REGULATED RIVERS: RESEARCH & MANAGEMENT, VOL. 10, 363–372 (1995)

0+ FISH ASSEMBLAGES IN A SECTOR OF THE RHÔNE RIVER INFLUENCED BY THE BREGNIÉR–CORDON HYDROELECTRIC SCHEME

MILAN PEŇÁZ AND PAVEL JURAJDA

Institute of Landscape Ecology, Academy of Sciences of the Czech Republic, Květná 8, 603 65 Brno, Czech Republic

and

ALBERT LUIS ROUX AND JEAN MICHEL OLIVIER

URA CNRS 1451 Ecologie des Eaux Douces et des Grands Fleuves, Université C.Bernard-Lyon I, 43 Boulevard du 11 Novembre 1918, 69622 Villeurbanne Cedex, France

ABSTRACT

A survey was undertaken to assess the effects of the construction of the Brégnier–Cordon hydroelectric power station in 1984 on the spawning and nursery habitats of the young of the year fish (YOY) in the River Rhône floodplain area. No obvious effect could be identified in the most important aquatic habitats studied, possibly due to the downstream drift and dispersion of juvenile fish. Some new habitats were created with a high production capacity, which proved suitable as nursery areas for YOY rheophilous fishes (e.g. riparian zones of the headrace canal and reservoir). The conditions for young fish were also improved in the section of the main channel, now by-passed, in which the discharge is stabilized and sufficiently high. However, a rapid decline in the abundance and species diversity of YOY fish assemblages was noted in parapotamic side-arms, caused by the side-arms drying up and becoming invaded by terrestrial plants. High YOY abundance, indicating good reproductive success, was nevertheless noted in some fishes considered as sensitive to such hydroengineering activities.

KEY WORDS: flow regulation; juvenile fish; floodplain aquatic habitats

INTRODUCTION

The Bregniér–Cordon hydroelectric scheme, completed in 1984, is the last to be constructed and put into operation on the French Upper Rhône River. It was designed and constructed on the basis of experience obtained on the construction of the previous Rhodanian hydroelectric stations, taking into account the preservation of all aquatic habitats, their connections with the main channel and the maintenance of all important floodplain functions (including fish production). It is well known that fish reproductive success in floodplain ecosystems varies in quality and quantity from year to year (Schlosser, 1985; Welcomme, 1985). In addition, some of the habitats and their fish assemblages seem to be the object of special succession, as documented for the Upper Rhône River by Persat (1994).

The monitoring of ichthyocoenoses, and its young of the year (YOY) assemblages in particular; was an important part of the interdisciplinary research programme (PIREN) conducted in the Bregniér–Cordon floodplain (Roux, 1982). Fish assemblages provide important and integrated information on the synergy of ecological, hydrotechnical and other anthropogenic influences. In addition, YOY fish monitoring provides more precise data than that of adult fish, both in temporal and spatial dimensions, presumably because there is a shorter time period between cause and effect, and because YOY fish are more sensitive than older fish. Thus this approach allows a more detailed assessment of impacts of various kinds on riverine ecosystems (Schiemer and Spindler, 1989; Peňáz *et al.*, 1991b). The aim of this study was, therefore, to use such an approach to monitor and assess the situation in the floodplain hydrosystem at the Bregniér–Cordon hydroelectric scheme during the first years of its existence.

CCC 0886-9375/95/040363-10

Accepted April 1995

MATERIAL AND METHODS

Fishing procedures

Young of the year fish were sampled using a light, battery-powered, portable electrofishing unit (Martin Pecheur II) modified and adjusted to increase its efficiency for capturing small fish. It was fitted with a 10 cm ring-shaped anode. The following settings were used: output voltage, ≈ 200 V; current, 8–12 A (at water temperatures of 12–34°C and conductivity 250–450 $\mu S\,cm^{-1}$); impulse shape exponential; frequency, 100–400 Hz; duty cycle, 5–25% (adjusted to 15–17%); surface area with provoked electrotaxis, 0·071 m^2 (this value, estimated for the same area, was taken from Copp 1989a).

The strategy of random point abundance sampling (RPAS), was used. All surveys were conducted during a short period (13–29 August 1991) at all stations. The survey could be thus considered 'synchronic' from a demographic viewpoint. The fish were preserved in a 6% formaldehyde solution after capture, identified and measured within a few days. Abundance was expressed in terms of CPUE, i.e. the number of fish caught per one RPAS point. More details about the methods used are given by Copp and Peňáz (1988), Copp (1989a; 1989b), Peňáz *et al.* (1991a; 1991b).

