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The fish assemblage of the Mondego estuary: composition, structure and trends over the past two decades

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Abstract The fish assemblage of the Mondego estuary was studied from June 2003 to May 2004. Five areas with different environmental conditions were sampled monthly, using a 2 m beam trawl (5 mm mesh size at the cod end). To complement information, sampling was also performed, seasonally, using a 7 m otter trawl with a 10 mm mesh size. Thirty-two species were identified. *Dicentrarchus labrax*, *Pomatoschistus microps*, *Pomatoschistus minutus*, *Solea solea*, *Platichthys flesus* and *Diplodus vulgaris* were the most abundant species. Marine juvenile migrants had the highest number of species, thirteen, followed by estuarine residents with eight species. Marine species that use the estuary as nursery grounds were the most abundant in terms of density and biomass. In spring and summer, juveniles occur in the upper, oligohaline areas, but afterwards, in autumn and winter, they tend to disperse to the middle and lower areas, with higher marine influence. Comparing the results obtained in this study with those reported in the early 1990's, a marked decrease in species richness can be noticed, which is probably due to anthropogenic factors, namely an increase in depth of the main channel and intense euthrophication processes in the middle and upper areas.

Keywords Fish assemblage · Ecological guilds · Nursery · Species richness · Anthropogenic impacts · Eutrophication

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Towards an integrated knowledge and management of estuarine systems

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Introduction

Estuaries have long been regarded as important sites for fish, both as nursery and overwintering grounds, migration routes and areas which naturally support large numbers of fish (Haedrich, 1983). This is related to high productivity levels, associated with increased availability of nutrients and abundance of primary producers, reduced incidents of piscivorous predators (McLusky, 1989) as well as high turbidity and sheltered areas.

The classification of species into ecotrophic guilds is a strong tool to assess the structure of the fish communities. In 1995, Elliott & Dewailly defined what may be termed a typical European (Atlantic seaboard) estuarine fish assemblage based on ecological guilds: a majority of *taxa* belonging to estuarine resident, marine adventitious or marine juveniles (each group, 25%); a small number of marine seasonal migrants and diadromous taxa (each 10%), and few (5%) freshwater adventitious taxa. In Portugal, estuarine fish assemblages are well documented (e.g. Gordo & Cabral, 2001; Costa et al., 2002; Jorge et al., 2002, among others) and, with few exceptions, follow this typical structure.

The Mondego estuary, located in the western coast of Portugal, has been historically impacted by human activities. Illegal fishing gear and nets of high efficiency and bycatch (such as fyke nets for glass-eel) have been continuously used in the Mondego estuary. In addition, from January to April, sea lamprey and shad are legally but still intensively fished using trammel and fyke nets, often below legal size and with large bycatch of other species.

Other sources of human pressure arrive from the regular dredging activities, in order to maintain shipping routes to a mercantile harbour, urban sewage still discharged without treatment and finally the areas typically used for salt exploration are being transformed into fish farm units where seabass and gilthead seabream are the most important cultivated species (Jorge et al., 2002). Additionally, the lower Mondego river valley consists of 15,000 ha of farming fields which supply an excess of nutrients into estuarine waters (Pardal et al., 2000; Martins et al., 2001). Similar to many estuaries all over the world, eutrophication largely increased in the Mondego since the 1980s, as a result of excessive nutrient release into coastal waters. The most visible feature of eutrophication in the Mondego estuary is the occurrence of seasonal green macroalgae blooms (mainly of *Enteromorpha* spp.), which have been reported in the south branch for several years (Marques et al., 1997; Pardal et al., 2000; Martins et al., 2001). Eutrophication, as a response to nutrient enrichment, commonly causes a shift from rooted plant communities, like the seagrass *Zostera*, towards free-floating (or partially free-floating) faster-growing macroalgae, like *Enteromorpha* or *Ulva*. In the Mondego estuary, seagrass beds declined rapidly throughout the 1980–1990 period, macroalgal blooms increased and there have been marked changes in macroinvertebrate assemblages, mainly a progressive impoverishment in species diversity (Marques et al., 1997; Lillebø et al., 1999; Pardal et al., 2000; Martins et al., 2001; Cardoso et al., 2004, 2005).

The available data for the Mondego estuary fish community refers to a study conducted in the years of 1988, 1991 and 1992 by Jorge et al. (2002). Surveys were conducted before the increase in channel depth of the northern branch that most likely resulted in a rise of salinity and changes in freshwater fish community. On the other hand, eutrophication in the south branch led to a decrease in *Zostera noltii* (Hornemann, 1832) area, possibly resulting in a reduction of species related to seagrass beds. Also, the presence of dams constitutes physical migration barriers, which are known to affect anadromous species (Costa et al., 2001).

