# REPARTITION OF FISH POPULATIONS IN THE DEPARTMENT OF CREUSE (FRANCE). THE GEOGRAPHICAL CONTRIBUTION OF ELECTROFISHING IN HEADSTREAMS

**Laurent TOUCHART[1]*, Y. CLAVÉ[2]**
[1]UFR Lettres, Langues et Sciences Humaines, Université d'Orléans, 10 rue de Tours, BP 46527, 45065 Orléans cedex 2, France
[2]Operations Manager for "Water", Parc Naturel Régional de Millevaches en Limousin, Le Bourg, 23340 Gentioux-Pigerolles, France

*** Correspondence:** Laurent TOUCHART, Professor of Geography, UFR Lettres, Langues et Sciences Humaines, Université d'Orléans, 10 rue de Tours, BP 46527, 45065 Orléans cedex 2, laurent.touchart@univ-orleans.fr
Received: march 2008; Published: may 2008

**ABSTRACT.** The department of the Creuse is hydrologically situated in headwaters, which ecologically healthy watercourses allow us to consider as a reference point. Electrofishing is used here in a geographical way in order to chart the repartition of fish species representative of a certain water quality, covering a period of seven years and a vast space of 5600km². Over the years, populations of the least sensitive species (chub and dace) progress towards upstream waters, while the most sensitive species (minnows) regress and only subsist in the headwaters. These species are indicators of a degradation of physicochemical or sedimentary conditions moving upstream.

**Keywords:** headwaters, headstream, freshwater fishing, European Water Framework Directive, cyprinid

## GENERAL PROBLEMS

The spatial distribution of fish populations is one of the most complex characteristics of watercourses to comprehend, insofar as the punctual methods generally used to define them give data which is difficult to visualize in the fluvial continuum. This type of research plays a role in defining piscicultural conditions in watercourses, the tracking of which allows us to monitor halieutic potentials and the development of these resources. In the context of the European Framework Directive (EFD) of December 2000, which outlines a Community policy in the field of water, the stakes have been raised considerably, particularly in terms of completing an inventory of each hydrographic district and identifying pressures caused by human action. Yet the spatial dynamics of fish populations are such insightful indicators of the overall quality of watercourses that they follow on beyond the food chain. However, apart from a few eminent examples (Bravard, 1987; Rougerie, 1993) or certain multidisciplinary studies (Amoros & Petts, 1993), French geographers have very seldom addressed this theme, leaving all initiatives on this subject, including cartography (Keith & Allardi, 2001), to biologists and technical organizations (Persat H. & Keith P., 1997, Oberdorf et al., 2002). As for geographical references concerning fishing in interior waters abroad (Carré, 1978) and in fresh water in France (Ardillier-Carras, 1997), they are even rarer. The principal goal of this article is to make a real geographical contribution, favoring small-scale cartographical research and spatial interpretation in a field traditionally dominated by the development of indexes and modeling. In order to achieve this, we have decided to focus the study on the specific contribution of electrofishing in regards to other methods of determining the state of fish populations.

## THE DEPARTMENT OF THE CREUSE: A UNIQUE RESEARCH SITE

Examining the hydrographic network of the entire department of the Creuse, in the Limousin region, offers both the originality of the study area's large size and the interest of a sparsely populated space at the source of several basins.

In contrast with very precise biological or hydrochemical studies which rely experimentally on a small drainage basin with a large cartographic scale, here we have decided to take into account a vast 5 600 km² space whose hydrographic distribution network stretches over 5500 km. Our small-scale cartographic research relies on an administrative organization which allows us to gather data from several source basins and geographic regions, mainly the Haute Marche region in the west and the Combraille in the east, whose interest justifies the choice of the area studied.