Statistical analysis

Statistical analyses were carried out using the ADE package (Chessel and Doledec, 1993). Multiple correspondence analysis (MCA) was used for the assessment of qualitative environmental variables (Pialot *et al.*, 1984; Tenenhaus and Young, 1985). Principal components analysis (PCA) (Rao, 1964) was used for the treatment of the stations by fauna matrix.

STUDY SITE

In total, 12 types of aquatic habitats were recognized and studied in the Bregniér–Cordon floodplain (French Upper Rhône). Seven of these types were considered as natural and five as artificial or semi-artificial (Table I). Altogether 37 sites (Figure 1; Table II), with 700 RPAS fishing points, were investigated. Normally 20–30 points were investigated at each station, where the distance between subsequent

Table I. Types of habitats

	Natural habitats		Stations
A	Main channel—natural; fluctuating discharge	Eupotamon	8, 30
B	Main channel—by-passed section; stabilized discharge		16, 17, 27, 32, 37
C	Lotic side-arm—superficial water		20, 21, 24, 26
Da	Side-arm, semi-lotic—stations usually well opened and permanently connected to main channel allochthonous processes prevail		22, 28, 33, 36
Db	Side-arm, lentic—low and/or temporary connectivity, stations rather distant from main channel, autogenic processes prevail		23, 25, 35
E	Partially connected backwaters, high level of autogenic processes	Parapotamon	4, 10, 11, 12, 13
F	Disconnected backwaters	Palaeopotamon and analogous	2, 18
Artificial habitats			
G	Headrace reservoir		1, 14, 15, 19, 29
H	Headrace canal		9, 31
I	Tailrace		7
J	Lagoon, connected to river, alimented by drained water		34
K	Drainage canals, lotic side-arms supplied by drained or groundwater, isolated from main channel		3, 5, 6

Table II. Ichthyological characteristics of different habitat types

Type*	SR	CPUE	H′	E	Relative abundance (%)			Dominant species (RA ⩾ 10%)†
					Rh	Eu	Li	
A	16	10·85	2·03	0·73	58·9	2·4	38·7	Lc, Lg, Cn
B	14	4·92	1·80	0·68	78·4	5·7	15·8	Lc, Bb
C	17	11·39	1·94	0·68	68·3	7·3	24·4	Lc, Rs
Da	14	6·29	1·55	0·59	69·2	4·6	26·3	Lc, Rs
Db	9	1·38	1·79	0·81	47·8	2·9	49·2	Lc, Rs, Tt
E	4	0·89	1·17	0·85	—	11·2	88·8	Se, Ab, Rr
F	3	1·63	0·34	0·31	—	—	100·0	Lg
G	15	8·25	1·96	0·72	73·2	9·6	17·2	Bb, Lc, Gg, Rs
H	10	2·78	1·66	0·70	60·4	13·5	26·1	Lc, Rr, Bb, Rs, Aa
I	8	4·50	1·60	0·77	42·1	44·4	13·4	Rr, Lc, Cn
J	6	1·10	1·21	0·67	40·9	9·0	50·0	Ga, Lc
K	5	0·73	1·17	0·73	6·8	2·3	90·9	Nb, Ga

* Key to types of habitats is given in Table I.
† Key to dominant species is given.
Explanation of symbols: SR = species richness; CPUE = catch per unit effort, N/point; H′ = diversity index (Shannon and Weaver); E = equitability index; RA = relative abundance (%); Rh = rheophilous species; Eu = eurytopic species; and Li = limnophilic species

