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Short Communication

Amplitude of ecological potential: chub *Leuciscus cephalus* (L.) spawning in an artificial lowland canal

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Summary

Chub *Leuciscus cephalus* (L.) is a rheophilic cyprinid which prefers lotic habitat conditions, shallow water (0.1–0.3 m) and gravel banks with moderate to high water flow (0.15–0.75 m s^{-1}) for spawning. In contrast to these spawning requirements, a self-sustaining chub population was detected in a German lowland canal, the Oder–Havel Kanal. This canal is monotonously embanked with rip rap and almost completely lacks water flow and habitats that are suitable for riverine species. In 1999 chub spawned in the absence of water flow, in depths up to 1.28 m on allochthonous gravel with a mean diameter of 39 ± 16 mm (SD). These findings indicate a substantially higher environmental plasticity and tolerance of chub than previously reported.

Introduction

Chub *Leuciscus cephalus* (L.) is a cyprinid fish considered as rheophilic (Schiemer and Waidbacher 1992) and lithophilic (Balon 1975). It spawns in shallow water (0.1–0.3 m) at gravel banks (> 5 mm substrate diameter) with moderate to high (0.15–0.75 m s^{-1}) flow velocities (Cowx and Welcomme 1998).

During a large-scale fish survey in German lowland waterways, a remarkably abundant chub population was detected in the still-water-like canal Oder–Havel-Kanal (OHK) (Wolter and Vilcinskas 1998). The habitat conditions in the OHK did not match the above-mentioned spawning requirements of chub. Thus, it was suggested that the environmental tolerance of chub is much higher than previously assumed. Therefore, during a fish recruitment study in the OHK (Arlinghaus 2000), special attention was given to chub reproduction. This short note summarizes the observations regarding chub spawning in the still water of a canal, which are contrary to various reports.

Materials and methods

The OHK is the central part of the 150 km long artificial Havel–Oder-waterway (HOW) crossing the watersheds between the rivers Havel and Oder in the north-eastern lowlands of Germany. It is a critically polluted, straightened canal that is 34 m wide and 3 m deep and has artificially embanked shorelines, steep bank slopes and a negligible flow velocity. The OHK is bordered by the Lehnitz lock in the west (water level difference 6 m) and the Niederfinow ship lift in the east (36 m).

In 1999 the young-of-the-year fish assemblage (0+) was studied by random point abundance sampling by electrofishing using a DEKA 3000 portable electrofishing unit (pulsed DC, 600 V) with a ring-anode, 17 cm in diameter. The stunned fish were captured with a separate 600 μm mesh size dip net. At two selected sites which were representative for habitat structures in the straightened canal course, a distance of 500–600 m was sampled at 100 randomly selected points once per month between May and October during daytime. The fish were identified (Koblickaya 1981), counted, measured (total length in mm below, TL) and immediately released.

At each point, a set of environmental variables was recorded: water depth (cm), distance from bank (cm), substrate diameter (mud, sand, gravel, rip rap), macrophytes (none, emergent, floating, submerged), plant cover (0%, 1–75%, > 75% per point area), and visibility (low, medium, high). At one site (HOW-km 70.5) where the bottom substrate was different from rip rap, gravel was sampled with an EKMAN-sampler and 300 particles were measured manually to estimate the mean spawning substrate diameter.

Fish length comparisons were performed by one-way analysis of variance (ANOVA) with a post-hoc Dunnett-T3 test in case of heteroscedasticity (Levene test, $P < 0.05$). Crucial environmental factors for 0+ chub were determined at the microhabitat level (sampling point per habitat variables matrix) by principal component analysis (factor analysis, PCA) using the Varimax-method, considering only eigen values > 1.0 and factor loadings > 0.5. Calculations and tests were performed with the SPSS 9.0 software package (SPSS Inc. 1999) at the 95% confidence level.

Results

From both sampling sites a total of 1317 juvenile fish were collected, 817 of which were 0+ fish. The relative abundance of chub was 4.7% (n = 62) of the total catch and 5.1% (n = 42) of the 0+ fish assemblage. Chub were caught exclusively at HOW-km 70.5 between July and October (Table 1). At this site, the dominant bank substrate was rip rap (92.5%), with a small area covered by allochthonous gravel, which was used to consolidate a small landing-stage; in May and June chub spawning was observed. The spawning site consisted of two gravel patches (in total 121.5 m^2) divided by a 10-m stretch of *Phragmitis communis* growing in the interstices of rip rap. The substrate diameter ranged from 2 to 80 mm, with a mean of 39 ± 16 mm standard deviation (SD). The gravel belonged mainly to the coarse gravel fraction (20–60 mm). Water depth ranged from > 0 to 1.28 m. Flow velocities were negligibly low (< 0.05 m/s), representing a still-water site.

