Consequences and limits to use of historical hydrobiological data in the current biodiversity context

Data on aquatic fauna and flora have been collected for almost two centuries. More or less well conserved, these old data are used in setting up projects for biodiversity conservation and evaluation. To what purpose can the data be put? What precautions must be taken to ensure judicious use?

Limnologic research may be dated to the founding of the Naples zoological station in 1872 by German zoologist Anton Dohrn. Its popularity led to the launch of numerous hydrobiological centres, notably in Germany, at the end of the 1800s and beginning of the 1900s (Arlinghaus *et al.*, 2008). In spite of the impetus provided by these organisations for neighbouring countries and the combined weight of over a century of applied research in limnology, the biodiversity of continental waters was significantly underestimated and the efforts for its conservation have not been judged very effective (Dudgeon *et al.*, 2006).

Parallel to the initial steps of European research on the ecology of continental waters, the accelerating impact of human activities has transformed most hydrosystems. Alpine rivers offering high potential for energy generation were substantially modified as early as 1830. The same is true for lakes which have been modified for energy purposes and subjected to massive nutrient inputs and fishery management. Problems were worsened by the increase in the number and volumes of artificial lakes, and regulation of water levels in natural lakes for urbanisation purposes and/or tourism. Fundamental research in limnology gradually folded over into applied research to reduce the impact of human activities, e.g. the OECD ecological-quality evaluation programme launched in 1982.

Our historical perspective in hydrobiology dates back approximately two centuries and the data acquired are increasingly affected by human activities. In response to new social demands reflecting worries arising from the destruction of the natural heritage, efforts to inventory life forms have regained momentum. Requests to transfer operational methods to environmental managers, in close conjunction with significant legislative progress such as the European Water framework directive (WFD), are also on the rise. Current environmental management thus needs reference data from the past and in fact cannot be organised without those data. Examples include programmes to re-establish large migratory fish in rivers, to conserve threatened species and to ecologically restore aquatic environments.

The use of historical data for ecological programmes addressing continental waters is presented using examples drawn from:

- the knowledge gained in the Rhône river basin on benthic macro-invertebrates and fish;
- work carried out on macrophytes in lakes (see photo ❶).

These examples will briefly illustrate the contribution of historical data from various origins to evaluating change in biodiversity and the limits to the use of those data.

Hydrobiological knowledge on the Rhône river

Long-term environmental monitoring and river biodiversity

We should mention, among the "historical" biological data series, the work by Josette Fontaine on Ephemeroptera insects starting in the 1950s. The long series, filled out with Trichoptera insects, was continued by Philippe Usseglio-Polatera. The data shed light on changes in living communities caused by the Pierre-Bénite dam after 1966. The series contains complete faunal lists before and after dam construction and elements for a reference condition of a "swift flowing river" without having to examine further archives.

However, most of the long data series on aquatic invertebrates have been compiled in the immediate vicinity of nuclear power stations, e.g. the Bugey series on the upper Rhône, launched in 1975 and continued using the same protocol ever since. Functional analysis of populations

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❶ Yellow water lilies (lake of Barterand, Ain).

revealed gradual changes in communities. Generally speaking, the changes consisted of an increase in the species richness due to the arrival of seven non-native taxa, the dissemination of numerous limnophilic taxa, notably molluscs from the upstream reservoirs, and of a progressive increase in the numbers of initially rare species. The changes over time were due, among other reasons, to temperature rise in the river, to large-scale modifications in the hydraulic conditions caused by continued development of the upper Rhône between 1980 and 1986, and to the flow-rate management.

The people in charge of monitoring had relatively set goals in mind and adopted a classic protocol based on three monitoring stations positioned upstream, downstream and at the cooling-water discharge outlet. They employed an overall evaluation method for hydrobiological quality, i.e. biotic indices that do not address the species level. For example, Oligochaeta were grouped in a single taxonomic unit, yet some 90 species have been observed in the French part of the upper Rhône. In addition, the spatially limited sampling zones provided only a limited view of river diversity. The Bugey monitoring programme detected the presence of some 30 Coleoptera species whereas the inventory for the upper Rhône and its backwaters lists 94 species.

It follows that though overall methods are sufficient to detect spatio-temporal modifications in populations and can inform on the functional biodiversity of hydrosystems, they cannot meet biodiversity requirements in terms of species richness.

