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Scientific Editors

Aquatic Ecology of the Mondego River Basin
Global Importance of Local Experience

Coimbra • Imprensa da Universidade

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FACTORS AFFECTING THE DISTRIBUTION OF FISH COMMUNITIES IN THE RIVER MONDEGO AND MAIN TRIBUTARIES

Abstract

Fish assemblage structure and factors affecting the distribution of fish communities were examined for 23 sites in the River Mondego basin during the summer of 1998. The cyprinids *Rutilus macrolepidotus*, *Barbus bocagei*, *Chondrostoma polylepis*, *Rutilus alburnoides*, *Leuciscus carolitertii* and *Gobio gobio* were the most abundant species among the 25 *taxa* forming the freshwater fish community. Species richness was generally higher in impoundments and in the watershed downstream from the Açude-Ponte dam, at Coimbra. The anadromous species were restricted to the area downstream from the Açude-Ponte, except for a landlocked population of *Alosa alosa* in the Aguieira reservoir. In the river stretches less affected by the construction of dams, the two main factors responsible for the structure of fish communities were the altitude and the distance from the source. *R. macrolepidotus* and *R. alburnoides* were dominant closer to the source, at lower altitudes, whereas *L. carolitertii* dominated in upper reaches. As the distance from the source increases and the altitude decreases, the fish communities become dominated by *B. bocagei* and *C. polylepis*, larger fishes that take advantage of the increase in river depth.

Introduction

The available information on the ecology of freshwater fish is considerably less than that which exists for brackish and marine species in Portugal. This is a consequence of the poor economic and commercial interest that lies in freshwater fish, except for the diadromous species.

Very little research work has been published on the fish community of the River Mondego basin and most of the studies were conducted on the estuary (Jorge and

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Sobral 1989, Guimarães 1990, Jorge 1991, Ribeiro 1991a, 1991b, Domingos 1992, Ribeiro and Gonçalves 1993). The work developed on the freshwater zone was either restricted to genetical problems (Collares-Pereira 1983, Coelho 1987, Alexandrino 1996) or to one species in particular as it is the case of *Gambusia holbrooki* (Cabral et al. 1998, Cabral and Marques 1999) and *Petromyzon marinus* (Almeida et al. 2000). An ecological approach to the freshwater fish community has recently started to take place (Domingos et al. 1999).

With the recent construction of dams and weirs in the Mondego river basin, several environmental impact studies have been done, but most of these are general reports and, although gathering some information about the fish fauna of those specific river stretches, usually have little scientific value and never refer to the ecological aspects of the fish community as a whole.

The aim of this study was to describe the fish fauna occurring in the freshwater zone of the River Mondego basin, to perform a preliminary analysis on the distribution and abundance of the species present in this watershed, and to relate the structure and composition of the communities with some environmental parameters. Changes in the ecosystem due to anthropogenic modifications were also analysed.

Materials and Methods

A total of 23 sites on the freshwater zone of the River Mondego basin, including the main river, the most important tributaries and the major existing impounded areas were prospected (Fig. 1). All sites located on rivers or streams were sampled by electrofishing, but data for reservoirs were obtained by enquiries and/or bibliography.

Sampling took place during the summer of 1998 and for that reason site 7, a small stream, was dry during that period. For the choice of the sampling sites several aspects of river morphology namely: altitude, distance from the source and type of substrate, as well as size and location of dams were taken into consideration.

Electrofishing was carried out using a semi-portable apparatus (Hans Grassl EL 62, 600 V-DC, 10A). Upon capture, fish were identified to the species level, counted and released. Since the correct identification of *Lampetra fluviatilis* and *Lampetra planeri ammocoetes* required a detailed observation and the sacrifice of the animals, they were only identified to the genus level.

Data obtained from the electrofishing surveys were transformed into catch-per-unit-effort (cpue), defined as number of individuals sampled during a 30 minute fishing period.