Due to the marked changes in the last 15 years on both branches of the estuary due to human disturbance, the aim of this work was to study the structure of the fish assemblage in the Mondego estuary, in order to assess the effect of dredging activities and eutrophication based on a comparison of two distinct temporal fish community data sets.

Materials and methods

Study site

The Mondego estuary is a warm-temperate coastal system on the western coast of Portugal with a surface area of 3.4 km^2. About 75% of the estuarine area is intertidal. The estuary consists of a northern branch and a southern branch, with distinct hydrologic characteristics. The northern part is regularly dredged to maintain a depth between 5 and 10 m at high tide. The southern part is shallow (2–4 m deep at high tide) and largely silted up in the upstream areas. As a consequence, freshwater flows largely through the northern branch and the water circulation in the southern branch is mainly dependent on tidal activity and on the small freshwater input of a tributary, the Pranto river, which is controlled by a sluice.

The southern branch, displays a gradient in eutrophication (Pardal et al., 2000; 2004; Cardoso et al., 2004), from an area where a macrophytes community *(Z. noltii)* is present, up to a heavily eutrophicated zone, in the inner areas, where *Enteromorpha* spp. blooms are frequently observed. In the 1980s, *Z. noltii* beds occupied a broad area along the southern branch (15 ha) reaching the innermost parts of the estuary. By the mid-1990s, *Z. noltii* become restricted to a small patch (200 m^2) located downstream (Cardoso et al., 2004). Recently, after the implementation of mitigation measures a slow recovery has been observed (Cardoso et al., 2005).

Fish sampling and data analysis

The fish assemblage of the Mondego estuary was studied monthly, between June 2003 and May 2004, using a 2 m beam trawl, equipped with a tickler chain and 5 mm stretched mesh size in the cod end. Sampling was carried out during the night, at low water during spring tides, at five stations (A, B, C, D and E) (Fig. 1). Beam trawl surveys consisted of three hauls of 5 min, covering a minimum area of 500 m^2, in each of the five sampling stations. Additionally, three hauls using an otter trawl were conducted seasonally (each three months), each of 10–15 min duration, at stations A, D and E. Data based on this sampling gear was only used to test the sampling efficiency of beam trawl and was not taken into account to characterize the fish community. Simultaneously, temperature, salinity, pH and dissolved oxygen were measured at the surface and near the bottom. During each season, sediment samples were collected using a Van Veen grab, in order to determine granulometry and benthic macroinvertebrates biomass at each site (g ash free dry weight m^{-2}). In order to compare the efficiency of both sampling strategies, a Mann-Whitney test was applied to densities and biomass data of the fish species that were caught using both beam and otter trawl. To perform this test, only the coincident sampling stations and months were taken into account.

Analysis of the community structure was based on six ecological guilds based on life history styles (adapted from Elliott & Dewailly, 1995): estuarine resident species (ER), marine adventitious species (MA), freshwater adventitious species (FW), diadromous species (DI), marine juvenile migrant (MJ) and species that use the Mondego estuary as a nursery area (NU). For the last category (NU), estuaries are preferential nursery areas, contrasting with MJ, whose juveniles use these habitats opportunistically, being more abundant in adjoining coastal areas (CCA).

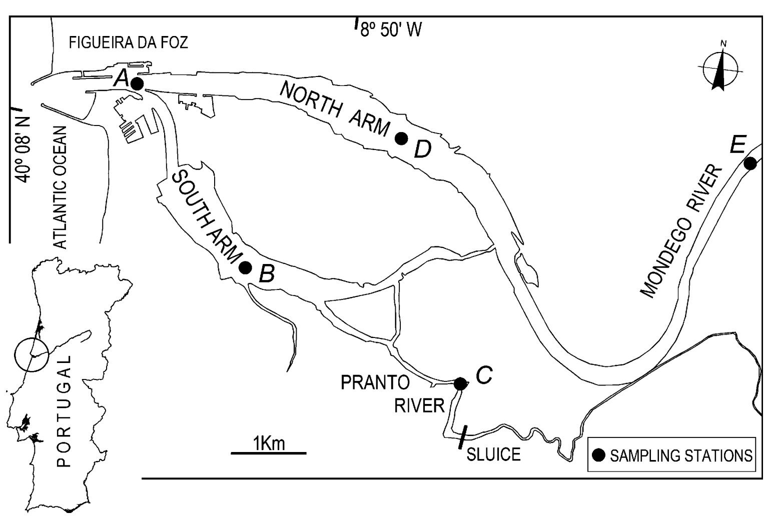

Fig. 1 Location of sampling stations in the Mondego estuary

A canonical correspondence analysis was used to evaluate both spatial and temporal variation of the fish assemblage of the Mondego estuary in 2003–2004 surveys, using CANOCO 4.0 (Ter Braak, 1998). For each ecological guild, fish abundance (fish density as ind 1,000 m^{-2}) was averaged by sampling area (A, B, C, D and E) and season (summer, autumn, winter and spring). The abundance of fish of the different ecological guilds was analyzed using a Kruskal-Wallis test and subsequent *a posteriori* tests (Zar, 1996).

