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SPATIAL AND TEMPORAL ORGANIZATION OF A COASTAL LAGOON FISH COMMUNITY - RIA DE AVEIRO, PORTUGAL

by

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ABSTRACT. - The fish community and its spatial and temporal organization were studied in the Ria de Aveiro. This lagoon system (43 km^2 in area), has both marine and fluvial influences and is located between 40º 30' - 40º 52'N and 8º35' - 8º 47'W on the central coast of Portugal. The ichthyofauna was sampled monthly, from December 1996 to November 1997, at nine selected stations, with "chincha", a traditionally-used beach-seine-type net of the region. A total of 14,598 specimens representing 43 species from 21 families were caught. The abiotic parameters (temperature, salinity and dissolved oxygen) showed significant seasonal variations, although only salinity and transparency showed statistically significant trends among sampling stations. The diversity and evenness were greater at the borders of the lagoon. The species richness, diversity and evenness peaked in mid-Summer. Marine seasonal migrant species were the most numerous, and the marine juvenile and estuarine resident categories had the highest number of species. Species number and diversity of the ecological guilds showed some spatio-temporal patterns due to some particular dominant species. Mugilidae, Atherinidae, Moronidae and Clupeidae were the most abundant families. Six species were dominant and represented more than 74% of the total fish abundance, although they did not occur over the whole lagoon area or during the whole sampling period. The study concludes that the fish community of the Ria de Aveiro has well-defined seasonal and spatial patterns.

RÉSUMÉ. - Organisation spatiale et temporelle de la communauté de poissons d'une lagune côtière – Ria de Aveiro, Portugal.

La communauté de poissons et son organisation spatiale et temporelle ont été étudiées dans la Ria de Aveiro. Ce système de lagune (43 km^2 de superficie) subit des influences maritimes et fluviales et est situé entre 40º 30' - 40º 52'N et 8º35' - 8º 47'W sur la côte centrale du Portugal. Des échantillons ont été prélevés mensuellement de décembre 1996 à novembre 1997, dans neuf stations, avec un filet de pêche traditionnel de la région, la "chincha". Au total 14

598 spécimens ont été collectés représentant 43 espèces et 21 familles. Les paramètres abiotiques (température, salinité et oxygène dissou) ont montré des variations saisonnières significatives, tandis que sur l'ensemble des stations de prélèvement seules la salinité et la transparence ont présenté une variation significative. La diversité et l'équatibilité ont été maximales le long des rives de la lagune. La richesse en espèces, diversité et équatibilité ont leur maximum été. Les espèces marines étaient les plus nombreuses et les catégories "juvénile marin" et "résident estuarien" sont celles qui avaient le plus grand nombre d'espèces. Le nombre d'espèces et la diversité des catégories écologiques ont montré des patterns liés à certaines espèces dominantes. Mugilidae, Atherinidae, Moronidae et Clupeidae étaient les familles les plus abondantes. Six espèces dominaient, même si elles n'étaient pas présentes sur toute la superficie de la lagune ou durant toute la période des échantillons, représentant plus de 74% du total de l'abondance en poisson. Cette étude permet de conclure que la communauté de poisson de la Ria de Aveiro a des patrons saisonniers et spatiaux très bien définis.

Key words. - Ichthyofauna – Portugal – Diversity – Evenness - Ecological guilds - Lagoon

The Ria de Aveiro, on the west coast of Portugal is a typical estuarine coastal lagoon. The particular abiotic attributes of this system - shallowness, high turbidity, nature of the substrate, temperature, salinity and oxygen - associated with its high biotic productivity, offer excellent conditions for colonisation by many species, especially teleosts (Potter *et al*., 1990; Rebelo, 1992).

This coastal lagoon is economically important because of its fisheries, industry, agriculture, sea farming, tourism and, more recently, aquaculture. With a good communication with the sea, that guarantees a seasonal fish recruitment, the lagoon is an area of considerable fish exploitation (commercial and recreational). Previous ichthyological studies in the Ria de Aveiro (Osório, 1912; Nobre *et al*., 1915; Arruda *et al*., 1988; Rebelo, 1992) contributed to the knowledge of the dynamics and evolution of the fish populations inside this lagoon and its relationship with the adjacent ocean.

This paper describes the spatial and temporal patterns of the fish community, in terms of ecological categories throughout their distribution, number of species, density and biomass. This allows an interpretation of the use and ecological importance of the lagoon for its various fish populations.

Study area

The morphology of the Ria de Aveiro (Fig. 1) shows relatively recent development starting in the tenth century, and in 1808 the connection with the sea (470 m width) was first stabilized by man. The topography and physical characteristics of the Ria de Aveiro were described by Barrosa (1980). The area is 42 km^2 at low tide and 47 km^2 at high tide. The depth at low tide is only 1 m over most of the lagoon, but can reach 10 m near the mouth and in the navigation channels. Tidal action mixes freshwater with seawater entering from the mouth. The tidal input is approximately between 25 and $90x10^6$ m^3 for tidal amplitudes of 1 and 3 m respectively. Currents produced by this tidal action are significant only in the mouth, the central part of the main channels and a few other restricted areas. There is a delay of 6 hours in the times of high and low water between the mouth and the extreme margins of the lagoon.

The nature of the sediments is extremely variable, particularly the granulometry. Its composition varies between 20 to 90% of sand, 10 to 80% of silt and 0 to 30% of clay. In the north the sediments are finer but become coarser with progression to the south (Borrego *et al*., 1994).

The lagoon receives considerable flows of raw and treated wastewater. Three main pollution types are apparent: organic and chemical pollution from paper-pulp factories (in the rivers of Vouga and Caima); chemical pollution, particularly mercury, from the industrial area of Estarreja (in Laranjo area); and microbial contaminants from the urban sewage effluent and cattle raising areas (Ílhavo channel, Vouga river and Ovar channel) (Lima, 1986; Lucas *et al*., 1986; Borrego *et al*., 1994).

MATERAL AND METHODS

Sampling period and study sites

Fish were collected monthly, from December 1996 to November 1997, at nine selected stations (Fig. 1): near the mouth of the lagoon (BAR, GAF and SJA); at the edges of the main channels (ARE, CAR and VAG); in the main freshwater area, highly organically enriched (RIO); in the area showing the highest levels of industrial pollution (LAR), and approximately in the middle of the longest channel (TOR).

Sampling methods

Samples were monthly taken in triplicate at low tide with a “chincha”, a traditional beach-seine (Fig. 2). The area enclosed by the chincha was approximately 1000 m^2 at all stations except at VAG where it was 800 m^2 due to a narrow topographic configuration. Stretched mesh sizes in the chincha were 19 mm at the wings, 17 mm at the cod mouth, 16 mm at the cod sleeve, and 10 mm at the cod-end piece.

Abiotic parameters (temperature and dissolved oxygen) were recorded with an oxygen meter (CONSORT Z621), salinity was recorded with a refractometer (ATAGO) and water transparency was estimated based on turbidity and Secchi depth, according to Yáñez-Arancibia *et al*., 1983 (*in* Rebelo, 1992).

Fishes were preserved by freezing. At the laboratory each specimen was identified, according to the taxonomic keys of Bauchot and Pras (1987) and Whitehead *et al*. (1986), measured (total length), and weighed (total weight).

Data analysis

Two-way ANOVA without replication (Zar, 1984; Sokal and Rohlf, 1995) was carried out to test significant differences among the abiotic parameters between stations and months. Homogeneity of variances was tested using the Fmax test (Zar, 1984; Sokal and Rohlf, 1995).