An hierarchical grouping of the 23 sites, based on the presence/absence of fish species, was performed by program SPSS (version 9.0) using the Squared Euclidian Distance and the Ward linkage clustering method (Norusis 1999). A canonical correspondence analysis (CCA) (ter Braak and Smilauer 1998) was used to relate fish population parameters (structure and abundance) with the environmental variables (altitude, substrate type and distance from source).

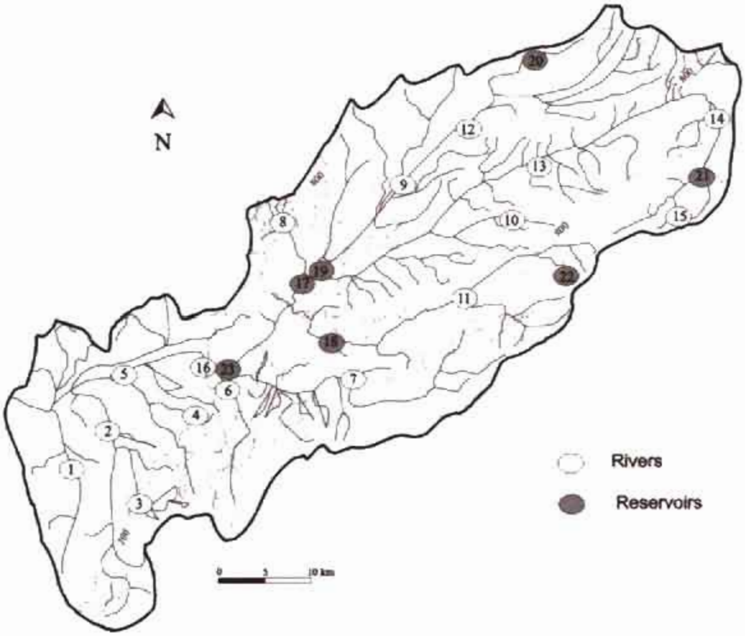


Figure 1. Location of sampling sites in the Mondego basin and corresponding altitude (m): 1 - river Pranto (4) ; 2 - river Arunca (7); 3 - river Anços (110); 4 - Alcabideque stream (179); 5 - river Mondego (6); 6 - river Corvo (103); 7 - river Sátão (247); 8 - Falheiros stream (214); 9 - river Dão (257); 10 - river Seia (401); 11 - river Alvôco (226); 12 - river Dão (168); 13 -river Mondego (300); 14 - river Mondego (420); 15 - Quêcere stream (846); 16 - Açude-Ponte dam (downstream) (25); 17 - Raiva dam (68); 18 - Fronhas dam (129); 19 - Aguieira dam (125); 20 - Fagilde dam (209); 21 - Caldeirão dam (502); 22 - Lagoa Comprida (1296); 23 - Açude-Ponte dam (upstream) (25). All sampling sites located on rivers or streams were sampled by electrofishing but the results for dams were obtained by enquiries and/or bibliography.

Results

Characterisation of the fish community

A total of 25 *taxa* of which eight are cyprinids, were recorded (Tab. 1). This family includes three Iberian endemisms (*Chondrostoma polylepis*, *Rutilus macrolepidotus* and *Leuciscus carolitertii*), and three introduced species (*Carassius auratus*, *Cyprinus carpio* and *Gobio gobio*). Besides these, there are four other exotic species: *Onchorhynchus mykiss*, especially in mountain areas, *Gambusia holbrooki*, and the centrarchids *Lepomis gibbosus* and *Micropterus salmoides* mainly in reservoirs where they can be the dominant species.

The analysis of fish general distribution shows that the most abundant species are the cyprinids, particularly *R. macrolepidotus*, *Barbus bocagei*, *C. polylepis* and *Rutilus alburnoides*, followed by *L. carolitertii* and *G. gobio*.

Table 1. Fish community in the Mondego watershed.