In addition to the size of the department, the Creuse has multiple advantages which legitimize its selection for a first geographical attempt at analyzing the distribution of fish populations. Its major interest lies in the fact that its location, northwest of the Massif Central, places this series of plateaus at the source of many rivers which later diverge downstream, flowing towards other regions. The crystalline, impermeable substrata of this ancient formation help create a rather strong drainage density of 0,98 km/km². As the divide between the Loire basin and that of the Garonne pass through the southern Combraille, between Crocq and la Courtine, the Creuse

possesses a major fluvial border which also exists inside the other principal Loire tributary basins. In fact, the department contains the upper segment of the Vienne and the source of the Cher, as well as the upstream portions of the main Sioulet tributaries, which run into the Allier. Because of this hydrographic divergence, waters from the department of the Creuse flow through the Perigord, Haut Limousin, Confolentais, Poitou, Berry and Bourbonnais regions. The Vienne basin dominates, covering 4128 km² of the department, directly for 73 km² or by intermediary of the regions draining towards the Maulde, the Taurion and the Creuse rivers (185 km², 835 km² and 3035 km², respectively). The upstream section of the Vienne has been officially designated as a test basin in order to prepare the Water Agency's eighth intervention program which aims to better define aid policy to aforementioned "headstream" regions. As it is located upstream of the Central-West region's basins, the department has an important responsibility towards regions situated downstream in terms of water-quality preservation. On the other hand, it is no way influenced by water coming from other territories and can thus be considered in this respect as a point of reference in which variables can be isolated without interference or the inherent, complex interrelations of other spaces located further upstream.

The second justification for the choice of the study area lies in the low population density, since the department average of 22 inhabitants/km² is one of the lowest in France.

With little urbanization or industrialization, this area is home to extensive rural activities and can, in principle, possess a high water quality in which ecological degradation may be revealed, appear or continue from an easily recognizable source. It is to be noted that tracking the ecological condition of water is part of the very principle of the EFD 2000, requiring the comparison of water inventories of 2004 and 2015. At the end of this ten year long comparison, France will have few regions like the Creuse, where the repartition of sensitive fish and the first piscicultural category could still be close to an undisturbed situation.

Finally, fishing activity represents an important influence in this region (Balabanian and Bouet, 1989). In the year 2000, the 37 *Associations Agrégées pour la Pêche et la Protection des Milieux Aquatiques* (AAPPMA)[1] in the Creuse assembled 10 400 fishermen in a department of only 120 000 inhabitants. The number of membership cards is inflated by an influx of tourism. 11% of the departmental totals are "vacation" fishing licenses which allow summer visitors to fish for two weeks between June and September, and 5% are day licenses which allow tourists an initiation. Attracting outside fishermen is essential, since local numbers are dropping sharply and for the three departments of the Limousin region, adherence has fallen 35% in the last twenty years (Ardillier-Carras, 1997). From the point of view of developing rural tourism in the Creuse, fishing is an essential traffic builder, dependent on the great proportional numbers of first class watercourses in the department.

## METHODOLOGY OF ELECTROFISHING AND GEOGRAPHIC SCALES

Following, and sometimes in parallel with studies which set up classification of watercourses based on morphometric criteria (Horton, Strahler, etc.), research concerning geographic zoning of fish in running water has evolved towards greater complexity since Huet's rule of slope (1949). The work of Illies (1955, 1961) and Illies and Botosaneanu (1963) was largely based on the force and speed of the flow. By the 1970s, Verneaux (1977) had classified the gradients of benthic and fish species from upstream to downstream waters, according to distance from the source, maximum water temperature, wet perimeter and water hardness. Later, the concept of a fluvial continuum (Vannote *et al.*, 1980) broadened criteria when associating on one hand primary production and invertebrates, and on the other hand taking into account spatial relations between upstream and downstream, the water channel and its valley, its alluvial plain and its groundwater. From this point of view, the amount and penetration of light in the water are determining factors (Descamps and Naiman, 1989). More recently, the Fish Index has created its models of fish populations based on the distance from the source, the surface area of the drainage basin, the station's average width and depth, average air temperature in January and July, and inclusion in a hydrographic basin (Oberdorf *et al.*, 2002, 2006). In general, the slow development of concepts has moved towards integrating more and more parameters (Karr, 1981).

