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Evidence for temporal changes in ray and skate populations in the Portuguese coast (1998–2003) – its implications in the ecosystem

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Abstract – In mainland Portugal, rays constitute an important by-catch of multi-gear shelf fisheries. However and despite their economical importance, landing information discriminated by species is scarce. The relative stability in Portuguese annual landings of rays and skates can be misinterpreted as no evidence for species declines. The present concern on the overexploitation of individual species arises from both theoretical considerations about biological and ecological traits and for historical reasons.
This work constitutes an approach for a retrospective analysis of ray landings in mainland Portugal. Data from research surveys carried along the Portuguese coast was used to infer possible changes in species composition on Portuguese landings. Clusters were determined based on data collected during surveys from species composition for three time-periods, 1989-1991, 1995-1997 and 2001-2003. The relative importance of the associate species within clusters was the input data to define discriminating rules posteriorly used to assign clusters to landings from each commercial vessel. The results show an increase of species relative importance and changes on species abundance: *Raja brachyura* and *Raja clavata* decreased, whilst *Leucoraja naevus*, increased. Furthermore, it was observed a decrease on the mean weight of the two first species and a relative stability in the last one. Such results reflect the importance of species life-history characteristics in particular, on the response to fishing impact.

Key words: Chondrichthyan fish / *Raja* spp. / Associate species / Commercial landings / Surveys / Cluster prediction / Species composition / Temporal changes

Résumé – Évidence de changements chez les populations de raies de 1998 à 2003 des côtes portugaises – conséquences pour l'écosystème. Au Portugal, les raies constitutent d'importantes prises accessoires des pêcheries multi-métiers. Cependant, et en dépit de leur importance économique, les informations sur leur débarquement, distingué par espèce, sont rares. La relative stabilité d'une année à l'autre des débarquements portugais de raies peut être mal interprétée car il n'y a pas dévidence de déclin des espèces. L'intérêt actuel porté à la surexploitation des espèces prises individuellement vient de considérations théoriques à propos de caractéristiques biologiques et écologiques, et pour des raisons historiques. Ce travail constitue une approche d'une analyse rétrospective des débarquements de raies au Portugal. Des données de campagnes de pêche ont été utilisées pour en déduire des changements éventuels dans la composition des espèces dans les débarquements commerciaux portugais. Des groupes ont été déterminés, basés sur des données de composition des captures de 3 périodes de campagnes de pêche, 1989-1991, 1995-1997 et 2001-2003. L'importance relative des espèces associées, à l'intérieur de chaque groupe, a servi de données d'entrée pour définir des règles permettant de distinguer ces groupes ultérieurement, dans les débarquements de chaque chalutier de la pêche commerciale. Les résultats montrent une diminution d'espèces importantes commercialement telles que *Raja brachyura* et *Raja clavata*, tandis que les débarquements de *Leucoraja naevus* augmentent. De plus, il a été observé une diminution du poids moyen des deux premières espèces, mais celui de *L. naevus* est stable. De tels résultats reflètent l'importance des caractéristiques biologiques, mettant en évidence une sensibilité différente à l'impact de la pêche de chacune des espèces de raies.

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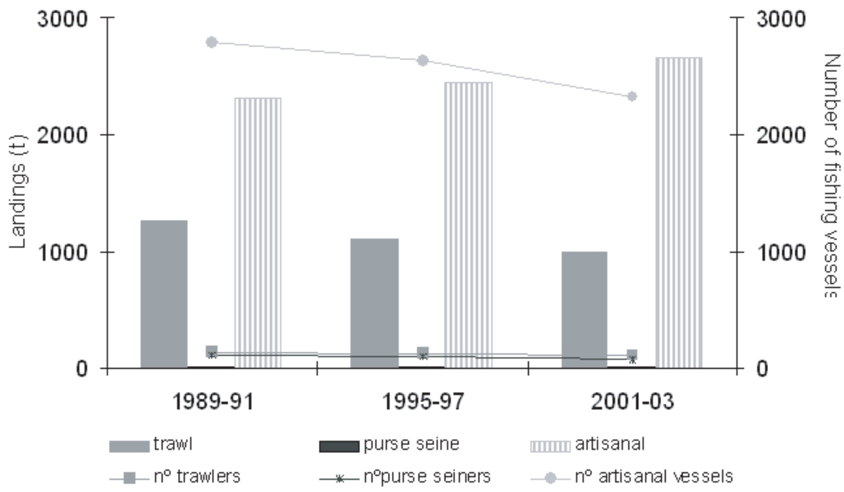

Fig. 1. *Raja* spp. total landings by fleet (*t*-tonnes) and number of vessels with positive landings of Rajidae (in mainland Portugal) for three-time periods (1989–1991, 1995–1997 and 2001–2003).