TAXA	ABBR	PHE	Abundance	BC	HD	PRDB
Family Petromizonidae						
Lampetra sp.	Lamp	-	●	-	-	-
Petromyzon marinus Linnaeus, 1758		AM	❍	III	II	V
Family Clupeidae						
Alosa alosa (Linnaeus, 1758)		AM	❍	III	II +V	V
Alosa fallax (Lacépède, 1803)		AM	❍	III	II +V	V
Family Anguillidae						
Anguilla anguilla (Linnaeus, 1758)	Aang	CM	●	-	-	CT
Family Cyprinidae						
Barbus bocagei Steindachner, 1865	Bboc	F	●●●	III	V	NT
Carassius auratus (Linnaeus, 1758)	Caur	F(I)	●	-	-	-
Chondrostoma polylepis Steindachner, 1865	Cpol	F(Ib)	●●●	III	II	NT
Cyprinus carpio Linnaeus, 1758	Ccar	F(I)	❍	-	-	-
Gobio gobio (Linnaeus, 1758)	Ggob	F(I)	●●	-	-	-
Leuciscus carolitertii Doadrio, 1988	Lcar	F(Ib)	●●	-	-	NT
Rutilus alburnoides (Steindachner, 1866)	Ralb	F	●●●	-	II	NT
Rutilus macrolepidotus (Steindachner, 1866)	Rmac	F(Ib)	●●●	III	II	I
Family Cobitidae						
Cobitis paludica (Debuen, 1930)	Cpal	F	●	-	-	NT
Family Gasterosteidae						
Gasterosteus aculeatus Linnaeus, 1758	Gacu	F	●	-	-	K
Family Centrarchidae						
Lepomis gibbosus (Linnaeus, 1758)	Lgib	F(I)	●	-	-	-
Micropterus salmoides (Lacépède, 1802)		F(I)	❍	-	-	-
Family Poeciliidae						
Gambusia holbrooki Girard, 1859	Ghol	F(I)	●	-	-	-
Family Mugilidae						
Liza aurata (Risso, 1810)		E	❍	-	-	-
Liza ramada (Risso, 1826)	Lram	CM	❍	-	-	-
Mugil cephalus Linnaeus, 1758	Mcep	E	❍	-	-	-
Family Atherinidae						
Atherina boyeri (Risso, 1810)		E	❍	-	-	-
Family Pleuronectidae						
Platichthys flesus (Linnaeus, 1758)		E	❍	-	-	CT
Family Salmonidae						
Onchorhynchus mykiss (Walbaum, 1792)		F(I)	❍	-	-	-
Salmo trutta fario Linnaeus, 1758	Stru	F	●	-	-	NT

Abbreviation (ABBR) used in the correspondence canonical analysis. Phenology (PHE): F – freshwater; AM – anadromous migrator, CM – catadromous migrator, E – euryhaline, (I) – introduced, (Ib) – iberian endemism. (I) Electrofishing, (m) Bibliography and/or enquires. Levels of abundance (Very common ≥15 CPUE – (●●●), 5 CPUE ≤ Common <15 CPUE – (●●) and Rare <5 CPUE – (●) with CPUE being the number of individuals caught per 30 min of fishing per site) do not include impoundments. Conservation value – Bern Convention (BC), Habitats Directive (**HD**) and Portuguese Red Data Book of Vertebrates (**PRDB**): (**V**) – vulnerable, (**I**) –indeterminate, (**K**) – insufficiently known, (**CT**) – commercially threatened, (**NT**) – non threatened.

The migratory diadromous fish species identified were the anadromous *Petromyzon marinus*, *Alosa alosa*, and *Alosa fallax*, and the catadromous *Anguilla anguilla* and *Liza ramada*. The distribution of the anadromous fish species is restricted to the area downstream from the Açude-Ponte dam, at Coimbra, except for a landlocked population of allis shad *(A. alosa)* in the Aguieira reservoir. It is also downstream from the Açude-Ponte dam that euryhaline species such as *Platichthys flesus*, *Atherina boyeri* and some mugilids *(Liza aurata* and *Mugil cephalus)* occur.

