Bull. Fr. Pêche Piscic. (1995) **337/338/339** : 241-247

MICROHABITATS UTILISÉS PAR LES ALEVINS 0^+ D'UNE COMMUNAUTÉ DE CYPRINS RHÉOPHILES : ANALYSE DE L'ÉVOLUTION DE LA COMMUNAUTÉ ET DES DENSITÉS DE POPULATION.

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RÉSUMÉ

L'évolution de l'occupation des microhabitats par les alevins de la communauté de cyprins rhéophiles de l'Ourthe a été étudiée au cours de l'été et de l'automne 1994 par échantillonnage ponctuel d'abondance (électrodes fixes prépositionnées, courant continu). 16155 poissons (10-75 mm) appartenant à 15 espèces ont été recensés sur 78 sites d'échantillonnage de 2 m^2. Les espèces les plus représentées étaient *Leuciscus cephalus*, *Leuciscus leuciscus* et *Chondrostoma nasus* (respectivement 43,6 %, 20,7 % et 16,7 % des captures estivales). L'analyse factorielle des correspondances d'une matrice site x (espèce x taille) met en évidence une subdivision progressive de la communauté au cours de l'été en espèces d'eau vive (*B. barbus* et *L. leuciscus*) et d'eau lente, davantage associées à un couvert végétal (*L. cephalus* et *C. nasus*). La densité maximale observée (fin juin) est de 1500 alevins (25 mm) m^{-2}, correspondant à une biomasse de 250 g m^{-2}. Le modèle explicatif de la densité généré par analyse de régression multiple pas-à-pas explique 60,0 % de la variabilité de la densité par les variables vitesse de courant, température de l'eau et date d'échantillonnage, cette variable intégrant le concept de mortalité-dispersion au cours de la saison de croissance. Les implications de la méthodologie et des résultats présentés au plan de la gestion des écosystèmes lotiques sont brièvement discutés.

Mots-clés : alevins 0+, cyprinidés rhéophiles, échantillonnage ponctuel d'abondance, pêche à l'électricité, Bassin de la Meuse.

MICROHABITAT USED IN A 0^+ RHEOPHILOUS CYPRINID ASSEMBLAGE : QUANTITATIVE ASSESSMENT OF COMMUNITY STRUCTURE AND FISH DENSITY.

ABSTRACT

DC electrofishing frames (2 m^2) were used to study the evolution of fish density and habitat use by the 0^+ rheophilous cyprinid community of the River Ourthe (barbel zone) in summer-autumn 1994. 16155 0^+ fish (10-75 mm) belonging to 15 species were captured at 78 sampling sites. The most frequently encountered species were *Leuciscus cephalus*, *L. leuciscus* and *Condrostoma nasus* (respectively 43.6, 20.7 and 16.7 % of summer captures). Correspondence analysis of the site-by-species x size matrix showed a progressive shift along the time axis and subdivision of the community into running water fish (*Barbus barbus*, *L. leuciscus*) and more phytophilous species preferring smooth substratum (*L. cephalus* and *C. nasus*). Densities as high as 1500 25-mm fish m^{-2} were recorded in late June, corresponding to a biomass of approximately 250 g m^{-2}. A stepwise multiple-regression model accounted for 60.0 % of the variation of fish density, based on velocity, water temperature and sampling date, the latter variable integrating the dispersion-mortality concept into the model. Implications of the methodology and results on a river management scale are briefly discussed.

Key-words : young-of-the-year, rheophilous cyprinids, electrofishing, point abundance sampling, River Meuse Basin.

INTRODUCTION

Since the mid 1980s, increasing attention has been given to 0^+ non-salmonid fish communities as functional describers of long-term ecological quality and carrying capacity for spawning guilds (COPP *et al.*, 1991). Most efforts were focused on lowland rivers and especially on backwater biotopes (side arms, dead arms or oxbows) or riparian ecotones which are strongly affected by regulation in such rivers (COPP, 1990 ; SCHIEMER & ZALEWSKI, 1992). Paradoxically, less attention has been paid to streams and rivers of the barbel zone, which support rheophilous fish assemblages and are increasingly threatened by hydraulic management (dredging of gravel bars) for flood control. Similarly, most studies addressed empirical or semi-quantitative approaches of the 0^+ fish community in respect to habitat variables, due to the inherent difficulties (depth, turbidity, muddy substratum) of estimating parameters such as fish density. Contrary to phytophilous and lentic species (e.g. *Rutilus rutilus* ; *Perca fluviatilis*), 0^+ rheophilous cyprinids (e.g. *Barbus barbus, Leuciscus cephalus, L. leuciscus, Chondrostoma nasus*) are known to live in shallow microhabitats (e.g. COPP, 1992). These species may thus be more prone for quantitative sampling with DC electrofishing in prepositioned frames (BARAS, 1995) and represent favourable targets for density assessment. The objectives of this preliminary study were : 1) to evaluate the evolution of habitat utilisation by 0^+ rheophilous cyprinid assemblage of the River Ourthe (R. Meuse Basin, Southern Belgium) during the growth period and 2) to generate quantitative models accounting for the variations of 0^+ rheophilous-lithophilous cyprinid density.

