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Use of stream mouth habitats by *Cottus perifretum* and *Leuciscus cephalus* along the River Meuse (the Netherlands)

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Abstract. Size-frequency data were collected for two rheophilic fish species, *Cottus perifretum* and *Leuciscus cephalus*, at the confluences of 18 lowland tributaries along the regulated River Meuse (the Netherlands) between May 2004 and April 2005. *Cottus perifretum* is a resident species, using these stream mouth habitats throughout its entire life: i.e. as a spawning, nursery and adult habitat. *Leuciscus cephalus* is a transient species that uses these stream mouth habitats only as a temporary 0+ juvenile habitat during fall and early winter. This study suggests that the stream mouth habitats along the River Meuse fulfil different ecological functions for *C. perifretum* and *L. cephalus*.

Key words: larvae, juveniles, nursery, resident, spawning, transient

Introduction

Over the last two centuries, extensive changes to the geomorphology of large lowland rivers in the Netherlands have resulted in a severe loss of habitat heterogeneity (Admiraal et al. 1993). Steepening and fortification of the river bank (to control bank erosion) together with continuous wave action (due to intense shipping traffic) have led to an increase in turbidity levels in the water column, a virtually complete absence of aquatic vegetation in the main channel, and have had a direct negative influence on the survival of fish eggs and larvae in the River Meuse (Admiraal et al. 1993, Arlinghaus et al. 2002, Wolter & Arlinghaus 2003). This, in turn, has led to a severe lack of spawning and nursery habitats, particularly for limnophilic and rheophilic fish species, in the River Meuse (Vriese et al. 1994). As a consequence, the fish fauna of the River Meuse in the Netherlands is currently dominated by eurytopic species (Van der Velde et al. 1990, Admiraal et al. 1993, Van den Brink et al. 1996, Raat 2001).

It has been argued that off-channel water bodies connected to the main channel, such as floodplain lakes (Grift et al. 2003), gravel pit lakes (Neumann et al. 1994), marinas (Copp 1997) or lowland tributary streams (Pollux et al. 2006), may function as alternative spawning and nursery areas for limnophilic and/or rheophilic fishes that lack suitable areas in the main channel of regulated rivers. In the Netherlands, the River Meuse is connected to over a 100 tributary streams (Maris et al. 2003). The confluences of these lowland tributaries with the main channel of the River Meuse (generally the last 100 to 200 meters before discharging into the river) have on average a width of 1-4 m and a depth of < 50 cm. Compared to the highly modified main channel of the River Meuse, these stream mouth areas are generally characterized by higher water velocities, a more heterogeneous and structurally complex habitat with diverse

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riverbed substrates (sand, pebbles, stones, bricks, logs), sparse patchy aquatic vegetation, (overhanging) riparian vegetation, clear and oxygen-rich waters and an absence of artificial migration barriers (Crombaghs et al. 2000). The conditions in these stream mouths suggest that these areas may offer suitable spawning and nursery areas to rheophilic fish species.

To date, little is known about the importance of these stream mouth habitats as alternative spawning and nursery habitats for rheophilic species. To gain a better insight into the ecological function of these stream mouth habitats, we studied the fish fauna at the confluence of 18 lowland tributaries along the River Meuse (the Netherlands) during May 2004 – April 2005. The first aim of our study was to describe the fish fauna in these stream mouth habitats. We hypothesized that the fauna would be dominated by both rheophilic (because of the reigning physical and environmental conditions in the stream mouth habitats) and eurytopic fishes (because of the close proximity and open access to the main channel of the River Meuse). The second aim of our study was to collect detailed size-frequency data for two rheophilic species, i.e. the bullhead (formerly referred to as *Cottus gobio* Linnaeus, 1758, but recently re-described as *C. perifretum* Freyhof et al. 2005, see Dorenbosch et al. 2008; Cottidae, Teleostei) and chub (*Leuciscus cephalus* Linnaeus, 1758; Cyprinidae, Teleostei), to assess the ecological function of these stream mouth areas for rheophilic species. These two species were selected because several studies indicated that they were among the most common rheophilic species in stream mouths along the River Meuse in the Netherlands (e.g. Crombaghs et al. 2000, Dorenbosch et al. 2005, Pollux & Kőrösi 2006). Specifically, we were interested in (1) whether *C. perifretum* and *L. cephalus* use these areas as a spawning habitat and/or nursery area for 0+ juveniles; and (2) during which period of the year these stream mouth habitats are used by *C. perifretum* and *L. cephalus*.