The assemblage structure and dynamics were calculated according to the following parameters:

a) species richness, Margalef index (R) (Margalef, 1958 *in* Ludwig and Reynolds, 1988; Legendre and Legendre, 1984b), which refers to a total number of species that compose a community, and is described by:

$R = \frac{S-1}{\ln(n)}$, with S the total number of species and n the total number of individuals observed in a sample.

b) species diversity index (N2), (Hill, 1973) is defined by the inverse of the Simpson index (λ), $N2 = \frac{1}{l}$, where $l = \sum_{i=1}^{S} \left(\frac{n_i}{N}\right), i = 1,2,3,..., S$ with n_i the number of specimens of i species and N the total number of individuals of the S species of a population.

c) evenness index, (E) (Ludwig and Reynolds, 1988) which varies between 0 and 1, $E = \frac{(1/\lambda)-1}{e^{H'}-1} = \frac{N2-1}{N1-1}$, λ is the Simpson index, *H'* is the Shannon-Wiener index and *N2* and *N1* are the diversity numbers (Hill, 1973), where $N1 = e^{H'}$ and $H' = -\sum_{i=1}^{S}\left[\left(\frac{n_i}{n}\right)\ln\left(\frac{n_i}{n}\right)\right], i = 1,2,3,\ldots,S$ with n_i the abundance of the *i* species, and *n* the abundance of all species.

In order to understand the use and importance of the lagoon for fish, species were grouped, using the method of Elliott and Dewailly (1995). Six categories were defined according to their biology and behaviour and using background information for the lagoon (Osório, 1912; Nobre *et al*., 1915; Arruda *et al*., 1988; Rebelo, 1992). The categories were *i*) estuarine resident species (ER), which spend their entire lives in the estuary; *ii*) marine adventitious visitors (MA), which occur irregularly in the estuary but have no apparent estuarine requirements; *iii*) diadromous (catadromous or anadromous) (CA) migrant species, which use the estuary to pass between salt and fresh waters for spawning and feeding; *iv*) marine seasonal migrant species (MS), which make regular seasonal visits to the estuary usually as adults; *v*) marine juvenile migrant species (MJ), which use the estuary primarily as a nursery ground, usually spawning and spending much of their adult life at sea but often returning seasonally to the estuary; *vi*) the freshwater adventitious species (FW), which occasionally enter brackish waters from fresh waters but have no apparent estuarine requirements.

The data were analysed using a multivariate approach; the sampling stations were clustered according to Bray-Curtis distance (Legendre and Legendre, 1984), by the ecological characteristics of their species, the diversity indexes and by the guilds abundance. The clustering was made using the unweighted, pair-group method using arithmetic averages (UPGMA) (Sneath and Sokal, 1973; Legendre and Legendre, 1984).

The influence of the abiotic parameters on the results of the previous clustering was studied by simple canonical analysis, using the Mahalanobis (D^2) multivariate distance between the abiotic parameters recorded in two clustered groups. The percentage contribution of each abiotic parameter was also estimated for the multivariate distance of the groups. These calculations were made using NTSYS-pc (Anon, 1989) and SDA.BAS (Ludwig and Reynolds, 1988).

RESULTS

Abiotic parameters

The Ria de Aveiro is influenced by a marine temperate climate. Water temperature varies from 6.5ºC in the winter to 27.6ºC in the summer. The spatial variation of temperature was not statistically significant (Table I); however, the observed seasonal temperature amplitudes, in each area, showed significant differences (Table I). At the channels edges (ARE, CAR, VAG) and at the intermediate stations (LAR, RIO, TOR), where the water turnover is lower, the water temperature followed the air temperature: 20.5 – 27.6ºC in summer and 6.5 – 14.0ºC in winter (Fig. 3).

The salinity significantly varied spatially with typically freshwater (ARE and RIO), brackish water (VAG, LAR and CAR), and marine water, close to the mouth of the lagoon (BAR, SJA, GAF and TOR) (Table I). Seasonally, salinity variations generally followed those of the temperature (Fig. 3).

The mean spatial variation of dissolved oxygen; although not significant (Table I), showed levels near the anoxia (1.25 $mg.l^{-1}$, in BAR), intermediate values (7.76 $mg.l^{-1}$, in RIO) and oversaturated values (11.39 $mg.l^{-1}$, in GAF). The seasonal variations of dissolved oxygen were significant and approximately inverse of the temperature and salinity (Fig. 3).

The transparency varied significantly among the stations, between 11.9% (LAR) and 100% (TOR and CAR) (Fig. 3), but the seasonal variation was not significant (Table I).

Community structure

A total of 43 teleost species was identified from 14,598 specimens. The data set of the fishfauna density over stations and months is given in table II. The six most abundant species (marked with an arrow), although not occurring across the whole lagoon area or during the whole sampling period, represented more than 74% of the total fish abundance.

The variation of community indices (species richness, diversity and evenness) is shown according to the distance from the mouth of the lagoon and by month in figure 4. Specific richness showed some fluctuations among the sampling stations. Species diversity and evenness were lower at the mouth of the lagoon; therefore the communities in the upper reaches of the channels were characterised as the best structured of the lagoon (Fig. 4).

The cluster analysis (Fig. 5) of sampling stations, in terms of diversity indexes, delimited 4 groups. RIO and BAR constitute the first group with similar diversity and evenness along the months, which mainly differs from the II and III groups by the transparency (more precisely, the turbidity) and differs from the IV group by the temperature (Table III). The second group is formed by a single station, SJA, with particular abiotic characteristics, which mainly differs from the other groups by the transparency (low turbidity and high depth) (Table III). The group that comprises the areas with higher pollution levels (LAR, VAG and GAF) shows intermediate levels of diversity index and exhibits higher levels of depth comparing to the fourth group. The latter group includes the edges of lagoon (CAR and ARE) and the main channel (TOR), with high levels of species richness and the highest levels of diversity and evenness.

Seasonally, species richness showed a general increase from spring to summer, with a single decrease in March and with a peak in August (Fig. 4). The diversity and evenness showed peaks in March and in August. In March the diversity index was the highest (8.3), as a consequence of the occurrence of the eight most dominant species (*Liza aurata*, *Dicentrarchus labrax*, *Atherina presbyter*, *Chelon labrosus*, *Atherina boyeri*, *Syngnathus acus* and *Mugil cephalus*), which represented 93% of the total density. The evenness recorded during that month (0.59) denoted a medially structured community. However, the evenness in August reached the maximum value (0.65). During that month the seven most abundant species showed a reduced density (between 33 and 196 specimens): *L. aurata*, *Symphodus bailloni*, *A. presbyter*, *S. acus*, *S. pilchardus*, *Pomatoschistus microps* and *Anguilla anguilla*. The diversity and evenness indices presented the lowest values in May (2.1 and 0.34, respectively). The two most abundant species, which represented 80% of the total density during that month, were *S. pilchardus* and *L. aurata*. The dominance of these two species (80% of total density) produced a very reduced evenness (0.34).

Spatial and temporal variation of fish fauna composition

In order to understand the dynamics of the fish community, species were grouped into the six ecological guilds described above. The frequencies of the number of species, density and biomass of each guild are shown in figure 6 indicating the use and importance of the estuary for fish.

