CURRENT STATUS OF THE RIVERINE FISHES OF THE FRENCH MEDITERRANEAN BASIN

Thomas Changeux & Didier Pont

Laboratoire d'écologie des systèmes fluviaux, URA, CNRS 1451, 1, Rue Parmentier, Arles 13200, France

Abstract

We have undertaken a study of current knowledge on the distribution and abundance of 10 freshwater fish species with a restricted geographical range, recorded since 1950 from French rivers flowing into the Mediterranean, including those in Corsica. In order of decreasing abundance these are: Leuciscus (Telestes) souffia, Chondrostoma toxostoma, Barbus meridionalis, Zingel asper, Blennius fluviatilis, Aphanius fasciatus, Alosa fallax rhodanensis, Aphanius iberus, Valencia hispanica and Cottus petiti. Distribution maps for the first seven taxa have been produced on the basis of 3124 fisheries surveys included within Fisheries Orientation Schemes carried out in French départements. These taxa are distributed in three different zoogeographical regions: a northern mainland region, a southern mainland region and the island of Corsica. The distribution of these taxa in the major rivers is shown on maps by means of lines of varying thickness and for the minor river courses by shading. The detailed habitat preferences of the first three species have been determined, showing a succession of Barbus meridionalis, Leuciscus (Telestes) souffia and Chondrostoma toxostoma going downstream within the southern mainland region. Following a discussion of the requirements of each of these species and of the threats that they face within the study area, their status is defined according to the International Union for the Conservation of Nature definitions.

Keywords: endemic, fish, conservation, France, riverine.

INTRODUCTION

The distinctive character of the fish populations of running waters in Mediterranean France and Corsica has been known for a long time (Roule, 1904, 1933; Mathias, 1921; Kreitmann, 1932). This distinctiveness has, however, rarely been integrated into studies that are currently used in this country to analyse fishery policies (Leger, 1937; Huet, 1954; Illies & Botosaneanu, 1963; Verneaux, 1973).

In France, the catchment area of rivers flowing into the Mediterranean covers 134,360 km² (24.4% of the area of France) and comprises mainly the catchment of the Rhône (15% of the total area of France), part of which lies in Switzerland and has been excluded from this study, plus small coastal rivers along the entire Mediterranean shoreline and the island of Corsica.

The centre of the Gulf of Genoa (Fig. 1). This area would appear to possess great diversity both in geographic and climatic terms. In his classification of world ecoregions, Bailey (1989) distinguished no less than four types within this area, all belonging to the wet temperate division.

This physical diversity is accentuated in biological terms by geological history. In recent periods, dominated by the quaternary glacial eradications, the fish populations of the Rhône basin benefited from a previous connection in the Pliocene with the Danube system (Thienemann, 1950), recognized as the centre of origin for European freshwater populations (Banarescu, 1989a). In addition, the north-south orientation of the main river valley (Saône valley continued south by the Rhône corridor) and the persistence of a temperate climate in the southernmost regions during the maximum extension of the ice caps (Riss: 200,000 BP) (Monjuvent 1984a, b) allowed refuge areas to be maintained for thermophilic species (Persat & Berrebi, 1990).

The combination of these special characteristics of our study area explains the presence of seven species (discussed below), which, according to the most recent of European freshwater fish atlases (Maitland, 1981; Lelek, 1987; Terofal, 1987), all have a restricted geographical range. None of these species has been recorded in the Swiss part of the Rhône basin, situated upstream of Lake Geneva (Pedroli et al., 1991).

An additional three species have been recorded from France since 1950 by single authorities, but their occurrence has not been subsequently confirmed: (i) Aphanius iberus Valenciennes, 1846 from near the Spanish border (Arnoult, 1957); (ii) Valencia hispanica Valenciennes, 1846, another cyprinodont, from the same sites (Arnoult, 1957); and (iii) Cottus petiti Bacescu, 1964, a cotti from the Lez, a short coastal river flowing into the Gulf of Lion (Bacescu & Bacescu-Mester, 1964). These species have not been accepted, and neither has the Corsican subspecies of the brown trout, Salmo trutta macrostigma Duméril, 1858.

The current status of these endemic taxa is worthy of re-examination because of the major man-made changes that have occurred to the French rivers, particularly during the second half of the 20th century (Persat, 1988).

This work aims to provide a review of the current status of these seven species or subspecies in France.
by defining their distribution range, the habitat types in which they occur and the accompanying fish fauna in the areas where they are still recorded. These results are compared with data from recent publications (Kiener, 1985; Allardi & Keith, 1991) and older maps published between 1924 and 1956 (references given later in the text) in order to produce a diagnosis of the risks of extinction and of measures that could be taken to guarantee the survival of the species concerned.

**MATERIAL AND METHODS**

**Study area**

The study area is typified by its location at the western end of the east–west chain of the Alps, which separates the north European plain from the catchment of the Mediterranean (BRGM, 1980). The Alpine geological system occupies the entire area to the east of the Rhône, including Corsica, and is prolonged to the south-east by...
the chain of the Pyrenees, the southern limit of the study area. The valley of the Saône, which represents the ancient river axis, communicates with the Mediterranean basin via a special geological formation (the Rhône trench), through which the River Rhône now flows in a north–south direction. The western boundary of the study area is the Massif Central.

Vegetation is an indicator that is much used to describe terrestrial habitat characteristics. From this point of view, the study area contains 10 different phytoclimatic and regions out of the 14 recorded for France as describe terrestrial habitat characteristics. From this point of view, the study area contains 10 different phytoclimatic and regions associated with the various mountain massifs such as the Alps, Massif Central and Corsica.

The Mediterranean climate of the south of France is typified by a negative hydrological balance (annual precipitation lower than evapotranspiration according to the definition of Pagney (1988)). The water supply of most rivers is therefore ensured by their sources being in other climatic regions. The Mediterranean rainfall pattern dominant in the south is typified by a summer drought that can lead to complete drying out of small rivers. With increasing altitude, the pluvial, pluvio-nival, nivo-pluvial, nival and glacial regimes succeed one another.

The combination of these regimes makes the discharge of the Rhône very high in comparison with its length: it has the 42nd highest discharge in the world according to Welcomme (1985).

Data sources and selection
French fresh waters, with the exception of the largest natural lakes, have recently been subjected to systematic investigations as part of the Departmental Fisheries Orientation Schemes, using a standardized method drawn up at a national level (Souchon & Trocherie, 1990). Rivers were divided into sections corresponding to ecologically homogeneous units. Habitat and faunal composition information was made accessible to our analyses in the form of an Oracle relational database (Trutna & Mone, 1990).

The field of study was purposely restricted to water courses showing a wide range of species diversity: only rivers containing at least three species in at least one section of their course were retained. If this was the case, the entire river course was selected, including the headwaters, where there may be fewer than three species. This preliminary selection led to the elimination of many small mountain streams (Alps and Corsica) and most of the tributaries of coastal rivers (Fig. 1). However, no river section containing endemic species was eliminated. In total, 20,181 km of river course were taken into account, divided into 2431 sections of lengths between 0.2 and 149 km, with a mean of 8.2 km \((s_i = 7.5)\). 74.2% of sections had a length of less than 10 km. The longest sections \((>20 \text{ km}: 3.6\%)\) belong to the lower courses of major rivers.

**Faunal lists**
Of the 2431 sections retained, 1,781 had been subject to one or more fishery investigations \((n = 3,124)\). These consisted of electric or net fishing operations in 72.8% and 0.3% of sections, respectively, or of angler questionnaires in 12% of cases. In the remaining cases \((14.9\%)\) the method of investigation was not stated in the original documents.

As far as the seven species considered are concerned, the frequencies at which the various investigation methods were used were comparable, except in the case of *Barbus meridionalis*, for which questionnaires were most frequent.

A total of 50 non-marine species was recorded from all of the rivers flowing into the Mediterranean; 14 of them non-native (Appendix 1). Among the latter, some were intentionally or accidentally released into the natural environment and have acclimatised (Holcik, 1991). Others, generally originating from the Danube, have extended their distribution towards the west by means of connections between river basins formed by navigation canals. Finally, some American species of Salmonidae, such as the rainbow trout *Oncorhynchus mykiss*, brook trout *Salvelinus fontinalis* and lake trout *Salvelinus namaycush* are mainly represented by artificially stocked populations.