Data on the Mondego fish assemblage based on samples taken in 1988, 1991 and 1992 were obtained from Jorge et al. (2002). Sampling was conducted monthly using a beach seine with a 7 m sac and 8 mm stretched mesh size in the cod end. Fishing was carried out during the day, at low water of spring tides, in three stations (A, C, and D). Available environmental data consisted of surface temperature and salinity. Only fish species and biomass data were available from this previous study. To compare the structure of both study periods, absolute biomass values were converted to percent composition, reducing the variability resulting from methodological differences while still retaining the relative abundance of individual taxa within each individual site's dataset (Mathieson et al., 2000). When comparing both study periods only the matching sampling stations were considered.

Results

Environmental characteristics of the sampling areas

The Mondego estuary shows a typical estuarine gradient, with depth, dissolved oxygen and salinity increasing downstream and reaching the highest values in station A, near the mouth (Table 1). Stations D and E, in the northern branch, registered a higher proportion of medium and coarse sand compared to the rest of the sampling

Table 1 Mean values (SD) of salinity, water temperature, dissolved oxygen, pH, percentage of silt, mud, fine sand, medium sand and large sand in the sediment, depth, benthic invertebrates biomass and algal cover biomass per sampling station

	Sampling station				
	A	B	C	D	E
Salinity (ppm)	30.3	28.3	22.7	20.1	1.2
	(3.4)	(4.3)	(4.4)	(6.6)	(1.7)
Temperature (°C)	15.6	17.2	18.0	16.8	17.2
	(2.7)	(3.1)	(5.3)	(3.6)	(5.4)
O_2 (%)	102.1	95.9	85.3	93.3	85.1
	(7.8)	(6.1)	(8.4)	(7.2)	(14.6)
pH	8.2	8.1	7.8	8.1	7.9
	(0.1)	(0.2)	(0.2)	(0.1)	(0.4)
% Silt	7.7	2.2	9.2	0.0	0.2
	(11.4)	(2.1)	(7.8)	(0.0)	(0.1)
% Mud	2.3	0.7	2.1	0.0	0.1
	(3.4)	(0.7)	(1.4)	(0.0)	(0.1)
% Fine sand	43.6	36.3	38.8	2.0	1.3
	(13.1)	(10.0)	(1.1)	(1.6)	(0.2)
% Medium sand	28.6	30.0	24.6	51.7	22.6
	(13.3)	(10.1)	(11.5)	(34.7)	(1.9)
% Coarse sand	16.5	30.5	24.1	45.9	75.5
	(21.4)	(19.1)	(12.5)	(36.5)	(1.5)
Depth (high tide) (m)	8.7	2.3	2.4	5.5	4.5
	(1.2)	(0.4)	(1.0)	(0.5)	(0.3)
Benthos biomass (g m^{-2})	3.6	0.4	1.2	0.0	3.8
	(5.3)	(0.2)	(1.2)	(0.0)	(4.6)
Algae biomass (g m^{-2})	0.5	0.9	2.9	0.0	0.0
	(0.5)	(2.3)	(3.6)	(0.0)	(0.0)

areas where the sediment was mainly composed of fine sand and silt. Turbidity and algae biomass were highest at station C, while station E presented the greatest benthic prey availability.

Species composition and ecological guilds

A total of 6371 individuals belonging to 22 families and 34 species were collected with beam trawl in the 2003–2004 surveys (Table 2). The fish assemblage of the Mondego estuary in the present study was dominated by *Dicentrarchus labrax* (Linnaeus, 1758), *Pomatoschistus microps* (Krøyer, 1838), *Pomatoschistus minutus* (Pallas, 1770), *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817), *Platichthys flesus* (Linnaeus, 1758) and *Solea solea* (Linnaeus, 1758), corresponding to 91% of the total individuals caught. Concerning biomass, *D. labrax, S. solea, P. flesus, Anguilla anguilla* (Linnaeus, 1758), *D. vulgaris* and *Barbus bocagei* (Steindachner, 1864), accounted for 85% of the total.