1 Introduction

In the NE Atlantic, skates and rays contribute more than 40% in weight to the reported landings of Elasmobranchs, but, despite their high importance, statistical information of landings discriminated by species is limited (Walker and Ellis 1998). Rays and skates all together usually exhibit more stable trends in landings than those from other elasmobranch fisheries (Dulvy et al. 2000). Since the middle of the last century, rays and skates caught by Portuguese commercial vessels have been reported at the fish markets under the designation of *Raja* spp. Now, they constitute important by-catches from various Portuguese mixed fisheries, particularly artisanal and trawl segments (Machado et al. 2004). The trawl fleet represents 31% of the total landings of *Raja* spp. while the artisanal fleet approximately 61% (Fig. 1). In recent years, there has been a reduction on the number of vessels but the total landings landing of *Raja* spp. increased as a consequence of the greater economic value of all ray species. Purse seine fleet lands rays occasionally (1% of the total landings).

The lack of species discrimination in landings is a cause of concern, making difficult the evaluation of the status of the different ray species and their sustainability under different fishing pressure (Stevens et al. 2000). This concern is further aggravated by life cycle peculiarities (Walker and Ellis 1998) and seasonal movements associated with different life-stages of rays (Hunter et al. 2006). In the case of highly vulnerable species to exploitation, long periods for recovery of populations subject to high fishing pressures are admitted. Evidences supporting that fact were already documented for some areas, namely North Sea (Walker and Heesen 1996; Walker and Hislop 1998), off the British Isles (Dulvy et al. 2000), in British coastal waters (Rogers and Ellis 2000) and in the Strait of Sicily (Garofalo et al. 2003). In the North Sea, long-term changes in ray populations were evaluated on the analysis of time series information on landings and research surveys (Walker and Hessen 1996). The results indicated changes in species abundance. *Raja radiata* increased and *Raja clavata* disappeared from Dutch coastal areas. Other studies have been conducted using only research surveys information, in order to evaluate the diversity of elasmobranch species and detect changes in abundance over time (Ellis et al. 2005; Dulvy et al. 2006).

The investigation of temporal changes on the composition of Portuguese *Raja* spp. landings is the main objective of this paper. A statistical procedure is developed to infer the species composition of the historical Portuguese *Raja* spp. landings using two main data sources – commercial landing statistics and research surveys. The approach followed presupposes the existence of different assemblages along the Portuguese coast sufficiently dissimilar in terms of biodiversity. The results from cluster and discriminant analyses supported this hypothesis, considering three equally spaced time intervals along the period from 1988 to 2003. Differences on species composition along the time period were obvious. An insight on the fishing impact over rays and skates populations, due to trawling, could also be achieved.

2 Material and methods

2.1 Data sources

The two main data sources were: (1) INIAP-IPIMAR research bottom trawl surveys data carried out from 1989 to 2003 along the Portuguese continental coast. These surveys followed a fixed grid of 97 sampling stations spread throughout the shelf (Sousa et al. 2006). Data from all surveys were converted to numbers and weight caught per hour. Further details about characteristics of the survey methodology and gear characteristics can be found in Cardador et al. (1997). Only the positive fishing hauls were considered. In the present context, positive haul corresponds to a haul in which rays were caught and identified. Under this criteria we only used data from 26 surveys which were divided by three year subgroup: 1989–1991 (number of hauls = 176); 1993–1995 (number of hauls = 125); 2001–2003 (number of hauls = 179). The survey samples were collected at fixed stations, though the number and location varied between years depending on factors such as weather, and presence of static fishing gear or fishing vessels. The information used in each positive haul consists of: i) Species composition, in weight and in number, of rays and skates; ii) Geographic coordinates of the fishing haul middle point (longitude, latitude – WGS84); iii) depth (in meters) and iv) biomass and abundance per trawling hour of each remaining species present in the total catch; (2) *Raja* spp. landings detailed by each trawler, month and port of landing. The data was extracted from the Database of the Portuguese Fisheries and Aquaculture Directorate (DGPA) and each register included: year, month, vessel, landing port and total landings in weight of remaining species. Partition of data by three-year periods.

Data was analysed for three equally spaced time intervals: 1989–1991, 1995–1997 and 2001–2003. These intervals were set in order to guarantee an even partition of data along the whole time interval for which landing data were available. Associated with this partition of time, it was implicitly assumed that the behaviour of variables, under study within each time interval, was similar.