The number of sections in which each endemic species is present provided a measure of its abundance divided into three classes: rare \((<30 \text{ sections})\), common \((30-140 \text{ sections})\) and very common \((>140 \text{ sections})\). For each species and section, a list of accompanying species was drawn up, distinguishing those accompanying species that were dominant (recorded from more than 50% of sections). This list was compared with the potential fish populations of Verneaux (1981), which in a non-perturbed situation would be equivalent to the association of species occurring in a river type'd according to the classification of Illies and Botosaneanu (1963).

**Habitat variables**
A maximum of nine habitat variables was recorded for each section. Quantitative variables were grouped into classes:

1. **Distance (km)** from the source (recorded for 2431 sections), measured with a map measurer on a 1:50,000 map from the source to the centre of the section and grouped into the following classes: \(<10, 10-30, 31-100\) and \(>100\) km.
2. **Mean altitude of the section**, or if unknown, the mean altitude of the fishing stations (recorded for 1,040 sections): altitude classes \(<100, 101-250, 251-500, 501-1000\) and \(>1000\) m.
3. **Mean discharge at the head of the section** (recorded for 368 sections): discharge classes \(<1, 1-3, 3-9, 9-27\) and \(>27\) m\(^3\) s\(^{-1}\).
4. **Mean gradient of the section** (recorded for 2,254 sections): gradient classes \(<1, 1-3, 3-10, 10-30\) and \(>30\%)\).
(5) the mean width of the section (recorded for 2294 sections): width classes <2, 2–5, 5.1–10, 10.1–25 and >25 m.

(6) mean temperature for the hottest month of the year (recorded for 310 sections), hereafter called the summer temperature: summer temperature classes <17, 17–20, 20.1–23 and >23°C.

(7) the hydrological status of the section (recorded for 2365 sections) according to four categories: main course (MC) secondary course or short-circuited section (SC), reservoir (R) and rivers drying out in summer (TW).

(8) the physico-chemical water quality for the section (recorded for 2011 sections) defined in terms of the physico-chemical index currently used by French river authorities (Anon., 1989) according to five categories: 1A, waters considered free from pollution; 1B, water quality slightly poorer, but suitable for all uses; 2, water quality satisfactory, possibly harmful for the reproduction of the most sensitive fish species; 3, poor quality, of possible danger for fish survival particularly at periods of low discharge; 4, water quality unsuitable for most uses.

(9) the influence of neighbouring bodies of standing water according to two categories: no nearby water bodies, or the presence of standing water upstream or downstream of the section whether directly connected or not.

The selection of sections occupied by a given species provided the distribution of the categories of each variable. This was then compared with the distribution for the entire 2431 sections by means of a chi-squared test. This comparison could only be carried out for the three most frequent species (Barbus meridionalis, Leuciscus souffia and Chondrostoma toxostoma) for which the statistical validity of the method could be ensured (Allardge & Ratti, 1985, 1992). For these three species, the habitat preferences were calculated for each variable using the following formula:

\[ F_{Si} = \frac{Fe_i \times 100}{Ft_i} \]

where \( F_{Si} \) is the number of sections in which the species occurred per 100 sections with category \( i \) of the variable in question; \( Fe_i \) is the total number of sections with category \( i \) in which the species occurs in the entire number of sections sampled; and \( Ft_i \) is the total number of sections with category \( i \) of the variable.

The habitat preferences (Fig. 2) are presented for each species in the form of relative frequencies for each of the \( n \) categories of the variable in question (\( P_{Si} \))

\[ P_{Si} = \frac{F_{Si} \times 100}{\sum_{i=1}^{n} F_{Si}} \]

Distribution maps

The geographical distribution of each species was mapped by distinguishing between major river courses and their smaller tributaries. The area containing the 3431 sections selected was first divided into 163 drainage units (Fig. 1). Within each unit, fish distributions in sections occurring on small water courses were mapped by shading the areas of the units (\( n = 163 \)), whereas sections on main river courses were shown as lines corresponding to the number of main rivers (\( n = 222 \)).

Species occurrences per linear or area unit were grouped into two classes. The entire data set was digitized with graphics software (Cohn et al., 1987–90) and exported to a cartographic analysis program (Brossier, 1990).

RESULTS

Cyprinidae

Leuciscus (Telestes) souffia Risso, 1826

Status and geographical distribution. Leuciscus (Telestes) souffia belongs to one of the genera of Cyprinidae (Leuciscus) best represented in French freshwater fish populations. The polymorphisms and possibilities of hybridization within the genus complicate its classification and several sub-genera, traditionally shown in brackets, are admitted.

The European distribution of \( L. \ souffia \) is centred on the Alps, around which it has developed several distinct morphological types ranging from Bavaria and Romania through to the Saône and Rhône basins as far as Italy (Spillmann, 1959). In France it is restricted to the basins of the Rhône and the Mediterranean (Allardge & Keith, 1991). Three forms with the status of subspecies can be distinguished (Spillmann, 1961). The main dividing line is located in south-east France at the River Var (Spillmann, 1960, 1962, 1965a,b), which separates the Italian form \( Leuciscus \ souffia multicellus \) to the east from the form inhabiting the Rhône basin and rivers on the coastal plain (Leuciscus souffia agassizi). An intermediate variety \( Leuciscus \ souffia souffia \), inhabiting the River Var, has been retained as the type. The polymorphism of this species has been interpreted as phenotypic variations resulting from environmental differences between (Spillmann, 1962) and within (Spillmann, 1970) basins and has been analysed by Aubenton et al. (1970–1971) and Daget and Bauchot (1976).

This very common fish (478 sections) occurs mainly in the Rhône basin and in coastal rivers to the east (Fig. 3). In agreement with Spillmann (1970) and in contrast to the observations of Kiener (1985) and Hillenius (1965), the Hérault basin forms the western limit of the species’ distribution. In contrast to earlier records, which showed a discontinuous distribution (Leger, 1901, 1927; Hesse & Paris, 1924, 1927; Leger et al., 1945; Spillmann, 1961) our study indicates that it is present in rivers around the confluence of the Rhône and Saône. The current distribution is more extensive not only in terms of basins but also in terms of the length of river occupied. There is, however, no evidence to suggest that this is due to a real extension in the distribution range, rather than faulty identification in old
### Status of French riverine Mediterranean fish

Barbus meridionalis  

| Slope (m.km⁻¹) |  |  
|----------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| > 30           | p < 0.001 (n = 102)         | p < 0.001 (n = 444)         | p < 0.001 (n = 112)         |
| 10-30          |                            |                            |                            |
| 3-10           |                            |                            |                            |
| < 1            |                            |                            |                            |

Leuciscus soufia

<table>
<thead>
<tr>
<th>Width (m)</th>
<th>p &lt; 0.001 (n = 192)</th>
<th>p &lt; 0.001 (n = 450)</th>
<th>p &lt; 0.001 (n = 116)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chondrostoma toxostoma

<table>
<thead>
<tr>
<th>Water Quality</th>
<th>p &lt; 0.05 (n = 176)</th>
<th>p &lt; 0.001 (n = 409)</th>
<th>p &lt; 0.001 (n = 112)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Hydrological status |  
|---------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| T.W.               | p < 0.001 (n = 178)         | ns (n = 386)                | ns (n = 100)                |
| R.W.               | ns (n = 386)                |                             |                             |
| S.A.               | ns (n = 386)                |                             |                             |
| M.C.               | ns (n = 386)                |                             |                             |

| Waterflow (m³.s⁻¹) |  
|--------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| > 25               |                             | ns (n = 103)                | p < 0.05 (n = 36)           |
| 9-25               |                             |                             |                             |
| 3-9                |                             |                             |                             |
| 1-3                |                             |                             |                             |
| < 1                |                             |                             |                             |

| Average temperature (°C) |  
|--------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| > 23                     |                             |                             |                             |                             |
| 20-23                    |                             |                             |                             |                             |
| 17-20                    |                             |                             |                             |                             |
| < 17                     | ns (n = 26)                 | p < 0.05 (n = 77)           | p < 0.01 (n = 24)           |
|                           |                             |                             |                             |                             |

Fig. 2. Habitat preferences of the three most abundant species. The histograms represent the frequency of occurrence of each species (the total is equal to 100%). n is the number of sections included for each variable, ns indicates that the distribution could not be tested by chi-squared, p is the probability of the null-hypothesis of a homogeneous distribution of the species and ns indicates that the species is uniformly distributed (p > 0.05).