MATERIAL AND METHODS

Study site

Sampling was conducted from late June to mid-October 1994 in two lotic stations (100 m long) of the River Ourthe (50°32'30" N, 5°35'00" E ; 13 km upstream from confluence with the R. Meuse in Liège) which are typical of the lower barbel zone (river width : 30-50 m ; maximum depth : 1.5 m ; mean slope : 1.3 ‰ ; mean water temperature in July : 19.2 °C ; records 1989-1994). Each station encompassed a major spawning ground for lithophilous species (available spawning areas : 350 and 450 m^2). The 0^+ fish assemblage was mainly represented by rheophilous-lithophilous, accompanying and lentic phytolithophilous cyprinids (Table I). The water level remained low with little fluctuation (± 8 cm) throughout the sampling season.

Methodology

Electrofishing is one of the most efficient methods to sample fish - even when dealing with small individuals (COPP & PENAZ, 1988) - except for fright bias, which can be substantially reduced through the use of prepositioned electrodes (BAIN *et al.*, 1985 ; review in COWX & LAMARQUE, 1990). When using direct current, the galvanotaxis area may be estimated from conductivity, voltage and anode size, though variables such as fish species, size or orientation towards the anode may further affect the catchability of fish.

The sampling methodology used in this study relied on DC electrofishing frames that combine the advantages of direct current (galvanotaxis) and electric barriers to discriminate between fish originating from inside and outside of the frame (BARAS, 1995). Each frame encompassed a 2 m^2 homogeneous microhabitat whose perimeter was delimited by a closed cathode (steel bars 2.0 x 0.3 cm), with a 0.04 m^2 steel plate anode placed in its centre. Due to avoidance behaviour of young fish towards the regular surface of the electrodes, both the anode and cathode were camouflaged in the substratum layer. The installation of the frame was completed within 5 min. Feasibility studies conducted in 1993 showed that the recolonisation of the sampling area by YOY averaged 6.5 min and never exceeded 15 min (BARAS, 1995). The voltage, size of anode and distance between anode and cathode influenced both straying and mortality rates, the best compromise (straying and mortality < 5 %) being obtained for the configuration mentioned above, powered by a DC generator (EPMC, 240 V). The frame remained energetised until the last fish was captured to prevent any escape from the sampling site. All sites were sampled on dry days at times of the day when 0^+ fish density within a microhabitat showed little hourly variation (10h00-17h00 GMT +2).

Tableau I : **Caractéristiques des sessions d'échantillonnage dans l'Ourthe en 1994 : régime thermique, nombre de sites échantillonnés par électrodes fixes (2 m^2, courant continu), effectifs et tailles des poissons 0+ capturés. Espèces peu représentées (non illustrées) : *Cottus gobio, Thymallus thymallus, Perca fluviatilis* et *Lempetra fluviatilis.***

Table I : **Characteristics of the sampling sessions conducted during summer and autumn 1994 in the River Ourthe : water temperature, number of sites sampled with 2 m^2 DC electrofishing frames, number and size of 0+ fish captured (most represented species). Species poorly represented : *Cottus gobio, Thymallus thymallus, Perca fluviatilis* and *Lampetra fluviatilis.***