Material and Methods

The stream mouth habitats of 18 tributaries along the River Meuse, in the province of Limburg (the Netherlands; Fig. 1), were sampled during May 2004 to April 2005. Sampling took roughly place every two weeks (a total of 35 sampling days). Due to the narrowness and shallowness of the tributaries, fishes were most effectively sampled with hand nets (Pollux et al. 2006). Sampling gear consisted of two types of D-shaped hand nets (net dimensions: Length of the straight side of the D-shaped mouth x Depth: 60 x 40 cm and 70 x 50 cm; mesh sizes: 1.0 x 1.0 mm and 3.0 x 3.0 mm, respectively). On each sampling day, several stream mouths (mean ± SE of 2.9 ± 0.6) were sampled in an upstream direction by two to three fishermen, according to the following standardized procedure (modified after Smyly 1955). Two fishermen were positioned in the stream, facing upstream, holding the straight side of the D-shaped nets on the bottom. A third person then waded towards them from an upstream position, while holding the D-shaped net on the bottom. This allowed mobile species that normally swim away at the first sign of danger (typically in a downstream direction), to be captured. Next, the fishermen walked the same stretch again in the upstream direction, specifically sampling the more structurally complex habitats, such as dense vegetation, overhanging tree roots and stony bottoms (using their feet to turn over the stones, while keeping the mouth of the net behind the stones facing upstream). This allowed them to capture the cryptic species, which utilize complex habitats for shelter rather than escaping by swimming away quickly. This process was repeated at 2-5 m intervals after which the sampled area was estimated. All captured fish species were counted, identified and subsequently released. The length of *C. perifretum* (TL) and *L. cephalus* (FL), in addition, were measured to the nearest mm (if during one single sampling effort more than 15 similarly sized fish were captured, then only the first 15 randomly selected individuals were measured). Relative fish densities ($N \cdot m^{-2}$) were obtained by dividing the number of observed fish by the estimated sampling area. Differences in the probability of occurrence (presence/absence) in stream mouth sites between *C. perifretum* and *L. cephalus* were tested by means of a generalized linear model using logit modelling, with fish species as a fixed effect, a binomial response distribution (for the binary presence/absence data) and a logit link function (Agresti 1996). Differences in fish density among sampling locations were assessed for each species separately, using sampling location as a fixed factor, a gamma distribution (for the response variable) and an inverse link function (Agresti 1996). All analyses were performed with the GENMOD procedure in SAS 9.1.2 (SAS Institute Inc.).

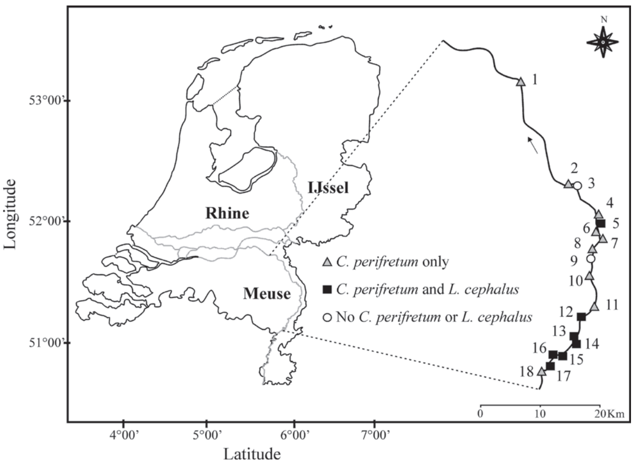

Fig. 1. Locations of the 18 stream mouth habitats along the River Meuse (the Netherlands).

