Prospecting for historical fish data from the Rhone River basin: a contribution to the assessment of reference conditions

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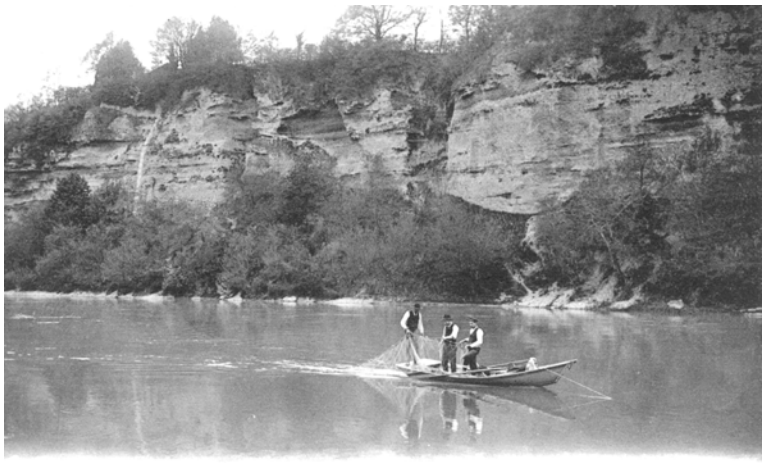

Abstract

This paper presents rare cartographic historical fish data known from the Rhone River Basin which give spatial and exhaustive data on fish assemblages. The maps may play a role in current research about fish reference conditions. The information recorded in these archives is presented and forms the basis of a critical analysis in order to define the limits of their use.

Introduction

At the turn of the century, the focus for both water resource managers and aquatic ecologists is the restoration of altered aquatic ecosystems. The European Water Framework Directive (EUR-Lex, 2000) formalised these imperative requirements and enacted the principal goals of a real joint community will. Amongst the environmental objectives are the protection, enhancement and restoration of all water bodies "*with the aim of achieving good ecological status at the latest 15 years after the date of entry in force of the Directive*". The first phase in the implementation of this directive aims at evaluating the quality of water bodies and defining their ecological status relative to type-specific reference conditions.

The keynote of the WFD lies in the conceptualisation and practical application of type-specific biological reference conditions. Ideally, these may be spatially based on a network of sites with high ecological status. If not, they may be based on predictive models or hindcasting methods using among other approaches historical data. Expert opinion may be sought if the above methods prove impracticable. If difficulties in defining reference conditions increase with regard to abiotic and biotic differences across Europe, serious problems arise from human impact on ecosystems over the centuries. Hence, the number of sites with high ecological status could be too low to provide a sufficient level of confidence in the values for the reference conditions, a situation which is serious in the case of fluvial ecosystems (WARD et al., 1999). As a result, the establishment of reference conditions by means of alternatives combining models, expert judgement and the use of historical data could become widespread, especially for rivers which have been regulated for a longer time.

As part of the ecological reference conditions, fish fauna is historically the best known piece in the biological jigsaw, at least before the radical transformation of hydrosystems by large civil engineering works. A first glance at the archives may give basic qualitative information about fish distribution on a large scale. Generally this allows to draw up native species lists and distribution maps. Reference may be made to some examples of exhaustive research as in Kansas streams (CROSS & MOSS, 1987) or in the Colorado River Basin (CARLSON & MUTH, 1989) in North America, and in the Rhine (LELEK, 1989) or in the Morava River, a tributary of the Danube (PENAZ et al., 1986) in Europe. When the quality of the data and the number of the surveys permitted, temporal comparisons were made, as in the Lower Missouri (PFLIEGER & GRACE, 1987), or in the Red River of the North basin in the United States (PETERKA & KOEL, 1996), or the Seine Basin (BELLIARD et al., 1995) in France. The ultimate stage of information is given by long term survey, unfortunately rare in running waters and often limited

to species of high fishery value, such as migratory species. For the large European rivers, some long term data prior to 1950 are available for Acipenseridae (BACALBASA-DOBROVICI, 1991; ELVIRA et al., 1991), Clupeidae of the genus *Alosa* (see a review in TAVERNY et al., 2000) or Salmonidae, in particular Atlantic salmon in the Rhine Basin (CAZEMIER, 1988; LELEK, 1989).

This paper presents rare historical data, above all published cartographical archives, known from the Rhone Basin. In spite of the relatively young age of these documents compared with older ones, they give spatial and exhaustive data on fish assemblages. This type of document is rare and as such is particularly pertinent. The maps, of implicit use in Rhone River ichthyology (PATTEE, 1988), may also play a role in current research about fish reference conditions. Information recorded in these archives is presented and forms the basis of a critical analysis in order to define the limits of their use. Analysis focuses on running waters courses.

Historical cartography of the Rhone Basin fish fauna

1. Description of the maps and data available

Several department (French counties) fish maps were drawn for the French Rhone Basin from 1924 to 1956 by Professor **Louis LEGER (1866-1948)** of the University of Grenoble and his colleagues. The aim of the authors was *"to give fishermen information on the distribution of species and to provide the Civil Service and Fishery Societies with an indispensable documentation on the economic value of the rivers"* (translation).

Eight department fish maps (Fig. 1) with a 1/200 000 scale are available : Isère (LEGER, 1924), Ain (LEGER, 1927), Haute-Savoie (LEGER & KREITMANN, 1931), Hautes-Alpes (LEGER, 1933/34), Savoie (LEGER, 1942/44), Rhone (LEGER, 1945/48a), Drome (DORIER, 1955) and Ardèche (DORIER, 1956/57).

These maps provide the list of **species**, their **location** in the hydrographic network. **Upstream or downstream limits** of distribution are given for some species. Relative frequency of each species in a river or a river section is indicated by a system of underlining in the species code (Fig. 2). In accordance with LEGER (1910b), *"no underlining indicates the presence of the fish, simple underlining indicates that the species was quite common, double underlining indicates a dominant species"*. Each section is characterised by dimensions (L = average width and P = average depth) and by a note known as **biogenic capacity** β. This value is indicated by Roman numerals and expressed from I to X. According to the expert judgement of the authors, it allowed to evaluate the approximate productivity K expressed in kilograms per kilometre as $K = \beta L$ for salmonid sections, and as $K = 2\beta L$ for cyprinid sections of the bream zone (LEGER, 1910b, 1945).