At higher altitudes, the dominant species are the cyprinid *L. carolitertii* and the salmonids, especially *Salmo trutta*.

As for conservation value it should be stressed that the most threatened species are the diadromous fish, followed by *P. flesus*, *R. macrolepidotus* and *Gasterosteus aculeatus* (Vários 1991). Despite being considered, in their majority, as non threatened, except for *R. macrolepidotus*, the Iberian endemisms do also present an important conservation value which should be taken into consideration (Tab. 1).

A number of species of this fish community is included in the Annex III of the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats) meaning that capture should be under restrictions. Some species are also included in the Annexes II and/or V of the Habitats Directive (92/43/CEE) (Tab. 1), requiring either the designation of special areas of conservation (for species included in the Annex II) or an exploitation which may be subject to management measures (for species included in the Annex V).

Hierarchical cluster analysis

The dendrogram constructed for the presence/absence data (Fig. 2) indicates a distinct grouping of the sites, clearly divided into two groups, A and B.

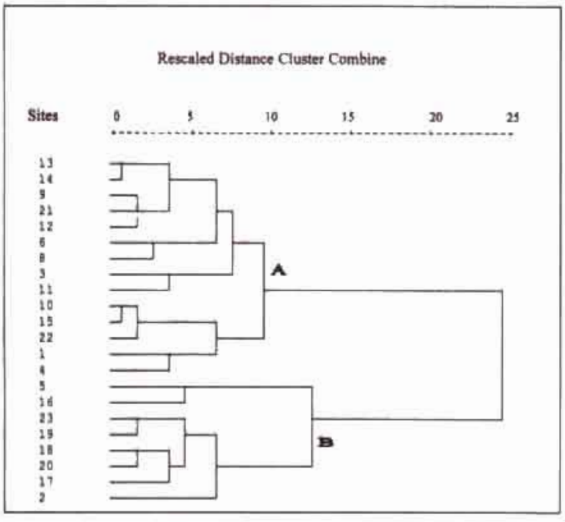


Figure 2. Dendrogram of the sampling sites, based on Squared Euclidian Distance and Ward linkage clustering. Names of the sampling sites are given in fig. 1.

Group A gathers the sites from the main river and tributaries upstream the Açude-Ponte dam at Coimbra which present a fish community with a lower species richness. Group B includes sites where a higher number of species is found, namely impounded areas, and the watershed downstream the Açude-Ponte dam, at Coimbra (Fig. 3). Considering a higher similarity level, each of the two previous groups can be divided into two different sub-groups. In group A, the sites with lower species richness (sites 1, 4, 10, 15 and 22) are separated from the rest of the group. This former sub-group includes mainly the sites located at higher altitudes except for site 1 (River Pranto) which despite of its low altitude presents an impoverished fish community.

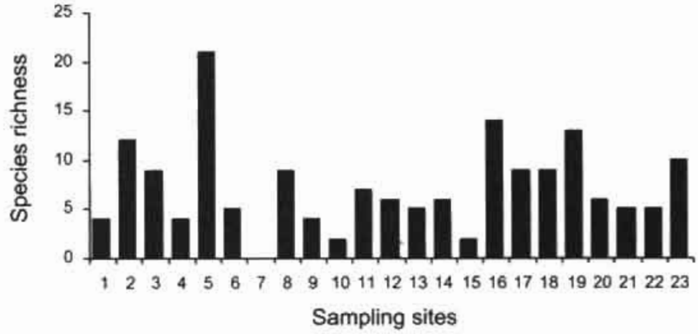


Figure 3. Species richness per sampling site.

