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Abundance, diversity, and community structure of the fish population in the Ria de Aveiro (Portugal)

Lagoon
Fish community
Evenness
Distributional patterns
Lagune
Communauté ichthyologique
Équitabilité
Distributions d'abondance

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ABSTRACT

The Ria de Aveiro lagoon communicates directly with the sea and tidal action mixes seawater with freshwater from drainage and groundwater. It is consequently subjected to environmental fluctuations on a large scale.

The fish population was sampled at two month intervals between October 1980 and July 1981. A total of 49 species was found in the lagoon but the maximum number of species in a single sampling zone was 22. The greater number of species found in the zone adjacent to the sea explains the variation both in species richness and in biomass. Migratory species were normally dominant, in terms of biomass.

The Shannon diversity index indicated that the communities of fish were heterogeneous, particularly in zones close to the sea and the evenness index was generally lower than 0.8. Two demographic models (those of Motomura and Preston) were tested. The Motomura model fitted most of the communities closest to the opening of the sea and the Preston model those most distant, especially to the north. The lowest value for the distance of Matusita determined which model was the most appropriate for the observed data.

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RÉSUMÉ

Abondance, diversité et structure de la communauté ichthyologique dans la Ria de Aveiro (Portugal)

La lagune Ria de Aveiro s'ouvre directement sur la mer, et l'action des marées y mélange l'eau de mer et l'eau douce de drainage. Elle est de ce fait très sensible aux fluctuations de l'environnement.

Les auteurs ont étudié le peuplement ichthyologique à partir de prélèvements effectués tous les deux mois, d'octobre 1980 à juillet 1981. Au total, 49 espèces ont été recensées, mais la richesse spécifique maximale observée n'a pas dépassé 22. Le grand nombre d'espèces rencontrées dans la zone proche de l'embouchure explique la variation numérique des espèces et celle de leur biomasse, où les espèces migratrices sont le plus souvent dominantes.

L'indice de diversité de Shannon révèle des communautés ichthyologiques hétérogènes, en particulier dans le secteur aval. En général, l'équitabilité était inférieure à 0,8. Sur deux modèles démographiques testés, celui de Motomura s'ajuste le mieux (meilleure valeur de la distance de Matusita) aux groupes d'espèces qui fréquentent la zone proche de l'embouchure, celui de Preston aux espèces qui vivent en amont.

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INTRODUCTION

The lagoon system of the Ria de Aveiro is the site of an important fishing industry for molluscs, crustaceans and fishes. Information on these fisheries is restricted to: lists of the flora and fauna in the lagoon (Osório, 1912; Rezende, 1944; Pato, 1948); early data on the distribution of fish (Nobre *et al.*, 1915); an investigation of the age distribution and growth of the sea-bass, *Dicentrarchus labrax* (Andrade, 1983; 1986); and a description of the reproductive cycle and the migration of the flounder, *Platichthys flesus* (Cunha, 1984*a*; 1984*b*).

These studies are not sufficient for an understanding either of the history, or of the status of this industry (Barrosa, 1980). Thus, in this paper, the relative abundance of 49 species of fish, as well as the structure and stability of their populations are described.

DESCRIPTION OF THE SITE

The topography and physical characteristics of the Ria de Aveiro are described by Barrosa (1980), Hall and Duarte (1984). The total area varies between 42 km^2 at low tide and 47 km^2 at high tide. The depth is only 1 m in most of the lagoon, but can reach 10 m in the navigation channels, the three main ones of which are: the Canal de São Jacinto, the Canal de Mira, and the Canal de Ílhavo. All three channels open into the "barra", which is a man-made connection between the lagoon and the ocean (Fig. 1).

Drainage and groundwater from the land contribute freshwater to the lagoon, but the volume is unknown. Tidal action mixes freshwater with seawater entering from the "barra". The tidal input is approximately 25 and 90 Mm^3 for tidal amplitudes of 1 and 3 m respectively. Currents produced by this tidal action are significant only in the "barra", the central part of the main channels ("cale") and a few other restricted areas. There is a delay of 6 hours in the tide between the "barra" and the extreme margins of the lagoon.