The maps list species inhabiting lakes and reservoirs as well, and relative abundances by the same criteria. They also give the distribution of two autochtonous crayfish (*Austropotamobius pallipes* and *A. torrentium*) but included them under the same symbol, and the first description of the exotic crayfish *Orconectes limosus*.

The authors *"equally made an effort to indicate obstacles, harmful rubbish dumps and drying up sections, main salmonid spawning grounds, location of Fishery Societies, fry fish farms"*.

Hydropower use is indicated by distinct symbols for dams and plants according to their fish clearing. These symbols are missing in the Isère Department (1924) and the Ain Department (1926) maps. They are few in the other maps. Knowing the centuries-old and extensive use of the rivers, those given were only the most noticeable.

With the exception of the Isère (1924), the Ain (1926) and the Haute-Savoie (1931) Department maps, they indicate locally harmful industrial dumps. Only dumps with strong negative effects on the environment and the fauna acknowledged by riverside residents were specified. This was the case for several rivers in the Rhone Department: the River Ardières, the Azergues River Basin, the River Gier (LEGER, 1945/48a). In the Savoie Department a *"toxic zone"* was noticed from Ugines to Albertville (LEGER, 1942/44). On the Upper Durance River, a harmful dump was noted in the industrial area of L'Argentière (LEGER, 1934) where various water uses for hydroelectricity, electrochemistry and aluminium manufacture converged (WILHELM, 1913).

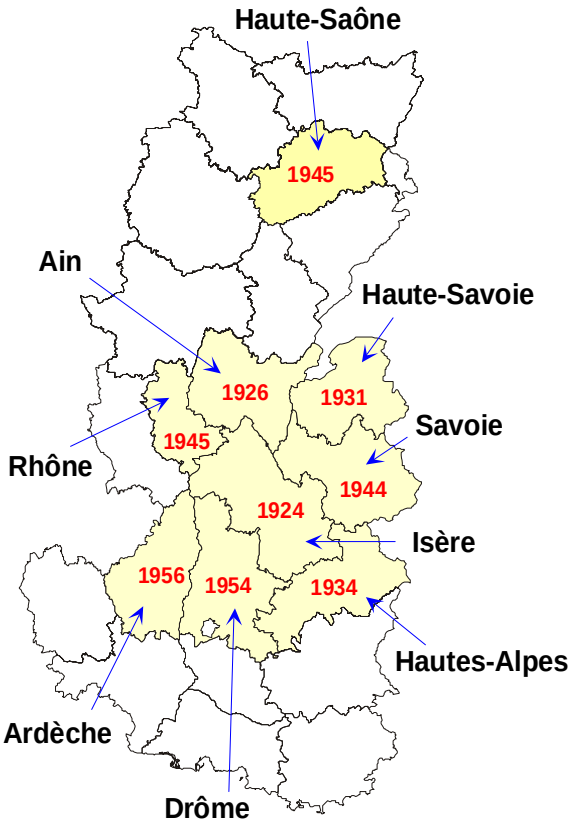

Fig.1. Location of the Department fish maps available for the French Rhone Basin. Eight of them were published by LEGER and co-workers from 1924 to 1956 (see references). The Haute-Saone fish map (Anonymous, 1945) was drawn by the Department Federal Fishery Society.

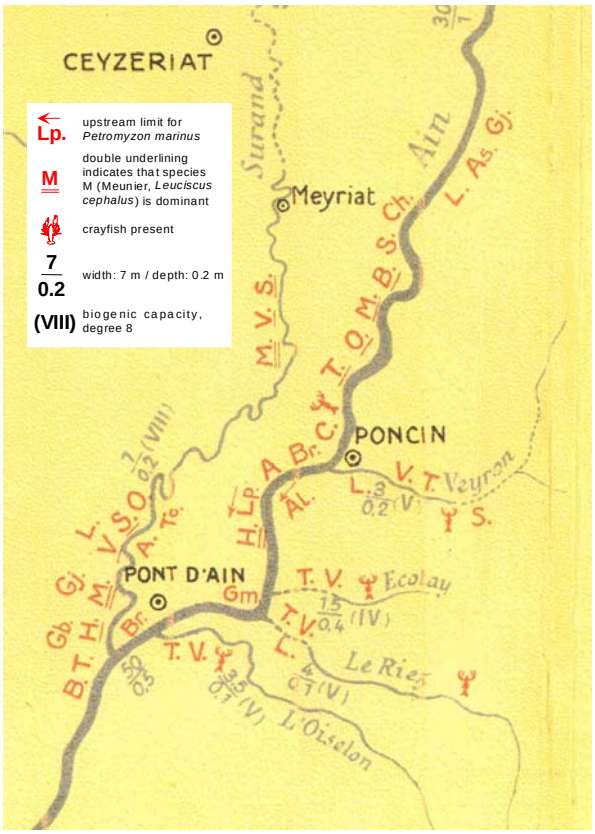

Fig. 2 An extract from the Ain Department map (1926) to illustrate the type of data available.

Most of the maps are accompanied by a brief text providing some extra information. The first published map (LEGER, 1924) *"only had the aim, under the title Carte touristique et Sportive, to inform fishermen and the Civil Service of the different fish species … without other additional data about the importance and economic value of the rivers"*. LEGER (1945/48b) considered it useful to complement this map with an ultimate paper. In spite of this additional paper, it remains the least accurate, especially in its species list.

A 1: 500 000 large scale fish map of the Rhone River and its main tributaries was also published (KREITMANN, 1932).

The department fish maps of L. LEGER and his colleagues from the University of Grenoble initiated other similar works. Thus, a department fish map was drawn in the Haute-Saone (Anonymous, 1945) by the Department Federal Fishery Society. It provides the list of species and their location in the upstream hydrographic network of the River Saone, the main tributary of the River Rhone (Fig. 1).

2. Critical analysis of the maps

2.1 Degree of physical alteration of the running waters

At the time of the publication of these maps, rivers had lost their pristine conditions owing to growing human water use for irrigation, mills and other industries, and the influx of sewage and industrial effluents. Furthermore, factories totally dependent on hydropower and water resource completely colonised the river network.