Thanks to these decades-long scientific advances, some French organizations working with water have been able to set up quality-monitoring protocols which are based in part on interlocking geographic scales. For water agencies and even the *Conseil Supérieur de la Pêche*[2] (CSP) at the national level, more and more subject European Union directives, broader political and environmental issues come into play. The *Réseau Hydrobiologique et Piscicole* (Hydrobiological and Piscicultural Network), the *Suivi National de la Pêche aux Engins* (National Fishing Monitoring group), and even the *Station de Contrôle des Migrateurs* (Migratory Species Monitoring Station) focus on fish populations. The piscicultural context is a second geographical level which corresponds with the functional repartition area of a given species, which contains all habitats necessary for carrying out the vital functions of reproduction, hatching and growth. The Departmental Water Protection and Piscicultural Management Plans try as much as possible to use the notion of piscicultural context, even though the two spaces do not overlap, thus creating a geographic distortion. The third level used for management and monitoring of fish populations and water quality is the segment, a linear unit of up to a few dozen kilometers which are homogeneous in terms of fluvial morphology. As used by the Habitation

[1] *Certified societies for fishing and the protection of aquatic habitats*

[2] *Fishing Council, a waterway preservation organization supervised by the Ministry of the Environment.*

Evaluation Network, the segment is used as a framework for describing links between the condition of the channel and the banks, the physico-chemistry of the water and the species present. The fourth and last level is that of the so-called station. Compared to the others, we can consider it as a punctual level, even though it is in fact defined as an approximately hectometer-sized segment of watercourse. The principal measures and samples which make up the indexes (Total Biological Index, Fish Index) are taken at this level. The last level is based on the aforementioned atmosphere in order to study the relationship between micro-habitat and fish.

It is within this context of overlapping scales that we must place the methodology of electrofishing. It may be defined as the counting of fish species at a station, using a particular device which when placed in the water produces an electric current which affecting nervous tissues and allowing fish to be captured in a landing net. Protocol precision can be of two different orders. It may be a consistent inventory and complete count of the station. In this case, the count includes all fish in a fluvial area whose length is at least ten times longer the its width, while two or more successive run-throughs allow for capturing fish which might have escaped the first time due to the positioning of the electric field or due to their biology, bottom feeders being rarely captured the first time. The protocol may also consist of a regular survey and a partial count meant to be representative of the station's population, carried out over an entire area or even according to an intermittent exploration based on potential habitats. The authors' orientation in electrofishing techniques has allowed a critical viewpoint on approximations in the case of surveys, or the technical limits of the material which can stun or even excite fish. This later helped to detect some deviant data at its source.

The essential geographical problem of the method lies in the difficulty of moving from a punctual sampling to a continuous representativeness and from an analytical measure to a cartographic one. This is where our first findings come in, before allowing a new geographical interpretation of the data. The objective of this study is doubly original, on one hand bringing geography into a technical domain neglected by academic research, and on the other hand, providing summary spatialization of data whose cartography is for the moment potential and analytical.

While officially, the electronic BDMAP[3] database records all counts carried out in France by the CSP since the 1980s, indicating length, weight and external pathology of individual specimens or lots of fish, in practice our first methodological step was the collection of all the electrofishing records made in the department of the Creuse from 1996 to 2002, a total of 301 official reports on paper covering seven full years. This extended period was to allow us to detect, if present, any changes over time. The information was then entered into a database, including not only the fish population and a description of all stations, but the procedure of each act of electrofishing as well. The information is linked to the geographical database *Carthage* in a GIS. Spatially pinpointed, the data is first processed in order to create a punctual, analytical cartography, species by species, per station in the hydrographic network. The alternative of either the absence or presence of a particular species gives information about each place and time. The third step consists of selecting those species which are most sensitive to changes in the water, for whom spatial changes is evident, and summarizing these variations. To trace the isograms a departmental scale, our insertion took into account the difference between large watercourses and tributary streams. In addition, we raised the amount of data collected in rotating counts (which do not visit the same locations each year) by adding the two following principles. In the case of a species representative of an enlarged colonized area in relation to a decrease in water quality, if said species is present in year n, it is therefore present in year n+1, and if absent in year n, then it is absent in year n-1. Finally, we have assumed that if a species is present in the tributary, it is present in the mainstem.

This interdisciplinary mix of geographical and biological methods, along with the association of applied field techniques and an academic approach, have enabled the study of spatial changes of piscicultural quality in watercourses covering the whole of the Creuse.