There are no measurements of either the physical parameters or the water quality for the lagoon. However, despite being an enormous body of water with favourable interchange conditions with the sea, the Ria de Aveiro is not immune to human mismanagement. Before the recent increase in the use of artificial fertilizer by agriculture, eutrophication of the lagoon was kept at bay by a healthy fishing industry and by the regular harvesting of floating and fixed macrophytes which were used in marginal fields as natural fertilizer and soil conditioner. This practice has declined considerably during the last few decades owing to increased labour costs and competition for manpower which have made it uneconomic (Hall, 1980).

MATERIAL AND METHODS

Between October 1980 and July 1981, 45 samples were taken at two-month intervals. The samples were col-

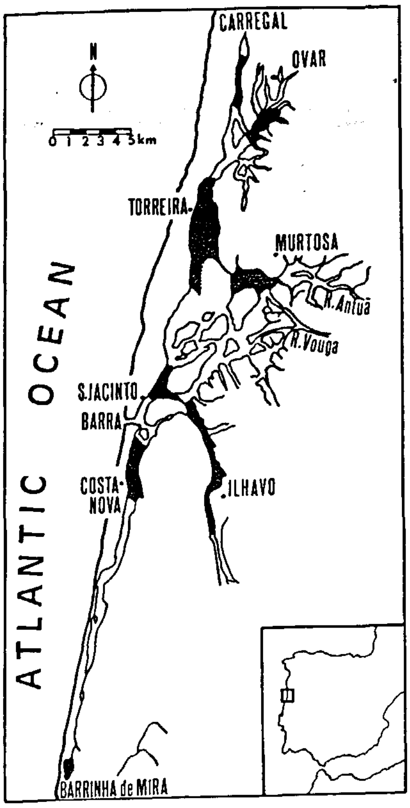

Figure 1
Map of the lagoon Ria de Aveiro, showing fishing zones (in black).
Stations de prélèvement (en noir) dans la lagune Ria de Aveiro.

lected from the 8 zones shown in Figure 1. These zones were chosen as representative of the different channels and water depths. A total of 11,386 fish from 49 species were caught by local fishermen especially hired for the project and accompanied by two of the authors.

Fishing methods

The fish were caught either by the "chincha" (Fig. 2) or the "botirão" (Fig. 3). Both are part of the characteristic fishing gear of the fishermen in Aveiro.

The "chincha" is nearly rectangular in shape and about 20 m long. Between the edge and the centre of the net, the width increases from 0.5 to 2.5 m and the mesh size decreases from 2.5 to 2.0 cm. A conical net is set into the middle of the "chincha" which has an even lower mesh size of 1.0-1.5 cm. Essentially, the net works like a purse seine with a cod-end (*see* details in Nobre *et al.*, 1915). The "chincha" is only selective when the lower edge loses contact with the bottom allowing fish to escape. In practice selectivity was low

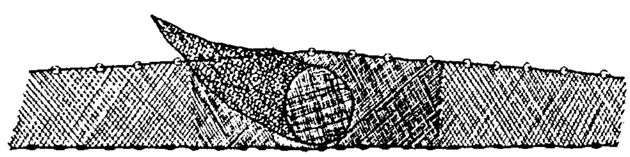

Figure 2
Perspective drawing of the "chincha", showing a conical cod-end in the centre of the net.
Perspective de la «chincha» montrant un sac conique au milieu du filet.

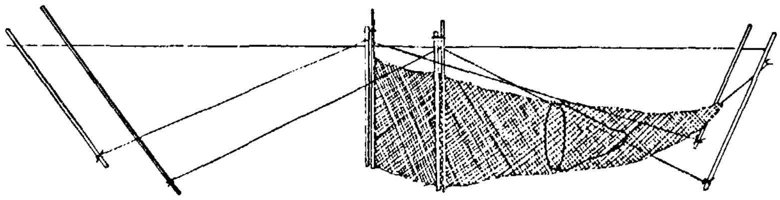

Figure 3
Perspective drawing of the "botirão", showing the "valve" in the cod-end.
Perspective du « botirão » montrant la « valve » dans le sac.

because six hauls were made in each sampling zone. Furthermore, a close homogeneity of the fishing effort was achieved because this same number of hauls was always made during the sampling period.