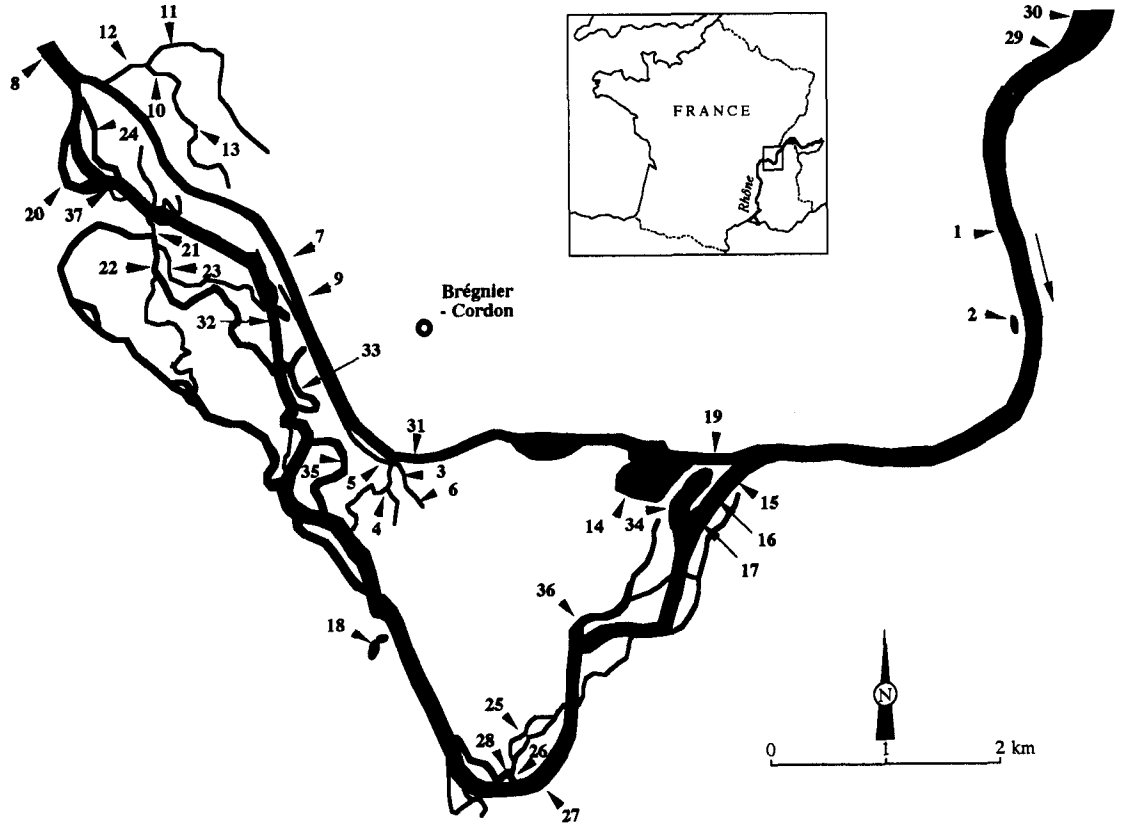

Figure 1. Schematic map of the Rhône floodplain at Bregniér–Cordon showing stations of point abundance sampling (RPAS)

Table III.

Variable	Classification
1, Situation	Mid-channel Shallow beach Gentle slope Steep
2, Width	0–10 m 10–20 m > 20 m
3, Depth	< 0·2 m 0·2–0·5 m 0·5–1·0 m > 1·0 m
4, Current	Still Weak Moderate Strong
5, Substratum	Organic mud Mineral mud Sand Gravel Pebbles Stone
6, Riparian cover	Absent Present
7, Woody debris	None Little Dense
8, Algae	None Little Dense
9, Submerged macrophytes	None Little Dense
10, Emergent macrophytes	None Little Dense

points was at least 4–5 m. Exceptionally, on some stations, when the area habitat was limited, the number of sampling points was lower (10 or 15). For the PCA and MCA analyses, only 34 sites with 680 points were used.

In total, 10 environmental variables with 35 were recorded at each studied point (Table III).

RESULTS

Fauna

In total, 40 species of fish and lampreys, including those now extinct, have been recorded in the French Upper Rhône River (Pattee, 1988; Persat, 1988). However, of these 40 species, only 33 have been registered in recent years (1988–1991) by routine experimental electrofishing (Olivier, 1992).