The cluster analysis (Fig. 7) of sampling stations, in terms of ecological guilds, defined 4 groups. BAR constitutes an isolated group with the highest abundance of marine seasonal category (Fig. 6), despite the occurrence of a low number of species (5), represented by higher density (54%) than biomass (46%). This ecological category showed a high proportion at all the sampling stations, especially at BAR with more than 80% of total density (Fig. 6). From April to July the highest density levels of this category correspond to the recruitment of *S. pilchardus*. The second group comprises the intermediate areas (LAR, RIO and SJA), in which the marine juvenile migrant species presented higher densities than the resident ones (Fig. 6). All the specimens included in this category belong to the families Moronidae, Sparidae and Soleidae, contributing to higher biomass than density (Fig. 6). The main food items of this ecological category are insects, mysids, molluscs, isopods and amphipods. Two species are noticeable for their large distribution in all the lagoon area and for their high density: *A. presbyter* and *D. labrax*. These species contributed to the general predominance of this category in this group during March and April. The station of this group differs from the first and third group by the transparency and from the fourth group especially by the oxygen levels (Table IV). On the TOR, VAG and GAF stations, in spite of high densities of marine seasonal species, the resident species are more abundant than the marine juveniles. The estuarine resident category is mainly characterised by small species, such as gobiidae and syngnathidae, inducing a biomass lower than the density. The diet of this category is based on isopods, insects and decapods. Compared with BAR the low salinity constitutes the abiotic parameter that contributes to the difference of species occurrence. Compared with the fourth group the low depth constitutes the most important parameter. The north and south edges of the lagoon (CAR and ARE, respectively) showed the highest abundance of resident species, especially during winter. The diadromous species contributed to more than 10% of total density, occurring particularly in this group during December, January and March, corresponding to the period of lagoon recruitment of the species *A. anguilla*, *Alosa* spp. and *Liza* spp. Diadromous species feed mainly on copepods, insects and mysids. This group differs from the others especially by its low transparency (Table IV). The freshwater group shows low representativity in density or biomass because only one *Carassius carassius* was caught.

DISCUSSION

In the estuarine coastal lagoon of Ria de Aveiro, the seasonal climatic variations produce regularly a high number of species, but also contribute to the occurrence of well-adapted species exhibiting high productive potential. The most abundant species occur in Torreira, Barra and Carregal, shallow areas with high levels of transparency and primary production (Rebelo, 1992), suggesting that the preference of these species are related to a high availability of food. Seasonally the most abundant species were found in mid-summer, when the oxygen levels, as well as the primary production, are higher than during the other periods. The biomass showed some flutuations along the year but was higher on the edges of the lagoon than in the other areas.

The fishfauna of the Ria de Aveiro is represented by a number of species (43) very similar to other European estuarine ecosystems (Table V and VI). The species well adapted to the environmental fluctuant conditions of this system stay in the lagoon during all their lifecycles (ER) or depend on the lagoon during their juvenile stage (MJ). These ecological groups have colonised the lagoon since 1912 (Osório, 1912; Nobre *et al*., 1915; Arruda *et al*., 1988; Rebelo, 1992). The marine seasonal species (MS) occurred in higher abundance at the entrance of the lagoon and during summer, corresponding to a period of intensive migratory activity. *Sardina pilchardus* and *Liza aurata* are noticeable in this group for their high abundance. The diversity of marine seasonal species (MS) is lower than of resident species (ER), like in other estuaries of the Atlantic coast (Table VII). The adventitious species (MA) accidentally visit the lagoon because of currents or for trophic motivations (Rebelo, 1992). In other European estuaries, such as El Abra, in Spain (Elliott and Dewailly, 1995) and Isefjord, in Denmark (Rasmussen, 1973) (Table VII), the number of species in this group is higher than in our study, reaching more than 40% of all species. In the present study, although the number of species is very similar to the other categories the abundance was very low. The dominant species in this group, *Symphodus bailloni* was very abundant in a region, Torreira, and during a period, between June and November, when the salinity values were close to the marine water, approximately 30 psu. The species that use estuaries as a nursery (MJ) occur at low salinity values. It is noticeable that *Dicentrarchus labrax* and *Atherina presbyter* dominate the other nine species of this category. These fish (MJ) are also well distributed in all the other European coastal lagoons (Table VII).

Catadromous species (CA), which include *Anguilla* spp., *Alosa* spp. and some *Liza* spp., are well represented in terms of number of species (12) compared to other European lagoons, from 4 species in El Abra, in Spain (Elliott and Dewailly, 1995) to 15 species in the Humber Estuary, in England (Marshall and Elliott, 1998). The freshwater species category (FW) comprised only one species, *Carassius carassius*, which distribution is restricted to Areão, with an average salinity of 6. This category is not known to occur in some Atlantic estuaries (Rasmussen, 1973; Nash, 1988; Costa and Elliott, 1991; Hamerlynck, 1993; Elliott and Dewailly, 1995; Thiel *et al*., 1995; Marshall and Elliott, 1998), but is abundant in others (Elbe) where the salinity may be low. Transparency was the most influencial factor, followed by salinity, in the colonization of the stations found in the intermediate and near entrance sites. The edges of the lagoon, due specially to their transparency but also their dissolved oxygen levels, constitute a preferential area of colonization by resident and seasonal species.

In global terms, the fish community in this system had only a few very abundant species (5) compared to the total number of captured species (43). The total number and the number of very abundant species in this work were lower than in the previous work on this lagoon by Rebelo (1992) who found 7 very abundant species for a total of 55 species (Table VIII). When both studies are cumulated, 62 species are known from Ria de Aveiro. The density of *Gobius niger* and *Liza ramada* highly decreased in the recent study. There are 19 species that exclusively occurred in Rebelo, 1992 while only 7 species have exclusive occurrence in the present work (Table VIII). In about 10 years, the level of evenness of the population of lagoon has slightly decreased. This fact could be related with the recent human actions that have been affecting this estuarine system, namely the extraction of sediments from the lagoon and an increase in fishing effort (artisanal and recreational). Between 1988 and 1997 more than 5 10^6 m^3 of sand were extracted from the main navigator channel and more than 3 10^6 m^3 of sand were extracted from the inner to the outer side of the lagoon, with deposition along beaches and in the sea.

Ria de Aveiro is well represented in number of species (62) compared with other estuarine lagoon systems: El Abra, in Spain (23 species) (Elliott and Dewailly, 1995) and Isefjorf, in Denmark (70 species) (Thiel *et al*., 1995) (Table V and VI). Latitude does not seem to play an important role, amongst European estuaries, according to Table VI. However this could be related to differences in sampling methods and effort. Differences in transparency between the medium sites and the edges of the lagoon could explain these changes. The temperature may also influence the different levels of diversity between the entrance of the lagoon and its edges. On the edges, the temperature is higher and the vegetation can grow intensely, allowing mainly the colonization by resident species (*Pomastoschistus microps*, *Mugil cephalus* and *Syngnathus acus*), protecting them against predation and supplying a high food supply.

The species richness increased along the year, except in March, when it showed a decrease, corresponding to the seaward migration of some seasonal migrant species, namely *Liza aurata*. The diversity and evenness were higher in spring and in the middle of summer. According to Bennett (1989) and Monteiro (1989), the seasonal variation of number, distribution and density of species in the lagoon system is more related with the migratory activity than with the variation of abiotic parameters. However, in this study, the temperature and the salinity allow to split the year into three seasonal discontinuities: November to April, May, and June to October. The first period corresponds to low temperature and salinity and high migration levels of seasonal migrant species. May is characterised by the massive recruitment of schooling species, especially *Sardina pilchardus*, which disturbs the evenness of the system, as well as the diversity index. The last period, from June to October, corresponds to the entrance in the lagoon of the catadromous species *Anguilla anguilla* and the adventitious species *Symphodus bailloni*, which comprises the best structured period with higher specific diversities.