Regarding the ecological guilds, also in 2003–04 surveys, the MJ were the dominant group with 32% of total number of species. Nursery (NU) group was the most abundant group, with 60% of the total number of individuals and 65% of the total biomass. Marine adventitious (MA) and estuarine residents (ER) groups represented 23% and 20%, respectively, of the number of species. Only three freshwater adventitious (FW) and two catadromous (DI) species were found (Table 2). All species caught by otter trawl (22) were also collected by the beam trawl surveys (34) (Table 2). No significant differences were found in densities ($U = 244.0$, $P > 0.05$) or biomass ($U = 201.5$, $P > 0.05$) of fish caught by the two methods.

Spatial and temporal patterns

In the summer, sampling station C registered the highest fish densities and station A during spring presented the highest species number (19). The first axis of the CCA performed using ecological guilds data according to sampling areas and seasons accounted for 50% of the total variance and 65% of the variance due to ecological groups-environment relationships. Second axis accounted for 14 and 18%, respectively (Fig. 2). Among the environmental variables considered, dissolved oxygen, depth and benthos were the most influent ones, while fine sand had the weaker influence. Salinity, dissolved oxygen and depth were positively correlated, following a typical estuarine gradient, and were negatively correlated with temperature.

Significant differences in abundance were observed between all sampling stations for all ecological guilds with the exception of the freshwater adventitious group ($H = 5.41$, $P > 0.05$). This revealed a spatial pattern with some fish occupying the upstream areas of the estuary and other being more abundant in sampling stations near the sea (*a posteriori* tests, $P < 0.05$). Concerning the seasonal pattern, only the estuarine residents and MJ groups presented differences between seasons ($H = 9.33$, $P < 0.05$ and $H = 10.77$, $P < 0.05$, respectively). In fact, and according to the CCA ordination diagram, two major groups were found: a) freshwater adventitious, nursery and catadromous species, associated with stations C and E in the upstream and less saline areas, and b) marine adventitious, MJs and estuarine residents, related to stations A, B and D (the downstream areas), with higher marine influence. The nursery group was closely related to stations C in spring, summer and autumn and E in summer and autumn. These stations were characterized by high algae biomass, elevated temperatures and a lower salinity.

Trends over the last two decades

Comparing data collected in both surveys we can see that average and maximum salinity in 2003–2004 was higher than in 1988, 1991 and 1992 while average temperature remained constant. Nevertheless, precipitation was slightly higher in 2003-2004 (Fig. 3). In the 1988–1992 surveys, a total of 62 species (27 families) were identified. Engraulidae, Centrarchidae, Gasterosteidae, Carangidae, Labridae and Scombridae were absent in the 2003–2004 samples (Table 2). In the baseline study (1988–1992), *Liza ramada* (Risso, 1810), *D. labrax, Chelon labrosus* (Risso, 1827), *Liza aurata* (Risso, 1810), *Atherina* spp. and *Engraulis encrasicolus* (Linnaeus, 1758) were the dominant

Table 2 Fish species found in the Mondego estuary in baseline (1988, 1991 and 1992) and recent surveys (2003–2004)

Species	EG	VG	1988	1991	1992	2003-2004	
						Beam Trawl	Otter Trawl
Ammodytidae							
Ammodytes tobianus	MA	B	X	X	X	X	
Anguillidae							
Anguilla anguilla	CA	B	X	X	X	X	X
Atherinidae							
Atherina boieri	ER	P	X	X	X	X	
Atherina presbiter	ER	P	X	X	X	X	X
Blennidae							
Parablennius gattorugine	MA	D			X	X	
Callionymidae							
Callionymus lyra	MA	B	X	X	X	X	X
Carangidae							
Trachurus trachurus	MA	D	X	X	X		
Centrarchidae							
Micropterus salmoides	FW	D		X			
Ciprinidae							
Barbus bocagei	FW	D	X	X	X	X	X
Carassius arautus	FW	P			X		
Carassius carassius	FW	P	X			X	
Chondrostoma polylepis	FW	D	X	X			
Cyprinus carpio	FW	D	X	X	X		
Rutilus macrolepidotus	FW	P	X	X			
Gobio gobio	FW	D		X	X		
Clupeidae							
Alosa alosa	CA	P	X	X	X		
Alosa spp.	CA	P	X	X	X		
Sardina pilchardus	MJ	P	X	X	X	X	
Congridae							
Conger conger	MA	B				X	X
Engraulidae							
Engraulis encrasicolus	ER	P	X	X	X		
Gadidae							
Ciliata mustela	MJ	B		X	X	X	X
Trisopterus luscus	MA	D				X	X
Gasterosteidae							
Gasterosteus aculeatus	FW	P	X	X			
Spinachia spinachia	ER	D			X		