2.2 Identification and mapping of clusters of fishing hauls

For each time interval, the *C*-means clustering procedure was applied to multivariate data set built using the survey information. The input data consisted on the observations (fishing hauls) and the variables were: latitude, longitude, depth, and catches (in weight and in number), per hour of trawling of a group of pre-selected ray and skates species. Species were selected whenever their rate of occurrence in the overall set of fishing hauls was higher than 10%. The exclusion of less frequent species was adopted as a way to avoid the zero inflated problems induced by low frequencies of species occurrence. *C*-means is a fuzzy clustering technique initially proposed by Dunn (1973) and generalized by Bedzek and Hathaway (1988). The fuzzy *C*-means algorithm calculates fuzzy partition matrix to group some data points into *C* clusters. The elements of the partition matrix consist of membership values varying within the interval [0,1] (Bezdek 1981). Fuzzy cluster indexes implemented in e1071R package (Dimitriadou et al. 2005) were calculated and the results used to determine the optimum number of clusters.

Fishing hauls assigned to a specific cluster but located far apart from the cluster's core were excluded. In the present context, cluster's core corresponds to the area where most of fishing hauls belonging to the same cluster were located. The potential lost of information associated with this criterion is partially justified by the main objective of this step – establishment of clusters with a low degree of spatial overlap. Cluster areas mapping was performed in ESRI ArcGIS^{TM} 8.3.

2.3 Establishment of discriminant rules

At the first step "associate species" were selected, by considering the relative importance of different species both in the list of species caught by hauls made during the research surveys and in the commercial landings. In the second case, commercial data was collated from trawlers with positive ray landings.

Discriminant rules by cluster were established using, as input data, the relative weight of the associate species in each survey fishing haul. Mixture discriminant analysis – MDA (Hastie et al. 1995) was used to establish the discriminant rules. MDA is an extension of the linear discriminant analysis (Fisher 1936) and is more adequate for situations for which classes are differentiated through the use of underlying mixture models. In MDA approach, each class is modelled by a mixture of several Gaussian distributions with different centroids but with every Gaussian component, both within and between classes, sharing the same covariance matrix.

2.4 Prediction and estimation of commercial trawl landings by ray species

The discriminant rules were used to predict the class membership of individual trips made by Portuguese trawl fleet with positive landings. Discriminant rules were refined by reapplying the MDA to the data in which the misclassified fishing hauls were excluded. The new discriminant rules were then applied to individual trawlers landing data and cluster membership of each of them predicted. As initial hypothesis, it was expected that fishing vessels would preferentially target areas close to the ports where their landings occur.

Estimation of the composition of *Raja* spp. landed, both in terms of species and total weight caught, using the results of the skate species composition in each cluster (weight relative importance) and the extrapolation for the total weight of *Raja* spp. landed by vessel.

Comparative analysis of species abundance and diversity estimated from landings between the three time periods was performed. Surveys data was also used to infer the mean weight of the main species and its tendency in the period under study. An analysis of variance (ANOVA) was performed, for each species to evaluate, the existence of significant differences between periods (significance level adopted 5%).

3 Results

The clusters are identified at each three-year time period (Fig. 2). For each period, six clusters were identified although the geographic limits differed between them. The clusters defined are probably related to special geologic and hydrologic conditions occurring along the coast. Nazaré, Lisbon and Sines are important limits for the definition of clusters in all the time periods. Considering the whole Portuguese coast, the number of clusters is higher in the southwest. After the species composition of Rajidae (Tables 1, 2 and 3), *Raja brachyura* and *R. clavata* are the more common species not only in all the time periods, but also in the majority of the identified clusters.

The relative abundance and biomass of associate species caught in fishing hauls also varied between clusters. However, some associate species were quite common in all clusters, such as the snipefish (*Macroramphosus* spp.),

Table 1. 1989–1991. Geographic area, depth range (in m) and species composition of rays and skates covered by each cluster. Other representative species, included in fishing hauls that compose each cluster, are listed on the last column by decreasing order of relative importance**.** A – Whole coast; B – Whole occidental coast; C – Occidental coast: northern region; D – Occidental coast: northern and centre regions; E – Occidental coast: centre and southern regions; F – Occidental coast: centre and southern regions and Algarve region; G – Occidental coast: southern region and Algarve region.