Fish in the Rhône river

Fish fauna is traditionally the best known in inventories or reference data sets on aquatic environments impacted by human activities. Older data on the Rhône river basin are essentially in the form of maps. They were collected by Professor Louis Léger from the University of Grenoble and his co-workers from 1910 to 1956. Fish assemblages at the time were determined on the basis of departmental maps (see table ❶) and a map of the Rhône river with its main tributaries. Information was also found in reports, occasionally uncovered per chance, and in older publications on the Swiss Rhône and Lake Geneva, the French Upper Rhône and the delta.

All the above documents were subjected to critical analysis (Carrel, 2002) and served for an updated review of the species in the major geographical sections of the Rhône.

Emblematic species

> *Rhône apron*

The apron (*Zingel asper*) is a small, endemic percid in the Rhône river basin, typically found in braided river sections in alluvial plains. Its extensive historical habitat range has been estimated on the basis of sightings by Jacques-Nicolas Vallot in the Saône river (Côte-d'Or), Guillaume Rondelet in the Rhône between Lyon and Vienne, Paul Gourret in the delta, as well as by M. Jullien and Louis Léger around Grenoble, in the Romanche, Drac and Isère rivers. In the latest issue of the *Life Apron II* information bulletin, the presence of the Rhône apron was confirmed along 240 kilometres of

❶ List and coverage of useful maps in defining fish fauna in the Rhône.

Author(s)	Departement and/or *river*	Coverage	Score
Dorier (1955)	Drôme	1/200 000	3
Dorier (1956-1957)	Ardèche	1/200 000	3
Kreitmann (1932)	*Rhône*	1/500 000	2
Léger (1927)	Ain	1/200 000	3
Léger (1942-1944)	Savoie	1/200 000	3
Léger (1945-1948a)	Rhône	1/200 000	3
Léger and Kreitmann (1931)	Haute-Savoie	1/200 000	3

The level of information is noted as 2 or 3 where 2 means the information is sufficient to signal presence/absence and 3 means an abundance indicator was added for each species in the inventoried reach.

river, i.e. 11% of a significantly underestimated part of its historical habitat range.

To raise un uncomfortable question, why focus on a relatively modest and poorly represented percid, of no fishery value and that has been ignored for decades? The answer is that, above and beyond its patrimonial value, the virtual disappearance of the apron and of other *European Zingel* species illustrates the radical loss of its habitats and, more generally speaking, of almost all the ecosystems created by the active meandering of alluvial rivers (Warner, 2000).

> *Twaite shad*

Whereas the apron is representative of an alluvial habitat, the Twaite shad (*Clupeidae, Alosa fallax rhodanensis*) is a migratory species and indicator of river continuity. Reported at the Bourget lake outlet and as far as 327 km up the Saône river, this species has lost ground in less than 50 years due to river obstacles. According to Louis Kreitmann, in 1932 the species no longer entered the Isère river following the construction of the Beaumont-Monteux dam and its progress along the Saône was partially blocked in Lyon by the Mulatière dam. In 1937, the Jons dam slowed its access to the upper Rhône. In 1952, the Donzère-Mondragon dam halted migrations 140 km from the sea. Then in 1974, the Vallabrègues dam blocked shad only 70 km from the sea.

In spite of its major fishery value and the criticism and suggestions made by Camille Gallois in 1947 concerning the future impact of the Donzère-Mondragon dam, it was many years before the Twaite shad met with sufficient "forced" interest to justify scientific, technical and financial efforts in favour of its return to the Rhône and its tributaries.

Following the Rhône fish-fauna inventory in 1992, the creation of the "Migrateurs Rhône-Méditerranée" association in 1993 federated professional and amateur fishing organisations, scientists and environmental managers in support of the Twaite shad. The efforts undertaken and the results achieved have helped other migratory fish such as eels and, to an even greater extent, species virtually forgotten along the Rhône such as sea and river lampreys, sturgeon. These species, for which there is a flagrant lack of knowledge, constitute future goals for the restoration of the Rhône.

Anthropogenic origins of fish invasions

In a study on evolution of vertebrate fauna during the Holocene in France, the authors showed that "*the temporal factor is indispensable in determining whether a species is native or non-native... the historical approach is indispensable for correct understanding of biological invasions*".

❷ Allochthonous fish species in the Rhône from its source to the delta.

