Effects of a micro hydroelectric power plant upon population abundance, mobility and reproduction behaviour of European grayling *T. thymallus* and brown trout *S. trutta* in a salmonid river

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ABSTRACT: This study examines the potential effects of a new micro hydroelectric power plant (MHPP) on the behaviour (habitat use, movements) and population abundance of European grayling (*T. thymallus*) and brown trout (*S. trutta*) in the Lhomme (Belgian Ardennes). Thirteen grayling and five brown trout were captured before their spawning period and were manually radio-tracked up to 6 times a week. Population density and biomass were estimated into two different sampling sectors with electric fishing, before and after the MHPP started up. The mobility patterns of grayling and trout in the reach of the river Lhomme influenced by the MHPP strongly contrasted with results obtained in an undisturbed river of the same type in the Belgian Ardennes. Movements were mostly restricted and rarely increased during the spawning period. Spawning took place, but was disturbed by hydropeakings. The population biomass of grayling and trout decreased by 61 % and 23 % respectively, five months after the start-up of the MHPP exploitation.

1 INTRODUCTION

Into by-passed stream sections, suitable habitat availability for fish was directly related to the amount of water released after hydro-electricity production (Reiser et al., 1989; Valentin et al., 1994; Bunt et al., 1999). When hydro-peakings occurred in a by-passed stream section fish populations have to adapt them to disturbance and variability associated with fluctuating flows (Power et al., 1988; Bunt et al., 1999). The effects of flow regulation on habitat use of different life stages and changes in population structure were intensively studied on salmonids in the last 15 years (Bain et al., 1988; Nestler et al., 1989; Valentin et al., 1994, Gouraud et al., 2001). Using electric fishing sampling as well as habitat and population dynamic models, studies showed highly site-specific results with different kinds and degrees of impact on resident fish populations.

Some authors have suggested that hydro-peaking may be less supported by trout than by grayling, as the latter showed more flexible requirements, segregate than trout, and were not as closely attached to instream cover (Vehanen et al., 2003). More recently, telemetry studies enabled to assess differently the habitat preferences and the movements of adult brown trout and European grayling in streams. Studies in an artificially modified river demonstrated a limited influence of hydro-peaking on habitat use (Bunt et al., 1999; Vehanen et al., 2003). However, to date, no study exists on how fish are able to deal with the transition between the feeding and growth phases and the reproduction period downstream a MHPP. Hydropeaking is associated with damming and artificial changes of environmental variables that may influence the reproductive behaviours of the two species**.** Indeed, the MHPP could disturb the fish in their perception of environmental stimuli that trigger migration (e.g., temperature and water levels). Moreover, a low water level could prevent their clearing capacities of physical obstacles while migrating upstream (Ovidio et al., 1998 and 2004 Ovidio & Philippart, 2002).

The aims of this study were (1) to examine the influence of a new MHPP on population abundance, mobility and reproduction behaviours of adult brown trout and European grayling in the river Lhomme, and (2) to compare these biological variables with those collected in similar and undisturbed rivers of the Belgian Ardennes.

2 METHODS

The study was conducted, in the Lhomme, a tributary of the Lesse in the River Meuse basin. The water quality of the Lhomme is excellent and its mean daily temperature ranges from 0.6 to 21.4 °C (mean 10.0 °C) (data from February 2002 to February 2003). The mean annual flow in Grupont (10.3 km downstream of the study site) is 2.7±1.5 $m^3.s^{-1}$ (data 1994-2002, DGRNE Water-division). The stream

slope in the study section is 1%. In the study site, the fish assemblage is typical of the grayling zone (Huet, 1949) and is composed of brown trout *S. trutta*, grayling *T. thymallus* and small-bodied species (bullhead *Cottus gobio*, river lamprey *Lampetra planeri* and stone loach *Barbatula barbatula*).

The MHPP "Louis Zoude" started up in January 2003 and is likely to produce 900,000 KW per year. This MHPP is located downstream four other MHPPs in the main course of the Lhomme (figure 1). The new MHPP exploitation bypass the river over a length of 1.2-km (12 m of fall), and is configured as presented on figure 1. The minimum flow allowed in the shorted-circuited stretch is currently fixed at 0.220 $m^3.s^{-1}$ (1/10 of the mean annual discharge).