Area	Depth range (m)	Ray species	Main associate species
A	100–140	*R. clavata* *R. miraletus*	*Micromesistius poutassou; Trachurus trachurus; Macroramphosus spp.; Merluccius merluccius; Pagellus acarne; Lepidopus caudatus; Zeus faber; Boops boops.*
B	50–120	*R. brachyura* *R. clavata* *R. miraletus*	*Macroramphosus* spp.; *Merluccius merluccius; Trachurus trachurus; Micromesistius poutassou; Pagellus acarne; Trisopterus luscus; Sardina pilchardus; Zeus faber.*
C North of Lisbon	120–170	*R. clavata* *R. brachyura*	*Macroramphosus* spp.; *Micromesistius poutassou*; *Capros aper*; *Zeus faber*; *Merluccius merluccius*; *Trachurus trachurus*; *Sardina pilchardus*; *Trisopterus luscus*.
D North of Sines	130–200	*R. clavata* *R.microocellata* *R.brachyura* *R. miraletus;* *R. montagui*	*Macroramphosus* spp.; *Micromesistius poutassou; Merluccius merluccius; Trachurus trachurus; Zeus faber; Capros aper; Trachurus picturatus; Pagellus acarne.*
F South of Peniche	50–110	*R. brachyura*	*Macroramphosus* spp.; *Capros aper; Trachurus trachurus; Trachurus picturatus; Pagellus acarne; Merluccius merluccius; Boops boops; Loligo vulgaris.*
G	170–330	*L. naevus* *R. brachyura* *R. miraletus* *R. clavata*	*Micromesistius poutassou; Capros aper; Merluccius merluccius; Lophius budegassa; Helicolenus dactylopterus; Boops boops; Galeus melastomus; Zeus faber.*

Table 2. 1995–1997. Geographic area, depth range (in m) and species composition of rays and skates covered by each cluster. For abbreviations, see legend to Table 1.

Area	Depth range (m)	Ray species	Main associate species
A	110–280	*L. naevus* *R. miraletus* *R. clavata* *R. brachyura* *D. oxyrinchus*	*Macroramphosus* spp.; *Capros aper; Trachurus trachurus; Merluccius merluccius; Galeus melastomus; Pagellus acarne; Scomber japonicus; Sardina pilchardus.*
D North of Sines	100–150	*R. clavata* *R. brachyura* *L. naevus*	*Macroramphosus* spp.; *Micromesistius poutassou; Trachurus trachurus; Capros aper; Merluccius merluccius; Scyliorhinus canícula; Scomber japonicus; Trisopterus luscus*
D North of Sines	140–250	*R. clavata* *R. brachyura* *R. montagui* *L. naevus*	*Capros aper; Micromesistius poutassou; Merluccius merluccius; Trachurus trachurus; Macroramphosus* spp.; *Trachurus picturatus; Helicolenus dactylopterus; Galeus melastomus.*
E South of Lisbon	50–100	*R. brachyura* *R. clavata* *D. oxyrinchus*	*Macroramphosus* spp.; *Capros aper; Pagellus acarne; Trachurus trachurus; Scyliorhinus canicula; Scomber japonicus; Scomber scombrus; Merluccius merluccius.*
F South of Lisbon	70–120	*R. clavata* *L. naevus* *R. brachyura* *R. miraletus* *R. montagui* *D. oxyrinchus*	*Capros aper; Macroramphosus* spp.; *Trachurus trachurus; Merluccius merluccius; Serranus hepatus; Pagellus acarne; Stichopus tremulus; Scyliorhinus canicula.*
F	120–200	*R. clavata* *L. naevus* *R. miraletus* *D. oxyrinchus* *R. brachyura* *R. montagui*	*Macroramphosus* spp.; *Serranus hepatus; Capros aper; Solea solea; Scyliorhinus canícula; Micromesistius poutassou; Merluccius merluccius; Lepidotrigla cavillone.*