The "botirão" is a conical fish trap some 15 m long, with a mouth that is 2 m high and 5 m wide. The mesh size, when the net is fully stretched, varies from 20 mm (knot to knot) at the mouth to 9 mm at the "valve". At the cod-end, the mesh is almost completely closed. Within the net there is a "valve" which allows fish to enter the conical end, or cod-end, of the net but prevents them returning towards the mouth (*see* details in Nobre *et al.*, 1915).

The "chincha" was used throughout the sampling period whereas the "botirão" was used in December and February at São Jacinto and Costa Nova, *i.e.* only during winter and in those zones where the currents were strong enough to drive the fish into the trap. Consequently, the use of both the "botirão" and the "chincha" in space and in time was not the same, and the results obtained did not have the same ecological significance. For these reasons, the species caught with the "botirão" were recorded but the number of individuals was not considered when determining the structure and ecological dynamics of the community.

Treatment of fish catch

The individuals caught were sorted into species and weighed before being preserved.

Species were classified according to life-history and ecological information from Andrade (1983), Cunha (1984*a*; 1984*b*), Lotina-Benguria and Camiña (1975), Lozano-Rey (1952; 1960) and Lythgoe and Lythgoe (1971) as follows:

a) sedentary species which spent their entire lives in the lagoon;

b) freshwater, migratory species;

c) marine, migratory species;

d) marine species which were restricted to the areas of greatest marine influence in the lagoon, and occasional species which entered from the ocean.

Treatment of data

The following parameters were recorded to determine the structure and ecological dynamics of the community;

a) species richness, *s*, that is to say, the number of species sampled at each sampling zone;

b) diversity index, H, where $H = -\sum_{i=1}^{s} p_i . \log_2 p_i$, being p_i the proportion of individuals in the *i*-th species (Shannon, 1948), and evenness, E, where $E = H/\log_2 s$ (Piélou, 1969; 1977). The evenness, varying between 0 and 1, indicates the degree of equitability of the species distribution in the community; comparison of E

Table 1
Checklist of the sedentary and migratory species of fish caught from the lagoon Ria de Aveiro.
Liste des espèces sédentaires et migratoires capturées dans la lagune Ria de Aveiro.

Sedentary species
Atherina (Hepsetia) presbyter Cuvier, 1829
Gobius paganellus Linnaeus, 1758
Pomatoschistus minutus (Pallas, 1770)
Pomatoschistus microps (Krøyer, 1838)
Pomatoschistus pictus (Malm, 1865)
Syngnathus acus Linnaeus, 1758
Freshwater migratory species
Barbus barbus bocagei Steindachner, 1864
Carassius carassius (Linnaeus, 1758)
Cobitis taenia Linnaeus, 1758
Rutilus macrolepidotus (Steindachner, 1866)
Micropterus salmoides (Lacepède, 1802)
Gambusia affinis holbrookii (Girard, 1859)
Gasterosteus aculeatus (Linnaeus, 1758)
Marine migratory species
Alosa fallax (Lacepède, 1803)
Anguilla anguilla (Linnaeus, 1758)
Dicentrarchus labrax (Linnaeus, 1758)
Liza (Liza) aurata (Risso, 1810)
Mugil cephalus cephalus Linnaeus, 1758
Liza (Liza) ramada (Risso, 1826)
Chelon labrosus (Risso, 1826)
Platichthys flesus flesus (Linnaeus, 1758)
Solea vulgaris vulgaris Quensel, 1806
Marine species restricted to the areas of greatest marine influence and occasional species
Ammodytes tobianus Linnaeus, 1758
Aphia minuta (Risso, 1810)
Belone belone (Linnaeus, 1761)
Biennius gattorugine Brünnich, 1768
Callionymus lyra Linnaeus, 1758
Ciliata mustela (Linnaeus, 1758)
Conger conger ([Artedi, 1738] Linnaeus, 1758)
Symphodus (Crenilabrus) bailloni (Valenciennes, *in* Cuv. Val., 1839)
Diplodus vulgaris (E. Saint-Hilaire, 1817)
Engraulis encrasicolus (Linnaeus, 1758)
Entelurus aequoreus (Linnaeus, 1758)
Gobius niger Linnaeus, 1758
Hyperoplus lanceolatus (Le Sauvage, 1824)
Mullus surmuletus (Linnaeus, 1758)
Psetta maxima (Linnaeus, 1758)
Solea lascaris (Risso, 1810)
Sardina pilchardus (Walbaum, 1792)
Scophthalmus rhombus (Linnaeus, 1758)
Solea senegalensis Kaup, 1758
Sparus aurata (Linnaeus, 1758)
Spondyliossoma cantharus (Linnaeus, 1758)
Sprattus sprattus (Linnaeus, 1758)
Syngnathus abaster Risso, 1826
Syngnathus typhle Linnaeus, 1758
Trachinus vipera Cuvier *in* Cuv. & Val., 1829
Trachurus trachurus (Linnaeus, 1758)
Trigla lucerna (Linnaeus, 1758)