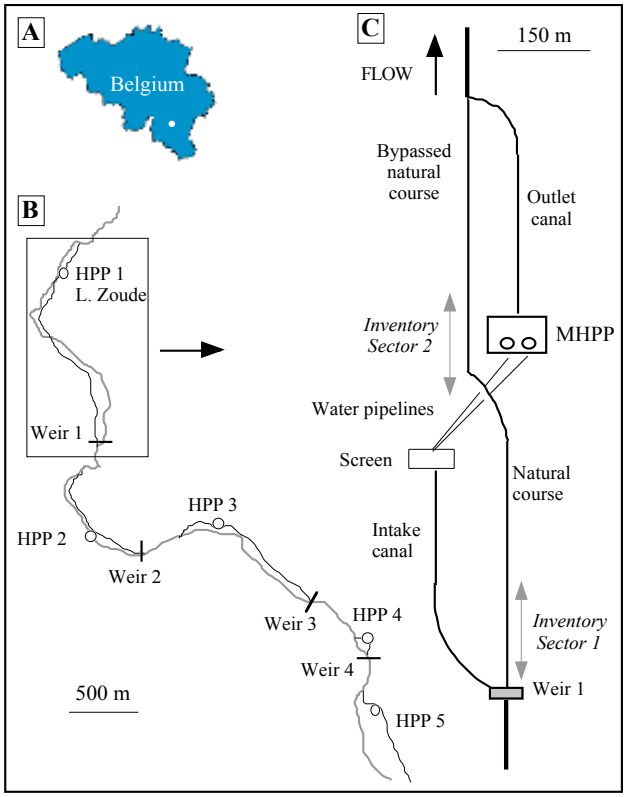
Before the construction of the MHPP, two 150 m-long sectors of the Lhomme were selected to estimate their total fish population abundance (figure 1). Sector 1 is located downstream the intake weir. It's a linear riffle section characterised by an abundance of instream cover (roots and large rocks). Sector 2 is characterised by the presence of a deep run and less instream cover. A first electric removal fishing was carried out into each of both sectors on 23 April 2002 with two successive passages with three electrodes. The second inventory was carried out on 6 May 2003 (5 months after the start-up of the MHPP), using exactly the same methodology. Fish to be used for radio-tracking were captured during three electric fishing sessions performed in the bypass section and in the outlet canal before their spawning period. N=13 grayling were captured on 11 February or 18 March 2003 and were tracked until 30 June 2003. N=5 brown trout were captured on 7 October 2003 and were tracked until 15 March 2004 (table 1). Radio transmitters (internal coiled antenna, 3.3 to 6.0 g) were implanted according the methodology used by Ovidio & Philippart (2002).

Table 1: characteristics of the tracked grayling and trout.

Species (n) (sexes)	FL (mean±SE) min-max (mm)	Weight (mean±SE) min-max (g)
grayling (n=13) (12 M - 1 F)	293.0 ± 5.4 261-328	260.8 ± 20.3 209-315
trout (n=5) (2 M - 3 F)	285.4 ± 8.5 263-311	257.3 ± 15.7 170-338

Fish were released at their capture site as soon as they had recovered posture and spontaneous swimming. During the pre-spawning and spawning season, fish were located at least three times per week and sometimes every day. Outside the spawning period, they were located at least one time per week until the end of the transmitter battery life or loss of the signal. Locations were made by biangulation using a mobile FieldMaster radio receiver and a loop antenna (ATS inc. Corp.). Water temperature was recorded every hour using data loggers (Onset Corp.®). Water flow of the Lhomme was recorded continuously at Grupont gauging station (data from DGRNE water division).

Figure 1. Study site. A. Belgium. B. Location of the five MHPPs in the Lhomme. C. New Louis Zoude MHPP.



3 RESULTS

3.1 Population abundance

The evolution of the population abundance between April 2002 and May 2003 is presented in table 2. Rainbow trout (159±0.83 mm LF) escaped from a fish farming a few days before the inventory and colonized the study site. They were not taken into account in the results presented on table 2 (all sp.).

Table 2: changes in fish abundance in the bypassed section of weir 1 (L.Zoude) in Lhomme between April 2002 (before start-up of the MHPP) and May 2003 (5 months after start-up of the MHPP).

	Biomass sector 1 (g)			**Biomass sector 2 (g)**		
	2002	2003	Change	2002	2003	Change
Trout	6612	4749	-29%	8490	7002	-17%
Grayling	3877	533	-86%	7726	4912	-36%
All sp.	15731	9236	-41%	19714	14360	-27%
	Number of fish sector 1			**Number of fish sector 2**		
	2002	2003	Change	2002	2003	Change
Trout	126	73	-42%	162	103	-36%
Grayling	37	6	-83%	52	39	-25%
All sp.	527	241	-54%	391	240	-39%

After the start-up of the MHPP exploitation, the population of brown trout and grayling decreased in each sector. Changes were more substantial in sector 1 with a decline of more than 80% of grayling population. When considering all the species (n=13 sp.) living in the Lhomme, results also showed abundant decline of the overall fish community. Contingency tables indicated a significant change of repartition of the number of grayling ($p<0.001$, $\chi^2=10.94$) and of all species ($p<0.01$, $\chi^2=6.78$) between sector 1 and 2 and between 2002 and 2003.