Results and Discussion

A total of 4679 fishes (n = 20 species) were caught in the 18 stream mouths (Table 1). The fish fauna consisted predominantly of rheophilic (34.23 %) and eurytopic fishes (63.77 %), with only a small proportion of the fishes being limnophilic (2 %). The high incidence of rheophilic fishes as well as the low frequency of limnophilic fishes are most likely related to the reigning environmental conditions in these stream mouths (i.e. high water velocities, coarse riverbed substrates, sparse patchy aquatic vegetation), which offer suitable habitats to rheophilic, but not to limnophilic, species. The high abundance of eurytopic fishes in these areas, moreover, is probably due to the open connection to the main channel of the River Meuse, allowing easy access to fishes from the main channel (which is inhabited by predominantly eurytopic species; Van der Velde et al. 1990, Admiraal et al. 1993, Van den Brink et al. 1996, Raat 2001) to the stream mouth habitats.

Cottus perifretum was caught in 16 of the 18 stream mouth locations (Table 1; Fig. 1), displaying a significantly higher occurrence in stream mouth sites than *L. cephalus* ($\chi^2 = 67.12$, df = 1, $P < 0.0001$). Relative densities of *C. perifretum* differed significantly among the 16 stream mouths ($\chi^2 = 39.31$, df = 15, $P = 0.0006$), ranging from 0.04 to 2.26 fishes·m^{-2} (Fig. 2). Highest monthly *C. perifretum* densities were observed in June (Fig. 3a), due to a sudden increase of recently hatched 0+ juveniles, which started at the end of May. In April 2005, egg clusters were occasionally found during fish sampling, suggesting that *C. perifretum* uses these stream mouths as a spawning habitat. The continued presence of 0+ juveniles in the stream mouths during the summer and fall (Fig. 3a) furthermore shows that *C. perifretum* uses these areas as a nursery habitat, while the presence of large adult specimens throughout the year suggests that *C. perifretum* uses these habitats during their adult life stages (Fig. 3b). During May – November the observed total lengths of juvenile *C. perifretum* gradually increased from approximately one cm in May to approximately five to six cm in November (at which time growth rates gradually declined with decreasing water temperatures; Fig. 3b). During the same period *C. perifretum* densities gradually decreased (Fig. 3a), potentially caused by three non-mutually exclusive processes: First, the observed decline in 0+ densities might be related to predation on juveniles. *C. perifretum* is known to be frequently consumed by pike (*Esox lucius*), perch (*Perca fluviatilis*) and European eel (*Anguilla anguilla*) (Tomlinson & Perrow 2003), as well as the kingfisher (*Alcedo*

Table 1. Compostition of the fish fauna observed in the 18 stream mouths along the River Meuse (the Netherlands) during May 2004 – April 2005, grouped according to flow preference (after Schiemer & Waidbacher 1992). An asterisk denotes the two study species; n_{SM} – the number of stream mouths where each species was observed; n – the total number of individuals caught; % – their relative abundance.