between samples with different species number is not valid, but some underlying pattern may be seen for each sample;

c) abundance distribution models of Motomura (1932; 1947) and Preston (1948; 1962). The criteria for choosing these models has been well developed by Amanieu *et al.* (1981). To adjust the data to the model of abundance distribution of Motomura or Preston, the species are ranked according to their decreasing abundance. The Motomura model, or logarithmic linear model ($\log q_i = ai + b$), shows a linear relation between the logarithm of abundance (q_i) and the rank (i); whereas the Preston model, or logarithmic normal model ($\log q_i = \sigma \mathrm{P}k_i + b$), shows a linear relation between the logarithm of abundance (q_i) and the probit of the rank ($\mathrm{P}k_i$) (Daget, 1976). The calculations carried out were based on the biomass. The model we have retained is that which led to the smallest variation between the observed values and the calculated values. The appreciation distance is that of Matusita (1955). Over each time-sequence of data the more frequently retained model was considered as appropriate for each sampling zone.

RESULTS

Species and their abundance in the lagoon

Table 1 is a list of the sedentary and migratory species of fish caught from the lagoon. All the species captured by the "botirão" were also caught by the "chincha".

Table 2 shows the four species which were most abundant by weight in each sampling zone. *Anguilla anguilla* was the dominant species to the north of the "barra", except in São Jacinto, where *Atherina presbyter* dominated. To the south the weights of *Liza aurata* and *Barbus bocagei* were greater.

The greatest number of species and biomass occurred in the areas closest to the "barra"; 22 species (biomass: 7,197 g) were caught in the zone of Costa Nova. There was a gradual decline to 4 species and to a biomass of 160 g as the distance from the "barra" increased (Tab. 3).

Table 4 shows the percentage weight of sedentary and migratory species found in each sampling zone and in

Table 2

Percent weight of the four most abundant species in each sampling zone.

Poids, en pourcentage, des quatre espèces les plus abondantes à chaque zone d'échantillonnage.

Sampling zone	Species			
Carregal	*A. anguilla* 25	*A. presbyter* 16	*C. labrosus* 15	*M. cephalus* 14
Ovar	*A. anguilla* 44	*A. presbyter* 27	*L. aurata* 9	*P. flesus* 4
Torreira	*A. anguilla* 20	*A. presbyter* 13	*L. aurata* 9	*T. lucerna* 9
Murtosa	*A. anguilla* 43	*L. aurata* 17	*A. presbyter* 9	*D. labrax* 8
São Jacinto	*A. presbyter* 24	*A. anguilla* 13	*S. pilchardus* 12	*L. aurata* 10
Costa Nova	*L. aurata* 23	*A. anguilla* 20	*A. presbyter* 12	*T. lucerna* 7
Barr. de Mira	*B. bocagei* 50	*C. carassius* 44	*A. anguilla* 13	*C. taenia* 7
Ílhavo	*L. aurata* 64	*A. anguilla* 8	*C. labrosus* 6	*L. ramada* 4

Table 3

Number of species and biomass (g) for each sampling zone and for each sampling period.

Nombre d'espèces et biomasse (g) pour chaque zone d'échantillonnage et pour chaque période d'échantillonnage.