Family Species	Common name	Report or initial observation
Centrarchidae		
Lepomis gibbosus (Linné, 1758)	Pumpkinseed sunfish	Lower Rhône (1920)
Micropterus salmoides (Lacépède, 1802)	Largemouth bass	Lower Rhône (1940)
Cyprinidae		
Cyprinus carpio (Linné, 1758)	Common carp	Roman period
Carassius carassius (Linné, 1758)	Crucian carp	(?)
Rhodeus amarus (Bloch, 1782)	European bitterling	Linked to expansion of carp farming
Carassius auratus (Linné, 1758)	Goldfish	France (1700s)
Chondrostoma nasus (Linné, 1758)	Common nase	Rhône (1880)
Carassius gibelio (Bloch, 1782)	Prussian carp	Lower Rhône (1989)
Pseudorasbora parva (Schlegel, 1842)	Topmouth gudgeon	Lower Rhône (1989)
Leucaspius delineatus (Heckel, 1843)	Belica	Lower Rhône (2001)
Leuciscus idus (Linné, 1766)	Golden orfe	Lower Rhône (2009)
Ictaluridae		
Ameiurus melas (Rafinesque, 1820)	Black bullhead	Rhône (1920)
Percidae		
Gymnocephalus cernuus (Linné, 1758)	Eurasian ruffe	Rhône (1860)
Sander lucioperca (Linné, 1758)	Zander	Lower Rhône (1930)
Poeciliidae		
Gambusia holbrooki (Girard, 1859)	Eastern gambusia	Camargue (1927)
Salmonidae		
Oncorhynchus mykiss (Walbaum, 1792)	Rainbow trout	Rhône (1880)
Salvelinus fontinalis (Mitchill, 1815)	Brook trout	Swiss Rhône (1800 s)
Siluridae		
Silurus glanis (Linné, 1758)	Wells catfish	Lower Rhône (1987)

Whereas we must note a reduction in habitats for several species and even their wide-scale disappearance from their original biogeographical zones, "visible" fish biodiversity in the Rhône, expressed in terms of species richness, is rising. This increase is due essentially to the introduction (voluntary or accidental) of species to the Rhône, from their original biogeographic zone, and then their natural tendency to colonise hydrographic networks, notably via new water ways.

To date, 67 species have been listed in the Rhône river basin, including 62 in the Rhône itself from its source to the delta. Among these species, there are 45 autochthonous (including one, sturgeon, that has disappeared) and 18 allochthonous[1] (see table ❷)

Analysis of maps drawn up prior to 1950 for the Rhône river basin and of the corresponding literature reveals that the goal of ichthyologists at the time was to improve fisheries and economic productivity of aquatic environments. This period of extensive changes in fish communities due to the introduction of species lasted close to one century. Species dissemination took place through pisciculture and voluntary introductions, e.g. rainbow trout, brook trout, largemouth bass. Other species can adapt rapidly outside of aquacultural efforts, notably the pumpkinseed sunfish and the black bullhead, whose success is not welcome. Two other introduced species of European origin have also been the subject of debate on their fishery value, the common nase and the zander (Kreitmann, 1930).

The common nase (*Chondrostoma nasus*) (see photo ❷), a rheophilic and lithophilic fish of the Cyprinidae family, found in the Rhône and its major tributaries extremely favourable conditions for its population explosion. Local fishers requested strong control measures that were authorised as early as 1901 in the Ain river.

The zander (*Sander lucioperca*), a large carnivorous percid, was favoured by our colleagues such as Louis Kreitmann. At the time, no one knew that the zander was infested with a trematode *Bucephalus polymorphus* (Baer, 1827) whose cycle required two other hosts, a bivalve mollusk also from central Europe, the zebra mussel (*Dresseina polymorpha*), and a fish of the Cyprinidae family. The parasite caused mortalities and an extension of larval bucephalosis in the Rhône river basin from the 1960s to the 1980s. Introduction of a species is in fact the introduction of a very complex host-parasite system that can cause unsuspected problems.

❷ **When he arrived in the Rhône in the nineteenth century, the common nase (*Chondrostoma nasus*) found extremely favourable conditions for its population growth.**

1. A fish species is considered allochthonous in a biogeographical region if it was initially absent from the aquatic environments, but currently constitutes one or more populations that reproduce in a durable manner.

Lake macrophytes

Macrophytes are important components in most aquatic environments and play a double role as primary producers and means of support for many plant and animal organisms. The term "macrophyte" comprises flora often identifiable by the naked eye and belonging to angiosperms (flowering plants), bryophytes (mosses), pteridophytes (ferns and horsetail) and macroscopic algae.