Habitat and accompanying species. The habitat preferences (Fig. 2) indicate that it is under-represented in the upper reaches of rivers (distance from source less than 10 km; chi-squared test: p < 0.001) and in rivers with a width of less than 5 m (chi-squared test: p < 0.001). It occurs preferentially in sections with a gradient of between 1 and 10% (chi-squared test: p < 0.001) and at altitudes of 100-500 m (chi-squared test: p < 0.001). It is affected little by the nearby presence of standing water (chi-squared test: p > 0.05) or by the hydrological status. Its under-representation in waters of very high quality (category 1A) is probably related to the fact that such waters tend to occur in the upper reaches. On the other hand it does not seem to be affected by a degradation of water quality (categories 3 and 4).

The only dominant accompanying species are Salmo trutta and Leuciscus cephalus. As indicated by Verneaux (1981), L. soufia forms part of the community that...
Fig. 3. Distribution map of the blageon *Leuciscus (Telestes) souffia*. Main river courses are shown as lines. Small water courses are pooled in surface drainage units.

*Leuciscus souffia*

occupies the zone extending from the mesorhithron to the epipotamon. However, this species is better represented than this author suggests in the part further upstream (mesorhithron), where the species diversity is low and the community restricted to the most rheophilic species.

**Particular biological characteristics.** Leger (1937) and Dorier (1957) suggested that *L. souffia* should be considered as the indicator species replacing *Thymallus thymallus* in southern rivers. In the northern part of the Rhône basin the two species are frequently associated (Verneaux, 1973). In the southern part, where *T. thymallus* is absent, since it belongs to a different zoogeographical assemblage, *L. souffia* tends to inhabit stations with a steeper gradient and narrower width than those occupied by *T. thymallus* (according to the diagram of Huet, in Anon., 1984). *L. souffia* has rarely been managed by man since it is difficult to rear in standing water (Spillmann, 1974); fish reared under such conditions have a smaller head compared with the rest of the body (Spillmann, 1965b).

**Chondrostoma toxostoma** Vallot, 1836

*Status and geographical distribution.* *Chondrostoma toxostoma* is the only native representative of the European genus *Chondrostoma* occurring in the south of France (Mathias, 1921).

This common species (129 sections) occurs in most of the Rhône basin and in coastal rivers to the west (Fig. 4). Nelva (1988), Nelva-Pasqual (1985) and Kiener (1985) indicated that it was present in coastal rivers to the east of the Rhône. Allardi and Keith (1991) also recorded it from several stations in the
Garonne basin and in the upper reaches of the Loire and Seine basins.

Old distribution records are not very reliable because of the similarity of the vernacular names of *C. toxostoma* and *L. souffia* and the difficulty in distinguishing the immature stages of *Chondrostoma nasus* and *C. toxostoma*.

**Habitat and accompanying species.** Most of the variables which are significantly different from the mean rank or mean profile of the habitats surveyed (Fig. 2) indicate a preferred distribution for the lower reaches of rivers, more than 100 km from the source (chi-squared test: $p < 0.001$), with altitudes of below 100 m (chi-squared test: $p < 0.001$), gradients of less than 3\% (chi-squared test: $p < 0.001$), widths of greater than 25 m (chi-squared test: $p < 0.001$) and discharges of greater than 27 m$^3$ s$^{-1}$ (chi-squared test: $p < 0.05$). It occurs preferentially in waters where the summer temperature greatly exceeds 20°C (chi-squared test: $p < 0.01$): the mean summer temperature in all of the sections in which it is recorded is 22.4°C ($s = 3.03$), with values ranging from 13 to 27°C. Its absence from waters of good physico-chemical quality (category IA) is related to its location in the lower reaches, whereas its presence in waters of poor quality shows that it has a certain resistance. Its distribution in the various hydrological categories could not be statistically tested. It does not seem to be affected by the presence of nearby water bodies (chi-squared test: $p > 0.05$).

This fish belongs to a community of 44 fish species, of which 12 are non-native. The dominant accompany-
ing species are, in order of frequency: *Leuciscus cephalus*, *Gobio gobio*, *Barbus meridionalis*, *Phoxinus phoxinus*, *Rutilus rutilus* and *Anguilla anguilla*. These data are more or less in agreement with the potential communities of Verneaux (1981) for the metarhithron, but extend downstream to beyond the hypopotamon.

**Particular biological characteristics.** As with the other species of the genus, it is typified by its inferior mouth, especially adapted for scraping the perilithon. Its growth, distribution, reproduction and diet during the filling of an artificial reservoir in the south of France have been studied by Chappaz (1986). It was located in the lotic habitats in the upstream part of the water body, and a decline in numbers by about 10% was recorded.

During the 19th century, a related but larger species (*Chondrostoma nasus*) spread from the Danube to most French rivers by way of canals connecting river basins (Nelva, 1988). It is still difficult to assess the impact of the arrival of *C. nasus* in the Rhône basin on the distribution of *C. toxostoma*. It seems that at the start of this century, *C. toxostoma* was really subject to competition since a decline was recorded in the Saône (Paris, 1932). It is possible, however, that *C. toxostoma* was never very common in river habitats (Nelva, 1988) and *C. nasus* does not seem to have colonised very far up tributary rivers (Spillmann, 1961).

In the Ardèche, an equilibrium seems to have been established between *C. toxostoma*, which occupies the areas upstream, and *C. nasus*, which is combined to the downstream parts (Nelva-Pasqual, 1985). The separation of the spawning seasons and dietary differences are sufficient to allow the two species to coexist in the contact zones (Chappaz et al., 1989). Nevertheless, in the

---

**Fig. 5.** Distribution map of the Mediterranean barbel *Barbus meridionalis*. Main river courses are shown as lines. Small water courses are pooled in surface drainage units.
absence of C. nasus, C. toxostoma occupies both upstream and downstream zones by adjusting its microhabitat preferences (Grossman et al., 1987a,b). C. nasus is currently continuing its spread towards the west via navigation canals (Kiener, 1985) although little is known of the interactions that exist between the two species. C. toxostoma does not seem to have been directly managed by man.

**Barbus meridionalis** Risso, 1826

**Status and geographical distribution.** Barbus meridionalis belongs to a genus of Cyprinidae whose distribution extends from Asia to Europe and North Africa. Taxonomic and zoogeographical problems associated with this genus were discussed in the 'International Barbus Workshop' (Berrebi, 1990), but no definitive solution to the classification was found, and some details still vary from one authority to another (Almaça, 1990; Doadrio, 1990). *B. meridionalis* is nevertheless always placed in the tetraploid group of European species along with the only other representative of the genus *Barbus* in France: *B. barbus*. *B. meridionalis* has been present since the Oligocene (c. 25 million years), whereas *B. barbus* probably arrived from the Danube basin at a much more recent time (Persat & Berrebi, 1990). Despite this, *B. barbus* is currently the more common and more widespread of the two species.

This very common fish (215 sections) seems to predominate in the Mediterranean region (Fig. 5) in coastal rivers and some of the southern tributaries of the Rhône. Kiener (1985) also recorded it from all the coastal rivers, with the exception of the Aude and the Arc. It has for a long time been recognized as a member of the communities of rivers in the south of France (Roule, 1904; Dorier, 1957). Outside our study area, Allardi and Keith (1991) mention it from four stations in adjoining rivers in the basins of the Garonne and Tarn.