Sampling zone	October 1980	December 1980	February 1981	May 1981	July 1981
Carregal	9	9	8	10	5
	1756	362	476	1185	765
Ovar	7	4	6	12	6
	1126	567	431	1278	227
Torreira	7	9	10	16	13
	163	2391	770	3340	2458
Murtosa	4	5	6	6	9
	160	296	213	416	446
São Jacinto	15	11	6	18	14
	3212	1272	342	5097	7101
Costa Nova	13	9	10	17	22
	2366	2133	2794	4400	7197
Barr. de Mira	5	7	8	7	8
	689	1359	824	2241	3228
Ílhavo	7	–	10	10	18
	2008	–	10926	4497	6918

Table 4

Percent weight of sedentary and migratory species for each sampling zone and for each sampling period. Abbreviations: MM: marine migratory; FM: freshwater migratory; S: sedentary.

Poids, en pourcentages, des espèces sédentaires et migratoires pour chaque zone d'échantillonnage et pour chaque période d'échantillonnage. Abréviations: MM.: migratoires marins; FM: migratoires d'eau douce; S: sédentaires.

Sampling zone		October 1980	December 1980	February 1981	May 1981	July 1981
Carregal	S	2	64	63	15	10
	MM	98	36	37	85	90
Ovar	S	7	55	71	28	27
	MM	93	45	29	72	73
Torreira	S	1	13	62	19	37
	MM	99	87	38	81	63
Murtosa	S	2	15	17	1	15
	MM	98	85	83	99	85
São Jacinto	S	15	10	9	9	44
	MM	85	90	91	91	56
Costa Nova	S	30	14	14	17	20
	MM	70	86	86	83	80
Barr. de Mira	S	1	1	10	4	2
	MM	0	0	89	0	41
	FM	99	99	1	96	57
Ílhavo	S	1	–	4	9	9
	MM	99	–	96	91	91

Table 5
Diversity index (Shannon, 1948) (H) and evenness (E) for the number of individuals for the different samples.
Indice de diversité (Shannon, 1948) (H) et d'équitabilité (E) pour les effectifs des espèces dans les différents échantillonnages.

Sampling zone		October 1980	December 1980	February 1981	May 1981	July 1981
Carregal	H	1.86	0.73	1.17	1.99	1.44
	E	0.75	0.28	0.39	0.60	0.62
Ovar	H	1.83	0.60	0.99	2.24	2.05
	E	0.65	0.30	0.38	0.63	0.79
Torreira	H	2.44	2.81	2.21	3.03	2.42
	E	0.87	0.89	0.66	0.76	0.65
Murtosa	H	1.25	2.06	1.79	1.72	2.10
	E	0.62	0.89	0.69	0.61	0.66
São Jacinto	H	2.36	1.87	2.51	3.09	1.88
	E	0.60	0.54	0.97	0.73	0.49
Costa Nova	H	2.50	1.79	1.95	2.94	3.17
	E	0.68	0.52	0.59	0.72	0.72
Barr. de Mira	H	1.52	2.16	2.14	2.19	2.31
	E	0.65	0.77	0.71	0.78	0.77
Ílhavo	H	1.99	–	1.51	1.76	2.66
	E	0.71	–	0.45	0.53	0.65

each catch. Marine migratory species were normally dominant throughout the year, although in the Barrinha de Mira nearly all the fish were freshwater migratory species.

Diversity and evenness

The maximum and minimum values for the diversity in number of individuals of the species in each sampling zone were not significantly different in the areas furthest away from the "barra". However, the difference between these values did increase as the distance from the "barra" decreased. The values of evenness calculated from these samples were generally lower than 0.8, and were only exceeded in a few isolated cases amongst the 45 samples (Tab. 5).

The effects of seasonal variation on the data can be reduced by combining all the samples from each sampling zone. Thus, the variation in diversity and evenness between each sampling zone was compared (Tab. 6). Values for the Shannon diversity index varied between 1.70 and 3.41 bits. The values calculated for the evenness were generally less than 0.8 except for the samples from the Murtosa.

Models of abundance distribution

The Motomura model fitted the frequency distribution in most of the sampling zones closest to the "barra" (Tab. 7). The Preston model best fitted the samples from the zones most distant from the "barra", especially to the north, where seawater input was greater than in other areas. Moreover, the Motomura and Preston models best fitted the summer and winter samples respectively. However, it was evident that the Motomura model described most of the community structures.