Species	EG	VG	1988	1991	1992	2003-2004	
						Beam Trawl	Otter Trawl
Labridae							
Labrus merula	MA	D			X		
Labrus viridis	MA	D		X	X		
Symphodus bailoni	MA	D	X	X	X		
Symphodus melops	MA	D	X	X	X		
Moronidae							
Dicentrachus labrax	NU	D	X	X	X	X	X
Mugilidae							
Chelon labrosus	MJ	D	X	X	X	X	
Liza aurata	MJ	P	X	X	X	X	X
Liza ramada	CA	P	X	X	X	X	X
Mugil cephalus	MJ	P	X	X	X	X	X
Mullidae							
Mullus surmuletus	MJ	B	X	X	X	X	X
Pleuronectidae							
Plathichthys flesus	NU	B	X	X	X	X	X
Poecilidae							
Gambusia holbrokii	FW	D	X	X	X	X	
Scombridae							
Scomber japonicus	MA	P			X		
Scophtalmidae							
Scophthalmus rhombus	MJ	B	X	X	X	X	X
Soleidae							
Solea senegalensis	MJ	B	X	X	X	X	X
Solea solea	NU	B	X	X	X	X	X
Sparidae							
Diplodus sargus	MJ	D	X	X	X		
Diplodus vulgaris	MJ	D	X	X	X	X	X
Sparus aurata	MJ	B	X	X	X	X	
Pagrus pagrus	MA	D			X		
Spondyliosoma cantharus	MA	B	X	X	X	X	
Boops boops	MA	D			X		
Syngnatidae							
Entelurus aequoraeus	MA	D			X		
Hippocampus ramulosus	ER	D		X	X		
Nerophys lumbriciformis	ER	B			X		
Nerophys ophidion	ER	D			X		

Table 2 (continued)

Species	EG	VG	1988	1991	1992	2003-2004 Beam Trawl	2003-2004 Otter Trawl
Gobidae							
Aphia minuta	MA	P	X	X	X	X	
Gobius cobitis	MA	B	X				
Gobius niger	ER	B	X	X	X	X	X
Pomatoschistus lozanoi	MA	B	X	X	X		
Pomatoschistus microps	ER	B	X	X	X	X	
Pomatoschistus minutus	ER	B	X	X	X	X	X
Pomatoschistus kneri	MA	B			X		
Pomatoschistus pictus	MA	B	X	X	X		
Syngnathus abaster	ER	D	X	X	X	X	
Syngnatus acus	ER	B	X	X	X	X	X
Syngnatus typhle	ER	D	X	X	X		
Trachinidae							
Echiichthys vipera	MA	B	X		X	X	X
Triglidae							
Trigla lucerna	MJ	B	X	X	X	X	X
Total number of species			46	48	56	34	22

X–presence, EG–ecological guild, ER–estuarine resident, CA–catadromous, FW–freshwater adventitious, MA–marine adventitious, MJ–marine juvenile migrants, NU–nursery; VG–vertical guild (water column use), P–pelagic, D–demersal, B–benthic

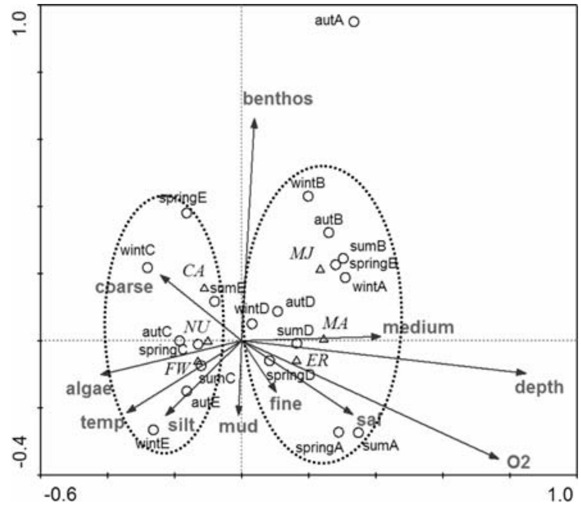

Fig. 2 Ordination diagram for the first two axis of the canonical correspondence analysis performed using fish density data (ER-estuarine resident; NU-nursery; MJ-marine juvenile migrant; MA-marine adventitious; CA-catadromous; FW-freshwater adventitious; temp-temperature; sal-salinity; depth-depth; algae-algae biomass; mud-% of mud; silt-% of silt; medium-% of medium sand; large-% of coarse sand; fine-% of fine sand; O2- dissolved oxygen; benthos-benthic invertebrates biomass; sum-summer; aut-autumn; wint-winter; spring-spring; A-sampling station A; B-sampling station B; C-sampling station C; D-sampling station D; E-sampling station E)

species in terms of biomass. *L. ramada* represented more than 65 % of the total biomass, while *D. labrax*, the most abundant species in 2003–2004, only accounted for 32% of the total in the baseline study surveys (Table 3). The major differences between the previous and present studies were the dominance of Mugilidae over Moronidae, the higher rank position of *Atherina* spp. in 1988–1992 and the absence of *E. encrasicolus* and *Alosa* spp. in 2003–2004, which ranked sixth and thirteenth, in the species rank-biomass. Also, *Symphodus bailloni* (Valenciennes, 1839), very common 15 years ago, was not caught during the 2003–2004 surveys. *S. solea* and *P. flesus* showed a marked increase between 1988–1992 and 2003–2004, while *Scophthalmus rhombus* (Linnaeus, 1758) showed a slight decrease over those years (Table 3).