The briefness of information regarding physical modifications by dams, or degradation of water quality in these maps, implies the need for additional data. For dams and power plants, recent thematic maps such as those of Fisheries Orientation Schemes (SDVP) during the 1980s (SOUCHON & TROCHERIE, 1990) or Water Planning and Management Schemes (SAGE, SDAGE) during the 1990s can provide the information. Quantifying historical levels of urban and industrial pollution seems unreasonable. But other historical data can provide information on industrial location, water use and the nature of effluents; they could help to explain local alterations in fish assemblages. For example, known polluting factories such as carbide calcium plants, paper mills, tanneries, dyeing or weaving factories, saw mills that release wood particles, were numerous on several salmonid rivers in the Ain Department (TRIPPIER, 1903). In addition, historical prospective studies on industrial planning such as that of the Durance River catchment (WILHELM, 1913) are of great interest.

By the end of the 19th century, extensive civil engineering had already been carried out on Alpine catchments to provide protection against erosion damage or flooding, and on the Rhone to improve navigation (BRAVARD & PEIRY, 1993; BRAVARD & PETTS, 1996; BRAVARD et al., 1997). Some large hydroelectric dams were already operating.

2.2 Constraints imposed by the data

2.2 1 Introduced species in the Rhone Basin

The maps were published from 1924 to 1956. During this long period of 32 years, some species introduced at the end of the 19th century or at the beginning of the 20th greatly expanded. Dissemination was by fish farming and intentional introduction: rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), largemouth black bass (*Micropterus salmoides*). Other species rapidly acclimatised outside the fishery network: pumkinseed (*Lepomis gibbosus*), black bullhead (*Ameiurus melas*); but their success was not appreciated (LEGER, 1945/48a). The same difference of opinion about fishery value existed for two European introduced species: pikeperch (*Stizostedion lucioperca*) and nase (*Chondrostoma nasus*). Nase, a rheophilic and lithophilic cyprinid, found conditions extremely favourable for its demographic explosion in the Rhone and its tributaries. Facing this situation, riverside residents rapidly demanded exceptional fishing operations to exterminate the nase. These costly measures were applied as early as 1901 in the River Ain where shoals of nase were accused *"of disturbing trout by their continuous wanderings"* (TRIPPIER, 1902). This temporal and artificial variability in introduced species distribution exclude them from the establishment of reference conditions. However, there is no incoherence in considering a new species as a good indicator of particular river habitat features if it has well specified requirements, as nase has.

2.2 2 Species occurrence

These department fish maps gave a list of 45 fish species (Table I). Four species were missing: three cyprinids (crucian carp, *Carassius carassius* – goldfish, *Carassius auratus* - white bream, *Abramis bjoerkna*) and one cobitid (weatherfish, *Misgurnus fossilis*). At the present time, 54 fish species have been sampled in the area described in the maps (KEITH & ALLARDI, 2001). Additional species are the last introduced: the cyprinids (belica, *Leucaspius delineatus* – topmouth gudgeon, *Pseudorasbora parva* – Prussian carp, *Carassius gibelio*), a silurid (wels, *Silurus glanis*) and a poeciliid (mosquitofish, *Gambusia affinis*).

Some difficulties arise in the reading of the lists used by the cartographers over decades, irrespective of common or scientific names. In most of the maps, some species have been grouped. For example, under the label trout (T) were included the brown trout (*Salmo trutta*) and exotic salmonids (rainbow trout and brook trout). In the map of the Rhone Department, the brook lamprey (*Lampetra planeri*) and the river lamprey (*Lampetra fluviatilis*) were under the same code. Coregonids, whose taxonomic complexity is always topical (GERDEAUX, in KEITH & ALLARDI, 2001), were also mixed.

It is astonishing to find only one bream species (*Abramis brama*), even though it has been mixed with white bream (*Abramis bjoerkna*) in the large rivers. The fish fauna inventory in the large rivers was obtained from the results of commercial fisheries, so it is likely that the two species had never been distinguished.

At the time, two species of the sub-family Alosinae were identified: the Rhone twaite shad (*Alosa fallax rhodanensis*) and the allis shad (*Alosa alosa*). LEGER (1945/48a) even specified the following proportions: 80% twaite shad and 20% allis shad in the upper third of the Lower Rhone River from

River Saone to River Isère. At present, only Rhone twaite shad has been genetically identified along the Rhone River axis (LE CORRE et al., 1997; LE CORRE et al., 1998). Extinction of the allis shad in the Rhone remains totally unexplained (SABATIE et al., 2000).

In the maps of the Drome (DORIER, 1955) and Ardèche (DORIER, 1956/57) Departments, sturgeon (*Acipenser sturio*) is indicated in the middle part of the Lower Rhone. When sturgeon was mentioned (KREITMANN, 1932), its dramatic decline had already placed it among endangered species. As early as 1930, the catch of one specimen was a special event (KIENER, 1985). Its extinction, as that of the Rhine populations (LELEK, 1989), was linked to extensive and uncontrolled catches.

One of the main interests of these maps is in the description of complete fish assemblages of river sections, but some small species were often underestimated or ignored in the inventories. This problem arises mainly in the downstream part of the large rivers where the species could not be directly observed and not caught by the fishing techniques in use. Such is the case of the freshwater blenny (*Salaria fluviatilis*), the stone loach (*Barbatula barbatula*), the bitterling (*Rhodeus amarus*), the sculpin (*Cottus gobio*) and the ruffe (*Gymnocephalus cernuus*). Problems also concerned some rare species in the Rhone Basin such as the nine-spined stickleback (*Pungitius pungitius*), or the weatherfish (*Misgurnus fossilis*) which inhabits fluvial wetlands.

2.2 3 Abundance notation

LEGER (1910a) assigned degrees from 1 to 3 (see descriptive part of the maps) as an estimation of relative abundance. But evaluation criteria were not specified: the question is whether they were a simple expert notation, or quantitative information based on occurrences, individual numbers, or biomasses of species.

Another difficulty occurs when a species alone was indicated in a section or a river, as commonly the trout in the headwaters, and the species was given a degree between 2 and 3. Here the link with relative abundance was lost; presumably the grading became an expert estimate of trout productivity.