Table IV. 0+ fishes registered in the Bregniér–Cordon sector of the River Rhône

Code	Scientific name	English name
St	*Salmo trutta*	Brown trout
El	*Esox lucius*	Pike
Rr	*Rutilus rutilus*	Roach
Ll	*Leuciscus leuciscus*	Dace
Lc	*Leuciscus cephalus*	Chub
Pp	*Phoxinus phoxinus*	Minnow
Se	*Scardinius erythrophthalmus*	Rudd
Tt	*Tinca tinca*	Tench
Cn	*Chondrostoma nasus*	Nase
Gg	*Gobio gobio*	Gudgeon
Bb	*Barbus barbus*	Barbel
Aa	*Alburnus alburnus*	Bleak
Ap	*Alburnoides bipunctatus*	Spirlin
Ab	*Abramis brama*	Bream
Bj	*Blicca bjoerkna*	White bream
Rs	*Rhodeus sericeus*	Bitterling
Cy	*Cyprinus carpio*	Carp
Nb	*Barbatula barbatula*	Stone loach
Im	*Ictalurus melas*	Black bullhead
Lt	*Lota lota*	Burbot
An	*Anguilla anguilla*	Eel
Ga	*Gasterosteus aculeatus*	Three-spined stickleback
Pf	*Perca fluviatilis*	Perch
Ms	*Micropterus salmoides*	Largemouth bass
Lg	*Lepomis gibbosus*	Pumpkinseed

Table V. Change in YOY fish composition in some habitats of the Bregniér–Cordon floodplain in 1986 (Copp, 1987) 1989 (Peňáz *et al.*, 1991a) and 1991 (this work)

Type of habitat	Station	Year	Species richness	Species diversity	Equitability	CPUE
A, natural main channel	Basse du pont	1986	9	1·65	0·75	6·86
	d'Evieu	1991	11	1·56	0·65	19·50
B, By-passed channel	Les Sables	1986	7	1·38	0·71	0·70
		1991	11	1·87	0·78	8·55
C, Lotic side-arm	Lône d'Illon	1986	11	1·75	0·73	4·10
		1989	6	1·05	0·59	2·30
		1991	10	1·19	0·52	16·03
	Graviér	1986	6	0·89	0·50	6·90
	Grand Jean	1991	11	2·05	0·85	6·00
	Petit	1986	9	1·60	0·73	1·16
	iles Sables	1991	6	1·32	0·74	8·05
Db, Lentic side-arms	Petit iles	1986	9	1·82	0·83	1·55
	Molottes	1991	3	0·90	0·82	1·50
E, Parapotamic backwaters	Le Mortier I.	1986	6	1·23	0·69	1·69
		1991	3	0·95	0·86	0·50
	Le Mortier II.	1986	1	0	—	1·68
		1991	4	1·07	0·77	1·30
G, Headrace reservoir	Les Curtieux	1989	0	0	—	0
		1991	10	1·74	0·76	1·95
K, Drainage canals	Vielle Lône	1986	1	0	—	0·06
	Rosillon I	1991	3	0·67	0·61	1·35
	Vielle Lône	1986	0	0	—	0
	Rosillon II	1991	2	0·64	0·92	0·45

During our electrofishing study, focusing on juvenile fish exclusively, we registered the occurrence of the 25 fish species (Table IV).

Abundance and habitat preference

When evaluating the overall number of fish ($N = 3687$) captured in all habitats, three species were identified as dominant (i.e. with an abundance > 10%): *L. cephalus* (34·55%), *B. barbus* (11·93%) and *R. sericeus* (10·47%). It is interesting that a relatively high abundance (6·73%) of *C. nasus* was also found, i.e. a species regarded as extremely sensitive to hydroengineering activities in central Europe (Peňáz, 1994).

The average abundance for all habitats reached 5·19 fish point^{-1} (= 74.22 fish m^{-2}). Maximum abundances were found in lotic habitats, namely in eupotamic side-arms (type D) (11·39 fish m^{-2}) and in the natural main channel (10·85 fish m^{-2}). Abundance was also high along the shorelines of the headrace reservoir (8·25 fish m^{-2}). Minimum values were registered in lotic drainage canals and/or in side-arms supplied by drained and groundwater (type K) (0·73 fish m^{-2}), in parapotamic habitats (0·89 fish m^{-2}) and in the tailrace (1·10 fish m^{-2}). In the latter habitat type, despite its otherwise convenient lotic environmental conditions, the low observed abundance seems to be the consequence of the considerable discharge fluctuation caused by electricity production (hydropeaking) and by the isolation of this section from the YOY in upstream stream sections.