## REGRESSION OF PISCICULTURAL QUALITY IN UPSTREAM

Cartographical work helps to underline the fact that headstream segments are no longer often home to the original combinations of Fario trout, chub, minnows and loach. These lithophilic species which inhabit cool, moving, well-oxygenated waters with a rough substratum are good indicators of the quality of the habitat. Each species certainly has its specific needs; for example, the loach tolerates the habitat's high content of organic matter much better than other species. Additionally, simple presence does not necessarily indicate reproduction in the whole of the cycle, and released fish must be taken into account. Yet studying the association gives rather reliable spatial information.

Inversely, other, less noble species of fish indicate some degradation of the aquatic habitat when their area of repartition expands. These are often species which tolerate a lower level of oxygenation, higher water temperatures and sometimes a greater turbidity. It is not necessarily pertinent to follow exotic species, those which once introduced to France, escaped from reservoirs and proved to be so resistant and ubiquitous that they do not show a progressive spatial change, but a general diffusion stemming from multiple sources. This is the case with catfish. Other species like the roach or the rudd are a little more interesting for geographical tracking, since they naturally occupy downstream portions of major watercourses. Yet their presence in upstream tributary channels is linked to sporadic draining of lakes and following them does not have a progressive significance. The study of native species which if not salmonids, are still moving water cyprinids not naturally occupying headstream waters is

[3] *Banque de données milieux aquatiques et poissons: Fish and aquatic habitat database*

more insightful. Their possible expansion upstream moves less rapidly, and as it is really progressive, can be followed geographically and is representative of a slow degradation of water quality.

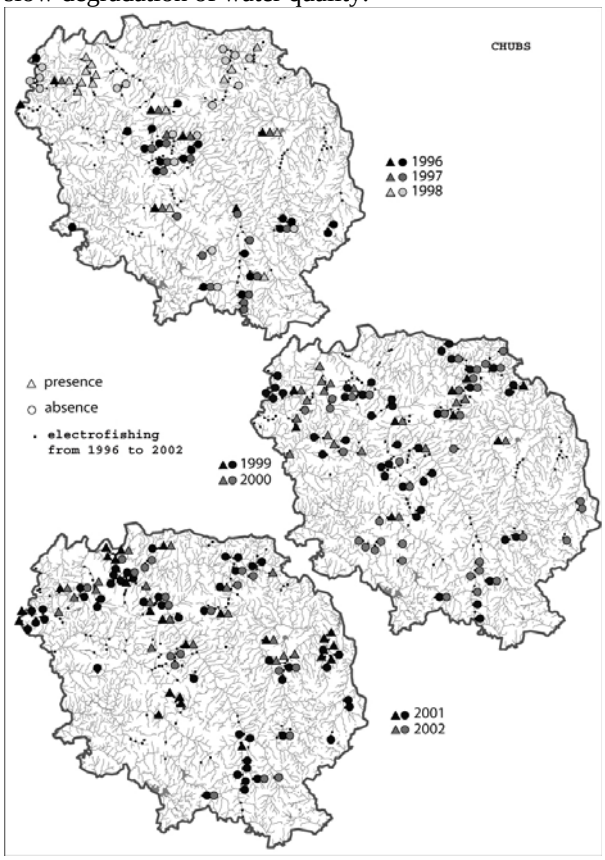


**Fig. 1** Map showing absence or presence of chubs in the Creuse

The chub is one of these precious indicators. This indigenous rheophilic cyprinid, quite present downstream, does not normally populate headstreams. However, it remarkable capacity for adaptation in changing habitats allows it to move upstream as soon as physical-chemical or morpho-sedimentological conditions degrade. The dace has rather similar characteristics, but provides fewer opportunities for tracking since it is very vulnerable to parasites, and thus less common and seldom present in electrofishing counts, which reduces cartographic possibilities.

The descriptive map of the absence or presence of chub during electrofishing counts for seven years shows that this species was practically never found in the department of the Creuse during the middle of the 1990's (fig. 1).