3. Use of the cartographic fish data from Louis LEGER and co-workers

The department fish maps were a deliberately simplified transcription of data with the aim of satisfying public demand and making them legible on large scale documents (LEGER, 1910b). Information can be locally improved by monographic studies of the rivers (PIRAUD, 1910; PIRAUD, 1912; PERRIER, 1913; HESSE & PARIS, 1924, 1927; SORNAY, 1933/34). Recent computer science such as Geographical Information System (GIS) and progress in statistical science provide new techniques of appropriation of these archives. With multidisciplinary expert work and organised data processing, these historical data can be made use of, even moderately.

In spite of real anthropogenic constraints, the major interest of those maps is in the description of **fish assemblages before construction of the large dams** on Rhone tributaries and the Rhone itself (Fig. 3). The status of fish communities could be characterised with almost absence of distinct barriers to biological exchange along the river network, and before (i) the modification of geomorphological active processes typical of alluvial braided rivers (BRAVARD & PETTS, 1996) and (ii) the regulation of discharges and flow regimes by dam operation (VIVIAN, 1989; LOIZEAU & DOMINIK, 2000).

3.1 Endemic species ranges

It can be possible to ascertain the maximum distribution range of native species. Projects for rehabilitation of species range thus may have knowledge of rivers or river sections which offered essential habitats for some species. They are therefore able to base the improvement of both quality and connectivity on tangible evidence.

Current knowledge of the historical range of two endemic species of the Rhone Basin: the twaite shad (*Alosa fallax rhodanensis*) and the Rhone streber (*Zingel asper*) benefited widely from these records. So historical information became the implicit foundation of rehabilitation measures undertaken in the last 30 years for the upstream migration of twaite shad to its redds (LARINIER et al., 1978; MENELLA & MAZENS, 1997; LEBEL et al., 1999; LEBEL et al., 2001), and for protection and restoration of Rhone streber populations (BOUTITIE, 1984; PERRIN, 1988; PERRIN et al., 2001).

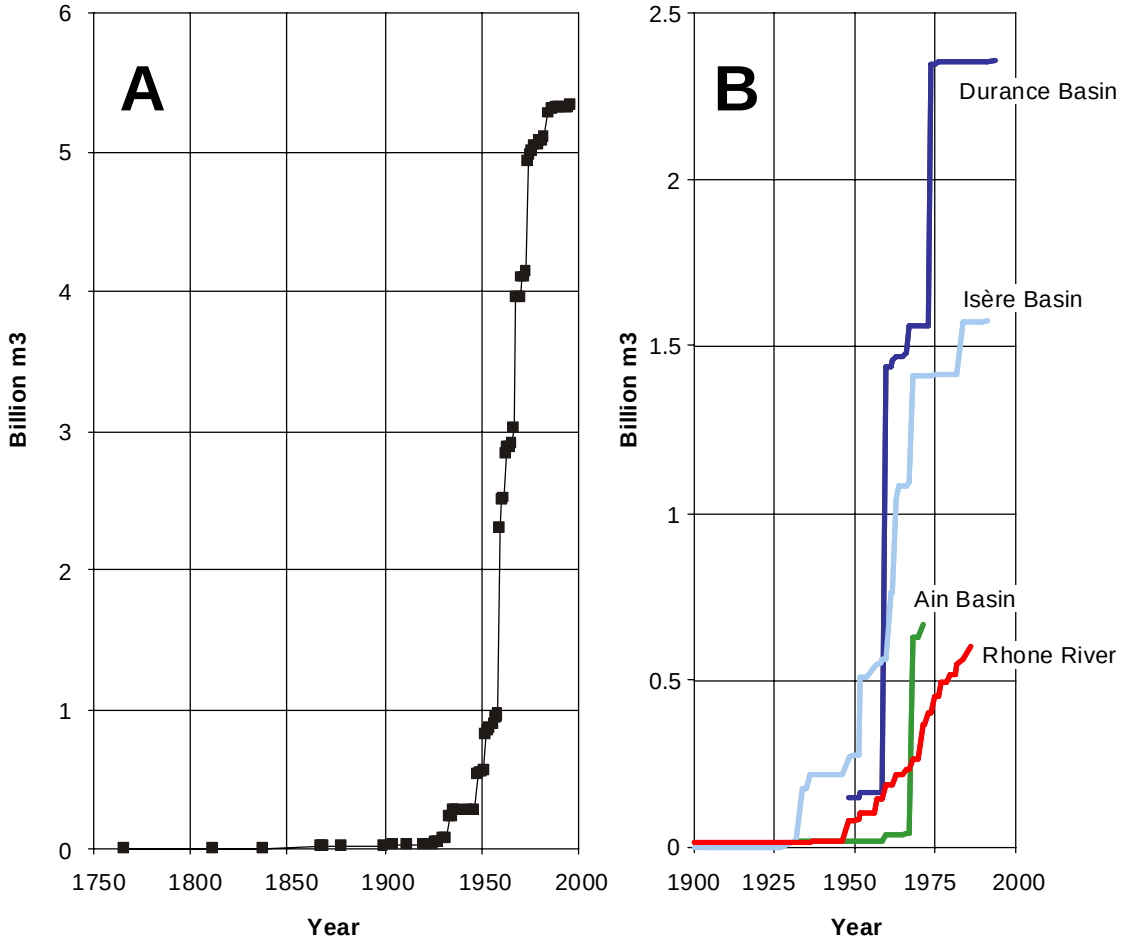

Fig. 3. Cumulative reservoir capacity of dams with a height of 15 metres or more. (A) All the dams of the French Rhone Basin. (B) Dams of the main tributary catchments (Durance, Isère and Ain Basins) and of the Rhone itself which significantly contribute to water storage in the basin. Data from the database of the International Commission on Large Dams (ICOLD, 2002).

3.2 Longitudinal zonation of fish fauna

Owing to the great number of rivers or river sections identified in the maps, longitudinal fish zonation prior to regulation could be known. This might be useful because:
the data concern several ichthyological regions of the Rhone catchment (CHANGEUX & PONT, 1995b) and Strahler ordering from 1 (headwaters) to 9 (Lower Rhone River),
of the large extent of alluvial braided rivers which had typical riverine fish assemblages including several indicative lithophilous species such as grayling (*Thymallus thymallus*), blageon (*Leuciscus souffia*), sofie (*Chondrostoma toxostoma*), Rhone streber (*Zingel asper*),
the historical zonation, linked with large scale physical variables, may be a tool for comparison with current data (CHANGEUX & PONT, 1995a), or for improvement of the “theoretical” assemblages obtained by probabilistic modelling (OBERDORFF et al., 2001), one of the approaches to obtain reference conditions.