3.2 Fish movements and reproduction

From 12 February to 30 May 2003, the tracked grayling occupied total longitudinal home ranges from 50 to 665 m. Mobility of grayling was relatively homogenous throughout these months and movements to reach spawning areas were not longer and different than those observed outside the spawning period (table 3). Grayling never cleared the intake weir of the MHPP. Tracked individuals used three spawning grounds. Two were located in the by-passed section of the river and the third downstream in the natural part of the Lhomme. Spawning was observed between 22 March and 4 April 2003 when mean daily water temperature ranged from 6.3 to 10.0 °C. Most tracked grayling were observed spawning. Reproduction behaviours of tagged and untagged individuals were sometimes disturbed and stopped by rapid hydropeakings, especially in a spawning area situated near the confluence between the MHPP outlet and the Lhomme (fig. 1). In this area, artificial changes in water level in the by-passed section and the outlet canal caused inversion of water flow direction and drying of the spawning grounds.

Table 3: Longitudinal home ranges of the tracked fish during and outside the reproduction period

	Longitudinal Home Ranges (m)		
Species	No reproduct. mean±SE (min-max)	Reproduction mean±SE (min-max)	Total mean±SE (min-max)
Grayling	303±58 (50-540)	221±70 (45-535)	343±61 (50-665)
Trout	218±108 (12-531)	900±386 (283-2400)	914±397 (288-2458)

After radio-tagging, trout remained most of the time in the pool-riffle sequence at which they had been captured and movements mainly consisted of changes of residence areas spaced-out over several meters. Between 17 and 20 November 2003, during an increase in water flow and temperature, three female trout started their spawning movements. The first migrated 2.5 km upstream in 4 days and successively cleared the intake weir of the "Louis Zoude" MHPP and the MHPP N°2 (figure 1). This trout stayed in a potential spawning area until 24 December 2003 and finally homed to its capture place in late December. A second moved 700 m downstream and stayed in this area until the end of the tracking period. The third moved 400 m upstream for several days and homed to its main residence in late November. The two males never really migrated to spawn. Spawning grounds were detected in different parts of by-passed section into Lhomme, but no spawning behaviour was observed.

4 DISCUSSION

4.1 Population abundance

The quantitative fish inventory performed five months after the start-up of the new MHPP revealed a reduction of fish population in comparison with the inventory performed one year before. Biomass of brown trout and grayling decreased by 23% and 61% respectively. The total fish population biomass showed a decline of 34%. In the Aisne, between 2002 and 2003, biomass of both trout and grayling decreased of 1% (Philippart, pers. comm.) In the Lhomme, the prevalent consequence of the exploitation of the MHPP is an artificial persistence of low flow during the entire annual cycle, causing numerous available refuges in the undisturbed riverbed remaining emerged throughout most of the year. In such a flow regime, the stability of the ecosystem is mostly conditioned by the availability of refuges (Sedell et al., 1990; Lancaster & Hidrew, 1993; Valentin et al., 1994) and this is consistent with the observed diminution of fish population biomass in the Lhomme. However our results indicated that grayling might be more affected by the MHPP exploitation than brown trout, contrary to what has been proposed by other authors (Henricson, 1984; Gönczi et al. 1986; in Vehanen et al., 2003) Our results remain preliminary and give a first general tendency of the evolution of the fish population that needs to be completed by further inventories (at least 5 years).

4.2 Fish movements and reproduction

Outside the spawning season, movements patterns and habitat use by radio-tracked grayling were similar to those observed in the Aisne, an undisturbed salmonid river of the Belgian Ardennes (Ovidio et al., 2004). When considering the entire tracking season (February to May), they travelled homogenous distances, occupied home ranges of max. 665m and never realised long range spawning migrations. These observations contradict op cit. studies in the Aisne, showing that most genitors migrated to spawn and travelled mean distances of 1.2 km (max. 4.9 km) to reach their spawning areas. In the river

Ilmenau (Germany), Meyer (2001) observed mean upstream migration of 8.2km (max. 11.3 km). However, in the Lhomme, most of the grayling spawned and the timing and progress of reproduction behaviour were quite similar to those observed in other studies and occurred in similar habitats. Grayling tagged in the bypassed part of the Lhomme seemed able to find there all their biological requirements.
Outside the spawning period, brown trout behaved similarly to what was observed in the Aisne and occupied aletrnatively several residences areas spaced-out over several meters (Ovidio et al., 1998). But during the spawning season, movements of the radio-tracked individuals were quite limited. Despite the fact that one individual migrated 2.4 km to spawn and cleared two physical obstacles, the mean distances travelled for spawning (mean 0.5 km) was much lower to those observed by telemetry studies in undisturbed rivers of the same basin (8.5 km, in the Aisne, 23.2 km in the Ourthe, Ovidio & Philippart 2002). Whereas spawning in tributaries is frequent in other rivers, trout in this part of the Lhomme never did it. But as was observed for grayling, spawning occurred and was triggered by environmental conditions similar to those in other studies (Ovidio et al., 1998).