This confirms its typical absence in the cool headstream waters. In 1996, chubs migrated only up the major watercourses- the Creuse, the Taurion, the Tardes and its tributary the Voueize. These successive years show the species' diffusion throughout the hydrographic network, but the number of counts made, differing between years, makes a more in-depth, direct reading more difficult. The interpretive map of isochronal lines tracking the chub's upstream movement reveals a progressive colonization of the entire northern half of the department (fig. 2).

It was between 1998 and 2000 that progression was strongest. The Petite Creuse was a major path of propagation, with the other entry point being the Gartempe in the west. As for the Creuse, however, the limit of the chub's presence was stabilized in the upstream segment.

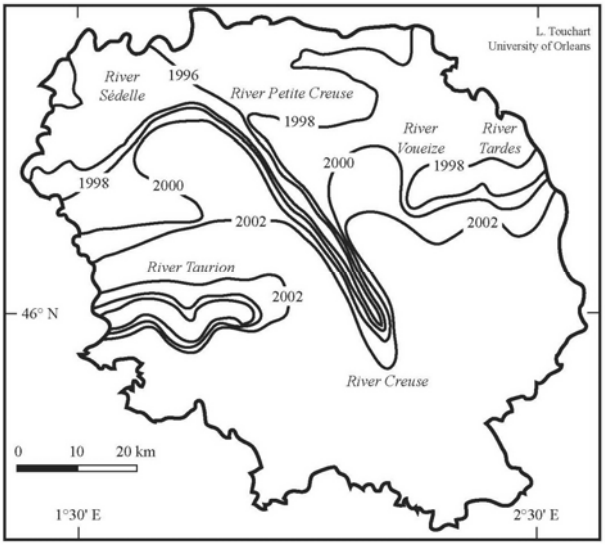


**Fig. 2.** Map of isochronal lines showing upstream movement of chubs in the department of the Creuse

Fish population maps which indicate the upstream movement of some water-quality degradation, while less demonstrative when taken one by one, nevertheless confirm the greater tendencies of the chub map and add nuance to some others. For example, the dace, already present in the Creuse, the Sédelle and the Voueize at the beginning of the study, moved up the Taurion somewhat later. As for the fish population maps tracking withdrawal of good water-quality downstream, they are often more difficult to interpret, but some are full of useful information. The minnow map shows that these fish are absent from the numerous electrofishing counts performed in the last few years in the Gartempe, the lower Sédelle, and to a lesser extent, the Petite Creuse, yet this was not the case before (fig. 3).

However, we must be careful with the interpretation, since minnow populations, and for that matter, gudgeon populations, are rather cyclical. The role of flood crests and refuge zones are fundamental in explaining the presence of these rather short-lived fish.

In total, the referencing and analytical cartography of 29 fish species has allowed for an attempt at a geographical summary on the scale of the entire department (fig. 4).

In the middle of the 1990s, some large watercourses, the Creuse downstream of Ahun, the Sédelle, the Taurion, and the Voueize, already had a mix of sensitive species and those living with less rigorous habitat conditions. In the last decade, the less sensitive species have colonized the north and the west-central regions of the department, traveling upstream in the Gartempe and Petite Creuse basins. To simplify, this situation now includes the northwest two-thirds of the department and leaves the

exclusive population of the most sensitive species to the southeast third. However, some large basins in the northwest remain preserved, for example, the Ardour, between the Gartempe and the Taurion. This thus points to the question of the causes of this change.