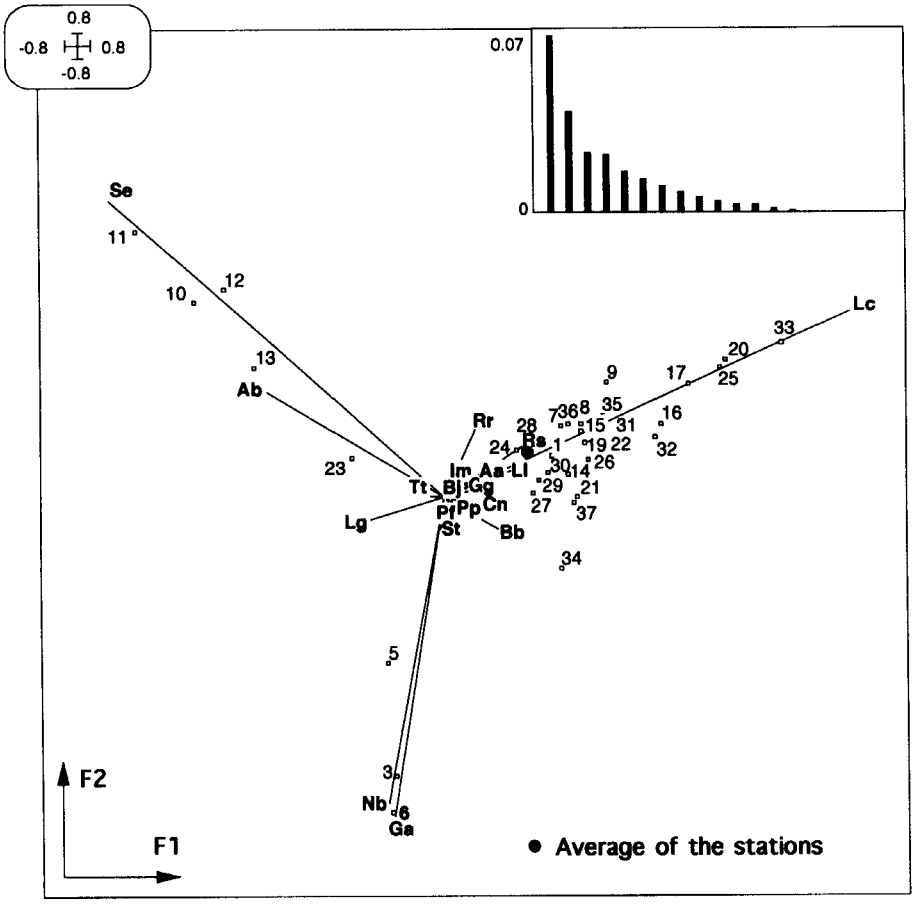

Figure 2. Ordination from principal components analysis of a sites by species matrix (34 × 19) of YOY fish (dominance in %) sampled in floodplain habitats of the Upper Rhône River

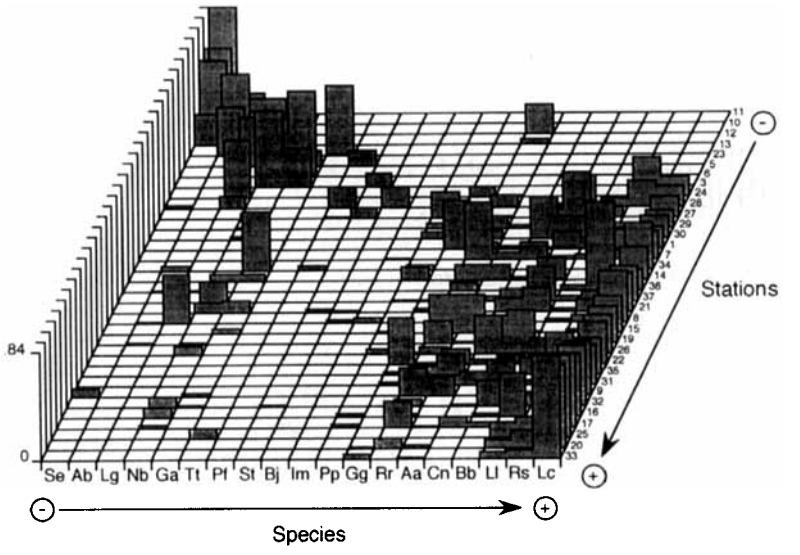

Figure 3. Histogram of species dominance (in %) ordinated for site by species matrix (34 × 19) according to factor 1

When analysing the fish composition separately, according to habitat type (Table II), we may conclude that rheophilic species, such as *L. cephalus*, *B. barbus* and *C. nasus* prevail in eupotamic habitats (types A–Db). However, in lotic side-arms augmented by drainage water and groundwater (habitat type K), a special fish community has formed, characterized by the predominance of *B. barbatula* and *G. aculeatus*.