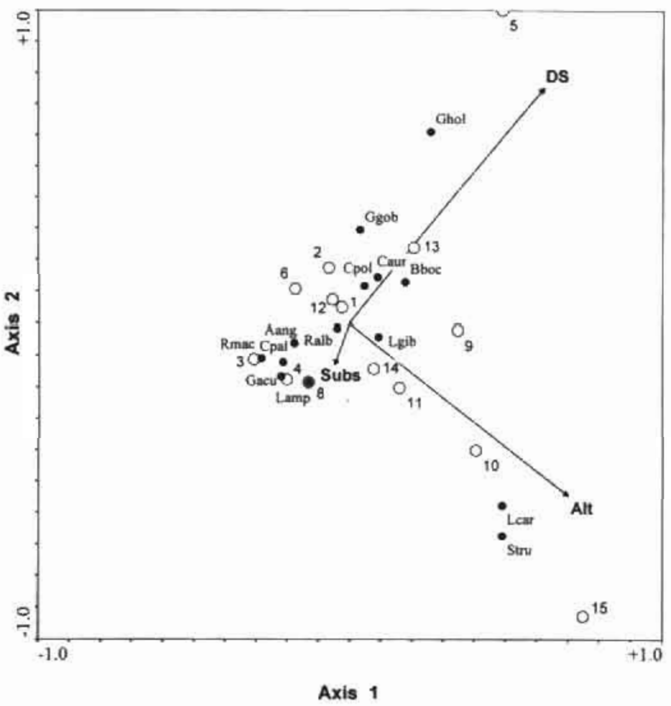
The same analysis applied to group B does also show evidence of two sub-groups. The first one grouping the two sites in the main river downstream from the Açude-Ponte dam (5 and 16) and the second including most of the impounded sites. Sampling site 2 (River Arunca), despite not being an impounded area, is also included in this sub-group, indicating a similar fish community.

Canonical Correspondence Analysis

The ordination diagram of the CCA (Fig. 4) explains 92% of the variance of species– environment relation. Table 2 shows that the variation in species composition in the first two axes is high ($\lambda_1 = 0.63$; $\lambda_2 = 0.51$) and that the environmental variables considered are highly related to the first two axes of the CCA, with the exception of substrate type, which is poorly related to the second axis.

The structure of the fish community in each sampling site is the result of the influence of two main environmental variables, the altitude and the distance from the source. The species *R. macrolepidotus*, *B. bocagei*, *C. polylepis*, *R. alburnoides*, *L. carolitertii* and *G. gobio* presented the highest weight in the CCA ordination diagram.

R. macrolepidotus and *R. alburnoides* dominate the communities closer to the sources located at lower altitudes (sites 3, 4 and 8). In the upper reaches, at higher altitudes (sites 10, 11, 14 and 15), *L. carolitertii* is the dominant species. As the distance from the source increases, at lower altitudes (sites 1, 2, 6 and 12) *B. bocagei* and *C.*



Subs - Substrate type; **Alt** - Altitude; **DS** - Distance to source

Figure 4. Species conditional triplot based on a CCA (canonical correspondence analysis) of the fish fauna from Mondego river basin. Sites are represented in fig. 1 and species abbreviations are given in tab. 1. The lenght of an arrow is relative to the importance of that environmental variable in the ordination.

Table 2. Results of the ordination by canonical correspondence analysis (CCA) of the River Mondego fishfauna data: eigenvalues, species-environment correlation coefficients, and intraset correlation of environmental variables with the first two canonical axes.

	Axis 1 (λ_1 = 0.63)	Axis 2 (λ_2 = 0.51)
Species – environment	0.90	0.88
Substrate	- 0.54*	0.15
Altitude	0.89*	- 0.73*
Distance from the source	0.56*	0.83*

(*) - $P < 0.05$; λ - eigenvalue *polylepis* are the species prevailing over the other fish species. In some of those sites (1 and 6) however, *G. gobio* can also be an abundant species. It is interesting to notice that this introduced species is the only exotic that can become almost dominating outside reservoirs.

Sampling sites 9 and 13, despite their medium altitude (257 m and 299 m, respectively), present fish communities very similar to those of the lower reaches, with great abundance of *B. bocagei* and *C. polylepis*, whereas sampling site 5 is clearly different from all the others, with a very poor community dominated by *G. gobio*.