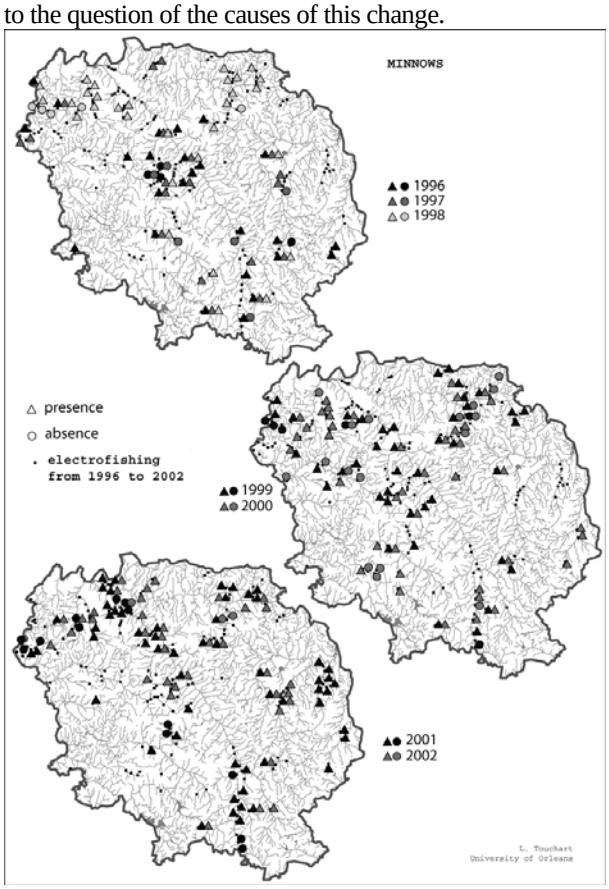


**Fig. 3.** Map showing absence or presence of minnows in the Creuse

The drainage of water bodies and the multiplication of the number of ponds seem to explain some modifications in fish population in the department's rivers. Indeed, the regions in which the expansion of water bodies was strongest in recent years, notably the northwest sector of the department and the downstream section of the Petite Creuse, correspond with areas of progressive diffusion of the least sensitive species, at least in terms of water temperature. There are now 5,579 bodies of water in the department, including 3,804 ponds of more than 10 ares, and among them, 2,764 are directly linked to the hydrographic distribution network (conference paper presented by P. Bartout). On the contrary, the stagnation of the number of ponds, characteristic of the Ardour, coincides with the northern half's basin, whose counts have stayed the closest to their initial results. However, a larger change of context, affecting the whole of the department, offers new conditions for progressive and generalized upstream movement, due to a declining rural population, less regular maintenance of riverbanks causing growing sedimentary accumulation and increased planting of conifers upstream.

## CONCLUSIONS

With its mix of fundamental and applied methodologies, and the interdisciplinary approach using biological and geographical methods, this research brings together the work of technicians in the field and that of academic cartography. On the scale of a department covering 5,600 km², we have been able to spatialize a type of data which is not solicited often enough- the results of electrofishing counts, and to interpret these maps in terms of ongoing changes in water quality, and more broadly, of habitats. This research helps to move beyond the classic indicators used by geographers for reflection on sustained development, and to actively work for reasonable management of the environment. The Parc Régional de Millevaches, which covers the southern part of the department, manages a territory with healthy hydrographic distribution network and the presence of a sensitive fish population, as shown by our work. Regions like this, with headwaters at mid-alpine level like the Massif Central and the Vosges, could become a refuge for prized species and thus acquire a new value and certain responsibility.