	24 & 28Jun	14 Jul	04 Aug	17 Aug	07 Sep	26 Sep	19 Oct
Water T° (°C) Daily min-max	18.9-24.9	21.0-23.5	20.4-25.9	16.0-17.6	13.8-14.0	12.8-15.4	6.6-8.4
Sampling sites (N)	8	8	12	12	13	12	13
Null samples (N)	0	1	2	3	2	3	6
Fish/site (min-max)	72-3044	0-241	0-300	0-521	0-142	0-119	0-2882
Total N 0^+ fish	8858	747	1507	1075	417	528	3023
Biomass (g)	1689	160	664	601	335	426	2665
B. barbus N	11	19	117	47	7	6	3
FL (mm) (min-max)	(16-20)	(15-31)	(21-56)	(30-64)	(42-57)	(43-62)	(43-49)
Fish/site (min-max)	0-5	0-6	0-66	0-24	0-3	0-4	0-2
L. cephalus N	4826	297	226	118	99	163	1196
FL (mm) (min-max)	(16-39)	(10-43)	(16-51)	(26-49)	(20-47)	(18-48)	(31-60)
Fish/site (min-max)	1-2873	0-105	0-116	0-75	0-38	0-71	0-1184
L. leuciscus N	1766	125	496	164	109	63	57
FL (mm) (min-max)	(21-36)	(25-49)	(31-69)	(42-67)	(48-75)	(45-75)	(51-73)
Fish/site (min-max)	0-994	0-42	0-116	0-72	0-58	0-86	0-34
C. nasus N	1704	56	42	38	167	178	439
FL (mm) (min-max)	(16-30)	(22-44)	(34-54)	(32-57)	(26-59)	(28-58)	(40-57)
Fish/site (min-max)	0-595	0-21	0-10	0-14	0-117	0-86	0-424
G. gobio N	61	49	149	159	1	12	75
FL (mm) (min-max)	(13-26)	(12-32)	(22-51)	(29-52)	(59)	(29-65)	(38-58)
Fish/site (min-max)	0-27	0-42	0-131	0-108	0-1	0-3	0-71
P. phoxinus N	303	108	7	40	17	19	156
FL (mm) (min-max)	(13-23)	(10-27)	(13-38)	(28-42)	(25-40)	(30-45)	(28-51)
Fish/site (min-max)	0-112	0-58	0-3	0-35	0-9	0-11	0-156
R. rutilus N	9	78	81	16	1	74	256
FL (mm) (min-max)	(15-17)	(14-33)	(24-42)	(27-53)	(39)	(27-55)	(35-54)
Fish/site (min-max)	0-8	0-30	0-58	0-5	0-1	0-25	0-223
A. alburnus N	30	3	376	450	0	1	275
FL (mm) (min-max)	(16-27)	(16-17)	(20-33)	(23-40)	(-)	(39)	(32-51)
Fish/site (min-max)	0-15	0-3	0-263	0-402	0-0	0-1	0-253
G. aculeatus N	86	2	0	0	16	3	0
FL (mm) (min-max)	(11-22)	(13-13)	(-)	(-)	(38-43)	(37-48)	(-)
Fish/site (min-max)	0-82	0-2	0-0	0-0	0-12	0-2	0-0
N. barbatulus N	45	8	11	25	0	3	2
FL (mm) (min-max)	(12-28)	(32-40)	(40-45)	(40-58)	(-)	(53-63)	(53-61)
Fish/site (min-max)	0-21	0-3	0-5	0-17	0-0	0-2	0-2
A. bipunctatus N	0	0	2	1	0	0	556
FL (mm) (min-max)	(-)	(-)	(32-43)	(40)	(-)	(-)	(32-52)
Fish/site (min-max)	0-0	0-0	0-2	0-1	0-0	0-0	0-553

Immediately after capture, each microhabitat was characterised from five randomly distributed measure points. Depth was measured to the nearest 0.5 cm, water velocity on the substratum and at the surface of the water to the nearest cm s^{-1} with a magnetic current meter (MARSH MCBIRNEY, model 201) and water temperature to the nearest 0.1 °C, both in the sampling site and in the main stream (velocity $\geq$ 50 cm s^{-1}). Vegetation cover was estimated (10 % steps) and substratum characterised according to a WENTWORTH index. All fish were identified, counted and a sample of 50 fish was measured (fork length, FL) for each species when the number of fish captured exceeded this value. All surviving fish (5-10 % mortality) were released nearby their capture site.