Conclusion

Data from Louis LEGER and his co-workers provided **a rough ecological status of fish assemblages** of lakes and rivers in the Rhone Basin **during the first half of the 20th century**. Conditions and fish communities described are not representative of pristine hydrosystems. But the data, obtained before the exponential increase in energy consumption (CATZ, 2001) which boosted human water use, really characterised less degraded water bodies than those of today.

In relation to the initial question as to the choice of reference conditions, these archives alone cannot satisfy all the criteria required in the normative definitions of icthyofauna ecological status. Species abundance cannot be assessed and the age structures of fish communities are totally unknown. Regional variability can be studied, but not temporal variability. Only a partial “photographic” comparison of successive ecological states can be considered, for example between pre-impoundment periods and recent periods. By providing more or less difference in ecological states between the periods according to the river zonation, it will help in the establishment of the levels of alteration considered for the classification of the ecological status of rivers. These historical data may be really useful for answering our lack of information about typical riverine fish assemblages in the medium and large alluvial braided rivers which were most affected by large scale civil engineering works (GALAT & ZWEIMÜLLER, 2001).

The use of historical data for ecological status establishment as made by SILIGATO & BÖHMER (2001) might become more common and even a complete research field of its own as part of WFD. However their use is not without constraints, as shown here. On the one hand, historical data are rare, often difficult to obtain due to sparse archives and abundant grey literature. They were produced in various media: written texts, maps, drawings or photographs, which make storage and analysis complex in spite of computer science progress (Mc LAUGHLIN et al., 2001). On the other hand, historical data were always partial, sometimes biased, and contain unverifiable mistakes. Effective use of historical fish data needs exhaustive documentary research, an awareness of the complementary nature of information sources and sufficient expertise to validate or invalidate the data. Furthermore, objective and perspective of the user of a historical document are different from those of the person who originally drafted the document. So, data analysis and its interpretation cannot be separated from the socio-economic context to which they belonged. A concrete example was given by a long-term study of fish community structure and fisheries in Berlin waters (WOLTER et al., 2000). Biological data as described above must be complemented by joint hydrological (GALAT & LIPKIN, 2000) and physical research. First air photographs (GURNELL, 1997) and post cards of the beginning of the 20th century are interesting for a macroscopic view of habitats just like physical cartography (BRAVARD & BETHEMONT, 1989; HOOKE & REDMOND, 1989; WARNER, 2000). Therefore, a correct analysis of the “ecological past” of water bodies becomes undeniably a multidisciplinary task.

Acknowledgements

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Table I – Fish species indicated in the maps. Department number: 38= Isère, 1= Ain, 74= Haute-Savoie, 5= Hautes-Alpes, 73= Savoie, 69= Rhone, 70= Haute-Saone, 26= Drome, 7= Ardèche. *O. mykiss* and *S. fontinalis* are introduced species indicated in written documents but their locations on the map were not given. Fish scientific and common names used here are in agreement with Fishbase (FROESE & PAULY, 2002).

	Department	**38**	**1**	**74**	**5**	**73**	**69**	**70**	**26**	**7**
	Year of publication	*1924*	*1926*	*1931*	*1934*	*1944*	*1945*	*1945*	*1954*	*1956*
Petromyzontidae										
Lampetra planeri (Bloch, 1784)	Brook lamprey						X		X	X
Lampetra fluviatilis (Linné, 1758)	River lamprey		X				X	X		
Petromyzon marinus Linné, 1758	Sea lamprey		X			X	X		X	X
Acipenseridae										
Acipenser sturio Linné, 1758	Sturgeon								X	X
Anguillidae										
Anguilla anguilla (Linné, 1758)	Eel	X	X	X	X	X	X	X	X	X
Clupeidae										
Alosa alosa (Linné, 1758)	Allis shad		X			X	X		X	X
Alosa fallax rhodanensis (Roule, 1924)	Twaite shad		X			X	X		X	X
Cyprinidae										
Alburnoides bipunctatus (Bloch, 1782)	Stream bleak		X	X			X	X	X	X
Alburnus alburnus (Linné, 1758)	Bleak		X	X		X	X	X	X	X
Barbus barbus (Linné, 1758)	Barbel	X	X	X	X	X	X	X	X	X
Barbus meridionalis (Risso, 1826)	Mediterranean barbel				X				X	X
Cyprinus carpio Linné, 1758	Carp	X	X	X	X	X	X	X	X	X
Abramis brama (Linné, 1766)	Bream	X	X	X		X	X	X	X	X
Chondrostoma nasus (Linné, 1766)	Nase		X	X		X	X	X	X	X
Chondrostoma toxostoma (Vallot, 1837)	Sofie				X		X		X	X
Leuciscus cephalus (Linné, 1766)	Chub	X	X	X	X	X	X	X	X	X
Leuciscus leuciscus (Linné, 1758)	Dace		X	X	X	X	X	X	X	X
Telestes souffia Risso, 1827	Blageon	X	X	X	X	X	X	X	X	X
Phoxinus phoxinus (Linné, 1766)	Minnow		X	X	X	X	X	X	X	X
Rutilus rutilus (Linné, 1758)	Roach	X	X	X		X	X	X	X	X
Scardinius erythrophthalmus (Linné, 1758)	Rudd	X	X	X		X	X	X	X	X
Tinca tinca (Linné, 1758)	Tench	X	X	X	X	X	X	X	X	X
Gobio gobio (Linné, 1766)	Gudgeon		X	X		X	X	X	X	X
Rhodeus amarus (Bloch, 1782)	Bitterling		X				X			
Cobitidae										
Cobitis taenia Linné, 1758	Spined loach		X							
Balitoridae										
Barbatula barbatula (Linné, 1766)	Stone loach		X	X	X	X	X	X	X	X
Ictaluridae										
Ameiurus melas (Rafinesque, 1820)	Black bullhead		X	X		X	X	X	X	X
Esocidae										
Esox lucius Linné, 1758	Pike	X	X	X		X	X	X	X	X
Gadidae										
Lota lota (Linné, 1758)	Burbot		X	X		X	X	X	X	X
Salmonidae										
Salmo trutta Linné, 1758	Brown trout	X	X	X	X	X	X	X	X	X
Oncorhynchus mykiss (Walbaum, 1792)	Rainbow trout	X	X	X	X	X	X		X	X
Salvelinus fontinalis (Mitchill, 1815)	Brook trout	X		X	X	X				
Salvelinus alpinus (Linné, 1758)	Charr	X	X	X		X	X			X
Thymallus thymallus (Linné, 1758)	Grayling	X	X	X		X	X	X	X	X
Coregonus lavaretus (Linné, 1758)	European whitefish	X		X		X				X
Gasterosteidae										
Gasterosteus aculeatus Linné, 1766	Three-spined stickleback		X	X			X	X	X	
Pungitius pungitius (Linné, 1758)	Nine-spined stickleback		X							
Percidae										
Gymnocephalus cernuus (Linné, 1758)	Ruffe		X				X	X	X	X
Perca fluviatilis Linné, 1758	Perch	X	X	X		X	X	X	X	X
Stizostedion lucioperca (Linné, 1758)	Pikeperch						X		X	X
Zingel asper (Linné, 1758)	Rhone streber		X		X	X	X		X	X
Centrarchidae										
Lepomis gibbosus (Linné, 1758)	Pumpkinseed		X				X	X	X	X
Micropterus salmoides (Lacépède, 1802)	Largemouth blackbass						X	X	X	X
Blenniidae										
Salaria fluviatilis (Asso, 1801)	Freshwater blenny					X				
Cottidae										
Cottus gobio Linné, 1758	Sculpin		X	X	X	X	X	X	X	X