Discussion

The fish fauna of the River Mondego, with 25 *taxa*, is slightly richer when compared with the 23 and 14 species, from rivers Vouga and Lis respectively (Domingos et al. 1999), and the 18 species from the Portuguese part of the River Guadiana watershed (Godinho et al. 1997).

The composition of the fish fauna in a river is diverse and, although a longitudinal pattern is usually expected along the river course (Lelek 1987, Schiemer and Zalewsky 1992, Cowx and Welcomme 1998), many factors, such as tributaries and presence of deteriorated habitats, mask or even change it in a way that the understanding of fish distribution becomes a difficult task. For example, dams divide rivers into more or less independent stretches and, for a given stretch, transverse interactions often dominate over the longitudinal ones (Decamps 1984).

In the river stretches less affected by the construction of dams, the two main factors responsible for the structure of fish communities are the altitude and the distance from the source. In areas close to the river source at a moderate altitude, the fish communities are dominated by *R. alburnoides* and *R. macrolepidotus*, but in the upper reaches the dominating species are *L. carolitertii* and the two salmonids, *O. mykiss* and *S. trutta*. As the distance from the source increases and the altitude decreases, the fish communities are dominated by *B. bocagei* and *C. polylepis*, larger fishes that take advantage of the increase in the river depth.

The presence of five diadromous fish species and three Iberian endemisms suggests that anthropogenic influences, namely the construction of dams and pollution levels have not yet been disastrous, and that in the River Mondego watershed there is an important potential in terms of conservation for this fish community. However, the existence of seven exotic species, and the fact that the anadromous species cannot pass the Açude-Ponte dam at Coimbra, which is equipped with a fish passage that does not function correctly (unpublished data), are indicative of the degradation of this ecosystem and of the reduction in the habitat available for those migratory species.

Other factors, such as pollution, are responsible for the reduction of the species richness, as can be concluded from the analysis of the dendrogram (Fig. 2), where sites 1 and 4, both polluted areas, mainly from agricultural practices, are linked quite close to each other.

The fact that some of the reservoirs have a relatively high species richness (Fig. 3), means that, in opposition to what has been happening in many reservoirs in our country, in the River Mondego watershed, probably due to the important tributaries that flow into the reservoirs, there are still conditions favourable to the maintenance of rheophilic species, such as *B. bocagei* and *C. polylepis*, and even a landlocked population of *A. alosa*. Despite all this, the fish communities in some of the Mondego impounded areas are dominated by introduced species such as *L. gibbosus*, *M. salmoides* and *C. carpio*.

One of the most serious impacts of the construction of dams is that they interrupt fish migration either by becoming impassable barriers to reproducers, or by decreasing the recruitment success. Before the construction of the Aguieira dam (1979), the diadromous fish migrated upstream reaching that area. After the construction of the Açude-Ponte dam, in 1981, the access of anadromous fish is limited to this point.

At the present situation, the most important stretch of the river, with a length of about 35 km, is located between Coimbra and Figueira da Foz, close to the river mouth and consequently an urgent conservation action is needed to promote the free circulation of diadromous fish up to the Raiva dam, as well as to implement measures for the protection of this part of the river. This protection could involve designating the river between Figueira da Foz and Raiva as a special area for conservation under the recommendations of the Habitats Directive since there are species from Annex II that would benefit by such an action.

If fish species are to be given adequate consideration, then appropriate management plans should be done in order to *(i)* make an inventory of the polluted areas and degradated communities, aiming at the rehabilitation of the aquatic ecosystem; *(ii)* increase the area available for diadromous fish, at least up to the Raiva dam, by introducing an effective fish passage in the Açude-Ponte; *(iii)* study the effect of river discharge on the fish community and make a careful regulation of discharge adjusted to biological needs of the several species along the year, similarly to what has been proposed by Almeida et al. (2000) for *P. marinus*, and Domingos (1992) for *A. anguilla;* and finally, (iv) carry out an active monitoring plan to be able to assess changes in the fish community.

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