It may be concluded that as the other European estuarine lagoon ecosystems (Alcolado, 1996), the fish community in the Ria de Aveiro can be organized in a well-defined seasonal and spatial patterns. This ecotone is greatly influenced by the abiotic conditions that affect the ichthyological system since it supports abundant sedentary species, provides a suitable nursery area to marine migratory species and is sought by many occasional species, particularly in their juvenile stage, as the other estuarine ecosystems in general (Leeuwen *et al*., 1994).

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REFERENCES

ALCOLADO P.M., 1996. - Controversia sobre la relación entre la diversidad de especies y la estabilidad de las comunidades. *Avicennia* 4/5: 13-26.

ANON, 1989. – NTSYS-pc. Version 1.5. Applied Biostatistics Inc.

ARRUDA L.M., ANDRADE J.P. & M.M. CUNHA, 1988. - Abundance, diversity and community structure of the fish population in the Ria de Aveiro (Portugal). *Oceanol. Acta*, 11(3): 235-240.

BARROSA J.O., 1980. - A Ria de Aveiro e a sua influência na economia da região. *Recur. hídr.*, 1(3): 83-96.

BAUCHOT M.L. & A. PRAS, 1987. - Guía de los peces de mar de España y de Europa. 432 p. Ediciones Omega, Barcelona.

BENNETT B.A., 1989. - The fish community of a moderately exposed beach on the Southwestern Cape Coast of South Africa and an assessment of this habitat as a nursery for juvenile fish. *Estuar. Coast. Shelf Sci*., 28: 293-305.

BORREGO C., CRUZ M.M. & P. GONÇALVES, 1994. - Estudo de avaliação da vulnerabilidade da capacidade de recepção das águas costeiras em Portugal. Relatório R 3.2. Meios receptores e suas características: (Be 1) - Ria de Aveiro, Pateira de Fermentelos e Barrinha de Mira. 69 p. IDAD - Projecto nº 13/94.

COSTA M.J. & M. ELLIOTT, 1991. - Fish usage and feeding in two industrialised estuaries - the Tagus, Portugal, and the Forth, Scotland. In: Estuaries and Coasts: spatial and temporal intercomparisons. pp. 289-297. Olsen and Olsen Eds., Fredensborg, Denmark.

ELLIOTT M. & F. DEWAILLY, 1995. - The structure and components of European estuarine fish assemblages. *Neth. J. Aquac. Ecol*., 29(3-4): 397-417.

ELLIOTT M., O'REILLY M.G. & C.J.L. TAYLOR, 1990. - The Forth estuary: a nursery and overwintering area for North Sea fishes. *Hydrobiologia*, 195: 89-103.

HAMERLYNCK O., 1993. - The ecology of *Pomatoschistus minutus* and *Pomatoschistus lozanoi* de Buen (Pisces, Gobiidae) in the shallow coastal waters and estuaries of the Southern Bight of the North sea. PhD thesis, Univ. of Gent, Belgium.

HILL M.O., 1973. - Diversity and evenness: A unifying notation and its consequences. *Ecologie*, 54: 427-432.

LEGENDRE L. & P. LEGENDRE, 1984 a). - Écologie numérique. Le traitement multiple des données écologiques. Masson et Les Presses de l'Université du Québec, 2e ed., Paris, 259p.

LEGENDRE L. & P. LEGENDRE, 1984 b). - Écologie numérique. La structure des donnés écologiques. Masson et Les Presses de l'Université du Québec, 2e ed., Paris, 335 p.

LEEUWEN P.I. van, RIJNSDORP A.D. & B. VINGERHOED, 1994. - Variations in abundance and distribution of demersal fish species in the coastal zone of the Southeastern North Sea between 1980 and 1993. *Demersal Fish Comm.*, 10: 1-19.

LIMA C., 1986. - Impacto da poluição por mercúrio nos organismos aquáticos da Ria de Aveiro. *Relat. Inst. Nac. Invest. Pescas*, 66: 28 p.

LUCAS M.F., CALDEIRA M.T., HALL A., DUARTE A.C. & C. LIMA, 1986. - Distribution of mercury in the sediments and fishes of the lagoon of Aveiro, Portugal. *Water Sci. Technol.*, 18: 141-148.

LUDWIG J.A. & J.F. REYNOLDS, 1988. - Statistical Ecology. A primer on Methods and Computing. 337 p. Wiley-Interscience Publications, New York.

MARSHALL S. & M. ELLIOTT, 1998. - Environmental influences on the fish assemblage of the Humber Estuary, UK. *Estuar., Coast. Shelf Sci.*, 46:175-184

MONTEIRO C.L.C., 1989. – La faune ichthyologique de la lagune Ria Formosa (sud Portugal). Dissertation, Instituto Nacional de Investigação das Pescas, Algés, Portugal, 218 p.

NASH R.D.M., 1988. - The effects of disturbance and severe seasonal fluctuations in environmental conditions on north temperate shallow-water fish assemblages. *Estuar. Coast. Shelf Sci.*, 26: 123-125.

NOBRE A., AFREIXO J. & J. MACEDO, 1915. - A Ria de Aveiro, Relatório oficial do regulamento da Ria de 28 de Dezembro de 1912. Imprensa Nacional, Lisboa, 197 p.

OSÓRIO B., 1912. - Pescas e peixes. Uma nota relativa à pesca e aos peixes da Ria de Aveiro. *Bol. Soc. Geogr. Lisboa*, 30(4-5): 216-224 e 30(6): 264-271.

POMFRET J.R., ELLIOTT M., O'REILLY M.G. & S. PHILLIPS, 1991. - Spatial and temporal patterns in the fish communities in two UK North Sea estuaries. *Estuar. Coasts: Spat. Temp. Intercomp.*, 87: 277-284

POTTER I.C., BECKLEY L.E., WHITFIELD A.K. & R.C.J. LENANTON, 1990. - Comparisons between the roles played by estuaries in the life cycles of fishes in temperate Western Australia and Southern Africa. *Environ. Biol. Fish.*, 28: 143-178.

RASMUSSEN E., 1973. - Systematics and ecology of the Isefjord marine fauna (Denmark). *Ophelia*, 11: 1-507.

REBELO J.E., 1992. - The ichthyofauna and abiotic hydrological environment of the Ria de Aveiro, Portugal. *Estuaries*, 15(3): 403-415.