References

Anonymous (1945): Carte piscicole du département de la Haute-Saône. - Fédération des Associations de Pêche et de Pisciculture Haut-Saônoises, Vesoul.

BACALBASA-DOBROVICI, N. (1991): Statut des différentes espèces d'esturgeons dans le Danube roumain : problèmes liés à leur maintenance. - In: WILLIOT, P. (Ed.), Acipenser. Cemagref, Bordeaux, France, pp. 185-192.

BELLIARD, J., BOET, P. & ALLARDI, J. (1995): Evolution à long terme du peuplement piscicole du bassin de la Seine. - Bull. Fr. Pêche Piscic. **337/338/339:** 83-91.

BOUTITIE, F. (1984): L'apron *Zingel asper* (L.), Percidae - poisson rare menacé de disparition (biologie, répartition, habitat). - Diplôme d'Etudes Approfondies, Université Claude Bernard, Lyon I.

BRAVARD, J.-P., AMOROS, C., PAUTOU, G., BORNETTE, G., BOURNAUD, M., CREUZE DES CHATELLIERS, M., GIBERT, J., PEIRY, J.-L., PERRIN, J.-F. & TACHET, H. (1997): River incision in South-East France: morphological phenomena and ecological effects. - Regul. Rivers **13:** 75-90.

BRAVARD, J.P. & BETHEMONT, J. (1989): Cartography of rivers in France. - In: PETTS, G.E., MÖLLER, H. & ROUX, A.L. (Eds), Historical change of large alluvial rivers: Western Europe. John Wiley & Sons, Chichester, pp. 95-111.

BRAVARD, J.P. & PEIRY, J.-L. (1993): La disparition du tressage fluvial dans les Alpes françaises sous l'effet de l'aménagement des cours d'eau (19-20ème siècle). - Z. Geomorph. N. F. **88:** 67-79.

BRAVARD, J.-P. & PETTS, G.E. (1996): Human impacts on fluvial hydrosystems. - In: PETTS, E. & AMOROS, C. (Eds), Fluvial hydrosystems. Chapman & Hall, London, pp. 242-262.

CARLSON, C.A. & MUTH, R.T. (1989): The Colorado River: lifeline of the American Southwest. - In: DODGE, D.P. (Ed.), International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences, Honey Harbour, Ontario, Canada, pp. 220-239.

CATZ, H. (2001): Mémento sur l'énergie 2001. Commissariat à l'Energie Atomique, Direction de la stratégie et de l'évaluation, Service des études économiques, Saclay, 85 p.

CAZEMIER, W.G. (1988): Fish and their environment in large European river ecosystems. The Dutch part of the River Rhine. - Sciences de l'Eau **7:** 95-114.

CHANGEUX, T. & PONT, D. (1995a): Current status of the riverine fishes of the French Mediterranean basin. - Biol. Conservation **72:** 137-158.

CHANGEUX, T. & PONT, D. (1995b): Ichthyogeographic regions and watershed size in the French river Rhône network. - Hydrobiologia **300/301:** 355-363.

CROSS, F.B. & MOSS, R.E. (1987): Historic changes in fish communities and aquatic habitats in plains streams of Kansas. - In: MATTHEWS, W.J. & HEINS, D.C. (Eds), Community and evolutionary ecology of North American stream fishes. Univ. Oklahoma Press, Norman, Oklahoma, pp. 155-165.

DORIER, A. (1955): Carte piscicole du département de la Drôme. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **47**.

DORIER, A. (1956/57): Carte piscicole du département de l'Ardèche. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **48/49:** 150.

ELVIRA, B., ALMODOVAR, A. & LOBON-CERVIA, J. (1991): Sturgeon (*Acipenser sturio* L., 1758) in Spain. The population of the river Guadalquivir: a case history and a claim for a restoration programme. - In: WILLIOT, P. (Ed.), Acipenser. Cemagref, Bordeaux, France, pp. 185-192.

EUR-Lex (2000): Directive 2000/60/EC of the European parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. - Official Journal of the European Communities **L 327, 43:** 1-73.

FROESE, R. & PAULY, D. (2002): FishBase. World Wide Web electronic publication. - www.fishbase.org.

GALAT, D.L. & LIPKIN, R. (2000): Restoring ecological integrity of great rivers: historical hydrographs aid in defining reference conditions for the Missouri River. - Hydrobiologia **422:** 29-48.