Common name	Scientific name	n_{SM}	n	%
Rheophilic A				
Chub	*Leuciscus cephalus* (Linnaeus, 1758)*	7	490	10.47
Bullhead	*Cottus perifretum* (Freyhof et al., 2005)*	16	287	6.13
Dace	*Leuciscus leuciscus* (Linnaeus, 1758)	1	1	0.02
Barbel	*Barbus barbus* (Linnaeus, 1758)	1	1	0.02
Rheophilic B				
Stone loach	*Barbatula barbatula* (Linnaeus, 1758)	16	453	9.68
Gudgeon	*Gobio gobio* (Linnaeus, 1758)	7	362	7.74
Spined loach	*Cobitis taenia* (Linnaeus, 1758)	3	7	0.15
Ide	*Leuciscus idus* (Linnaeus, 1758)	1	1	0.02
Eurytopic				
Three-spined stickleback	*Gasterosteus aculeatus* (Linnaeus, 1758)	17	1677	35.84
Roach	*Rutilus rutilus* (Linnaeus, 1758)	13	1073	22.93
Perch	*Perca fluviatilis* (Linnaeus, 1758)	11	218	4.66
Pike	*Esox lucius* (Linnaeus, 1758)	2	9	0.20
Bleak	*Alburnus alburnus* (Linnaeus, 1758)	2	3	0.06
European eel	*Anguilla anguilla* (Linnaeus, 1758)	1	2	0.04
Pikeperch	*Stizostedion lucioperca* (Linnaeus, 1758)	1	1	0.02
Ruffe	*Gymnocephalus cernuus* (Linnaeus, 1758)	1	1	0.02
Limnophilic				
Nine-spined stickleback	*Pungitius pungitius* (Linnaeus 1758)	9	88	1.90
Topmouth gudgeon	*Pseudorasbora parva* (Temminck & Schlegel, 1846)	2	2	0.04
Bitterling	*Rhodeus sericeus* (Pallas, 1776)	2	2	0.04
Rudd	*Scardinius erythrophthalmus* (Linnaeus, 1758)	1	1	0.02
Σ			4679	

atthis; Reynolds & Hinge 1996), all of which have been observed in, or along, the stream mouths in this study (Table 1; B.J.A. Pollux, unpublished data). Secondly, occasionally, dead half-decayed 0+ juvenile *C. perifretum* were observed in our catches, suggesting that juvenile mortality (e.g. due to disease or starvation) may also have played a role in the decline of fish densities. Finally, 0+ juvenile densities might have declined as a result of increased size-specific competition with larger adult *C. perifretum* in the stream mouths. Several studies have shown pronounced differences in microhabitat use between 0+ juvenile and adult *Cottus* species (e.g. Legalle et al. 2005, Van Liefferinge et al. 2005). Intraspecific competition for microhabitats might increase as the 0+ juveniles grow and display ontogenetic microhabitat shifts (Davey et al. 2005), potentially inducing the emigration of weaker 0+ juveniles when suitable microhabitats are scarce.

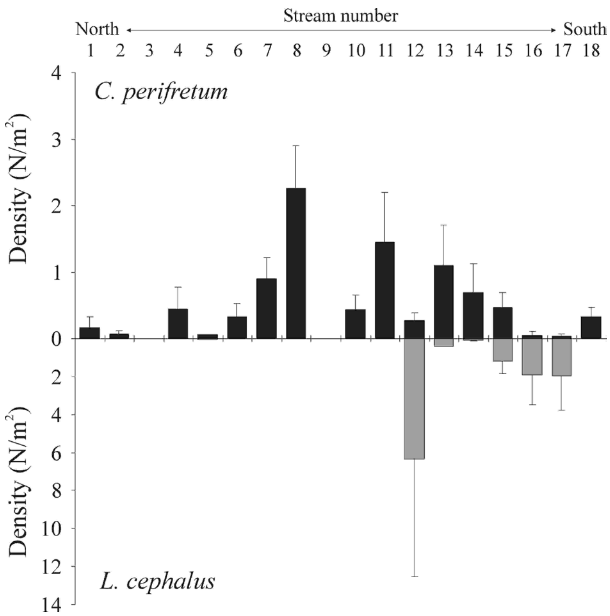

Fig. 2. Mean (±SE) densities of *C. perifretum* (black bars) and *L. cephalus* (grey bars) in 18 stream mouth habitats along the River Meuse (the Netherlands).