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Table 1
Distribution of 0+ chub in the Oder–Havel Kanal at Havel–Oder waterway-km 70.5 during late summer and autumn 1999 (n = number of specimens, values with the same superscript are not significantly different, ANOVA, Dunnett-T3, $P > 0.05$)

	July	August	September	October
n	7	13	9	13
TL (in mm, mean ± SD)	40.3 ± 4.8^{a}	58.4 ± 5.8^{b}	69.4 ± 8.8^{c}	66.8 ± 6.6^{c}
Range (mm)	35–48	52–72	53–82	52–76
Relative abundance (%)	23.3	12.7	20.9	20.3

Table 2
Principal component (factor) analysis results of environmental variables at sampling points with 0+ chub. Three factors (eigenvalue; percentage variance) were extracted and are presented with factor loadings. Categories used were: plant cover (0%, 1–75%, > 75%), macrophytes (none, emergent, floating, submergent vegetation), water depth (cm), substrate diameter (mud, sand, gravel, rip rap), distance from bank (cm) and visibility (low, medium, high)

	Factor 1 (2.105; 30.07%)	Factor 2 (1.474; 21.05%)	Factor 3 (1.205; 17.21%)
Plant cover	0.897		
Macrophytes	0.863		
Water depth		0.784	
Substrate diameter		0.757	
Distance from bank			0.815
Visibility			0.675

The PCA of environmental factors at sampling points with 0+ chub is summarized in Table 2.

Discussion

Several studies reported 0+ chub from lakes and reservoirs with tributary affluents (e.g. Fischer and Eckmann 1997); a still-water spawning site, however, has not been described. Chub was the only lithophilic species reproducing in the OHK (Arlinghaus 2000) and a still-water spawning site was found at HOW-km 70.5. This judgement is based on the direct observation of spawning activities and later on the capture of 0+ chub. Although these observations did not directly verify successful recruitment, the immigration of 0+ chub into the study area was excluded. The spawning site was 7.4 km from the Niederfinow ship lift and 42 km from the Lehnitz lock. Neither of these migration barriers are equipped with fish passage facilities and, in addition, the lack of an orientation flow inhibits directional fish migrations (Wolter and Vilcinskas 1998). The existence of suitable spawning sites within the canal was also indicated by the length–frequency distribution of adult chub caught in 1994/1995 (n = 94) and in April 2001 (n = 166) (unpublished results), suggesting a natural age structure of the stock and a successful spawning in several consecutive years.

The present findings correspond to studies suggesting that chub is more ubiquitous than typically riverine fish with complex habitat requirements (e.g. Carrel and Rivier 1996). In contrast to literature reports (summarized in Cowx and Welcomme 1998), chub spawning seemed independent of flow velocity but dependent on coarse gravel. The length frequencies of 0+ chub, range and standard deviation (Table 1) indicated multiple spawning (Mann 1976). However, the length variance of 0+ chub could as well have been caused by varying individual growth rates.

The chub larvae and juveniles were usually reported from lentic, shallow, littoral areas with some vegetation cover (Mann 1976; Copp 1992). They are adapted to rip rap and boulder banks (Carrel and Rivier 1996), but prefer pebble and gravel substrate (Copp 1992). In the OHK the 0+ chub preferred macrophytes (factor 1, Table 2), increasing water depth and distance from the bank as well as coarser substrate (factor 2 and 3, Table 2). The preference for coarser substrate, however, was biased by the almost completely artificial embankment of the OHK with rip rap. It is suggested that coarser substrate (e.g. rip rap interstices) in deeper water, with some plants may provide shelter and protect the 0+ chub from temporary high currents and turbulence during ship passages.

To conclude, the existence of a reproductive chub population with natural age structure in a monotonous canal without habitats favourable for riverine fishes, indicated its wide ecological potential. Investigations in canals or similar artificial systems, where fish are exposed to extreme environmental conditions, improve our knowledge about their ecological plasticity or threats, especially at their tolerance limits.

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