**Habitat and accompanying species.** *B. meridionalis* is absent from sections further than 100 km from the source (chi-squared test: $p < 0.01$) (Fig. 2). It occurs preferentially in zones with a gradient of between 3 and 30% (chi-squared test: $p < 0.001$) and of widths of between 2 and 10 m (chi-squared test: $p < 0.001$). The mean discharge in the sections that it inhabits is very low (mean 3.42 m$^3$ s$^{-1}$, $s_n = 3.35$) and does not exceed 11.5 m$^3$ s$^{-1}$. In the light of such results, the preference of this species for altitudes of less than 100 m (chi-squared test: $p < 0.01$) can only be explained by its strictly southern distribution. Indeed, the Mediterranean region is characterized by the association of a particularly low discharge and a lower altitude than the average for the entire study area. Its preference for the upper reaches of rivers in this region also leads to an absence of any significant temperature profile (chi-squared test: $p > 0.05$).

The hydrological status of the sections that it occupies shows that it is absent or rare in habitats that have undergone major modifications (categories SC and R), whereas it is very frequent in sections of river that are subject to drying out in summer (chi-squared test: $p < 0.001$). Similarly, the proximity of a standing water body leads to its under-representation (chi-squared test: $p < 0.001$). Waters of poor quality (categories 3 and 4) are also unfavourable for it (chi-squared test: $p < 0.05$).

This fish forms part of the fish community that occupies the upper and middle reaches of rivers. The cumulative number of species occurring in the sections where it is present is 38, of which eight are non-native. The dominant accompanying species are, in decreasing order of frequency: *Salmo trutta, Leuciscus cephalus, Phoxinus phoxinus* and *Gobio gobio*. It does not figure in the potential communities of Verneaux (1981).

**Particular biological characteristics.** There is still little information on the ecology of *B. meridionalis* in our study area. However, there are publications on the eastern subspecies concerning: its growth, reproduction, density and mortality in Greece (Neophitiou, 1987) and in Yugoslavia (Soric & Jankovic, 1989) and its essentially benthic, but selective, diet in Serbian rivers (Filipovic & Jankovic, 1978) and the great temperature resistance of its skeletal muscles (Pocnrnic & Omeragic, 1976; Omeragic et al., 1980). The closely related Spanish species (*B. haasi*) only survives in the highest reaches of the River Matarranja in shallow areas, where it lives close to the substrate or under shelter (Grossman et al., 1987b). Similarly the distribution of *B. meridionalis* in France is restricted to the most isolated tributaries (Leger, 1910; Blaive, 1934; Dorier, 1957). It has been subject to management and artificial rearing (Raveret-Wattel, 1913; Dorier, 1957; Philippart & Berrebi, 1990).

**Percidae**

**Zingel asper L.1758**

**Status and geographical distribution.** Zingel asper belongs to a genus of Percidae whose distribution is restricted to rivers zoogeographically connected with the Danube (Colette, 1977). Its endemic status within the Rhône basin is witness to an ancient connection between the two rivers.

This rare fish (22 sections) only occurs in major river courses within the Rhône basin (Fig. 6). It occurs in four separate geographical areas: the north-east of the Saône basin, the middle Rhône (around the city of Lyon), a few tributaries of the lower Rhone and the upper reaches of the Durance basin. Kiener (1985) also mentioned its presence in a few additional sites.

In 1900 it had a continuous distribution throughout the major river courses (Rhône and main tributaries), whereas currently it only occupies 17% of this area (Boutitie, 1984a).

**Habitat and accompanying species.** The few habitat data available in our database indicate a preference by the species for sections typified by gradients of between 3 and 10%, with widths of 2 to 5 m, distant from the source (more than 30 km), but having water of good quality (category 1A). The five values of mean dis-
charge recorded for this species are between 7.5 and 126 m$^3$ s$^{-1}$. Its preference for faster flowing waters in the south of the region (Boutitie, 1984b) can be related to its requirements for a spawning temperature (between 6 and 14°C) that is particularly low for a percid (Perrin, 1988).

The cumulative number of species recorded in all sections in which it is present is 34, of which eight are non-native. The dominant associated species are, in decreasing order of frequency: *Salmo trutta*, *Barbus barbus*, *Noemacheilus barbatulus*, *Leuciscus cephalus*, *Leuciscus souffia*, *Gobio gobio*, *Chondrostoma nasus* and *Phoxinus phoxinus*. According to Verneaux (1981), this fish belongs to the fish communities of the middle and lower reaches of rivers, from the mesorhithron to the epipotamon.

**Particular biological characteristics.** There are practically no publications on the biology of the species. The related species from the Danube are better known (Banarescu, 1964) and could provide biological analogies in terms of the description of the habitat type (Hensel, 1979), morphological variation (Smirnov, 1971; Holcik, 1979), breeding parameters (Bastl, 1981), growth and diet (Geracopol, 1970; Makara & Stranai, 1980). This species is active at night, lives close to the bottom in large rivers and is easily overlooked (Spillmann, 1961).

Its rarity, already reported from the start of the century, makes it likely that its populations have always had low densities, especially as it is a species with a particularly low fecundity for a percid (Boutitie, 1984b). It is recognized as being sensitive to overall habitat degradation (Verneaux, 1981), but the precise...
Status of French riverine Mediterranean fish

Presence of *Blennius fluviatilis* in 25 to 100% of the included sections

in 1 to 25% of the included sections

Absence of *Blennius fluviatilis*

Presence of *Blennius fluviatilis* in 30 to 100% of the included sections

in 1 to 30% of the included sections

Absence of *Blennius fluviatilis*

Non sampled areas

---

**Fig. 7.** Distribution map of the freshwater blenny *Blennius fluviatilis*. Main river courses are shown as lines. Small water courses are pooled in surface drainage units.

causes of its decline are not clear (Boutitie, 1984a). The disappearance of riffle-pool sequences in the major rivers is still the most obvious explanation. First, nonsilted bottoms are required for spawning and egg survival and, secondly, calm water areas are essential for the surface-dwelling planktivorous larval stages (Leger & Stankovitch, 1921). The related species from the Danube are considered to be the percids most sensitive to changes in current speed caused by river management (Zauner, 1988). This species is not highly esteemed by anglers and does not seem to have been artificially managed up till now. Its territoriality causes problems for aquarium rearing (Perrin, 1988).

*Blennius fluviatilis* Asso, 1801

**Status and geographical distribution.** *Blennius fluviatilis* belongs to a genus of marine origin (Roule, 1935b).

This species occurs both in rivers with a direct connection to the Mediterranean and also, outside our sampling network, as isolated populations on the rocky shores of some alpine lakes (Bourget and Anney) (Leger, 1943; Allardi & Keith, 1991). Outside of the Mediterranean basin, the species has been recorded for a long time from a station in the mid-Garonne (Roule, 1904; Spillmann, 1961; Allardi & Keith, 1991). Its presence in the Canal du Midi, which provides a connection between the Aude and the Garonne, indicates that it could have entered the Garonne basin by this route.

This rare fish (28 sections) occurs essentially in three main river types: in small coastal rivers on mainland France and Corsica, in some sections of major rivers (Rhône, Aude) and in some tributaries flowing directly into the Rhône or into the Lac du Bourget (Fig. 7). This distribution differs from that published recently by
Within our study, which only takes into account running waters, it only appears in two sections of small streams situated at either end of the eastern coastal plain of the island of Corsica (Fig. 8). The presence of *A. fasciatus* on the island, where it occurs in all the lagoons along the east coast, has been known since the start of the 19th century (Kiener & Schachter, 1974; Kiener, 1985; Almaca, 1988). As the lagoon habitat is at the limits of the freshwater environment, this species has not usually been included in studies of the fish populations of the river network of the island (Roule, 1933; Roche, 1988).

Its distribution, extending to Sardinia, where it is considered as rare (Almaca, 1988), and to nearby coastal Italy, probably results from possible connections between these three regions at periods of lowered sea level during the glaciations. Its occurrence in Tunisia in inland oases is a relic of former ancient coastlines (Villwock, 1970).

Records from the coasts of mainland France (Arnoult, 1957; Moreau, 1881) have never been confirmed by later surveys (Spillmann, 1961; Kiener & Schachter, 1974). This absence could be the result of the sensitivity of this fish not only to temperatures (Kiener & Schachter, 1974), but also to the depth of the submarine trench that separates the French coast from Corsica and forms a barrier to dispersion. Despite its tolerance of salinity variations, the species could be excluded from the marine fauna by competition (Villwock, 1970) or because of its poor swimming ability (Kiener, 1985).