Data processing

The structure and evolution of the fish community was assessed by correspondence analysis of the site-by-species matrix using ADECO on Macintosh (CHESSEL & DOLEDEC, 1992). Each case of the contingency table corresponded to the number of fish belonging to given species and size class captured within a sampling site. Seven size classes (10 mm interval ; class 1 = 5-14 mm) were taken into account. Rare species - captured at less than five sites or representing less than 0.5 % of the total number - were eliminated from the original matrix which was further reduced to non-null samples only. Stepwise multiple-regression analyses were used to generate explicative models of fish density, based on habitat variables, physical variables (temperature, thermal gradient), time of the year and their Log and $x^{(n)}$ transformates. Mean fish size at the time of the year were also entered as independent variables for specific models since size may affect density of space utilisation. The last sampling session (October 1994) was withdrawn from the quantitative analyses, due to its low thermal regime, well below summer temperatures and probably below the activity limit for most 0^+ fish, a parameter that possibly affects their propensity to aggregate .

RESULTS AND DISCUSSION

Community structure and evolution

16155 0^+ fish belonging to 15 species were collected during the study period (61 out of 78 sampling sites containing at least one fish). Most null samples corresponded to high water velocity riffles or deep habitats ($\geq$ 50 cm) where 1+ or older fish were captured, except for the last sampling session when six of 13 sites were empty and four others with five 0^+ fish or less. Except for *Leuciscus leuciscus*, the size distribution of 0^+ cyprinids captured (10-75 mm) encompassed all post-larval stages until the wintering size (Table I). The highest densities were recorded in early summer, with two shallow sites (depth : 8-12 cm) exceeding 1000 fish m^{-2} (mean size : 24-26 mm), corresponding to a biomass of 224-253 g m^{-2} (Table I). The highest biomass (1230 g m^{-2}) was found on October 19, with 2882 fish (mean size : 43 mm) gathered in a 2 m^2 shelter consisting of submerged ligneous riparian vegetation, probably corresponding to an overwintering refuge. *Leuciscus cephalus*, was the most frequently encountered species and had the highest propensity to aggregate, both in summer and in early autumn. Similar tendencies were observed in *Leuciscus leuciscus* and *Chondrostoma nasus*. The two other rheophilous cyprinids (*B. barbus* and *Alburnoides bipunctatus*) were more rare and dispersed — except for *A. bipunctatus* in autumn — possibly due to unfavourable thermal conditions following their first spawning in early May 1994 (mean T° = 13.9 °C) that negatively affected recruitment. Accompanying cyprinids (*Gobio gobio*, *Phoxinus phoxinus*) spawning in the same season were also relatively rare. The phytolithophilous cyprinids *Rutilus rutilus* and *Alburnus alburnus* were also less abundant and typical phytophilous species (*Tinca tinca*, *Cyprinus carpio*) were absent from the sampling sites, mainly due to the paucity of potential spawning sites. *Thymallus thymallus*, *Perca fluviatilis*, *Cottus gobio* and *Lampetra planeri* were occasionally encountered (total amount < 5). The only non-cyprinid species represented in more than five samples were *Noemacheilus barbatulus* and *Gasterosteus aculeatus*.

From the material collected, a contingency matrix of 61 non-null samples x 43 size-species categories was created. Three eigen vectors were retained from the variance table (Figure 1), of which axis 2 was almost exclusively correlated with time of the year.