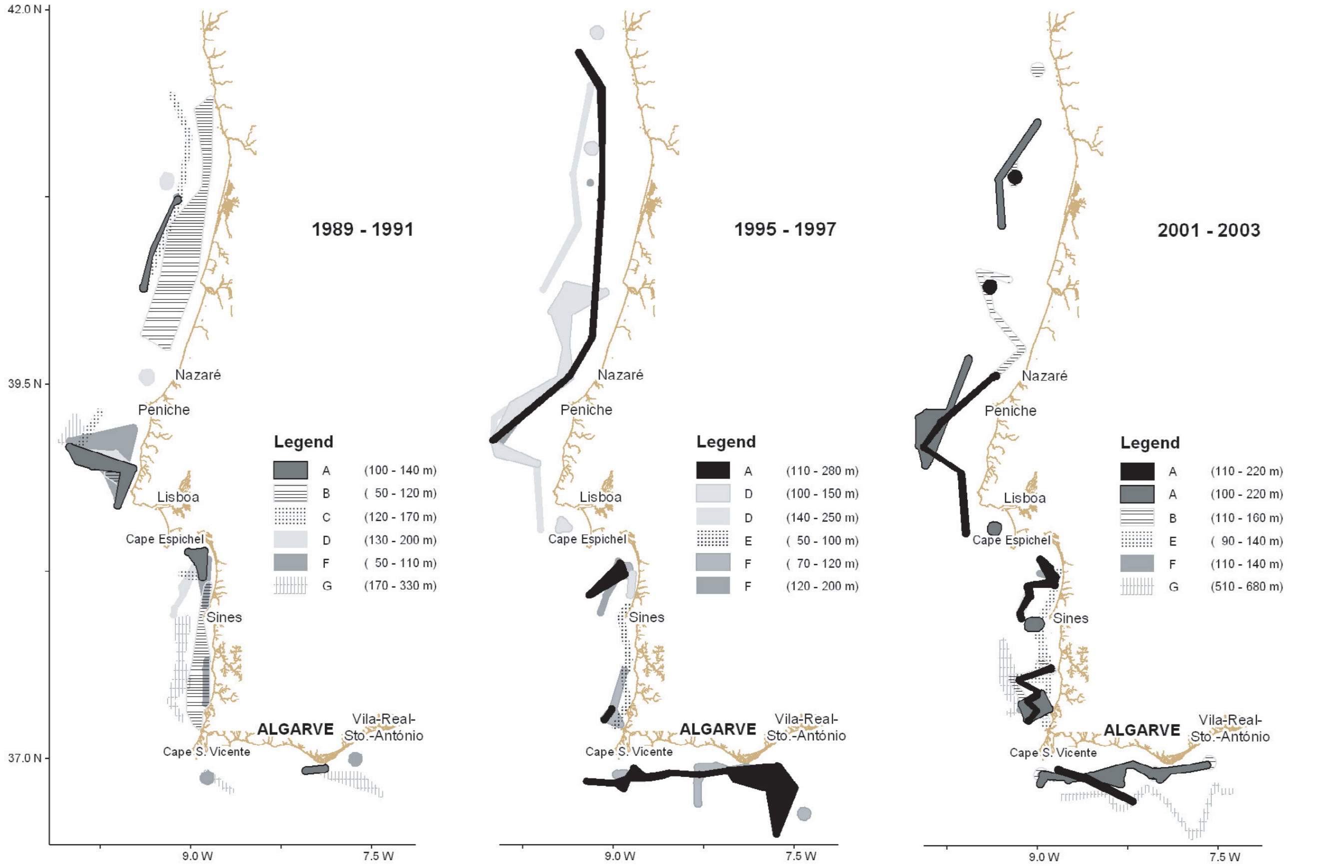

Fig. 2. Rajidae. Spatial distribution of the clusters in the three time periods. A – Whole coast; B – Whole occidental coast; C – Occidental coast: northern region; D – Occidental coast: northern and centre regions; E – Occidental coast: centre and southern regions; F – Occidental coast: centre and southern regions and Algarve region; G – Occidental coast: southern region and Algarve region.

boarfish (*Capros aper*), Atlantic horse mackerel (*Trachurus trachurus*), hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), pouting (*Trisopterus luscus*) and axillary sea-bream (*Pagellus acarne*). Although being species with high relative importance, *Macroramphosus* spp. and *Capros aper* were excluded from the analysis, as they represent a group of low commercial value and commonly discharged at the sea. The list of associate species used to establish the discriminant rule is presented (Table 4). For each time period, discriminant rules defined had a low error of misclassification (<10%).

The application of these rules to data on the associate species from commercial trawlers allowed to estimate the landings *Raja* spp. discriminated by species, which altogether represent nearly 30% of the total landings of this generic group in the Portuguese continental coast (31% in 1989-91; 36% in 1995-97 and 27% in 2001-03).

The clusters assigned to each landing were, in some cases, located far away from the landing port (Table 5). For example in the first time period some landings at the eastern side of Algarve were assigned to the cluster located at south occidental coast (OcS). A closer analysis of species composition showed that red shrimp, *Aristeus antennatus* constituted a great fraction of the landing, which is a species particularly abundant in south occidental coast (Figueiredo et al. 2001). Other examples were, for instance, the assignment of landings taken placed at the north occidental coast to clusters located at the south. A closer inspection of the behaviour of the fishing vessels indicated that those vessels commonly landed in southern ports. This apparent lack of spatial proximity between landing ports and fishing grounds, determined that for the analysis of the diversity and the landings of rays species the landing port is not an adequate variable. Consequently, landing ports were not considered and the analysis was restricted to the evaluation and comparison, between three-year periods, of ray species composition estimated from total *Raja* spp. landings.