**Habitat and accompanying species.** *A. fasciatus*, a lagoon species, is a member of the euryhaline fish community (*Anguilla anguilla, Liza aurata, Atherina moschon, Dicentarchus labrax* and *Mugil cephalus*) together with one non-native species (*Gambusia affinis*). It is absent from the potential communities of Verneaux (1981), which exclude estuarine zones. The Corsican populations of *A. fasciatus* use macrophytes as a refuge and form shoals when they make excursions into open water (Kiener & Schachter, 1974).

**Particular biological characteristics.** The fact that *G. affinis* is always dominant numerically over *A. fasciatus* suggests that there is a competitive relationship between these two ecologically related species. Nevertheless, a study carried out in Spain on a local species of *Aphanius* (*Aphanius iberus*) has shown that there is no dietary overlap with *G. affinis* since *A. iberus* feeds deeper in the water column (Vargas & Sotostoa, 1991). According to these authors, the advantage of *G. affinis* resides in a better utilization of the various microhabitats.

There have been numerous studies on this species around the Mediterranean. The main subjects covered are: its capacity to withstand extreme conditions (Kiener, 1985), its sexual dimorphism (Kiener & Schachter, 1974; Boumaiza, 1980), variation in breeding parameters (Boumaiza et al., 1979; Penaz & Zaki, 1985), its morphological polymorphism (Kiener &

---

**Allardi and Keith (1991), in which it is recorded in the Ardèche, Isère and Saône, but these records require confirmation. The species lists of Kiener (1985) extend its distribution in coastal rivers to the lower parts of the most important rivers situated to the west of the Aude.**

Our information confirms that it is well represented in Corsica (15 sections) as shown in recent studies (Almaca, 1988; Roche, 1988), whereas it was formerly considered as rare (Roule, 1933, 1935a).

This fish is always uncommon in the Rhône. For example, in the upper Rhône it only occurred in 6% of fish catches and only as a few individuals per catch, and has not increased in numbers in the last 10 years of monitoring (Persat, 1988). The oldest record in the Rhône basin is from the Luc du Bourget and in the Rhône next to it (Leger, 1943). Recent information would therefore seem to indicate an expansion in its range within this basin although its preference for relatively deep water could have led to it being overlooked in inventories from the start of the century. In addition, its numbers are always low and suggest that the river is not a very favourable site for this species, which according to our results and the conditions recorded in the additional sites provided by Allardi & Keith (1991) prefers smaller rivers and lakes.

**Habitat and accompanying species.** The habitat characteristics indicate a preference for the lower courses (great distance from the source, low mean gradient, low altitude), although the largest rivers do not seem to be included since the best represented width class is 2–5 m. The mean discharges are varied (1-1421 m³ s⁻¹), but these sections nevertheless have rather high summer temperatures (from 19.6 to 23°C).

This fish belongs to a fish community of 48 species of which nine are non-native. The number of dominant accompanying species is only two (*Anguilla anguilla* and *Salmo trutta*) because the majority of sections are located on the island of Corsica. It does not figure in the potential communities of Verneaux (1981).

**Particular biological characteristics.** Freeman et al. (1990) showed, in a moderate-sized southern Spanish river, that this benthic and territorial species requires non-silted pebbles on which to site its nests. In addition it needs a minimum water depth at the period of low water where it can find lower temperatures. It is held in non-silted pebbles on which to site its nests. In addition (Persat, 1988). The oldest record in the Rhône basin is from the Luc du Bourget and in the Rhône next to it (Leger, 1943). Recent information would therefore seem to indicate an expansion in its range within this basin although its preference for relatively deep water could have led to it being overlooked in inventories from the start of the century. In addition, its numbers are always low and suggest that the river is not a very favourable site for this species, which according to our results and the conditions recorded in the additional sites provided by Allardi & Keith (1991) prefers smaller rivers and lakes.

**Habitat and accompanying species.** The habitat characteristics indicate a preference for the lower courses (great distance from the source, low mean gradient, low altitude), although the largest rivers do not seem to be included since the best represented width class is 2–5 m. The mean discharges are varied (1-1421 m³ s⁻¹), but these sections nevertheless have rather high summer temperatures (from 19.6 to 23°C).

This fish belongs to a fish community of 48 species of which nine are non-native. The number of dominant accompanying species is only two (*Anguilla anguilla* and *Salmo trutta*) because the majority of sections are located on the island of Corsica. It does not figure in the potential communities of Verneaux (1981).

**Particular biological characteristics.** Freeman et al. (1990) showed, in a moderate-sized southern Spanish river, that this benthic and territorial species requires non-silted pebbles on which to site its nests. In addition it needs a minimum water depth at the period of low water where it can find lower temperatures. It is held in low esteem by anglers, but is sometimes used as a bait. Its unusual reproductive behaviour and ornamental properties make it interesting as an aquarium specimen and for ethologists (Wickler, 1957).

**Cyprinodontidae**

*Aphanius fasciatus* Cuvier & Valenciennes, 1821

**Status and geographical distribution.** This member of the Cyprinodontidae is not particularly restricted to fresh water. Its present distribution is strictly related to the brackish waters of coastal lagoons with salinities of between 10 and 35 g litre⁻¹ (Kiener, 1985).

**Cyprinodontidae**

*Aphanius fasciatus* Cuvier & Valenciennes, 1821

**Status and geographical distribution.** This member of the Cyprinodontidae is not particularly restricted to fresh water. Its present distribution is strictly related to the brackish waters of coastal lagoons with salinities of between 10 and 35 g litre⁻¹ (Kiener, 1985).
Presence of *A. fasciatus* in 25% of the included sections

Absence of *A. fasciatus*

Non sampled areas

---

**Fig. 8.** Distribution map of the toothcarp *Aphanius fasciatus*. Small river courses are pooled in surface drainage units. This species does not occur in main water courses.

*A. fasciatus* is of small size, reputedly has toxic flesh and does not appear to have been managed by man up till now, but its low requirements and ornamental qualities make it interesting as an aquarium species. It inhabits lagoons which have been the site of major piscicultural developments during the last 15 years, but nothing is known of their effects on *A. fasciatus*.

**Clupeidae**

*Alosa fallax rhodanensis* (Roule, 1924)

*Status and geographical distribution.* *Alosa fallax* belongs to a genus of euryhaline migratory riverine Clupeidae.

Because of the morphologic plasticity of the species, it is difficult to base the identification of the Mediterranean subspecies *Alosa fallax rhodanensis* on morphological criteria. Individuals of this subspecies have a much faster growth and attain sexual maturity later than their Atlantic counterparts, which gives them a larger size when they enter rivers on migration. Douchement (1981) interpreted these distinctions as an adaptation by *Alosa fallax rhodanensis* to a migration of longer distance.

The same author also considered that the migrations into rivers of *Alosa alosa* and *A. fallax* are controlled by homing behaviour, leading to genetic isolation of populations. However, his morphometric analysis was unable to distinguish clearly between the Mediterranean populations of *Alosa fallax* occurring in the
Alosa fallax and alos shad Alosa alosa. Main river courses are shown as lines. These species do not occur in small water courses.

Aude from those of the Rhône, although homing has been established for the USA, and has been demonstrated indirectly in France (Douchement, 1981).

This rare species (10 sections) only appears in major river courses where there is a permanent direct connection with the sea (coastal rivers, lower Rhône) except in the case of the Ardèche (Fig. 9). The distribution of Alosa alosa is also given (Fig. 2) because the difficulties in distinguishing between the two species and the very precise information given by Douchement (1981) on breeding individuals in the Var make us think that A. fallax is also present in the Aude and Argens. Alosa alosa has always been considered to be much rarer and less widespread than A. fallax (Leger et al., 1945; Douchement, 1981; Zylberblat et al., 1991).

The construction of insurmountable dams on the Rhône from 1952 onwards prevented its migration (Rameye et al., 1976) and led to its distribution range being restricted to the lower 60 km (Larinier et al., 1978; Petit, 1979). The recent record of this species in the Ardèche, which was formerly an important breeding site (Gallois, 1947a), is only based on information provided by fishermen and needs confirming.