The total number of species was always higher in the past surveys (Table 2), particularly freshwater, catadromous and MA (Fig. 4). Regarding the ecological guilds, diadromous were the

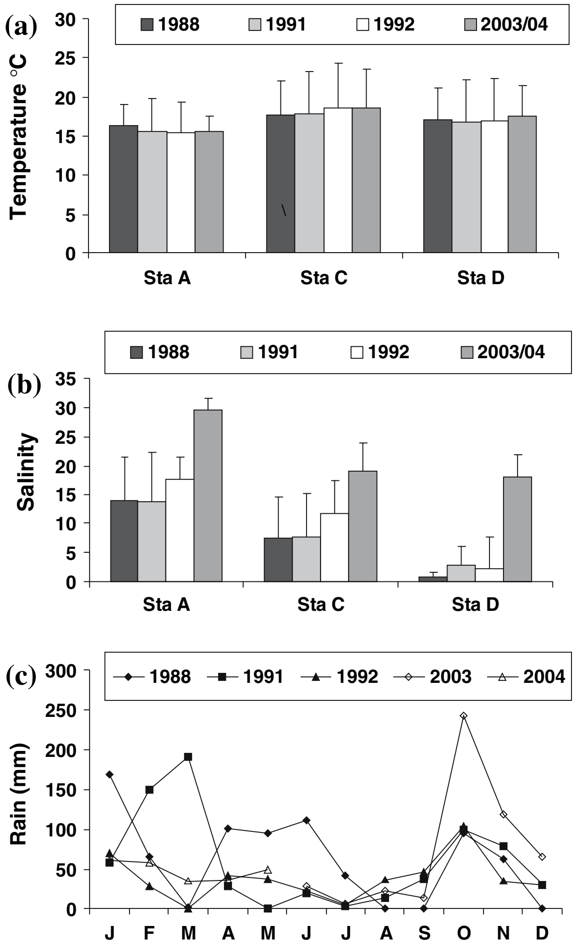

Fig. 3 Mean water temperature (**a**) and salinity (**b**) measured at the surface in stations A, C and D, in 1988, 1991, 1992 and 2003-2004; and monthly rain fall values in 1988, 1991, 1992, 2003 and 2004 (**c**)

dominant group in biomass in 1988, 1991 and 1992, mainly due to *L. ramada*, while in 2003–2004 the nursery group had the higher biomass values. The proportion of the other groups didn't change much over the years (Fig. 4).

Discussion

Spatial and temporal pattern in fish assemblage

In 2003–2004, species numbers according to ecological guild did not differ considerably from what Elliot & Dewailly (1995) found for 17 European estuaries, being *D. labrax*, *S. solea* and *P. flesus* (species that use the Mondego estuary as nursery grounds) among the most abundant species.

The Mondego estuary fish assemblage is influenced by a longitudinal environmental gradient. Marine adventitious and marine juvenile species were associated with higher salinity and deeper areas and freshwater and catadromous species occupied areas with high freshwater input, indicating the spatial gradient as the main structuring factor of the fish community. However, and as reported for other estuarine systems, community structure is probably a result of a particular combination of several environmental factors, which renders the assessment of their individual importance difficult (Gordo & Cabral, 2001).

While the movements of estuarine residents were not closely related to environmental variables, species from the nursery guild presented marked seasonal patterns of abundance. A summer and autumn abundance peak was observed, particularly for the juveniles, in stations C and E. In winter and early spring, a downstream dispersion occurred, with nursery species being found in stations D and A, closer to the sea. This behavior was also referenced in other European estuarine systems (Aprahamian & Barr, 1985; Jennings et al., 1991).

Trends-pollution and anthropogenic effects

The differences in the ichthyofaunal composition between the two study periods (1988–1992 and 2003–2004) are so pronounced that different sampling methods alone cannot be invoked to explain the observed trends. Nevertheless, in the 2003–2004 surveys, density and biomass estimates of *L. ramada* (a DI) and the other Mugilidae (marine migrant species) were possibly underestimated, which resulted in a higher frequency of nursery species biomass in 2003–2004. However, no differences between the two study periods, concerning nursery species, were registered. *Atherina* spp., another pelagic species, had also different rank positions. This could be attributed to the fact that beam trawl sampling provides a good indication of demersal and benthic fish communities (Hemingway & Elliott, 2002) but may underestimate pelagic species (Thiel et al., 2003). On the other hand, beach seine virtually covers the entire water column.