A brief history

Research on lake plant communities began with the work by François-Alphonse Forel (1893) in Lake Geneva. French researchers followed, the most famous work being that of Antoine Magnin (1904) on 74 lakes in the Jura region and Marc Le Roux (1907-1908) on Lake Annecy. The more recent work by Louis Kreitmann (1935-1937) on three Jura lakes, then in the 1970s, the renewed studies on macrophyte communities in Jura lakes by J.P. Vergon, J. Barbe and their co-workers (1977) made possible initial comparisons on the evolution of macrophyte communities.

Research was also carried out on pond vegetation, notably by J.C. Felzines (1982) in central France. Little information was available on lakes and ponds in SW France before the 1960s and the work by C. Vanden Berghen (e.g. 1969). However, observations by P. Allorge, M. Denis (1923, 1930) and P. Jovet (1951) provide partial information on certain water bodies.

Mapping of communities

Initial work mapped aquatic-plant communities, divided into vegetal groups according to various parameters such as the depth, water transparency, type of sediment, etc. Figure ❶ illustrates the relative temporal continuity of the documents and shows, in the case of a lake, the stable distribution of the two main vegetal groups from 1904 to 1984, reeds and sedges (*Phragmites australis* and *Scirpus lacustris*), and water-lilies (*Nuphar lutea*). However, the 1984 survey reported the absence of two underwater phanerogams (*Utricularia vulgaris* and *Potamogeton lucens*) and major regression in shallow depths of the *Chara* and *Nitella* algae (Characeae family).

Similar comparative work on the Remoray and Saint-Point lakes in the same region of France made it possible to evaluate the gradual and strong regression of reeds and changes in plant communities due to a major decrease in water transparency.
The historical maps on plant distribution thus remain useable, but provide, at best, trends and a "semi-quantitative" evaluation of the presence and abundance of species.

The phytosociological approach

The next phase studied the types of plant relationships, the subject matter of phytosociology, the science with defines plant communities based on characteristic species. The data produced are floristic lists and percentages of species coverage in surveys of stipulated surface areas. This approach, still widely used, is drawn from studies dating back to the end of the 1800s.
Starting in the 1960s, studies using this method were carried out on various lakes and ponds, notably in the south-west and centre of France. They contributed significantly to knowledge on the relationships between plants in lakes. They also served for Tome 3 of the French Habitats Guide devoted to wet habitats and phytosociological data on aquatic environments.

Management of plant proliferation

Starting in the 1970s, proliferation of native and exotic plants, due in part to gradual eutrophication in aquatic environments, raised new problems. They require specific studies in order to define management techniques.
In the Landes department (SW France), the constant progression in the colonisation of several lakes by exotic plants, both submerged such as oxygen weed (*Lagarosiphon major*) and amphibious such as water primrose (*Ludwigia grandiflora*), made necessary a management plan. The method used for the surveys and management of invasive exotic species was generalised to take into account all littoral aquatic species (Dutartre, 2002).

From patrimonial management to bioindication

Over the same period, studies dealing more specifically with rare and/or protected species and flag species were launched in the framework of ZNIEFF (zone of floristic, faunal and ecological value) inventories. The creation of the European Natura 2000 network was also an occasion to study numerous sites. These inventories continue today, carried out by both volunteer naturalists and private engineering offices. The establishment of French botanical conservatories since the beginning of the 1990s considerably reinforced data acquisition on the distribution of plants in continental France.

What is more, water-quality assessment methods, originally based on invertebrate communities, have been expanded to include diatoms, fish and macrophytes. In 2000, the European Water framework directive (WFD) reinforced bioindication needs for rivers and lakes on the basis of these four "biological elements".