The landing weights are estimated for each ray species in each of the three time periods (Fig. 3).

An increase on species diversity is obvious, from the first to the third period, and also a decrease of the relative importance of *R. brachyura* and *R. clavata* and a small increase of *Leucoraja naevus*. Concurrently with these trends, changes on the estimates of the mean weight of these species were registered (Fig. 4). The decrease in *R. brachyura* was statistically significant in the three time periods (F-test, $p < 0.05$). A slight decrease in was detected in *R. clavata*, although this was not statistical significant (F-test, $p > 0.05$). No trend was registered in *L. naevus* (F-test, $p > 0.05$).

Table 3. 2001–2003. Geographic area, depth range (in m) and species composition of rays and skates covered by each cluster. For abreviations, see legend to Table 1.

Area	Depth range (m)	Ray species	Main associate species
A	110–220	*R. clavata* *R. alba* *R. brachyura* *R. montagui* *D. oxyrinchus* *R. miraletus* *L. circularis* *R. microocellata*	*Capros aper; Macroramphosus* spp.*; Micromesistius poutassou; Merluccius merluccius; Scyliorhinus canícula; Lepidotrigla cavillone; Zeus faber; Pagellus acarne.*
A	100–220	*R. clavata* *R. miraletus* *L. naevus* *R. undulata* *L. circularis* *R. montagui*	*Micromesistius poutassou; Capros aper; Merluccius merluccius; Pagellus acarne, Serranus hepatus; Macroramphosus* spp.*, Scyliorhinus canícula; Trachurus trachurus.*
B	110–160	*R. clavata* *R. brachyura* *D. alba* *R. montagui* *L. naevus* *D. oxyrinchus* *R. miraletus*	*Microchirus variegatus; Macroramphosus* spp.*; Trachurus trachurus; Pagellus acarne; Merluccius merluccius; Sardina pilchardus; Zeus faber; Serranus hepatus.*
E South of Lisbon	90–140	*L. naevus* *R. montagui* *R. alba* *R. brachyura* *R. undulata*	*Mullus barbatus; Microchirus variegatus; Trigla lucerna; Microchirus azevia; Trichiurus lepturus; Hyperoplus lanceolatus; Hoplostethus mediterraneus.*
F South of Lisbon	110–140	*R. clavata* *L. naevus* *R. brachyura* *R. miraletus*	*Lepidotrigla cavillone; Scyliorhinus canícula; Macroramphosus spp., Trachurus trachurus; Trigla lyra; Pagellus acarne; Merluccius merluccius; Lepidorhombus boscii.*
G South of Sines	510–680	*L. circularis* *R. clavata* *L. naevus* *R. montagui* *D. oxyrinchus* *R. brachyura* *R. undulata*	*Galeus melastomus; Helicolenus dactylopterus; Micromesistius poutassou; Chlorophthalmus agassizi; Scyliorhinus canícula; Gadiculus argenteus; Capros aper; Hoplostethus mediterraneus.*

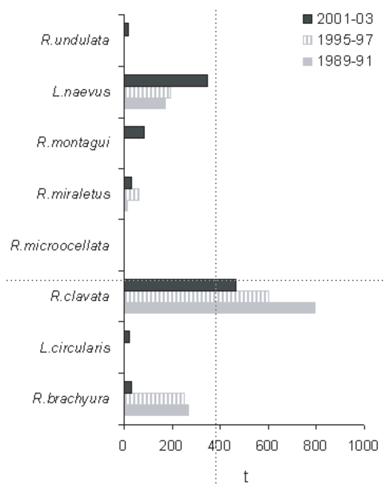

Fig. 3. Estimation of the ray species composition and total landed in weight for each time period.

4 Discussion

The results gave support to the initial hypothesis that data on the composition of associate species of landings from trawlers with positive catches of rays was sufficient to make the assignment to clusters established from surveys.

The geographic distributions of clusters overlapped and reflect the topography and hydrographic conditions that characterize the Portuguese coast. Interesting to note that the geographic limits (Nazaré, Lisboa, Sines, Cape São Vicente) of clusters reflected important topographic features known to determine the subdivision of the Portuguese continental coast into different regional areas (Cunha 2001). At the occidental coast from northwards down to Nazaré canyon, the continental shelf is flat and wide. Between Nazaré and the system of Lisboa/Setúbal canyons, the shelf is more irregular and the coastline shows a westward protrusion, the Estremadura headland that acts as a barrier to the northward progression of the subtropical component of the Eastern North Atlantic

Table 4. List of associate species selected in each three-year period to establish the discriminant rules.