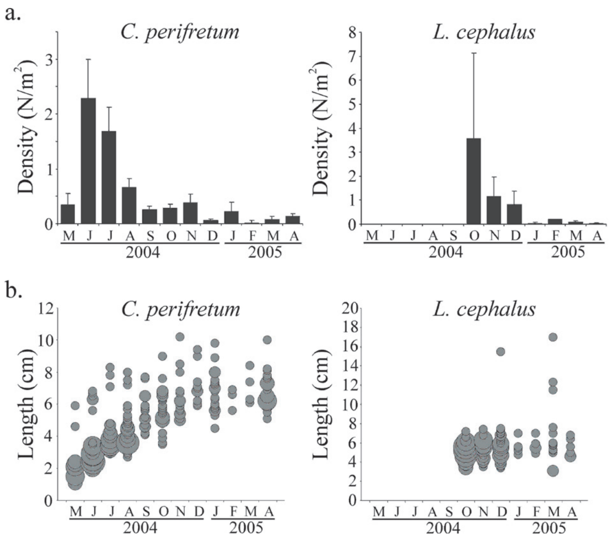

Fig. 3a. Mean (±SE) monthly densities (May 2004 to April 2005) of *C. perifretum* and *L. cephalus* in stream mouth habitats along the River Meuse (the Netherlands) (monthly catches from the 18 stream mouths habitats were pooled together). **b.** Observed fork lengths of *C. perifretum* and *L. cephalus* (dot sizes are proportional to the number of fish of that length that were measured).

Leuciscus cephalus was caught in seven of the 18 stream mouth locations (Table 1; Fig. 1). Most individuals were 0+ juveniles (n = 486; 4-7 cm), with only 4 of the caught specimens being 1+ juveniles (12-18 cm; Fig. 3b). Mature adults were not observed in any of the 18 sampling locations. Relative densities differed among the locations ($\chi^2 = 12.92$, df = 6, $P = 0.0443$), ranging from 0.02 to 6.36 fishes·m^{-2} (Fig. 2). During spring and summer, larvae and small juveniles (< 4 cm) of *L. cephalus* were not observed in the stream mouths, indicating that *L. cephalus* does not use these areas as either a spawning area or as a nursery habitat during early life. During fall, however, there was a sudden immigration of 0+ *L. cephalus* to the stream mouths (Fig. 3a) with fork lengths ranging from 4 to 7 cm (Fig. 3b). This sudden increase in 0+ juveniles was followed by a gradual decline in density during the following months (Fig. 3a). The results suggest that *L. cephalus* predominantly uses the stream mouths as a juvenile habitat during fall and early winter. Juvenile *L. cephalus* prefer shallow, slow-flowing, inshore shelters, with overhanging shoreline vegetation and fallen tree leaves (Copp 1992, Baras & Nindaba 1999), conditions that are present in the stream mouth habitats. Interestingly, suitable spawning conditions are absent in most parts of the River Meuse in the Netherlands (Vriese et al. 1994). It is therefore argued that these juveniles originate from upstream locations in the River Meuse, and subsequently drifted or migrated downstream towards our study area (Sonny et al. 2006). The only known locations in the Netherlands, where spawning behaviour of *L. cephalus* has been observed and larvae have been found, are the Rivers Swalm and Rur (two of the River Meuse's major side branches) and the 'Grensmaas', a 40 km stretch of the River Meuse in the most southern tip of the Netherlands near the Border with Belgium (Gubbels 2000, Crombags et al. 2000). Juveniles may even have originated from tributaries further upstream, along the River Meuse in Belgium (e.g. Sonny et al. 2006). An upstream origin would be consistent with the observation that the massive immigration of 0+ juveniles was restricted to the most southern located (i.e. most upstream situated) stream mouths of our study area (locations 12-17; Fig. 1, 2).

In conclusion, the results of this study reveal a strong spatiotemporal variation in the utilization of stream mouths between these two species, most likely reflecting a difference in the ecological function of these habitats: i.e. the stream mouths act as a spawning, nursery and adult habitat for *C. perifretum*, while they serve as an 0+ juvenile habitat during fall and early winter for *L. cephalus*. Future research should be directed towards understanding the ecological role that these stream mouth habitats offer to other fish species as well (Table 1).

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