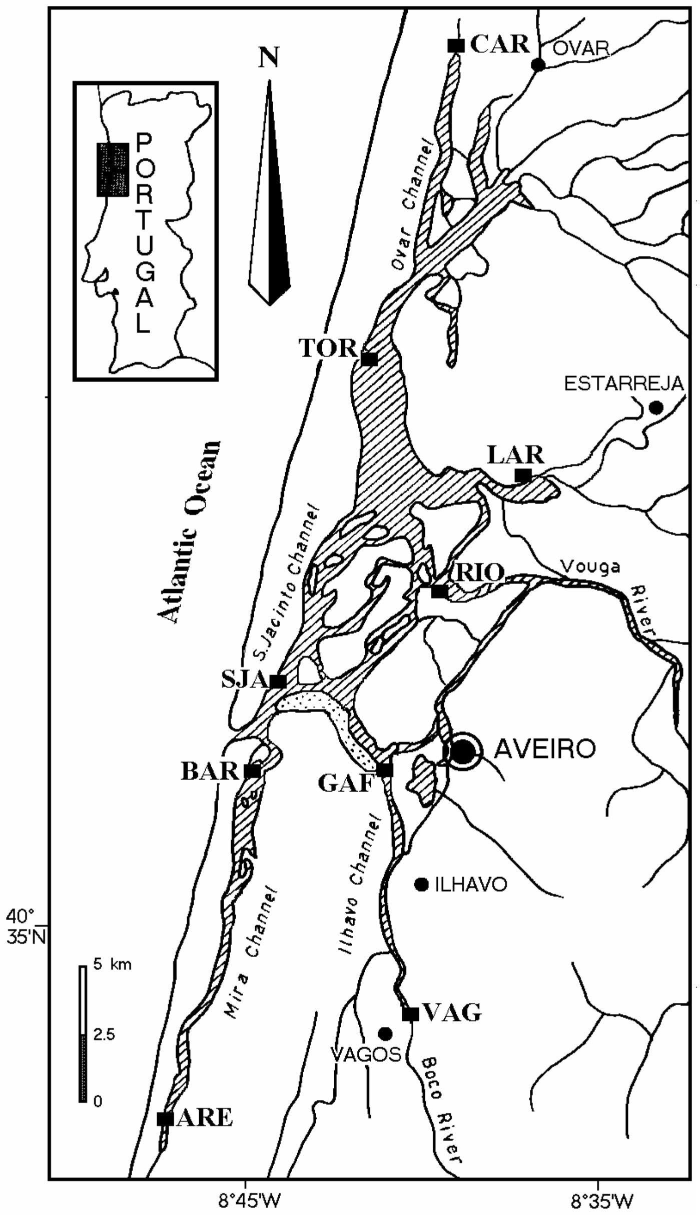
SNEATH P.H.A. & R.R. SOKAL, 1973. - Numerical Taxonomy. W.H. Freeman and Company, San Francisco, 573 p.

SOKAL R.R. & J.F. ROHLF, 1995. - Biometry. W.H.Freeman and company, New York. 3rd ed., 887 p.

WHITEHEAD P.J.P., BAUCHOT M.-L., HUREAU J.-C., NIELSEN J. & E. TORTONESE, 1986. - Fish. North-eastern Atl. Med.. 3 vols. UNESCO, U.K., 1984 p.

THIEL R., SEPULVEDA, KAGEMAN R. & W. NELLEN, 1995. - Environmental factors as forces structuring the fish community of the Elbe estuary. *J. Fish Biol*., 46:47-69.

ZAR J.H., 1984. - Biostatistical Analysis. 718 p. Prentice-Hall, Inc., 2nd ed., New Jersey.



CAR
OVAR
N
PORTUGAL
Ovar Channel
TOR
ESTARREJA
LAR
Atlantic Ocean
S.Jacinto Channel
RIO
Vouga
River
SJA
AVEIRO
BAR
GAF
Mira Channel
Ilhavo Channel
ILHAVO
40° 35'N
5 km
2.5
0
VAG
VAGOS
Boco River
ARE
8°45'W
8°35'W

Fig. 1

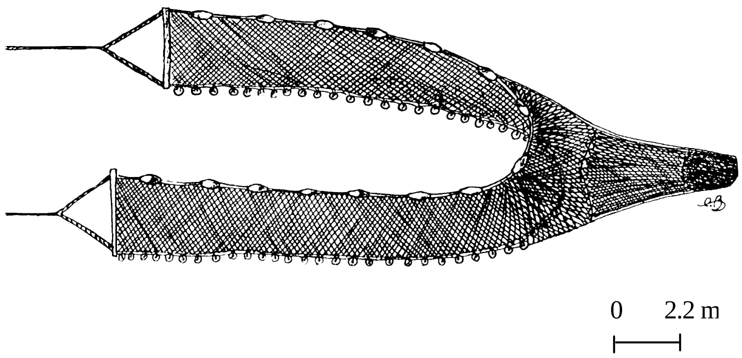
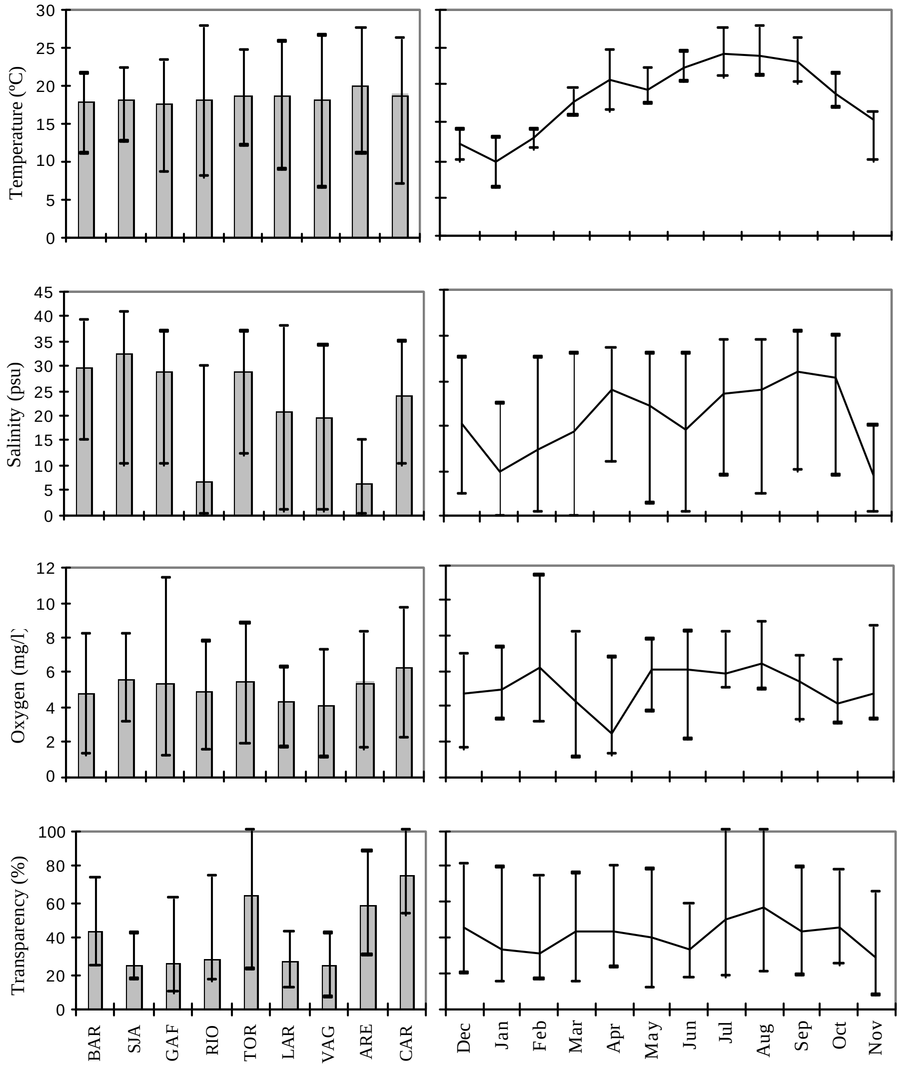