1989–1991	1995–1997	2001–2003
Conger conger	*Lepidotrigla cavillone*	*Alloteuthis* spp.
Alloteuthis spp.	*Loligo* spp.	*Boops boops*
Boops boops	*Lophius* spp.	*Conger conger*
Loligo spp.	*Merluccius merluccius*	*Eledone cirrosa*
Lophius spp.	*Micromesitious poutassou*	*Helicolenus dactylopterus*
Merluccius merluccius	*Octopus vulgaris*	*Lepidorhobus boscii*
Micromesitious poutassou	*Pagellus acarne*	*Loligo* spp.
Mullus surmuletus	*Sardina pilchardus*	*Merluccius merluccius*
Octopus vulgaris	*Scomber japonicus*	*Microchirus azevia*
Pagellus acarne	*Scomber scombrus*	*Micromesitious poutassou*
Pagellus bogaraveo	*Scyliorhinus spp.*	*Mullus surmuletus*
Pagrus pagrus	*Sepia officinalis*	*Octopus vulgaris*
Sardina pilchardus	*Trachurus picturatus*	*Pagellus acarne*
Scomber japonicus	*Trisopterus luscus*	*Scomber japonicus*
Scomber scombrus	*Zeus faber*	*Scomber scombrus*
Scyliorhinus spp.		*Scyliorhinus* spp.
Sepia officinalis		*Trachurus picturatus*
Solea solea		*Trachurus trachurus*
Spondyliosoma cantharus		*Trigla lucerna*
Trachurus picturatus		*Trisopterus luscus*
Trachurus trachurus		*Zeus faber*
Trigla lucerna		
Trisopterus luscus		

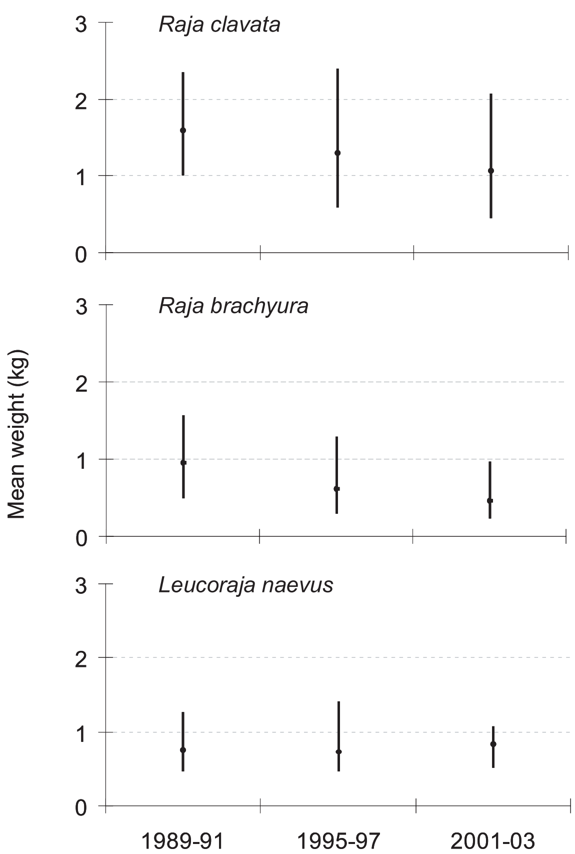

Fig. 4. *R. clavata, R. brachyura* and *L. naevus*. Estimates of the mean weight (in kg) for these main landed species, based on survey information from the three time periods.

Water. Between Cape Espichel and Cape S. Vicente the coastline is straight and steeper. This region is more favourable to the upwelling, due to strong winds. In a subarea from Cape Espichel to Cape Sines the coast forms a sheltered bight, constituting an important area for primary production. In another subarea, from Sines to Cape of São Vicente, the water is colder and less dense, probably associated to plumes of cold coastal water and the upwelling seems to be more persistent. Algarve has a complex bottom topography being highly influenced by the Mediterranean Sea current. The distribution area of clusters suggests a higher diversity of ray species at the southwest and Algarve regions.