Compared with the RPAS sampling, a higher relative proportion of roach (37·4%) and a lower number of barbel (13·2%) were registered in the lotic habitats by concurrent YOY samplings by drift nets (Peňáz *et al.*, 1992). This could reflect both the different behaviour patterns of the various species and different sampling methods.

The analysis of the fauna matrix (19 species × 34 different sites) was performed by PCA. The data were transformed to obtain the frequency distribution of species per station (i.e. the faunistic profile for each station). Then, the data were centred by species (columns) to reduce the effect of the most abundant species (i.e. chub and roach). Species that occurred only once were suppressed in the analysis.

The resulting distribution of 19 species at 34 sites of the Upper River Rhône flood plain is shown on the factorial map F1 × F2 (Figure 2) (Gabriel, 1971; Ter Braak, 1983). The location of each station corresponds to the relative abundance of species occurring at that station. A clear separation of *S. erythrophthalmus* and *A. brama*, inhabiting old backwaters and, on the other hand, the stone loach and three-spined stickleback in the drainage canals was predictable. The separate position of chub is explained by its presence at almost all stations; however, its dominance varied across a great range of 0·14–0·81. Stations located along the first axis separate limnophilic species occupying vegetated backwaters (rudd, bream, sunfish, tench) and stone loach, three-spined stickleback and brown trout inhabiting clean, cold water drainage canals. The YOY fish community on the right-hand side of Figure 3 is composed mainly of rheophilic and eurytopic species. The main information following from this figure concerns the ordination of stations according to their fauna. The parapotamic stations (Mortier) are followed by a group of old arms (Rossilon), a group of side-arms connected to main channel and by stations in the by-pass section, ordinated according to the dominance of the chub and other rheophilic species (Ll, Bb, Cn).

The point by environmental variables matrix analysed by MCA shows that the nursery sites under study could be clearly separated into three groups, based on the microhabitat characteristics (depth, current, substratum, etc.) (Figure 4). Each square represents the position of points with the same combination of habitat variables. The station number is located at the centre of a group of station points. These were grouped into

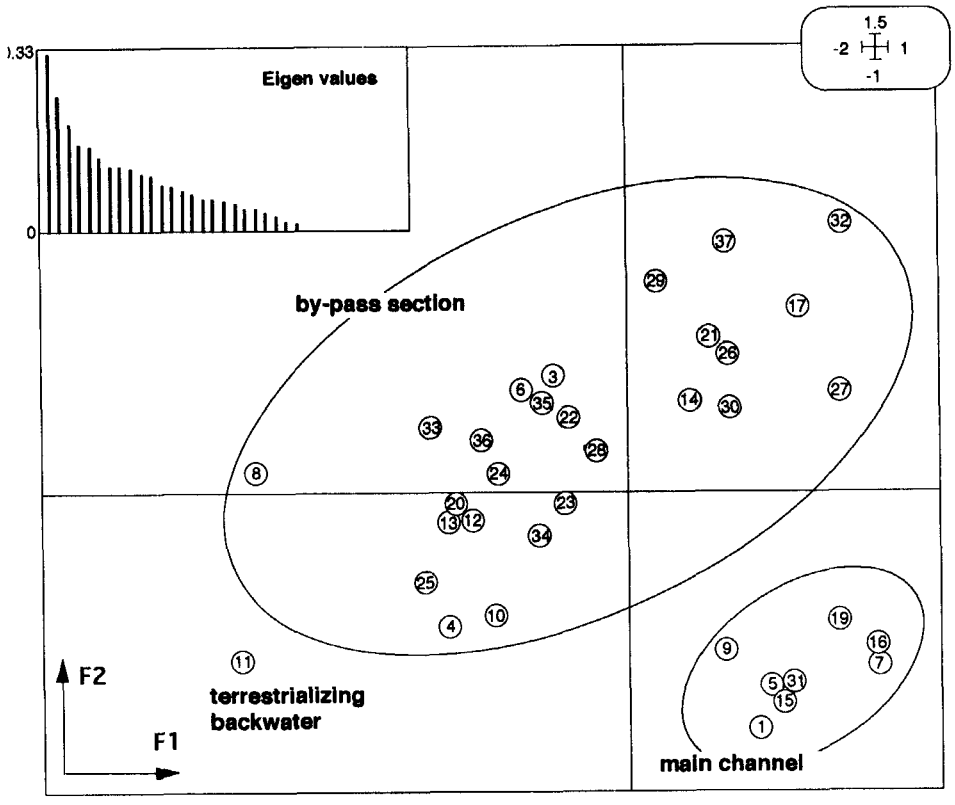

Figure 4. Multiple correspondence analysis of point by environmental variables matrix (680 × 35) for floodplain ecosystems of the Upper Rhône River