Habitat and accompanying species. The quantitative variables show a preference for the lower reaches with a high temperature and which are frequently subject to serious pollution. Roule (1929) and Quignard (1978) have noted a preferential orientation of the migratory routes towards the warmest river courses.
In the sections where *A. fallax* is present, the total cumulative number of species is 37, of which nine are non-native. The most frequent in decreasing order are: *Anguilla anguilla*, *Ictalurus melas*, *Scardinius erythrophthalmus*, *Alburnus alburnus*, *Stizostedion lucioperca*, *Perca fluviatilis*, *Rutilus rutilus*, *Leuciscus cephalus* and *Tinca tinca*. It does not figure among the potential communities of Verneaux (1981).

**Particular biological characteristics.** Of all the endemic fishes included in this study, *A. fallax* is the only one subject to fisheries exploitation. Estimated catches in 1988 for the whole of the Rhône were under 4 tonnes (Changeux & Zylberblat, 1989; Zylberblat et al., 1991), compared with 34 tonnes or more before 1944 (Ramey et al., 1976; Pattée, 1988). Nevertheless the economic importance of this fish has not been judged sufficient to maintain the population by artificial stocking, due to the difficulties of artificial rearing (Gallois, 1946a, b 1947b, c; Hoestlandt, 1948). Studies of the variety of *A. fallax* occurring in the Nile show that the Mediterranean subspecies seem to be able to adapt to a more varied bottom substrate and depth for reproduction than its Atlantic counterpart (Ivanovic, 1977).

**DISCUSSION**

**Status of the species**

Of all the species with a restricted distribution recorded from French running waters flowing into the Mediterranean, *Aphanius iberus* and *Valencia hispanica* have only been reported once, without subsequent confirmation. In addition the existence of *Cottus petiti* (Bacescu & Bacescu-Mester, 1964) as a true species has still to be confirmed.

Of the seven species or subspecies considered in this study, only *Zingel asper* shows a distribution restricted to the Rhône basin. It is the only one in our study area that can be classified as being endemic *sensu stricto*, since the other species also occur in other countries around the Mediterranean basin. The distribution range of two (*B. meridionalis* and *L. souffia*) also extends to north and eastern Europe.

The status of the seven endemic species as isolated reproductive communities is debatable, at least for being able to hybridize with related coexisting species: the hybrid *A. fallax × A. alosa* accounts for 10% of the French population according to Douchement (1981), but the degree of hybridization seems to vary from one basin to another and its extent is debatable (Taverny, 1991; Boisnue et al., 1992); species of the genera *Leuciscus* and *Chondrostoma* can hybridize with other Cyprinidae including species belonging to other genera (Collares-Pereira, 1989); *B. meridionalis* crosses in the wild with *B. barbus* (Berrebi et al., 1986, 1988; Philippart & Berrebi, 1990).

Although the hybrids are not always fertile, the transfer of genes from one species to another is possible. This is particularly recorded between *B. meridionalis* and *B. barbus*. Thus, in the absence of reproductive genetic isolation, the integrity of these species can be altered by the introduction of new species or by modification of spawning sites.

According to Banarescu (1990), the species included in this study do not all have the same zoogeographical status in terms of their relation to fresh water. The cyprinids *L. souffia*, *B. meridionalis* and *C. toxostoma* belong, together with the percid *Z. asper*, to the group of ‘primary freshwater fish’ which are strictly restricted to fresh water and generally spread by overland routes. *A. fasciatus* is a ‘secondary freshwater fish’, and has a distribution related to the sea, as do *B. fluviatilis* and *A. fallax*, which are classed as ‘peripheral and vicarious freshwater fishes’.

**Geographical distribution and species abundance**

The distribution maps and the abundance values obtained for the French Mediterranean catchment can be considered as correct, with the exception of two species which occur in habitats located at the margins of our study area (*A. fasciatus* in the lagoon environment and *B. fluviatilis* in large alpine lakes).

As evidence of the evolutionary success of the Cyprinidae in fresh waters, the three representatives of this family are all common or very common, whereas all the other species are rare (Appendix 1). The cyprinids belong to three different genera (*Barbus*, *Leuciscus* and *Chondrostoma*). There are no genera containing more than one endemic species within the study area, which, together with the low level of genetic isolation between species, suggests that a minimum degree of taxonomic separation is needed for endemicism to appear within this area.

In addition, these endemic species differ from sympatric species of the same genus by having smaller maximum lengths (30 cm for *B. meridionalis* compared with 80 cm for *B. barbus*, 30 cm for *C. toxostoma* compared with 52 cm for *C. nasus*, and 20 cm for *L. souffia* compared with 65 cm for *L. cephalus*, or 30 cm for *Leuciscus leuciscus*). This finding is in agreement with the principles relating distribution to body size—smaller sizes occurring in species with restricted distributions (Peters, 1983), situated at lower altitudes (Linsley, 1966). However, this suggests, in response to Gaston and Lawton (1990), that in freshwater fish the relation between extent of distribution and body size must be studied by using the genus as the unit.

Three main zoogeographical regions are distinguished: the island of Corsica, the northern mainland region situated to the north of the confluence of the Isère and to the south a southern mainland region comprising the coastal rivers. Because of its isolation, Corsica is only populated by secondary species (*A. fasciatus*) or by peripheral and vicarious freshwater fish (*B. fluviatilis* and *A. fallax*) for which the sea is no obstacle to dispersion. In contrast, the northern mainland region, which is distant from the sea, is populated almost entirely by primary species. The only exception, *B. fluviatilis*, occurs here as a land-locked population mainly in alpine lakes. The southern mainland region is
distinguished from the above region by the presence of *B. meridionalis*. Its coastal situation means that its endemic community is enriched by a peripheral species of marine origin (*A. fallax*), although at the start of the century this species ran up the rivers to spawn as far as the northern mainland region (Kreitmann, 1932). The catchments of the coastal rivers form a series of zoogeographical islands remarkable for their primary species: none of these rivers has been colonized by *Z. asper* and *L. souffia* remains absent from rivers situated to the west of the Hérault.

**Habitat and accompanying species**

Habitat preferences could only be established for the three most abundant species. These occur both in main river courses (mapped linearly) and in small tributaries (mapped on an area basis), whereas the other species show a preference for main river courses (*Z. asper, A. fallax* and *B. fluviatilis*) or small water courses draining into coastal lagoons (*A. fasciatus*).

*B. meridionalis, L. souffia* and *C. toxostoma* succeed one another along the longitudinal gradient, by occupying the upper, middle and lower reaches, respectively (correlated with reduced gradient, increased width and distance from the source). As most variables change along this longitudinal gradient, it is difficult to distinguish between what is related to the position of the species along the gradient and what is the effect of any given variable.

The absence of some endemic species in the definition of the potential communities of Verneaux (1981) means that this method cannot be applied to the entire study area. An additional approach would be needed to include the special zoogeographical features of the south of France and Corsica. *C. toxostoma* does not change its relative position in the south of France since it is placed in accordance with the potential communities. In contrast, in the south of the study area, *L. souffia* is placed in communities further upstream and certainly does occur in areas higher up-river.

**Analysis of changes in distribution and abundance**

The decreases in both distribution and abundance of *A. fallax* and *Z. asper* are certain, according to our definition, but it is difficult to establish for sure that there has been an increase in the distribution range of *L. souffia* or *B. fluviatilis*. Similarly, it remains uncertain whether there has been a decline in the populations of *C. toxostoma* and *B. meridionalis* and any changes in the abundance of *A. fasciatus* are unknown.

According to the Agence de Bassin Rhône Méditerranée Corse (RMC) (1988) and Pattée (1988) human actions are largely responsible for these changes.

The *reduction in migration routes* by the construction of dams that form obstacles to fish movements is the reason for the decline in the stocks of *A. fallax*. However, the effects of dams on the entire fish community are poorly known as there is very little information on the importance of fish movements in the life cycles of other species, particularly the endemics.

**Habitat destruction** following river management and sand and gravel extraction from within river courses is probably responsible for the disappearance of *Z. asper*.

*Water abstraction*, leading to seasonal drying out of rivers, is a practice that is becoming increasingly widespread in areas with a Mediterranean climate. This causes the extinction of those species that are not adapted and, if the fish are specially adapted, it can accentuate the effects of pollution by decreasing dilution and favouring sedimentation. This is the case for *B. meridionalis*, which is still sensitive to water quality even though it can resist very low water levels.