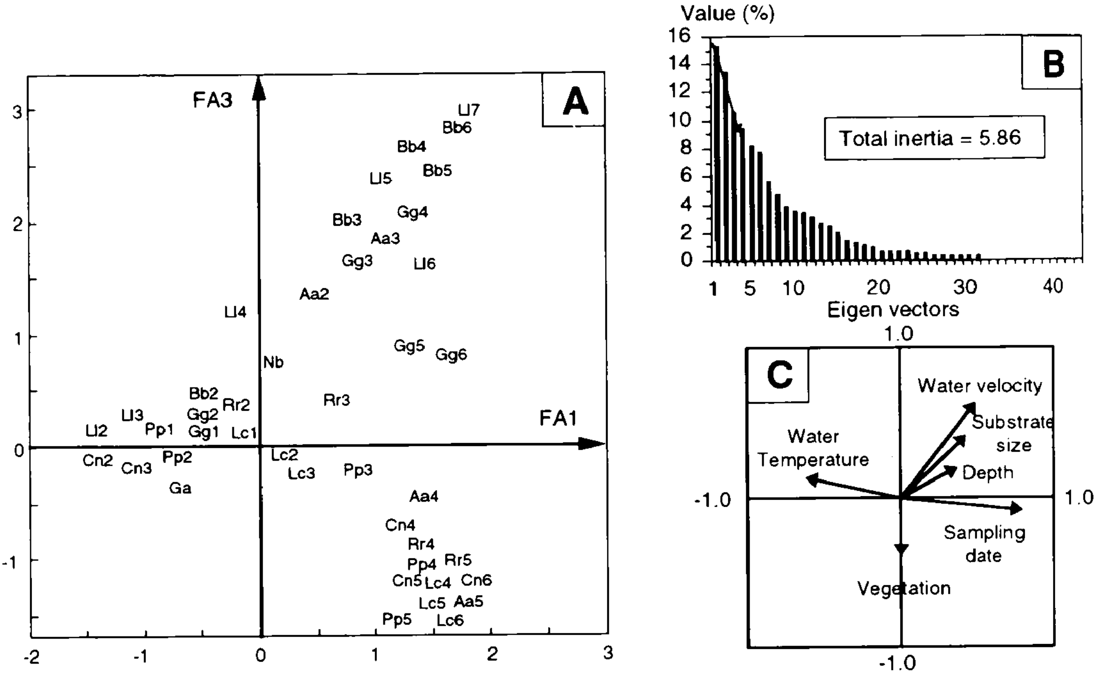

Figure 1: A. Analyse factorielle des correspondances sur les 10 espèces de poissons O+ les mieux représentées. B. Valeurs propres, exprimées en % de l'inertie totale. C. Coefficients de corrélation des variables environnementales avec les axes factoriels 1 et 3.

Aa, *Alburnus alburnus* ; Bb, *Barbus barbus* ; Cn, *Chondrostoma nasus* ; Ga, *Gasterosteus aculeatus* ; Gg, *Gobio gobio* ; Lc, *Leuciscus cephalus* ; Ll, *Leuciscus leuciscus* ; Nb, *Noemacheilus barbatulus* ; Pp, *Phoxinus phoxinus* ; Rr, *Rutilus rutilus*. 1-7, classes de tailles : 1 = 5-14 mm, 2 = 15-24 mm, ... 7 = 95-75 mm.

Figure 1 : A. Correspondence analysis biplot for the 10 most represented 0+ fish species. B. Eigen values expressed as % of total variance. C. Correlation coefficients of environmental variables with axes 1 and 3.

Aa, *Alburnus alburnus* ; Bb, *Barbus barbus* ; Cn, *Chondrostoma nasus* ; Ga, *Gasterosteus aculeatus* ; Gg, *Gobio gobio* ; Lc, *Leuciscus cephalus* ; Ll, *Leuciscus leuciscus* ; Nb, *Noemacheilus barbatulus* ; Pp, *Phoxinus phoxinus* ; Rr, *Rutilus rutilus*. 1-7, size classes : 1 = 5-14 mm, 2 = 15-24 mm,... 7 = 65-75 mm.

Therefore, a biplot along axes 1 and 3 was preferred (Figure 1). The major gradient (axis 1) was regarded as the time axis, with increasing scores for fish of increasing size and age. Axis 3 corresponded predominantly to an inverse gradient from open habitats to "closed" environments with high vegetation cover. Depth, substratum size and water velocity were positively correlated with both axes. In early summer, all 0^+ fish were encountered in multispecific shoals in shallow, calm and warm microhabitats, along the edges of gravel bars corresponding to mid-spring spawning grounds. During summer, barbel and dace progressively colonised microhabitats of increasing depths and velocities, with coarser substratum. Chub, nase, roach, minnow and to a lesser extent bleak selected lentic microhabitats characterised by the presence of vegetation and smooth substratum (e.g. chub Lc1 to Lc6 had similar scores along the substratum axis; Figure 1 C). This evolution and subdivision of the community was interpreted as an ontogenetic shift along increasing trophic specialisation towards insectivorous *(L. leuciscus, B. barbus)*, herbivorous *(C. nasus)* and omnivorous feeding guilds *(L. cephalus)*.

Tableau II : Analyses par régression multiple pas-à-pas de la densité d'utilisation de l'habitat par les poissons 0+. Variables explicatives présentées par ordre d'entrée dans les modèles.

Table II : Stepwise multiple-regression analyses on fish density based on environmental and habitat variables. Variables presented in order of appearance in the models.