three sets: old backwaters (site 11), artificial stony rip-rap banks along the main channel (sites 1, 5, 7, 9, 15, 16, 19, 31) and the most common, more or less natural sites in the by-passed section.

Temporal changes in the YOY structure

Tendencies in the succession and dispersion of YOY fish, coincident with the completion and start of operation of the Bregniér–Cordon hydroelectric system (Table V), were analysed using data obtained by the same methods, at the same stations, and at nearly the same periods of the year, during two or three (in some instances) periods: 1986 (Copp, 1987); 1989 (Peňáz *et al.*, 1991b) and 1991 (present data).

Eupotamic habitats. In both the natural and by-passed main channels (habitats A and B), the species composition seems to remain similar, but species richness and, especially, abundance increase.
In lotic side-arms (habitat C), the qualitative structure also seems to be stable at some sites (20, 21); however, in favour of *G. aculeatus* on 'Petit Iles des Sables' (site 24). The increase in abundance, especially on 'Lône d'Illon' from 4·10 to 16·03 ind./point, is there very noticeable.

Parapotamic habitats. In partially disconnected lentic side-arms (habitat E) after management, the intensity of autogenic processes increased and habitat senescence intensified. Connections with the main channel became reduced or even interrupted, at least temporally. The structure of YOY assemblages reflected these changes by decreasing overall abundance, reducing species richness and diversity, and by changing species composition in favour of limnophilic and eurytopic species.

Artificial habitats. In the headrace reservoir (habitat G), mud deposition and macrophyte development along the shoreline was followed by a rapid development of abundant and diverse YOY assemblages

(mostly rheophilic species) along the entire length of the reservoir. The downstream drift from the upstream spawning sites explains the relatively high abundance of those YOY fish in the reservoir.

Drainage canals and lotic side-arms augmented by drained and underground water (habitat K) showed substantial changes in their species composition, *G. aculeatus* and *B. barbatula* becoming the most dominant species.

DISCUSSION

The technical design of the Bregniér–Cordon hydroelectric scheme on the Upper Rhône River, especially the relatively high water discharge maintained in the by-passed stream section, guarantees a sufficient water level and good lateral connectivity within the floodplain (some side-arms act as refuges for fish during spates). This seems to be very profitable for YOY fish assemblages.

Some of the new, artificially created aquatic habitats (headrace canal and reservoir) seem to serve as new substitute nursery habitats for juveniles of rheophilic species drifting there from the upstream river stretch. However, their true value would be better determined by the YOY survival into the next year. The YOY fish abundance and diversity tended to increase in most lotic habitats, both the natural and by-passed, which indicates better conditions for spawning and juveniles.

The abundance and diversity of YOY were low in the parapotamic habitats, which indicates their poor value as spawning and nursery sites, owing to increased autogenic processes, intensified habitat senescence and reduced connections to main channel. Without management, this type of habitat would loose its importance as a habitat for fish communities in a very short time.

A noticeable increase in the abundance of species considered generally as sensitive to river engineering activities in central Europe, such as *C. nasus* (cf. Kirchhofer, 1994; Peňáz, 1994) was observed. Long-term studies are required to evaluate more accurately the reproductive success in this floodplain system, mainly because of considerable seasonal and year to year discharge fluctuations.

REFERENCES

Chessel, D. and Doledec, S. 1993. 'ADE–3.6', *URA CNRS 1451*, Univ. de Lyon I.

Copp, G. H. 1987. 'Le role et le fonctionnement des milieux aquatiques du Haut-Rhône Francais comme sites de reproduction et de nurserie pour les poissons du fleuve', *These de Doctorat*, Univ. Claude-Bernard, Lyon I, 97pp.

Copp, G. H. 1989a. 'Electrofishing for fish larvae and 0+ juveniles: equipment modification for increasing efficiency with short fishes', *Aquat. Fish. Manage.*, **20,** 453–462.

