOM fishing tactic is of little importance and is substituted mainly by the T_MIX fishing tactic. Therefore, the ports in the eastern Cantabrian Sea land the fewest trips targeting horse mackerel, except the first 3 years at Gijón. The situation is similar to that described by Lema *et al*. (2006), in which the area where most horse mackerel are discarded is that denominated VIIIc Central, i.e. the continental shelf located in front of the ports there, and where the fleet would tend to operate. Similarly, it is at those ports that proportionally more mixed trips (T_MIX) are landed. This is an area where the continental shelf is narrower (Figure 1), which, as stated earlier, may favour such activity. It must be mentioned that at the port of Avilés in the years before 2000 the number of trips made by the T_HOM fishing tactic was considerable, as stated by Villamor *et al*. (1997).

Despite the low affinity between vessels, two vessel types were identified. The most discriminatory variables according to the DCA were horse power, the variable traditionally used together with fishing days to quantify effort (ICES, 2006a, b), and grt, and the most common vessels throughout the time-series considered were the small vessels, mostly built in the 1980s.

Significant relationships were not found between fleet type and fishing tactic, unlike the situation found for the Iberian Peninsula (Jiménez *et al*., 2004; Campos *et al*., 2007), where there is a relationship between vessel type, through technical characteristics, and fishing tactic. Any vessel, therefore, independently of its technical characteristics could pursue any of the fishing tactics described above.

In summary, of all métiers identified for the otter trawl in Atlantic waters of the Iberian Peninsula, the structure of the fisheries developed using that gear becomes simpler from south to north. For the Gulf of Cádiz (ICES Subdivision IXa South), Jiménez *et al*. (2004) identified 22 fisheries or types of trip, for waters of the Portuguese continental shelf (Subdivision IXa Central), Campos *et al*. (2007) identified six fisheries, and for the Cantabrian Sea, we have identified just four types of fishery. For the Cantabrian Sea, the structure is similar to that described by Campos *et al*. (2007), not only in the number of fisheries, but also in the target species of the fisheries targeting horse mackerel, blue whiting, and mixed species, although the last is of a different nature between the two areas. For the T_MIX fishing

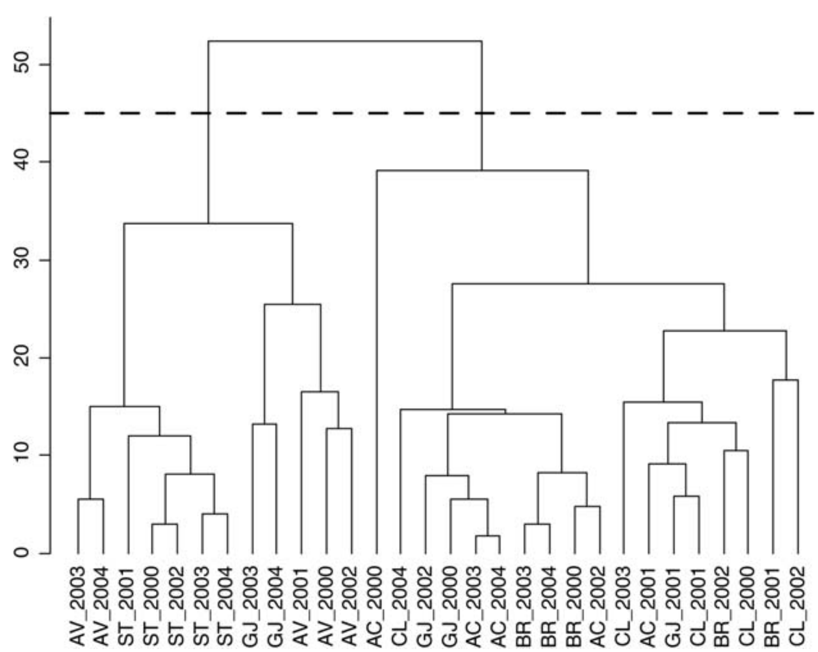

Figure 7. Hierarchical cluster of the types of trip landings at each port each year. The codes on the *x*-axis denote harbour (AC, A Coruña; AV, Avilés; BR, Burela; CL, Celeiro; GJ, Gijón; ST, Santander) and year.