Table 3 Most abundant fish *taxa* ranked by biomass (%) in 1988, 1991, 1992 and 2003–2004

Rank	1988		1991		1992		2003–2004	
	Species	Biomass	Species	Biomass	Species	Biomass	Species	Biomass
1	*L. ramada*	67.21	*L. ramada*	70.77	*L. ramada*	80.01	*D. labrax*	35.07
2	*L. aurata*	8.89	*S. pilchardus*	8.92	*D. labrax*	5.81	*S. solea*	16.43
3	*D. labrax*	8.26	*D. labrax*	4.93	*C. labrosus*	3.64	*P. flesus*	11.96
4	*C. labrosus*	4.24	*C. labrosus*	4.03	*E. encrasicolus*	2.14	*A. anguilla*	10.72
5	*S. aurata*	2.27	*L. aurata*	2.85	*L. aurata*	1.40	*D. vulgaris*	6.57
6	*S. rhombus*	2.12	*D. vulgaris*	2.37	*Atherina* spp.	1.17	*L. ramada*	4.74
7	*Atherina* spp.	2.06	*Alosa* spp.	1.47	*Alosa* spp.	0.87	*B. bocagei*	2.90
8	*M. cephalus*	1.02	*Atherinidae*	0.95	*D. vulgaris*	0.59	*S. senegalensis*	1.80
9	*E. encrasicolus*	0.86	*E. encrasicolus*	0.80	*S. rhombus*	0.48	*C. labrosus*	1.50
10	*A. anguilla*	0.65	*S. rhombus*	0.67	*M. cephalus*	0.43	*S. rhombus*	1.33
11	*T. lucerna*	0.53	*T. lucerna*	0.37	*S. pilchardus*	0.42	*T. lucerna*	1.24
12	*D. vulgaris*	0.38	*M. cephalus*	0.35	*S. bailoni*	0.39	*P. minutus*	1.19
13	*Alosa* spp.	0.27	*A. anguilla*	0.32	*T. lucerna*	0.39	*L. aurata*	0.91
14	*G. niger*	0.22	*S. aurata*	0.15	*B. belone*	0.36	*S. aurata*	0.72
15	*P. flesus*	0.18	*M. salmoides*	0.13	*A. anguilla*	0.26	*P. microps*	0.66
16	*C. carpio*	0.18	*A. tobianus*	0.12	*B. bocagei*	0.23	*C. conger*	0.48
17	*S. solea*	0.13	*B. bocagei*	0.11	*G. niger*	0.21	*Atherina* spp.	0.37
18	*P. minutus*	0.14	*G. niger*	0.10	*C. lyra*	0.20	*C mustela*	0.33
19	*A. tobianus*	0.10	*C. carpio*	0.09	*C. carpio*	0.14	*G. niger*	0.21
20	*M. surmuletus*	0.09	*B. belone*	0.09	*E. vipera*	0.13	*M.surmuletus*	0.20

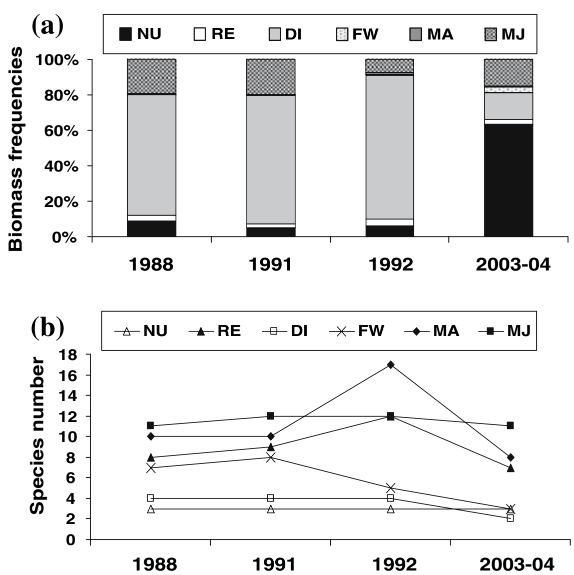

Fig. 4 Fish biomass (%) (**a**) and species numbers (**b**) per ecological guild in 1988, 1991, 1992 and 2003–2004 (ER–estuarine resident, CA–catadromous, FW–freshwater adventitious, MA–marine adventitious, MJ–marine juvenile migrants, NU–nursery)

Otter trawl, gifted with a wider area for catching, is more appropriate for capturing larger fish (Hemingway & Elliott, 2002). Even though the fact that no new species were captured in otter trawl surveys could be used as an indicator of the efficiency of beam trawl sampling, particularly in a shallow estuary such as the Mondego estuary.