*Organic, chemical and thermal pollution* affect many water courses (37% of sections are in categories 2, 3 or 4). The presence of four major cities (Lyon, Marseille, Nice and Grenoble) leads to heavy organic loads. There are several major industrial centres associated with these cities (Rhône valley south of Lyon, Golfe de Fos near Marseille, alpine valleys around Grenoble, etc.) that discharge nitrogen, phosphorus, organochlorides and heavy metals (Cu, Hg, Cr, Pb), to which must be added the radioelements discharged by various nuclear research centres. Seven nuclear and fossil-fuel burning power plants heat the water of the Rhône by 1.5 to 4°C, depending on the season. The influence of background levels of this (chronic) pollution is not known in detail. Studies carried out in the Rhône basin have shown that: (1) it favours the most tolerant species in the community (*L. cephalus, R. rutilus* and *A. alburnus* (Pattée, 1988)); (2) it leads to bioaccumulation of pollutants that render the fish unfit for human consumption (commercial fishing has been prohibited upstream of Lyon); (3) it modifies metabolism (excess detoxifying enzyme levels in the liver (Monod et al., 1986)); (4) it leads to more abundant mucus secretion (Pattée, 1988); (5) it renders fish more susceptible to disease (Kiener, 1985); (6) it can increase mortality among young stages (Pattée, 1988) and (7) it can lead to siltation of gravel beds needed for spawning. In contrast, there are great risks of accidental mortality by chemical pollution (nine accidents reported on the Rhône in the last 20 years (Agence de Bassin RMC, 1988). The flushing out of sediments accumulated at the bottom of reservoirs led to massive fish kills every 3 years up until 1978. The enormous tourist influx into the Mediterranean region leads to increased sewage loads during the summer when river levels are at their lowest, which accentuates problems associated with eutrophication. The same is also true of the intensification of aquacultural activities in coastal lagoons.

*Allosa* is the only endemic fish that is exploited by commercial fishermen. The fishing effort using fixed net installations is declining continuously as is the quantity of catches (Rameye et al., 1976; Kiener, 1985; Changeux & Zylberblat, 1989, 1993). Populations are currently at a very low level. The promotion of a new type of exploitation of *Allosa* sp. by angling needs to be monitored (Zylberblat et al., 1991). Angling for *B. meridionalis* is popular (Berrebi et al., 1988), whereas *L. souffia* and *C. toxostoma* are only of minor importance
for anglers. The possibility of *B. fluviatilis* and *A. fassciatus* being exploited as aquarium fish is a threat that must be considered in the future.

The responsibility of man for introducing new species likely to compete with endemic species concerns *A. fassciatus*, which is outnumbered by *G. affinis* in lagoon environments, and *C. toxostoma*, which has declined in favour of *C. nasus* in the Saône. The first case is an example of the inter-continental introductions dating from the start of the century which also include *Leptomis gibbosus, Ictalurus melas, Micropterus salmoides, Oncorhynchus mykiss, Salvelinus fontinalis* and *Salvelinus namaycush*. The second case results from the current extension of the distribution of species from the Danube (*Stizostedion lucioperca, Silurus glanis, C. nasus, etc.*) towards western Europe, that has been accelerated by man by the construction of connections between basins.

**Legal status of species and conservation measures**

Two types of laws that provide lists of protected species are applicable in France.

*International laws ratified by France*

The Washington Convention (3 March 1973) does not list any of our endemic species.

The Berne Convention (19 September 1979) distinguishes (i) *strictly protected* species for which conservation measures are needed including habitat protection, and for which capture and possession are prohibited; (ii) *species needing special management*, but whose populations may be exploited. All of our endemic species are affected by one or other of these measures, *Z. asper* and *V. hispanica* having the status of strictly protected species.

The directives of the European Communities (21 May 1992) reiterate the Berne convention lists and define those species that should be subject to *special management* (*B. meridionalis* and *A. fallax*). *B. fluviatilis* is omitted from the EC lists.

*French laws*

The decree of 8 December 1988 prohibits the destruction or collection of eggs or the alteration or degradation of the breeding sites of four of our seven endemic species. *A. fassciatus, L. souffia* and *C. toxostoma* do not benefit from any protection measure at the national level.

The IUCN Red Data Book (Keith et al., 1992) has recently established a reference status for endangered species within France (Appendix 1). All the endemic species, except *C. petitti*, appear in this list:

- *L. souffia* is considered as rare within France as it is endemic to the south-east. Our results confirm this status and show that this species is relatively insensitive to man-made changes. It is unlikely therefore to be endangered;
- *C. toxostoma* is considered as endangered because of possible competition from *C. nasus*, which is spreading towards the west in other French river basins. Our results cannot either support or refute this status;
- *B. meridionalis* is considered as rare, because of the disjointed nature of its distribution range. Our results cannot either support or refute this status. However, this species is certainly not extending its range.
- *Z. asper* is considered as threatened with extinction. Our results confirm this status.
- *Alosa fallax* is considered as vulnerable. Our results confirm this status. In contrast to Atlantic populations, the Rhône shad has not benefited from the programmes in favour of migratory fish recently developed in France. Activities are currently in progress to allow shad to get past the first few dams blocking its migration on the Aude at Moussoulens (Desjames, 1988), on the Hérault at Agde (Cruz, 1989), on the Vidourle at Mas de Terre de Port (Bourgogne, 1988), on the Rhône at Beaucaire (Zylberblat et al., 1991) and on the Argens at Roquebrune (Anon., 1988).

In proportion to the number of species present in the basin, those in Rhône-Mediterranean-Corsica are the most endangered with 46% of the species present listed in Keith et al. (1992). Our results also show that the majority of these species occur in the lower reaches of the river, which are the habitats most affected by human activities. These species are therefore particularly vulnerable.

**ACKNOWLEDGEMENTS**

We would like to thank J. F. Perrin for giving us his old maps of fish distribution. This work was supported by the Agence de l'Eau Rhône Méditerranée Corse. It forms part of the Programme Interdisciplinaire de Recherche sur l'Environnement of the Centre National de Recherche Scientifique entitled 'Environmental factors, spatial habitat use and spatio-temporal structure of fish populations'.