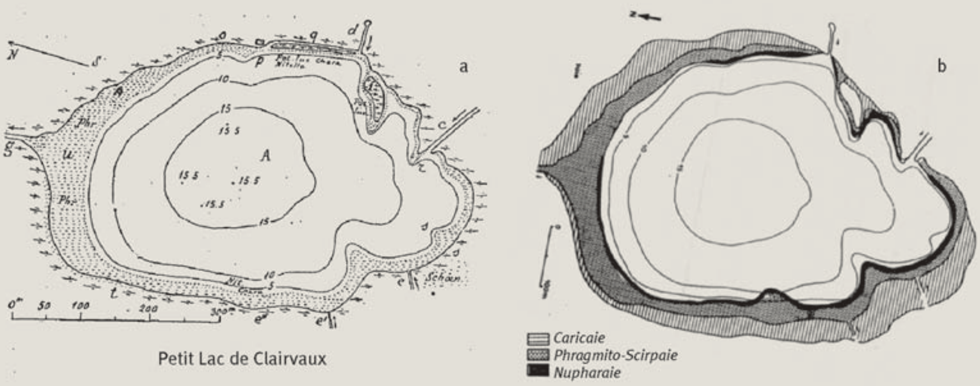
To meet WFD requirements for ecological-status evaluations, including the development of a "macrophytes" index necessarily based on a very large set of data, the preliminary analysis of the available historical data resulted in the development of a new protocol to ensure that comparable data are gathered.

Previously, the disparities in objectives, in rationales for the positions of observations, the diversity of survey methods and data media were leading to a situation where the database would not have been useable for developing an index to assess ecological status. Due to increasing needs to "quantify" the presence and/or abundance of species, in view of meeting new goals, a major part of the historical information, essentially qualitative in nature, cannot be used directly.

❶ Maps of lake vegetal groups in the small Clairvaux lake (Jura)

a) map by Mangin (MAGNIN, A., 1904, *La végétation des lacs jurassiens, Monographies botaniques de 74 lacs jurassiens, suivies de considérations générales sur la végétation lacustre*, Paris, Paul Klincksieck, 426 p.).
b) map from 1984 (Service Régional de l'Aménagement des Eaux de Franche-Comté, 1984, *Les lacs de Clairvaux, Monographies écologiques*, Rapport d'étude, 99 p. + annexes).

On the map by Magnin (1904), the contour of the sedge wetland (marked "Caricaie" in the French legend) along the shore is not shown, perhaps because not directly located in the water.



Conclusion

Historical data in the field of ecology represent an important heritage. Access is often difficult because archives are dispersed, obscure and sometimes even partially destroyed. The data are stored in highly diverse forms, including texts, maps, drawings and photographs, which make reading, analysing and compiling the data that much more complex. Old texts follow out-dated writing codes and criteria, meaning much more time is required to read, interpret and code the information for uses other than those intended by the author. In spite of the considerable progress made in computing, document digitisation and new storage solutions, problems in terms of archiving, storage and access are far from solved.

If we assume that they will be solved and the data will be available, their rational use, e.g. identification of an endemic species, is not guaranteed because expert analysis of the source is required to validate the taxonomic identification and to locate it spatially and temporally. Then, the species must be replaced in a habitat for studies going beyond simple inventories. Last important point, the historical context and scientific goals pursued by the author of the document must be known.

Human societies require a great deal of time to assimilate scientific progress. In spite of vast amounts of applied research, growing environmental problems were not acknowledged by universal and media awareness of the role and benefits of biodiversity until the Earth summit in Rio de Janeiro in 1992. This was the case even though the conservation of ecosystems and living communities has always been a central concept in the scientific approach to applied ecology. The priorities of applied ecology, a field at the interface between fundamental ecology and environmental problems, are essentially dictated by current socio-economic concerns. Ecological data acquired to solve a problem are part of a research effort and vast political and socio-economic situations. Both are sufficiently instable to produce a durable effect on the scientific discipline. This long-standing societal control has been reinforced by the extent and the costs of the anthropogenic damage and by rapid access to digital information. It has brought back into favour the forgotten knowledge of applied ecology and the work, often deemed boring, of museums for natural history, in a context of real urgency, recognised by the media and spanning the planet.

For ecologists studying continental waters, this new social context explains, for example, the debates on the concept of reference conditions for the assessment of the ecological status of continental aquatic environments in the framework of the WFD or in developing ecological indicators (Statzner *et al.*, 2001).

From a multi-disciplinary point of view, a review of the historical data, their correct use and our own vigilance in maintaining the quality of that heritage all constitute one of the fundamental elements of applied ecology. The data, indispensable for setting up an effective policy for sustainable development and biodiversity conservation, can also help avoid the famous "shifting baseline syndrome" defined by Daniel Pauly. This concept describes the inherent drift in an evaluation of significant changes in an ecosystem with respect to an "initial" status, itself different than an original status, caused by insufficient understanding of or even ignorance of historical observations.

Without a doubt, use of historical data could guide future efforts for ecological restoration and avoid limiting restoration goals caused by the use of incorrect ecological reference data. ■

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