The conversion of absolute biomass values to percent composition, during data treatment, was a way of reducing the variability resulting from methodological differences and still retaining the relative abundance of individual taxa within each individual site's dataset (Mathieson et al., 2000).

The lower fish diversity in the 2003–2004 surveys could be in part a result of an impoverishment of the environmental quality of the Mondego estuary in the last fifteen years. One of the main differences between the previous and present study is the low number of FW in 2003–2004 surveys, with only three species found: *B. bocagei, Carassius carassius* (Linnaeus, 1758) and *Gambusia holbrooki* (Girard, 1859), while in the 1988–1992 study ten species were registered. This major difference could be attributed to salinity changes. The average surface water salinity in 2003–2004 in the sampling stations common to both studies was always higher compared to baseline values, although it was a rainy year (Fig. 3). This situation was more significant in station D (the north branch), where freshwater species were previously more abundant. This situation could be a result of the dredging activities near the mouth, in order to deepen the shipping channel. The increase of depth induces an increase of the tidal exchange: the tidal range increases, the tide incursion progresses to upstream, the salinity front and the turbidity maximum zone migrate to the upper reaches and, the current speed increases leading to the filling of shallow areas and erosion of banks (Marchand et al., 2002).

In the Mondego estuary (Portugal), eutrophication has triggered serious biological changes, which led to an overall increase in primary production and to a progressive replacement of seagrass *Z. noltii* beds by coarser sediments and opportunistic macroalgae (Cardoso et al., 2004). The lower number of species observed in the present study could be also a result of this process. According to Raffaelli et al. (1998), in shallow sublittoral or intertidal habitats, biomass accumulations of attached or drift macroalgae reduce survival of invertebrate recruits, and reduced abundance of invertebrate prey for fishes and shore birds. Many authors (Reise, 1983; Hull, 1987; Raffaelli et al., 1989; Pihl et al., 1994; Cardoso et al., 2004; Pardal et al., 2004) already described these changes in invertebrate and fish assemblages. In the Clyde estuary (United Kingdom), reductions in organic pollution led to the return of missing fish species (Warfe et al., 1984). Henderson & Hamilton (1986) related the continuing improvements in water quality and recovery of the invertebrate benthos, with positive changes in the fish populations in Clyde estuary. Indeed, *Hippocampus hippocampus* (Linnaeus, 1758), *Symphodus melops* (Linnaeus, 1758), *S. bailloni* and *Labrus* spp., which are species that live in association with seagrass beds (Costa et al., 2002), were present in the 1988–1992 surveys and absent in 2003–2004.

Alosa spp., highly abundant in the past study, was also missing in 2003–2004. It is known that river flow regulation by dams causing unnatural seasonal flow conditions has important effects on the diadromous fish species, namely shad (*Alosa* spp.) and lamprey (*Petromyzon marinus* Linnaeus, 1758) (Costa & Cabral, 1999). There are evidences of shad reduction (Tagus estuary) or even complete disappearance (Thames estuary). By the end of the nineteenth century twaite shad (Al*osa fallax* (Lacepède, 1803)) was not found in the middle or upper reaches of the tidal Thames. This demise was probably linked to the increase of pollution levels and overfishing (Whitfield & Elliott, 2002), a situation also observed in the Mondego estuary.

The slight decrease in biomass-species rank position of the *S. rhombus* and the increase in the abundance of *S. solea* and *P. flesus* could reflect some competition behavior between those species and/or different tolerances to habitat changes. These three species are flatfishes with similar ecological niches (individuals belonging to the second and third year class of those species concentrate in stations A and D) and differences in sampling methods will have no influence in their captures.

The disappearance of the anchovy, *E. encrasicolus*, an abundant species in the past (Jorge et al., 2002), remains without explanation. There are evidences of this situation in other Portuguese estuaries, namely the Tagus Estuary, where the anchovy has become extremely rare within the estuary but occur in the adjacent coastal area (Prista et al., 2003).

Overall, this work has provided evidence of changes in the structure of the Mondego estuary fish assemblage over the last fifteen years, which may be a result in a large extent, from dredging activities (mainly in the north branch) and, indirectly, from eutrophication process (mainly in the south branch). Nevertheless, an integrated monitoring plan is recommended to be extended in the future, in order to assess the success of the mitigation measures implemented since 1999 (Cardoso et al., 2004), and to evaluate interannual variation in fish assemblage and to try to distinguish anthropogenic pressures effects from natural induced changes.

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