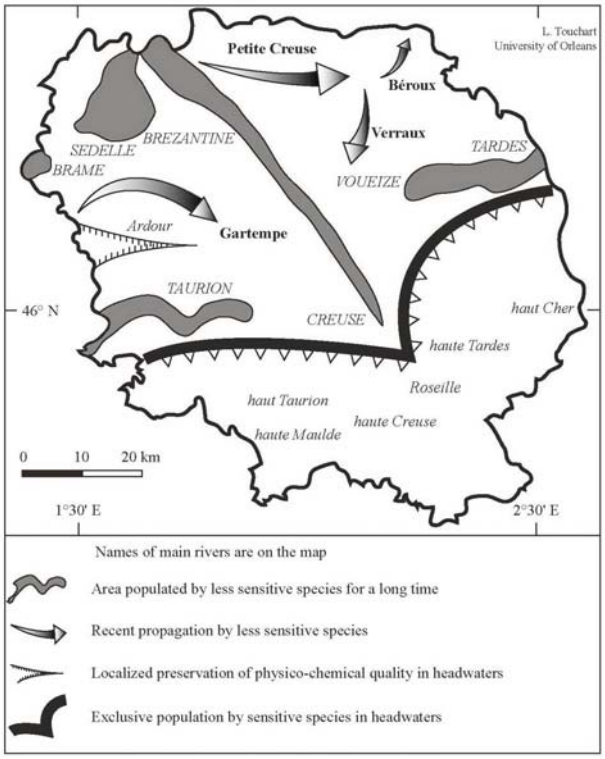


**Fig. 4** Map of piscicultural changes in the Creuse's watercourses, a geography of mid-alpine headstream waters

## ACKNOWLEDGEMENTS

The authors wish to thank Mr. L. Dubois, chief ranger of the CSP of the Creuse, for providing records and an initiation in counting techniques in the field; Mr. P. Bartout, Geography teacher at the collège Dun-le Palestel, for the use of never before seen data concerning pond census from his current PhD research; Mr. F. Carré, professor of Marine Geography at the Université de Paris IV la Sorbonne, for bibliographical information regarding fishing geography and for his constructive criticism of this paper; Mr. D. Monnier, member of the center "zones humides intérieures " (interior wetlands) and the Délégation Régionale de

Metz du Conseil de la Pêche, for providing the most recent bibliography, an attentive eye to the manuscript and judicious suggestions for improvement.

## REFERENCES

Ardillier-Carras F. (1997) L'eau ressource pour le développement d'un espace rural, l'exemple du bassin de la Gartempe. Limoges, Pulim, 592 p.

Balabanian O. & Bouet G. (1989) L'eau et la maîtrise de l'eau en Limousin. Treignac, Les Monédières, 302 p.

Amoros C. & Petts G.E., Dir. (1993) Hydrosystèmes fluviaux. Paris, Masson, 300 p.

Bravard J.-P. (1987) Le Rhône du Léman à Lyon. Lyon, La Manufacture, 451 p.

Carré F., Les pêches en mer Caspienne, Annales de Géographie, 87(479), pp. 1-39, 1978

Descamps H. & Naiman R.J., L'écologie des fleuves, La Recherche, 20(208), pp. 310-319, 1989

Huet M., Aperçu des relations entre la pente et les populations piscicoles des eaux courantes, Schweizerische Zeitschrift der Hydrologie, 11(3-4), pp. 332-351, 1949

Illies J., Der biologische Aspekt der limnologischen Fliessgewässer" Archiv für Hydrobiologie, Suppl., 22, pp. 337-346, 1995

Illies J., Versuch einer allgemeinen biozönotischen Gliederung der Fliessgewässer, Internationale Revue der gesamten Hydrobiologie, 46, pp. 205-213, 1961

Illies J. & Botosaneanu L. (1963) "Problèmes et méthodes de la classification et de la zonation écologique des eaux courantes considérées surtout du point de vue faunistique" Mitteilungen der Internationale Vereinigung für theorische and angewandte Limnolologie, 12 : 1-57.

Karr J.R. (1981) "Assessment of biotic integrity using fish communities" Fisheries, 6 : 21-27.

Keith P. & Allardi J. (2001) Atlas des poissons d'eau douce de France. Paris, Muséum National d'Histoire Naturelle, col. "Patrimoines naturels", 47 p.

Oberdorff T., Pont D., Hugeny B., Belliard J., Berrebit dit Thomas R. & Porcher J.-P. (2002) "Adaptation et validation d'un indice poisson (FBI) pour l'évaluation de la qualité biologique des cours d'eau français" Bulletin Français de Pêche et Pisciculture, 365/366 : 405-433.

Oberdorff T., Pont D., Hugeny B., & Porcher J.-P. (2006) "Development and validation of a fish-based index (FBI) for the assessment of "river health" in France" Freshwater Biology, in press.

Persat H. & Keith P. (1997) "The geographic distribution of freshwater fishes in France: which are native and which are not ?" Bulletin Français de Pêche et Pisciculture, 344/345, pp. 15-32.

Rougerie G. (1993) Biogéographie des milieux aquatiques. Paris, A. Colin, 252 p.

Vannote R.L., Minshall G.W., Cummins K.W., Sedell J.R. & Cushing C.E. (1980) "The river continuum concept" Canadian Journal of Fisheries and Aquatic Science, 37, pp. 130-137.

Verneaux J., Biotypologie de l'écosystème 'eau courante'. Détermination approchée de l'appartenance typologique d'un peuplement ichtyologique, Compte-rendus de l'Académie des Sciences, 284, pp. 675-678, 1977