GALAT, D.L. & ZWEIMÜLLER, I. (2001): Conserving large-river fishes: is the highway analogy an appropriate paradigm? - J. N. Am. Benthol. Soc **20:** 266-279.

GURNELL, A.M. (1997): Channel change on the river Dee meanders, 1946-1992, from the analysis of air photographs. - Regul. Rivers **13:** 13-26.

HESSE, E. & PARIS, P. (1924): Cours d'eau de la Côte-d'Or - Dossiers piscicoles - 1. Bassins de l'Ouche et de la Vouge. Texte et Carte au 1/100 000. - Imprimerie Allier Père et Fils, Grenoble, 62 p.

HESSE, E. & PARIS, P. (1927): Cours d'eau de la Côte-d'Or - Dossiers piscicoles - 2. Bassins de la Vingeanne, de la Bèze et de la Tille. Texte et Carte au 1/100 000. - Imprimerie Allier Père et Fils, Grenoble, 99 p.

HOOKE, J.M. & REDMOND, C.E. (1989): Use of cartographic sources for analysing river channel change with examples from Britain. - In: PETTS, G.E., MOLLER, H. & ROUX, A.L. (Eds), Historical change of large alluvial rivers: western Europe. John Wiley & Sons, Chichester, pp. 79-93.

ICOLD (2002): International Commission on Large Dams (ICOLD). Commission Internationale des Grands Barrages (CIGB). - http://www.icold-cigb.org.

KEITH, P. & ALLARDI, J. (Eds) (2001): Atlas des poissons d'eau douce de France. - Muséum National d'Histoire Naturelle, Paris, 387 pp.

KIENER, A. (1985): Au fil de l'eau ... en pays méditerranéen. Milieux aquatiques, poissons et pêche, gestion. - Aubanel, Avignon, 307 p.

KREITMANN, L. (1932): Les grandes lignes de l'économie piscicole du bassin français du Rhône. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **24:** 127-131.

LARINIER, M., RIVIER, B., ALLARDI, J. & TROCHERIE, F. (1978): Possibilités de franchissement du seuil de Beaucaire par les aloses du Rhône. - Bull. Fr. Pêche Piscic. **268:** 107-120.

LE CORRE, M., BAGLINIERE, J.L., SABATIE, R., MENELLA, J.Y. & PONT, D. (1997): Données récentes sur les caractéristiques morphologiques et biologiques de la population d'alose feinte du Rhône (*Alosa fallax rhodanensis* Roule, 1924). - Bull. Fr. Pêche Piscic. **346:** 527-545.

LE CORRE, M., LINHARES, D., CASTRO, F., ALEXANDRINO, P., SABATIE, R. & BAGLINIERE, J.L. (1998): Premiers éléments de caractérisation génétique de l'alose du Rhône (*Alosa fallax rhodanensis* Roule, 1924). - Bull. Fr. Pêche Piscic. **350/351:** 635-645.

LEBEL, I., BAGLINIERE, J.-L., PORCHER, J.-P. & SABATIE, R. (1999): Le Rhône et ses affluents retrouvent leurs grands migrateurs. Bilan des actions et des études menées par l'Association Migrateurs Rhône-Méditerranée de 1991 à 1998. - 1/7. Migrateurs Rhône-Méditerranée, Arles, 124 p.

LEBEL, I., MENELLA, J.Y. & LE CORRE, M. (2001): Le contrat "Retour aux sources" sur le bassin Rhône-Méditerranée-Corse : bilan et perspectives. - Bull. Fr. Pêche Piscic. **357/358:** 277-292.

LEGER, L. (1910a): Dossiers piscicoles des cours d'eau alpins. - Trav. Lab. Piscic. Univ. Grenoble **2:** 569-570.

LEGER, L. (1910b): Principes de la méthode rationnelle du peuplement des cours d'eau à Salmonidés. La capacité biogénique. - Trav. Lab. Piscic. Univ. Grenoble **2:** 533-568.

LEGER, L. (1924): La pêche sportive et touristique en Dauphiné avec une carte de la pêche dans le département de l'Isère. - Annales de l'Université de Grenoble **1:** 1-6.

LEGER, L. (1927): Carte piscicole du département de l'Ain avec une notice explicative. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **19:** 149-155.

LEGER, L. (1933/34): Etudes d'hydrobiologie piscicole alpine. Cours d'eau et lacs du département des Hautes-Alpes avec une carte au 1/200000 en trois couleurs. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **25/26:** 187-212.

LEGER, L. (1934): Carte piscicole du département des Hautes Alpes (avec notice explicative et considérations sur l'économie piscicole régionale), 28 pages + carte hors texte. - Allier, Grenoble.

LEGER, L. (1942/44): Etude sur l'hydrographie et l'économie piscicoles du département de la Savoie avec une carte et un graphique. Notice sur la carte hydrobiologique piscicole de la Savoie. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **34/36:** 51-66.

LEGER, L. (1945): Economie biologique et productivité de nos rivières à cyprinidés. - Bull. fr. Piscic. **139:** 1-21.

LEGER, L. (1945/48a): Etude sur l'hydrobiologie et l'économie piscicoles du département du Rhône avec une carte et un graphique. - Trav. Lab. Piscic. Univ. Grenoble **37/40:** 1-14.

LEGER, L. (1945/48b): Graphique piscicole explicatif des cours d'eau du département de l'Isère. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **37/40:** 45-49.

LEGER, L. & KREITMANN, L. (1931): Etudes d'hydrobiologie piscicole des eaux alpines. Carte piscicole du département de la Haute-Savoie. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **23:** 145-155.

LELEK, A. (1989): The Rhine river and some of its tributaries under human impact in the last two centuries. - In: DODGE, D.P. (Ed.), International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences, Honey Harbour, Ontario, Canada, pp. 469-487.

LOIZEAU, J.L. & DOMINIK, J. (2000): Evolution of the Upper Rhone River discharge and suspended sediment load during the last 80 years and some implications for Lake Geneva. - Aquat. Sci. **62:** 54-67.