DISCUSSION

The list of 49 species from the lagoon shows that only 6 are permanent residents. Among the others, 7 are freshwater migratory, 9 are marine migratory and 27 are occasional marine species. These species are similar to those found by Osório (1912) and Nobre *et al.* (1915), except that these authors found more occasional

Table 6
Shannon diversity index (H) and evenness (E) for the number of individuals for each sampling zone.
Indice de diversité de Shannon (H) et d'équitabilité (E) calculés pour les effectifs des espèces pour chaque zone d'échantillonnage.

Sampling zone	H	E
Carregal	1.93	0.49
Ovar	1.70	0.50
Torreira	3.41	0.73
Murtosa	3.35	0.86
São Jacinto	3.25	0.70
Costa Nova	3.33	0.68
Barr. de Mira	2.50	0.75
Ílhavo	2.70	0.61

Table 7
Values for the Matusita distance calculated between the observed distributions of abundances and the theoretical distribution. Abbreviations: M: Motomura model; P: Preston model.
Valeurs de la distance de Matusita calculées entre les distributions d'abondance observées et la distribution théorique. Abréviations: M: modèle de Motomura; P: modèle de Preston.

Sampling zone		October 1980	December 1980	February 1981	May 1981	July 1981
Carregal	M	0.25	0.13	0.09	0.09	0.15
	P	0.29	0.21	0.09	0.08	0.16
Ovar	M	0.19	0.39	0.11	0.13	0.07
	P	0.12	0.41	0.09	0.09	0.08
Torreira	M	0.14	0.11	0.13	0.12	0.05
	P	0.19	0.14	0.10	0.21	0.10
Murtosa	M	0.09	0.16	0.09	0.19	0.18
	P	0.09	0.14	0.12	0.15	0.25
São Jacinto	M	0.20	0.10	0.04	0.09	0.09
	P	0.29	0.15	0.07	0.15	0.14
Costa Nova	M	0.15	0.33	0.15	0.15	0.23
	P	0.10	0.38	0.19	0.14	0.38
Barr. de Mira	M	0.12	0.18	0.15	0.12	0.16
	P	0.13	0.14	0.12	0.09	0.15
Ílhavo	M	0.42	–	0.46	0.36	0.11
	P	0.05	–	0.36	0.28	0.14

marine species. The greater number of species found in the zone adjacent to the sea explains the variation both in species richness and biomass. Furthermore, the greatest in biomass are *Anguilla anguilla* and *Atherina presbyter* in the fully saline and brackish zones of the lagoon, but these change to *Liza aurata* in the Canal de Ílhavo and Costa Nova, and to *Barbus bocagei* in the Barrinha de Mira. Three of these species are migratory, which reflects the importance of this group in the fish community of the lagoon. The resident species in the lagoon are relatively low in biomass.

The values obtained for the Shannon diversity index indicate that the communities of fish are heterogeneous, particularly in zones near the "barra", where the variation between the maximum and minimum values of this index is greatest. In addition, most of the values obtained for evenness are below 0.8, which suggests that the communities of fish in the lagoon are not in evenness. Values greater or equal to 0.8 are usually considered as indicators of equitability in the communities (Daget, 1976).

The data on the species abundance of the fish communities in the lagoon can be fitted to both the Motomura and Preston models, depending on the zones of the lagoon in which the data has been collected.

In general, the Motomura model fits data where the interspecific associations are relatively simple. This model is therefore appropriate for the population of fish near the "barra" and also for a wider area of the lagoon during the summer, when the input of freshwater is markedly reduced.

The Preston model is more complex and can fit two different sets of circumstances. In the first, the interspecific relationships are well established. In the second, the species of fish occur together in the same zone but where there is little interaction between them. The second situation describes the abundance distribution of the fish community furthest away from the "barra" and also for a wider area during winter, when the input of freshwater is greater.

This interpretation is also supported by the evenness values. Evenness is in fact low where the Preston model fits best. This probably signifies the existence of a community formed by migratory species.

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