The low level of misclassification error found in the discriminant analysis proved that the data on associate species was sufficient for the separation of clusters and, due to that, to get the underlying specific community structure. Most of the inconsistencies on the assignment of clusters to commercial landings, suggests no spatial agreement between cluster assignment and the port where landings took place, despite the initial idea that fishing vessels tend to operate preferentially in fishing grounds close to the ports where they land. This observation stresses the fact that commercial exploitation of resources is nothing else than an economic activity and, because of that, landing ports where fishermen land their captures are highly influenced by the benefits they receive (i.e. revenue) and the cost they incur (Pascoe 2006). In fact, species commercial value varies from port to port and the fuel expenses may be compensated by the total profit of landing in another port. The estimates of individual ray species landings from trawlers suggested the existence of temporal changes on the composition and relative importance between Rajiid species,

Table 5. Percentage (%) of vessels, by landing port, with agreement between the landing area and the cluster attributed.

Landing Port	1989–2001	1995–1997	2001–2003
Viana Castelo	63	30	51
Matosinhos	46	37	67
Aveiro	70	31	62
Figueira	78	43	51
Nazaré	50	46	50
Peniche	100	80	27
Cascais	100	100	100
Lisboa	100	100	100
Setubal	—	—	100
Sesimbra	—	100	100
Setúbal	84	100	100
Sines	100	92	100
Lagos	34	45	24
Portimão	40	40	86
Tavira	83	67	0
Vila Real- S.Antonio	51	32	62

which may be wrongly interpreted as an increase of diversity. Less frequent species, with low commercial value, and which were not considered in the extrapolation process of *Raja* spp. landings, had, in more recent surveys, higher occurrences, particularly in clusters at the south. This was noted for *Dipturus oxyrhynchus, Rostroraja alba* and *Leucoraja circularis* considered in terms of geographical distribution as boreal the first one or boreal/Lusitanian the remaining two species (Daan 2001). *L. circularis* is actually the foremost Rajidae component that characterize one of the clusters with spatial distribution southern Sines. Even in the absence of fisheries exploitation, it may not be ecologically feasible to have no declining species in a community affected by ecological interactions and environmental variation and change (Dulvy et al. 2006). The apparent increase of the distribution area of those species is sometimes associated with global warming, which is considered an important factor for a more southward distribution of some northern species (Brander et al. 2003).

Besides the influence of climatic alterations, changes on species composition may also reflect a higher vulnerability to fishing of some species that resulted from differences on structure of the assemblages. The increase of fishing pressure commonly has negative impact on populations through a decrease on size (Rogers and Ellis 2000). In addition, distribution-abundance relationships may be the cause for changes in distribution patterns, with populations contracting to core habitats with high suitability as abundance decreases (Ellis et al. 2005).

The decrease on the mean weight in *R. brachyura*, which is a quite frequent species along the Portuguese coast particularly between Peniche and Cape S. Vicente at relative shallow depths, may be considered an example of this. *R. clavata*, a species also very common in Portuguese coast but extending deeper than *R. brachyura*, showed a slight decrease on its mean weight while in *L. naevus* no differences on mean weight were observed.

Based on other studies, the females maximum length (Linf) and the length at first maturity (L50%) for the three species are:

- *R. brachyura*: Linf = 113 cm, L50% = 92 cm after Holden (1972);
- *R. clavata*: Linf = 139 cm; L50% = 72 cm (Holden 1972; 1975; Ryland and Ajayi 1984);
- *L. naevus*: Linf = 70 cm, L50% = 59 cm (Du Buit 1976a,b).

So the trends on mean weight in the three species may reflect changes on the fishing strategy by the Portuguese trawl fishing fleet trawlers or be related to the hypothesis of smaller species being less vulnerable to fishing than larger ones and tend to substituted them (Walker and Hislop 1998; Dulvy et al. 2000; Ellis et al. 2005). This study covered only one Portuguese fishing fleet segment catching ray species and that in total only representing 30% of the total landings of *Raja* spp. Under this framework, results can not be extrapolated for the remaining fleets. Furthermore, since the surveys used in this work were not designed for the estimation of abundance and spatial distribution of ray species the results have to be viewed an indication of population status.

Being aware of the complex nature of the system, in which natural processes and human activities interact determining changes on fish communities, the facts mentioned above should be taken in line in adoption of future management actions to rays. Moreover, the assessment and management should also get in line with the multispecific and multigear nature of most of the fisheries for rays, due to the complexity of the biological and technological interactions that may occur (Hilborn and Walters 1992). In order to reduce fishing mortality on key life-history stages, more information on size and sex composition of rays in mixed fisheries is required. An improved knowledge of the mortality/survivorship of rays for different fishing gears would further enable managers to evaluate the effectiveness of alternative management strategies such as, minimum and maximum landing size (Hunter et al. 2006).

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