Fig. 2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Salinity (psu)
Oxygen (mg/l)
Transparency (%)
BAR
SJA
GAF
RIO
TOR
LAR
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CAR
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Jan
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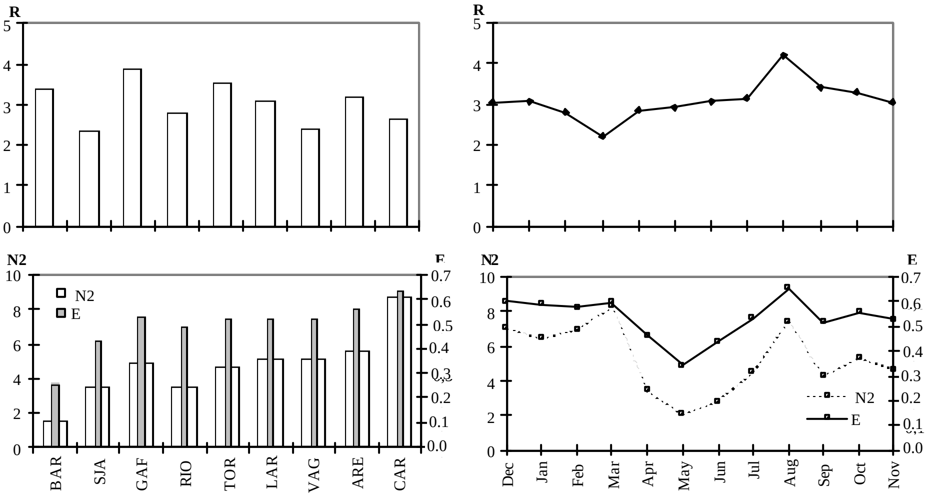
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

Fig. 3



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N2
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10
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N2
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BAR
SJA
GAF
RIO
TOR
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N2
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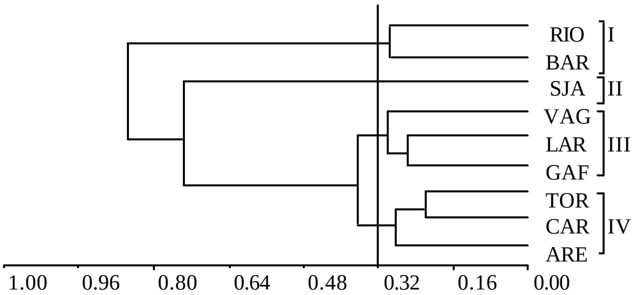
Fig. 4


RIO
BAR
SJA
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GAF
TOR
CAR
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II
III
IV
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0.64
0.48
0.32
0.16
0.00

Fig. 5

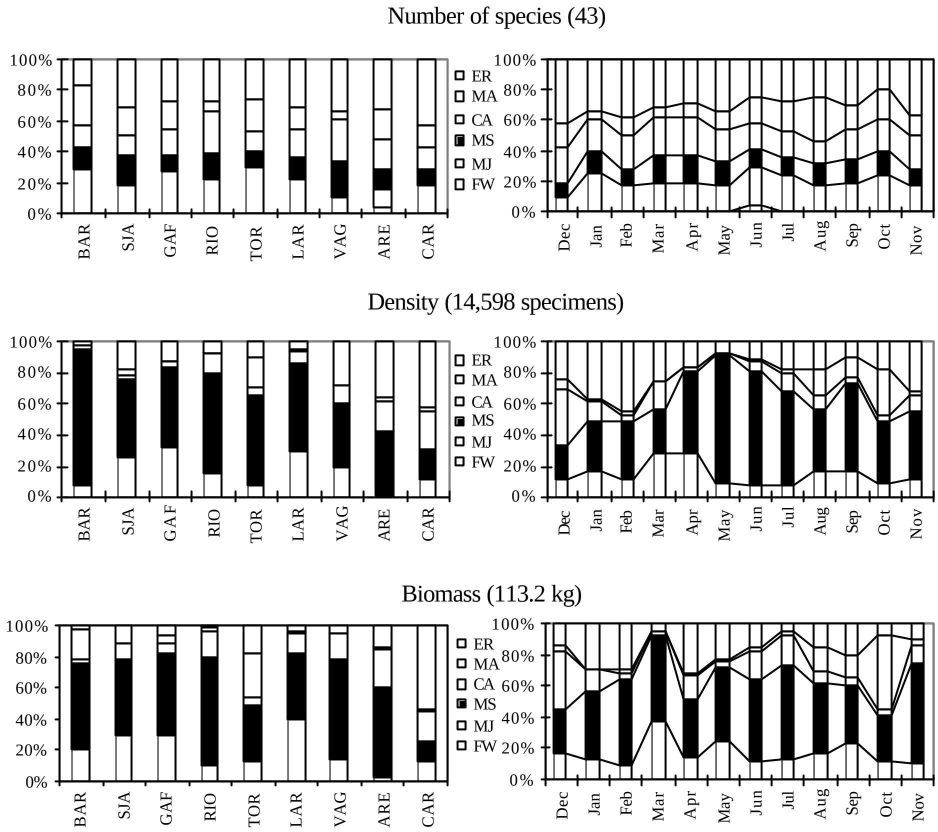
Number of species (43)
Density (14,598 specimens)
Biomass (113.2 kg)
ER
MA
CA
MS
MJ
FW
100%
80%
60%
40%
20%
0%
BAR
SJA
GAF
RIO
TOR
LAR
VAG
ARE
CAR
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

Fig. 6

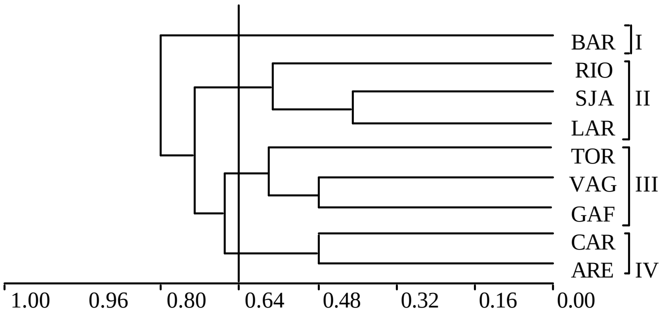
BAR
RIO
SJA
LAR
TOR
VAG
GAF
CAR
ARE
I
II
III
IV
1.00
0.96
0.80
0.64
0.48
0.32
0.16
0.00

Fig. 7

Figure legends

Fig. 1. - Map of the Ria de Aveiro lagoon showing sampling stations (■): ARE= Areão, BAR= Barra, CAR= Carregal, GAF= Gafanha, LAR= Laranjo, RIO= Rio Novo de Príncipe, SJA= São Jacinto, TOR= Torreira, VAG= Vagos.

Fig. 2. - Perspective drawing of the “chincha”, showing the conical cod-end in the centre of the net. Scale bar= 1:220 cm.

Fig. 3. - Minimum, mean and maximum values of abiotic parameters by sampling stations and months.

Fig. 4. - Variation of diversity indices by sampling stations and by months. **A**: Margalef index (R); **B**: Diversity (N2) and evenness (E).

Fig. 5. - Dendrogram of sampling stations, for the diversity indexes. The vertical line defines the groups (I, II, III and IV) used in the discriminant analysis.

Fig. 6. - Frequencies (%) of the number of species, density and biomass of estuarine resident species (ER), marine adventitious visitors (MA), diadromous (catadromous and anadromous migrant species) (CA), marine seasonal migrant species (MS), marine juvenile migrant species (MJ) and freshwater adventitious species (FW).

Fig. 7. - Dendrogram of sampling stations, for the ecological guilds abundance. The vertical line defines the groups (I, II, III and IV) used in the discriminant analysis.