Copp, G. H. 1989b. 'The habitat diversity and fish reproductive function of floodplain ecosystems', *Environ. Biol. Fishes*, **26,** 1–27.

Copp, G. H. and Peňáz, M. 1988. 'Ecology of fish spawning and nursery zones in the flood plain, using a new sampling approach', *Hydrobiologia*, **169,** 209–224.

Gabriel, K. R. 1971. 'The biplot graphical display of matrices with application to principal component analysis', *Biometrika*, **58,** 453–467.

Kirchhofer, A. 1994. 'The identification of threatening causes as a key in species conservation: *Lampetra planeri*, *Chondrostoma nasus* and *Coregonus* sp. in Switzerland', *Proc. Symp. Conservation of Endangered Freshwater Fish in Europe, Bern, 20–22 July 1994*, p. 31.

Olivier, J. M. 1992. 'Rytmes de dérive des alevins en milieu fluvial. Suivi dans le Rhône au niveau des prises d'eau et influence des vidanges de barrages', *These de Doctorat*, Univ. Claude Bernard, Lyon I, 393 pp.

Pattee, E. 1988. 'Fish and their environment in large European river ecosystems: the Rhône', *Sci. Eau*, **7** (1), 35–74.

Peňáz, M. 1994. 'Chondrostoma nasus—its reproduction strategy and possible reasons for a widely observed population decline—review', *Proc. Symp. Conservation of Endangered Freshwater Fish in Europe, Bern, 20–22 July 1994*, p. 66.

Peňáz, M., Olivier, J. M., Carrel, G., Pont, D. and Roux, A. L. 1991a. 'A synchronic study of juvenile fish assemblages in the French section of the Rhône River', *Acta Sci. Nat. Brno*, **25** (5), 1–36.

Peňáz, M., Copp, G. H., Olivier, J. M. and Roux, A. L. 1991b. 'Ichthyocoenosis as functional describer of fluvial ecosystems and of their dynamics', *Seminar, Biological Monitoring of Large Rivers, Brno*, pp. 93–98.

Peňáz, M., Roux, A. L., Jurajda, P. and Olivier, J. M. 1992. 'Drift of larval and juvenile fishes in a by-passed floodplain of the upper River Rhône, France', *Folia Zool.*, **41,** 281–288.

Persat, H. 1988. 'De la biologie des populations de l'ombre commun *Thymallus thymallus* (L. 1758) a la dynamique des communautes dans un hydrosysteme fluvial amenage, le Haut-Rhône Francais. Elements pour un changement d'echelles', *These de Doctorat*, Univ. Claude-Bernard, Lyon I, 223 pp.

Persat, H. 1994. 'Fish population instability in a regulated river, the upper Rhône', *Proc. Sixth Int. Symp. Regulated Streams, České Budějovice, 3–6 August, 1994.*

Pialot, D., Chessel, D. and Auda, Y. 1984. 'Description de milieu et analyze factorielle des correspondances multiples', *C.R. Acad. Sci. Paris*, **298,** 309–314.

Rao, C. R. 1964. 'The use and interpretation of principal component analysis in applied research', *Sankhya, A*, **26**, 329–359.
Roux, A. L. (Ed.) 1982. 'Cartographie polythématique apliquée à la gestion écologiques des eaux, étude d'un hydrosysteme fluvial: le Haute-Rhône francais', *A. L. Edition du CNRS Centre Region Publ. Lyon*, 116 pp.
Schiemer, F. and Spindler, T. 1989. 'Endangered fish species of the Danube river in Austria', *Regul. Riv.*, **4**, 397–407.
Schlosser, I. J. 1985. 'Flow regime, juvenile abundance, and the assemblage structure of stream fishes', *Ecology*, **66**, 1484–1490.
Tenenhaus, M. and Young, F. W. 1985. 'An analysis and synthesis of multiple correspondence analysis, optimal scaling, dual scaling, homogeneity analysis and other methods for quantifying categorical multivariate data', *Psychometrika*, **50**, 91–119.
Ter Braak, D. J. F. 1983. 'Principal components biplots and alpha and beta diversity', *Ecology*, **64**, 454–462.
Welcomme, R. L. 1985. 'River fisheries', *FAO Tech. Pap.*, **262**, FAO, Rome.