A Variable: Log (1+N 0^+ fish sampling site^{-1}) (all species)

F = 30.72 R^2 = 0.600 DF = 64 P < 0.001

Independent variable	Coefficient	Std Error	t	P
Intercept	12.420			
Water velocity (surface, cm s^{-1})	-0.017	0.004	-5.85	0.0001
Log (time, Julian days)	-4.530	1.470	-3.08	0.0084
ΔT° vs stream (°C)	0.890	0.060	2.39	0.0106

B Variable: Log (1+N 0^+ chub *L. cephalus* sampling site^{-1})

F = 37.27 R^2 = 0.650 DF = 64 P < 0.001

Independent variable	Coefficient	Std Error	t	P
Intercept	10.450			
Log (substratum size) (mm)	-0.510	0.070	-7.41	0.0001
Log (time, Julian days)	-3.900	1.260	-3.11	0.0029
ΔT° vs stream (°C)	0.114	0.055	2.06	0.0432

C Variable: Log (1+N 0^+ nase *C. nasus* sampling site^{-1})

F = 22.46 R^2 = 0.600 DF = 64 P < 0.001

Independent variable	Coefficient	Std Error	t	P
Intercept	22.560			
Water velocity surface (cm s^{-1})	-0.009	0.002	-3.91	0.0002
ΔT° vs stream (°C)	0.070	0.062	4.36	0.0001
Log (time, Julian days)	-8.400	2.010	-4.17	0.0001
Water T° microhabitat (°C)	-0.108	0.030	-3.59	0.0087

D Variable: Log (1+N 0^+ dace *L. leuciscus* sampling site^{-1})

F = 9.77 R^2 = 0.400 DF = 64 P < 0.001

Independent variable	Coefficient	Std Error	t	P
Intercept	-0.300			
Water T° microhabitat (°C)	0.065	0.016	4.12	0.0001
Water velocity surface (cm s^{-1})	-0.012	0.003	-3.64	0.0006
Log (substratum size) (mm)	0.186	0.091	2.04	0.0461
Log (1+ % vegetation cover)	-0.259	0.132	-2.01	0.0493

The positions of the taxa along the temperature axis suggested that the most thermophilous species was *L. leuciscus* whereas *G. gobio* preferred lower temperatures, confirming the results obtained by COPP (1992) in a lowland river catchment. The apparently less thermophilous status of species preferring vegetation cover - e.g. *P. phoxinus* - probably emerged as a direct consequence of the shading by vegetated areas along the banks.

Quantitative models

These interpretations were further substantiated by the models of fish density for the three most widespread species (Table II B, C, D) : the density of dace was negatively correlated with increasing proportion of fine substratum and vegetation cover, whereas the presence of chub or nase was favoured in such microhabitats. With regard to thermal preferences, the three species aggregated in larger amounts in shallow microhabitats with high temperatures, a phenomenon interpreted as a strategy aimed at decreasing the hazards of predation by larger fish while exploiting habitats with high productivity. Nase emerged as less thermophilous than the two other species (negative correlation with water temperature). Chub and nase densities decreased throughout the season, possibly reflecting high mortality patterns. By contrast, the density of dace was not significantly affected by time-related variables, probably because the sampling period started at a time of the year when young 0^+ dace had already gone through their most critical period.

The model for overall fish density per sampling site accounted for 60 % of variance and revealed the overhang influence of low water velocity - related with the limited swimming capacities of young fish - and high water temperature (Table II A). The integration into the model of a time-related variable in its logarithmic transformate probably reflected fish mortality that progressively decreased as juvenile fish grew, along with higher swimming capacities or possibilities of escaping predator attacks. The rather high r^2 for such a model probably arose from 1) the 0^+ fish assemblage being dominated by few species (dace, chub and nase representing 81 % of the total amount of fish captured in summer and early autumn), 2) the very large samples provided by the methodology in use and 3) the absence of major variation of water level - and possible increased drift of 0^+ fish - during the study period.

CONCLUSIONS

This study of the fish community in the River Ourthe provided a preliminary description of the evolution of the 0^+ cyprinid assemblage throughout the growth period. With regard to river management, the results emphasised the importance of the edges of gravel bars as nurseries for young 0^+ cyprinids and the necessity to maintain a minimum habitat diversity for older individuals (small riffles, riparian ecotones, lentic areas) to ensure a balanced fish community. From a methodological point of view, this study showed the suitability of DC electrofishing frames to address high fish densities and the possibility to generate confident figures entering quantitative models. Due to the strong dependence of fish density upon spawning success, these models can not be used directly to predict densities. However they can be used as a reference basis to assess in a more quantitative way the success of spawning and recruitment in various sites or at various times of the year (incidence of spates, dredging, quality or carrying capacity of spawning grounds,...).

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