Table I

Parameters	Stations		Months	
	F	P	F	P
Temperature	0.254	ns	64.500	***
Salinity	13.990	***	4.744	***
Dissolved oxygen	1.343	*	4.068	***
Transparency	19.860	***	1.167	*

Table II

Ecological categories	Total	Stations									Months											
Species		BAR	SJA	GAF	RIO	TOR	LAR	VAG	ARE	CAR	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
EST. RESIDENT (ER)																						
Aphia minuta	2	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0
Atherina boyeri	837	21	95	103	17	100	25	146	66	264	73	89	64	90	73	36	46	63	18	61	100	124
Gobius niger	197	10	0	18	0	166	2	0	0	1	17	11	2	0	23	17	14	20	10	16	61	6
Mugil cephalus	228	3	0	1	4	15	4	7	90	104	67	6	65	54	20	4	6	0	1	4	0	1
Platichthys flesus	16	0	0	1	1	2	0	0	12	0	1	0	0	0	0	8	0	0	1	2	0	4
Pomatoschistus microps	413	36	3	20	6	27	4	172	87	58	1	3	21	19	7	7	22	72	36	36	60	129
Pomatoschistus minutus	28	0	1	2	0	1	1	2	21	0	24	2	0	0	0	0	0	2	0	0	0	0
Symphodus melops	44	0	0	5	0	38	0	0	0	1	11	10	3	3	8	9	0	0	0	0	0	0
Syngnathus abaster	16	0	0	0	0	0	0	0	9	7	0	0	0	0	0	2	0	5	0	1	0	8
Syngnathus acus	662	2	2	0	2	19	5	20	333	279	31	11	40	60	40	87	97	171	43	18	23	41
Syngnathus typhle	38	0	2	1	0	0	1	2	5	27	1	0	0	0	0	0	11	15	1	3	3	4
M. ADVENTITIOUS (MA)																						
Blennius gattorugine	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Callionymus lyra	6	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3
Caranx crysos	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Echiichthys vipera	22	1	18	0	0	3	0	0	0	0	3	2	2	3	1	3	2	3	3	0	0	0
Mullus surmuletus	59	47	0	9	0	3	0	0	0	0	0	0	0	0	0	0	0	7	18	5	29	0
Oedalechilus labeo	61	0	0	0	0	7	8	0	18	28	61	0	0	0	0	0	0	0	0	0	0	0
Solea lascaris	12	0	0	0	0	9	0	0	3	0	1	0	0	0	0	3	2	4	2	0	0	0
Sparus aurata	36	3	0	2	2	1	1	2	2	23	0	0	0	0	13	13	2	1	2	4	1	0
Symphodus bailloni	738	26	1	11	0	697	2	0	1	0	0	0	0	0	0	0	11	46	80	189	397	15
Trachurus trachurus	17	6	0	1	0	0	0	0	1	9	0	0	8	0	0	0	0	0	1	0	7	1
DIADROMOUS (CA)																						
Alosa alosa	17	0	1	1	9	1	3	1	1	0	3	1	1	0	2	1	0	0	0	2	6	1
Alosa falax	40	13	8	5	1	0	11	1	1	0	3	5	4	1	3	4	10	5	1	2	1	1
Anguilla anguilla	287	2	0	1	1	10	0	4	199	70	4	0	1	8	3	10	26	188	33	1	10	3
Liza ramada	247	3	0	18	12	72	12	37	46	47	95	31	0	18	5	6	16	15	16	2	3	40
Liza saliens	667	7	0	10	30	81	38	105	92	304	243	9	9	136	12	7	59	40	9	45	31	67
MAR. SEASONAL (MS)																						
Belone belone	9	9	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	0	0	0	0	0
Chelon labrosus	455	6	8	32	49	25	49	65	128	93	11	25	114	103	45	55	30	14	18	5	3	32
Engraulis encrasicholus	9	0	0	0	0	0	0	3	6	0	0	0	0	0	0	0	0	0	1	1	7	0
Liza aurata	2906	153	33	186	214	836	202	459	570	253	206	88	50	161	536	311	247	385	196	191	136	399
Sardina pilchardus	4644	2365	262	488	13	1270	245	1	0	0	0	1	0	1	2	1728	999	808	37	639	429	0
MAR. JUVENILE (MJ)																						
Atherina presbyter	833	150	131	232	19	141	47	64	5	44	41	33	44	110	69	103	86	44	45	91	73	94
Dicentrarchus labrax	872	40	7	163	37	72	200	190	16	147	61	19	8	129	238	111	47	82	31	128	10	8
Dicentrarchus punctatus	11	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0
Diplodus annularis	15	1	0	3	0	5	0	0	0	6	0	3	0	6	2	3	1	0	0	0	0	0
Diplodus sargus	59	17	0	13	0	29	0	0	0	0	0	0	0	0	0	0	0	1	27	27	2	2
Diplodus vulgaris	11	2	0	6	0	2	1	0	0	0	0	0	0	0	0	0	5	0	3	0	3	0
Scophthalmus rhombus	2	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Solea senegalensis	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Solea vulgaris	5	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	0	1	1	1	1	0
Spondyliosoma cantharus	56	29	10	1	0	11	4	0	1	0	0	0	0	0	0	0	0	4	0	5	42	5
Trigla lucerna	17	3	0	0	0	14	0	0	0	0	0	0	1	0	3	13	0	0	0	0	0	0
FRESHWATER (FW)																						
Carassius carassius	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Total density	14598	2958	587	1336	429	3659	866	1281	1714	1768	958	351	439	902	1113	2542	1742	2007	636	1481	1439	988
Number of species	43	28	16	29	18	30	22	18	25	21	21	20	18	16	21	24	24	25	28	26	25	22

Table III

	I-II	I-III	I-IV	II-III	II-IV	III-IV
D^2	596475.3	82266.2	101401.7	-5351583.1	745421.3	239416.4
Temperature	-2.4	0.3	**110.8**	0.2	-48.4	82.1
Salinity	116.4	-200.2	3.1	11.9	175.3	-37.1
Dissolved oxygen	-101.1	-42.1	-32.8	-2.3	-34.4	-62.9
Transparency	-33.4	19.6	50.2	**47.7**	**340.2**	**148.1**

Table IV

	I-II	I-III	I-IV	II-III	II-IV	III-IV
D^2	-1659936.1	-230939.8	262630.5	-218197.8	-767564.3	61225.1
Temperature	0.7	-4.2	-71.8	2.8	-7.3	-78.1
Salinity	30.6	**50.1**	42.3	33.3	7.1	16.8
Dissolved oxygen	3.4	29.6	-15.4	-6.5	**65.8**	-19.8
Transparency	**106.9**	22.1	**143.2**	**111.2**	10.3	**182.6**

Table V

Estuary	Country	Latitude	Source of publication
Tagus	Portugal	38º 40' N	Costa and Elliott, 1991
El Abra	Spain	43º 50' N	Elliott and Dewailly, 1995
Loire	France	47º 10' N	Marchand, 1993
Voordelta	The Netherlands	52º 00' N	Hamerlynck, 1993
Humber	England	53º 40' N	Marshall and Elliott, 1998
Elbe	Germany	53º 50' N	Thiel *et al*., 1995
Isefjord	Denmark	55º 50' N	Rasmussen, 1973
Oslofjord	Norway	59º 10' N	Nash, 1988
Ria de Aveiro	Portugal	40º 40' N	Present study

Table VI

Estuary	Period	Frequency	Stations	Species	Families	Gear
Tagus	1976-91	monthly	6	45	23	Beam trawl
El Abra	1989-93	annually	7	23	16	Beam trawl
Loire	1981-82	monthly	unknown	36	24	Beam trawl
Voordelta	1989	monthly	22	40	24	Beam trawl
Humber	1992-93	quarterly	14	26	18	Beam trawl
Elbe	1989-92	unknown	11	62	28	Framed gape stow net, Demersal otter trawl
Isefjord	1940-70	monthly	110	70	38	Commercial, angling, beam trawl
Oslofjord	1981-82	unknown	2	40	20	Bag beach seine
Ria de Aveiro	1996-97	monthly	9	43	21	Purse seine-type net ("chincha")