Mc LAUGHLIN, R.L., CARL, L.M., MIDDEL, T., ROSS, M., NOAKES, D.L.G., HAYES, D.B. & BAYLIS, J.R. (2001): Potentials and pitfalls of integrating data from diverse sources: Lessons from a historical database for Great Lakes stream fishes. - Fisheries **26:** 14-23.

MENELLA, J.-Y. & MAZENS, Y. (1997): Le Rhône et ses affluents retrouvent leurs grands migrateurs. Première étape: l'alose dans le bassin du Rhône jusque dans l'Ardèche. Rapport de synthèse 1993-1997. MRM - Association Migrateurs Rhône-Méditerranée, Arles, 46 p.

OBERDORFF, T., PONT, D., HUGUENY, B. & CHESSEL, D. (2001): A probabilistic model characterizing fish assemblages of French rivers: a framework for environmental assessment. - Freshwat. Biol. **46:** 399-416.

PATTEE, E. (1988): Fish and their environment in large European river ecosystems. The Rhône. - Sciences de l'Eau **7:** 35-74.

PENAZ, M., STERBA, O. & PROKES, M. (1986): The fish stock of the middle part of the Morava River, Czechoslovakia. - Folia Zool. **35:** 371-384.

PERRIER, L. (1913): Dossiers piscicoles des cours d'eau alpins. Monographie hydrobiologique piscicole du bassin de la Romanche, avec carte. - Trav. Lab. Piscic. Univ. Grenoble **5:** 1-47.

PERRIN, J.F. (1988): Maintien en aquarium de l'apron du Rhône, *Zingel asper* (L.), espèce menacée d'extinction. - Revue française d'Aquariologie **15:** 17-20.

PERRIN, J.-F., MARI, S., COQ, F. & CRAPSKY, S. (2001): L'apron, poisson endémique du Rhône, est-il sauvé ? Scientifiques & Décideurs. Agir ensemble pour une gestion durable des systèmes fluviaux. Agence de l'Eau Rhône Méditerranée Corse, Lyon, France.

PETERKA, J.J. & KOEL, T.M. (1996): Distribution and dispersal of fishes in the Red River basin. - Report submitted to Interbasin Biota Transfer Studies Program. Water Resources Research Institute, Northern Prairie Wildlife Research Center, Fargo, ND, USA.

PFLIEGER, W.L. & GRACE, T.B. (1987): Changes in the fish fauna of the Lower Missouri River, 1940-1983. - In: MATTHEWS, W.J. & HEINS, D.C. (Eds), Community and evolutionary ecology of North American stream fishes. Oklahoma University Press, Norman, Oklahoma, pp. 166-177.

PIRAUD, V. (1910): Dossiers piscicoles des cours d'eau alpins - Monographie hydrobiologique piscicole des bassins de Roize et de Vence et des ruisseaux du Saint-Eynard. - Trav. Lab. Piscic. Univ. Grenoble **2:** 365-391.

PIRAUD, V. (1912): Dossiers piscicoles des cours d'eau alpins. Monographie et carte hydrobiologiques piscicoles des cours d'eau de la partie sud du massif de Belledonne. - Trav. Lab. Piscic. Univ. Grenoble **4:** 323-358.

SABATIE, M.R., BOISNEAU, P. & ALEXANDRINO, P. (2000): Variabilité morphologique. - In: BAGLINIERE, J.L. & ELIE, P. (Eds), Les aloses (*Alosa alosa* et *Alosa fallax* spp.). Ecologie et variabilité des populations. Hydrobiologie et Aquaculture. INRA, Paris, pp. 137-178.

SILIGATO, S. & BÖHMER, J. (2001): Using indicators of fish health at multiple levels of biological organization to assess effects of stream pollution in southwest Germany. - J. Aquat. Ecosyst. Stress. Recov. **8:** 371-386.

SORNAY, J. (1933/34): Etude hydrobiologique piscicole des lacs de barrage de Beaumont-Monteux et de Pizançon sur l'Isère. - Trav. Lab. Hydrobiol. Piscic. Univ. Grenoble **25/26:** 105-120.

SOUCHON, Y. & TROCHERIE, F. (1990): Technical aspects of French legislation dealing with freshwater fisheries (June 1984): "fisheries orientation schemes" and "fishery resources management plans". - In: VAN DENSEN, W.L.T., STEIMETZ, B. & HUGHES, R.H. (Eds), Management of Freshwater Fisheries. FAO, Göteborg, Sweden, pp. 190-214.

TAVERNY, C., BELAUD, A., ELIE, P. & SABATIE, M.R. (2000): Influence des activités humaines. - In: BAGLINIERE, J.L. & ELIE, P. (Eds), Les aloses (*Alosa alosa* et *Alosa fallax spp.*). Ecologie et variabilité des populations. Hydrobiologie et Aquaculture. INRA, Paris, pp. 227-248.

TRIPPIER, L. (1902): Etude des eaux et de la pêche dans le département de l'Ain (I-V). - Annales de la Société d'Emulation de l'Ain **35:** 321-377.

TRIPPIER, L. (1903): Etude des eaux et de la pêche dans le département de l'Ain (VI-VIII). - Annales de la Société d'Emulation de l'Ain **36:** 81-145.

VIVIAN, H. (1989): Hydrological changes of the Rhône River. - In: PETTS, G.E., MÖLLER, H. & ROUX, A.L. (Eds), Historical change of large alluvial rivers: Western Europe. John Wiley & Sons, Chichester, pp. 57-77.

WARD, J.V., TOCKNER, K., EDWARDS, P.J., KOLLMANN, J., BRETSCHKO, G., GURNELL, A.M., PETTS, G.E. & ROSSARO, B. (1999): A reference river system for the Alps: the "Fiume Tagliamento". - Regul. Rivers **15:** 63-75.

WARNER, R.F. (2000): Gross channel changes along the Durance River, Southern France, over the last 100 years using cartographic data. - Regul. Rivers **16:** 141-157.

WILHELM, I. (1913): La Durance. Etude de l'utilisation de ses eaux et de l'amélioration de son régime par la création de barrages. - Lucien LAVEUR, Paris, 360 p.

WOLTER, C., MINOW, J., VILCINSKAS, A. & GROSCH, U.A. (2000): Long-term effects of human influence on fish community structure and fisheries in Berlin waters: an urban water system. - Fish. Mgmt Ecol. **7:** 97-104.