**REFERENCES**


---

**APPENDIX 1 SPECIES LIST OF FRESHWATER FISH IN THE STUDY AREA.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
<th>Threat</th>
<th>Status</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PETROMYZONIDAE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lampera fluviatilis (Linnaeus, 1758)</td>
<td>R</td>
<td>E</td>
<td>M</td>
<td>North-eastern Atlantic &amp; Mediterranean</td>
</tr>
<tr>
<td>Lampera planeri (Bloch, 1786)</td>
<td>C</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petromyzon marinus (Linnaeus, 1758)</td>
<td>R</td>
<td>E</td>
<td>M</td>
<td>North Atlantic &amp; Mediterranean</td>
</tr>
<tr>
<td><strong>ACIPENSERIDAE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acipenser sturio (Linnaeus, 1758)</td>
<td>Extinct</td>
<td>Ex</td>
<td>M</td>
<td>North Atlantic &amp; Mediterranean</td>
</tr>
<tr>
<td><strong>ANGUILLIDAE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anguilla anguilla (Linnaeus, 1758)</td>
<td>CC</td>
<td>V</td>
<td>M</td>
<td>Northern Atlantic</td>
</tr>
<tr>
<td><strong>CLUPEIDAE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alosa alosa (Linnaeus, 1758)</td>
<td>R</td>
<td>E</td>
<td>M</td>
<td>North-eastern Atlantic &amp; Mediterranean</td>
</tr>
<tr>
<td>Alosa fallax rhodanensis (Roule, 1924)</td>
<td>R</td>
<td>E</td>
<td>M</td>
<td>North-eastern Atlantic &amp; Mediterranean</td>
</tr>
<tr>
<td><strong>SALMONIDAE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salmo trutta (Linnaeus, 1758)</td>
<td>CC</td>
<td>N</td>
<td></td>
<td>European</td>
</tr>
<tr>
<td>Salvelinus alpinus (Linnaeus, 1758)</td>
<td>R</td>
<td>E</td>
<td>N</td>
<td>Northern Atlantic</td>
</tr>
<tr>
<td>Salvelinus fontinalis (Mitchill, 1815)</td>
<td>C</td>
<td>S</td>
<td></td>
<td>North-Eastern American</td>
</tr>
<tr>
<td>Salvelinus namaycush (Walbaum, 1794)</td>
<td>R</td>
<td>S</td>
<td></td>
<td>North-Eastern American</td>
</tr>
<tr>
<td>Hucho hucho (Linnaeus, 1758)</td>
<td>R</td>
<td>S</td>
<td></td>
<td>Danubian</td>
</tr>
<tr>
<td>Oncorhynchus mykiss (Walbaum, 1792)</td>
<td>CC</td>
<td>S</td>
<td></td>
<td>Northern-Western American</td>
</tr>
<tr>
<td>Coregonus sp (Linnaeus, 1758)</td>
<td>R</td>
<td>N</td>
<td></td>
<td>Holarctic</td>
</tr>
<tr>
<td>Thymallus thymallus (Linnaeus, 1758)</td>
<td>C</td>
<td>V</td>
<td>N</td>
<td>Holarctic</td>
</tr>
<tr>
<td><strong>ESOCIDAE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esox lucius (Linnaeus, 1758)</td>
<td>CC</td>
<td>V</td>
<td>N</td>
<td>Holarctic</td>
</tr>
<tr>
<td><strong>CYPRINIDAE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abramis brama (Linnaeus, 1758)</td>
<td>CC</td>
<td>N</td>
<td></td>
<td>European</td>
</tr>
<tr>
<td>Alburnoides bipunctatus (Bloch, 1782)</td>
<td>CC</td>
<td>N</td>
<td></td>
<td>European</td>
</tr>
<tr>
<td>Alburnus alburnus (Linnaeus, 1758)</td>
<td>CC</td>
<td>N</td>
<td></td>
<td>European</td>
</tr>
<tr>
<td>Barbus barbus (Linnaeus, 1758)</td>
<td>CC</td>
<td>N</td>
<td></td>
<td>European</td>
</tr>
<tr>
<td>Barbus meridionalis Risso, 1826</td>
<td>CC</td>
<td>R</td>
<td>E</td>
<td>Southern European</td>
</tr>
<tr>
<td>Blicca bjorkeana (Linnaeus, 1758)</td>
<td>C</td>
<td>N</td>
<td></td>
<td>European</td>
</tr>
<tr>
<td>Carassius auratus (Linnaeus, 1758)</td>
<td>R</td>
<td>A</td>
<td></td>
<td>East Asian</td>
</tr>
<tr>
<td>Carassius carassius (Linnaeus, 1758)</td>
<td>R</td>
<td>A</td>
<td></td>
<td>Euro-Siberian</td>
</tr>
<tr>
<td>Chondrostoma nasus (Linnaeus, 1758)</td>
<td>CC</td>
<td>C</td>
<td></td>
<td>Central European</td>
</tr>
<tr>
<td>Chondrostoma toscothoma Vallot, 1836</td>
<td>C</td>
<td>V</td>
<td>E</td>
<td>Southern European</td>
</tr>
<tr>
<td>Cyprinus carpio (Linnaeus, 1758)</td>
<td>CC</td>
<td>A</td>
<td></td>
<td>Palaearctic</td>
</tr>
<tr>
<td>Gobio gobio (Linnaeus, 1758)</td>
<td>CC</td>
<td>N</td>
<td></td>
<td>Holarctic</td>
</tr>
<tr>
<td>Leuciscus daceus (Heckel, 1843)</td>
<td>R</td>
<td>I</td>
<td>A</td>
<td>Central European</td>
</tr>
<tr>
<td>Leuciscus cephalus (Linnaeus, 1758)</td>
<td>CC</td>
<td>N</td>
<td></td>
<td>European</td>
</tr>
<tr>
<td>Leuciscus leuciscus (Linnaeus, 1758)</td>
<td>CC</td>
<td>R</td>
<td>E</td>
<td>Southern-European</td>
</tr>
<tr>
<td>Leuciscus souffia Risso, 1826</td>
<td>CC</td>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 1 — contd

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Abundance</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CYPRINIDAE—contd</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phoxinus phoxinus (Linnaeus, 1758)</td>
<td>CC</td>
<td>Holarctic</td>
</tr>
<tr>
<td></td>
<td>Pseudorasbora parva (Schlegel, 1842)</td>
<td>R</td>
<td>East Asian</td>
</tr>
<tr>
<td></td>
<td>Rhodeus amarus (Bloch, 1785)</td>
<td>C</td>
<td>Palaearctic</td>
</tr>
<tr>
<td></td>
<td>Rutilus rutilus (Linnaeus, 1758)</td>
<td>CC</td>
<td>Euro-Siberian</td>
</tr>
<tr>
<td></td>
<td>Scardinaeus erythrophthalmus</td>
<td>CC</td>
<td>European</td>
</tr>
<tr>
<td></td>
<td>(Linnaeus, 1758)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tinea tinca (Linnaeus, 1758)</td>
<td>CC</td>
<td>Euro-Siberian</td>
</tr>
<tr>
<td><strong>COBITIDAE</strong></td>
<td>Cobitis taenia Linnaeus, 1758</td>
<td>R</td>
<td>Holarctic</td>
</tr>
<tr>
<td></td>
<td>Misgurnus fossilis (Linnaeus, 1758)</td>
<td>R</td>
<td>European</td>
</tr>
<tr>
<td></td>
<td>Noemacheilus barbatulus (Linnaeus, 1758)</td>
<td>CC</td>
<td>Holarctic</td>
</tr>
<tr>
<td><strong>SILURIDAE</strong></td>
<td>Silurus glanis Linnaeus, 1758</td>
<td>R</td>
<td>Central European</td>
</tr>
<tr>
<td><strong>PERCIDAE</strong></td>
<td>Gasterosteus aculeatus Linnaeus, 1758</td>
<td>C</td>
<td>Northern Atlantic &amp; Mediterranean</td>
</tr>
<tr>
<td></td>
<td>Pungitius pungitius (Linnaeus, 1758)</td>
<td>R</td>
<td>Northern Atlantic</td>
</tr>
<tr>
<td><strong>GASTEROSTEIDAE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aphanius fasciatus (Cuvier &amp; Valenciennes, 1821)</td>
<td>R</td>
<td>Circum-Mediterranean</td>
</tr>
<tr>
<td><strong>POECILIIDAE</strong></td>
<td>Gambusia affinis Baird &amp; Girard, 1853</td>
<td>C</td>
<td>North-Eastern American</td>
</tr>
<tr>
<td><strong>GADIDAE</strong></td>
<td>Lota lota (Linnaeus, 1758)</td>
<td>C</td>
<td>Holarctic</td>
</tr>
<tr>
<td><strong>ICTALURIDAE</strong></td>
<td>Ictalurus melas (Rafinesque, 1820)</td>
<td>C</td>
<td>North-Eastern American</td>
</tr>
<tr>
<td><strong>BLENNIIDAE</strong></td>
<td>Blennius fluviatilis Asso, 1801</td>
<td>R</td>
<td>Circum-Mediterranean</td>
</tr>
</tbody>
</table>

*Abundance in three categories depending on number of occurrences in sections included in the database (R, ≤30; C, 30–140; CC, ≥140).

*In accordance with IUCN rules according to Keith (1992) (Ex, species not recorded since 1961; E, species having disappeared from a large part of their original range and whose numbers are reduced to a minimal threshold; these species are threatened with extinction if the causes responsible for their current situation continue to act. V, species whose numbers are declining strongly because of unfavourable external factors; these species are likely to become E if the factors responsible for their vulnerability continue to act. R, species which are not immediately threatened with V or E, but whose populations are limited because of a restricted geographical distribution, which exposes them to risks. I, species that may be E, V or R, but whose status is unclear because of the lack of information).

The origin of the various species according to Holcik’s classification (1991) (N, natives; E, endemic, A, introduced by man; C, introduced by means of inter-basin connections; S, maintained by artificial stocking).

The distribution of the species according to Banatescu’s classifications (1964, 1989a,b).