Table VII

Estuary	ER	MA	CA	MS	MJ	FW
Tagus	25	16	13	13	29	4
El Abra	18	48	4	9	22	0
Loire	14	20	14	9	31	11
Voordelta	30	25	5	10	30	0
Humber	31	15	15	8	31	0
Elbe	19	13	13	8	16	31
Isefjord	24	41	9	10	14	1
Oslofjord	33	28	8	8	23	3
Ria de Aveiro	25	23	12	12	26	2

Table VIII

Family	**Species**	**1987**	**1996/97**
Clupeidae	*Sardina pilchardus* (Waulbaum, 1792)	826	4644
Mugilidae	*Liza aurata* (Risso, 1810)	1755	2906
Moronidae	*Dicentrarchus labrax* (Linnaeus, 1758)	871	872
Atherinidae	*Atherina boyeri* (Risso, 1810)	5976	837
Atherinidae	*Atherina presbyter* Cuvier, 1829	3185	833
Labridae	*Symphodus bailloni* (Valenciennes, 1839)	199	738
Mugilidae	*Liza saliens* (Risso, 1810)	629	667
Syngnathidae	*Syngnathus acus* Linnaeus, 1758	704	662
Mugilidae	*Chelon labrosus* (Risso, 1826)	38	455
Gobiidae	*Pomatoschistus microps* (Krøyer, 1838)	0	**413**
Anguillidae	*Anguilla anguilla* (Linnaeus, 1758)	753	287
Mugilidae	*Liza ramada* (Risso, 1826)	1247	247
Mugilidae	*Mugil cephalus* Linnaeus, 1758	16	228
Gobiidae	*Gobius niger* Linnaeus, 1758	802	197
Mugilidae	*Oedalechilus labeo* (Cuvier, 1829)	4	61
Sparidae	*Diplodus sargus* (Linnaeus, 1758)	22	59
Mulliidae	*Mullus surmuletus* Linnaeus, 1758	0	**59**
Sparidae	*Spondyliosoma cantharus* (Linnaeus, 1758)	14	56
Labridae	*Symphodus melops* (Linnaeus, 1758)	49	44
Clupeidae	Alosa fallax (Lacepède, 1803)	18	40
Syngnathidae	*Syngnathus typhle* Linnaeus, 1758	16	38
Sparidae	*Sparus aurata* (Linnaeus, 1758)	167	36
Gobiidae	*Pomatoschistus minutus* (Pallas, 1770)	295	28
Trachinidae	*Echiichthys vipera* (Cuvier, 1829)	85	22
Triglidae	*Chelidonichthys lucerna* (Linnaeus, 1758)	98	17
Carangidae	*Trachurus trachurus* (Linnaeus, 1758)	0	**17**
Clupeidae	*Alosa alosa* (Linnaeus, 1758)	0	**17**
Syngnathidae	*Syngnathus abaster* Risso, 1826	188	16
Pleuronectidae	*Platichthys flesus* (Linnaeus, 1875)	156	16
Sparidae	*Diplodus annularis* (Linnaeus, 1758)	2	15
Soleidae	*Solea lascaris* (Risso, 1810)	9	12
Sparidae	*Diplodus vulgaris* (E. Geoffrey Saint-Hilaire, 1817)	11	11
Moronidae	*Dicentrarchus punctatus* (Bloch, 1792)	0	**11**
Engraulidae	*Engraulis encrasicholus* (Linnaeus, 1758)	7	9
Belonidae	*Belone belone* (Linnaeus, 1761)	2	9
Callionymidae	*Callionymus lyra* Linnaeus, 1758	95	6
Soleidae	*Solea solea* (Linnaeus, 1758)	4	5
Gobiidae	*Aphia minuta* (Risso, 1810)	83	2
Scophthalmidae	*Scophthalmus rhombus* (Linnaeus, 1758)	36	2
Soleidae	*Solea senegalensis* Kaup, 1858	26	1
Cyprinidae	*Carassius carassius* (Linnaeus, 1758)	8	1
Blennidae	*Parablennius gattorugine* (Linnaeus, 1758)	0	**1**
Pomatomidae	*Caranx crysos* (Mitchill, 1815)	0	**1**
Gobiidae	*Deltentosteus quadrimaculatus* (Valenciennes, 1837)	**198**	0
Gasterosteidae	*Gasterosteus aculeatus* Linnaeus, 1758	**151**	0
Gobiidae	*Gobius strictus* Fage, 1907	**128**	0
Poecilidae	*Gambusia affinis* (Baird & Girard, 1853)	**59**	0
Labridae	*Labrus viridis* Linnaeus, 1758	**20**	0
Gobiidae	*Gobius ater* Belloti, 1888	**19**	0
Blenniidae	*Parablennius gattorugine* (Linnaeus, 1758)	**18**	0
Ammodytidae	*Ammodytes tobianus* Linnaeus, 1758	**13**	0
Cobitidae	*Cobitis taenia* Linnaeus, 1758	**7**	0
Gadidae	*Gaidropsarus mediterraneus* (Linnaeus, 1758)	**6**	0
Tetraodontidae	*Lagocephalus lagocephalus* (Linnaeus, 1758)	**3**	0
Ammodytidae	*Hyperoplus lanceolatus* (Le Sauvage, 1824)	**2**	0
Gadidae	*Ciliata mustela* (Linnaeus, 1758)	**2**	0
Gobiidae	*Gobius paganellus* Linnaeus, 1758	**2**	0
Blenniidae	*Parablennius sanguinolentus* (Pallas, 1814)	**1**	0
Cottidae	*Taurulus bubalis* (Euphrasen, 1786)	**1**	0
Petromyzontidae	*Petromyzon marinus* Linnaeus, 1758	**1**	0
Sparidae	*Pagellus bogaraveo* (Brunnich, 1768)	**1**	0
Syngnathidae	*Hippocampus hippocampus* (Linnaeus, 1758)	**1**	0
	62 species		

Table legends

Table I. - Two way anova without replication of hydrologic abiotic parameters by sampling stations and months. The statistic test (F) and the probability value (P) and are showed: n.s. ($P \geq 0.05$); * ($P<0.05$); ** ($P<0.01$); *** ($P<0.001$).

Table II. - Species distribution of the fish fauna of the Ria de Aveiro, by sampling stations and months, showing total densities. The species are grouped by ecological categories using the method of Elliott and Dewailly, 1995. The arrow points to the six most abundant species over the whole sampling period.

Table III. - Discriminant analysis between pairs of sampling stations groups, for the diversity indexes, from the medium values of temperature, salinity, dissolved oxygen and transparency. D^2 is the multivariate distance.

Table IV. - Discriminant analysis between pairs of sampling stations groups, for the ecological guilds abundance, from the medium values of temperature, salinity, dissolved oxygen and transparency. D^2 is the multivariate distance.

Table V. – List of the European estuaries investigated until now and references (adapted from Elliot and Dewailly, 1995).

Table VI. - Summary of the sampling effort for each estuary given in Table V, number of species and families of fish fauna (adapted from Elliot and Dewailly, 1995).

Table VII. - Percentage of number species in the ecological guild for each estuary given in Table V. ER - estuarine resident species; MA - marine adventitious visitors, CA - diadromous (catadromous and anadromous migrant species), MS -marine seasonal migrant species, MJ - marine juvenile migrant species, FW - freshwater adventitious species (adapted from Elliot and Dewailly, 1995).

Table VIII. - Ranking in abundance of species in 1987 (Rebelo, 1992), at ten sampling stations, and in the present study, 1996/97, at nine sampling stations. The same sampling method was used in both studies. In bold are the species specific to each study. The circled mark is referred to the very abundant species in both studies.