tactic in ICES Subdivision IXa Central, the main species are horse mackerel, mackerel, and blue whiting. In our case, the T_MIX fishing tactic seems to be a combination of the mixed fishing tactic targeting horse mackerel, mackerel, and blue whiting (mainly in surface waters), and that targeting crustaceans (mainly Norway lobster and *Parapenaeus longirostris*) along with hake and blue whiting in deeper water, similar to that described by DCA (axis IV; Figure 2). Considerable overlap was observed among the T_MIX, T_HOM, and T_WHB fisheries when applying Horn's index. Campos *et al*. (2007) similarly described the same fisheries based on the volume of landings caught by each type of fishing tactic. Finally, the fishing tactic targeting mackerel (T_MAC) in Portuguese waters is not described here for our area, but seems instead to be included in the IXa Central mixed fishing tactic.

In addition to the possibility of being impacted by the availability of resources by diversity, quantity, geographic characteristics, or simple economic criteria, the progressive geographic simplification of the otter trawl fisheries from south to north may be due also to the classification technique used. Depending on the cluster technique applied, the sensitivity to atypical elements varies. Hierarchical techniques based on the centroid method are more robust to outliers than other hierarchical techniques (Milligan, 1980). Non-hierarchical techniques are less susceptible to atypical elements than hierarchical ones (Hair *et al*., 1999), and of non-hierarchical techniques, a PAM, on which CLARA is based, is less sensitive to irregular values than a partition around centroids (Anon., 1999). All of this may lead to simplification of fisheries by eliminating poorly represented ones (in terms of number of trips).

The changes detected in the time structure of the fishery may have led to changes in the trends of the calibration indices (i.e. cpue) used by stock assessment groups unrelated to species abundance. These indices are used traditionally under the assumption that a fleet using a certain gear and landings at a certain port behaves similarly throughout, vessels operating in the same way. This study has shown, however, that within one port, the vessels can direct their effort among different métiers. Therefore, cpue series should be computed for each métier, providing more homogeneous indices and yielding trends in cpue that are more representative and independent of the set of fisheries traditionally considered.

Such modifications to the cpue series were mentioned by Preciado *et al*. (2006) and Fariña and Herraiz (2003), who detected abnormal trends in the cpue series. The changes may have been brought about by alterations over time detected in the relative importance of the different fishing tactics, and as a result they may have had some effect on the calibration indices, such as the trawl indices for A Coruña for southern hake and megrim stocks. There, the disappearance of the T_WHB fishing tactic from 2001 on may have altered trends in the two target populations of the fishing tactic we have denominated mixed (T_MIX). For the Avilés fleet, the calibration index used to assess the western population of horse mackerel was omitted from the assessment for reasons of quality (ICES, 2004), perhaps attributable to the large decrease in the fishing tactic targeting horse mackerel in Avilés from 1995.

To summarize, we have identified four métiers in the Cantabrian Sea for the years 1983–2004. The métier denominated mixed and that targeting horse mackerel remained more or less constant throughout the series (except at Avilés). The métier targeting blue whiting has now practically disappeared as a consequence of the increasing pairtrawl effort, and that targeting mackerel, although present throughout the historical series, has become more important since the second half of the 1990s. Differences in the behaviour of the vessels have been identified in the years for which information from all landing ports is available. Moreover, two areas have been identified, those in which trips targeting horse mackerel are important (waters of the western Cantabrian Sea), and those of the eastern Cantabrian Sea, where horse mackerel are scarce. Our results clearly demonstrate that the indices used in calibrating the assessments of stocks exploited by otter trawl in the Cantabrian Sea area need to be reviewed.

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