4.3 Conclusion

Our preliminary results suggest that the exploitation of the new MHPP caused a reduction of the fish population in the by-passed section downstream weir 1 into Lhomme and resulted in restricted movements of brown trout and grayling during the spawning period. The first impact can be considered as a short-term effect, essentially due to the persistence of a low flow throughout most of the year and the associated diminution of available habitats. The second impact would probably be a long-term effect originating from the historic existence of four MHPPs and weirs in this section of the Lhomme that strongly complicate or prevent the upstream movements of genitors and the downstream drift of young-of-the-year in this part of the river. Hydropeaking also disturbed spawning activity of fish. If next monitoring confirms these observations, this may be considered as a major trouble in the population dynamics of brown trout and grayling and could have a negative impact on the genetic diversity of both species in the Lhomme.

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REFERENCES

Bain, M.B., Finn, J.T. & Booke, H.E., 1988. Streamflow regulation and fish community structure. *Ecology* 69, 382-392.

Bunt, C.M., Cooke, S.J, Katapodis, C. & McKinley, S. 1999. Movements and summer habitat of brown trout (*Salmo trutta*) below a pulsed discharge hydroelectric generating station. *Regulated Rivers: Research & Management* 15: 395-403.

Gouraud, V., Baglinière, J.L., Baran, P., Sabaton, C., Lim, P. & Ombredane, D., 2001. Factors regulating brown trout populations in two French rivers: application of a dynamic population model. *Regulated Rivers: Research & Management* 17: 557-569.

Huet, M. 1949. Aperçu de la relation entre la pente et les populations piscicoles des eaux courantes. *Schweiz. Z. Hydrol. 11: 332-351*.

Lancaster, J. & Hildrew, A., 1993. Characterising in-stream flow refugia. *Canadian Journal of Fisheries and Aquatic Sciences* 50: 1663-1675.

Meyer, L. 2001: Spawning migration of grayling *Thymallus thymallus* (L., 1758) in a Northern German Lowland river. *Archiv für Hydrobiologie*. 152: 99-117.

Nestler, J.M., Milhous, R.T. & Layzere, J.B., 1989. Instream habitat modelling techniques. In Gore, J.A. & Petts, G.E. (Eds), *Alternatives in regulated river Management*, CRC Press, Boca raton, FL, pp. 295-315.

Ovidio, M. Baras, E. Goffaux, D. Birtles, C. & Phillipart, J.-C., 1998. Environmental unpredictability rules the autumn migrations of brown trout (*Salmo trutta*) in the Belgian Ardennes. *Hydrobiologia* 371/372: 262-273.

Ovidio, M. & Philippart J.-C., 2002. The impact of small physical obstacles on upstream movements of six species of fish. Synthesis of a five years telemetry study in the River Meuse Basin. *Hydrobiologia* 483: 55-69.

Ovidio, M., Parkinson, D., Sonny, D. & Philippart, J.-C., 2004. Spawning movements of the European grayling Thymallus thymallus (L.) in the river Aisne (Belgium). *Folia Zoologica* 53, 87-98.

Power, M.E., Stout, R.J., Cushing, C.E., Harper, P.P., Haner, F.R., Matthews, W.J., Moyle, P.B., Statzner, B., and Wais de Badgen, I.R. 1988. Biotic and abiotic controls in river and stream communities, *Journal of the North American Benthological Society* 7 : 456-479.

Reiser, D.W., Wesche, T.A. & Estes, C., 1989. Status of in-stream flow legislation and practice in North America. *Fisheries*, 14: 22-29.

Sedell, R.J., Reeves, G.H., Hauer, F.R., Stanford, J.A. & Hawkins, C.P., 1990. Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. *Environmental Management* 14:711-724.

Valentin, S., Sempeski, P., Souchon, Y. & Gaudin, P., 1994. Short-term habitat use by young grayling Thymallus thymallus L., under variable flow conditions in an experimental stream. *Fisheries Management & Ecology* 1:57-65.

Vehanen, T., Huusko, A., Yrjäna, T., Lahti, M., Mäki-Petäys, A., 2003. Habitat preference by grayling (*Thymallus thymallus*) in an artificially modified, hydropeaking riverbed: a contribution to understand the effectiveness of habitat enhancement measures. *Journal of Applied Ichthyology* 19:15-2