

Behaviour and microhabitat of early life stages of *Cobitis taenia*

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Abstract. The present study investigates the mobility and phototactic behaviour of early life stages of spined loach in order to define the microhabitat of the different ontogenetic phases. The eggs were placed by the spawning adults into dense vegetation. Since the embryos did not show any mobility until eye pigmentation, they face the same microhabitat as the eggs. After eye pigmentation, they became negatively phototactic. In the field, the light gradient would lead them beneath the centre of the vegetation. With the beginning of exogenous feeding, phototaxis changed into a positive reaction. This would lead the larvae towards the lighter marginal areas under the vegetation. Afterwards, the spontaneous mobility of the larvae increased and the phototactic behaviour lost its importance. When early life stages of *Cobitis* were exposed to 13 invertebrate and vertebrate predators, they showed a high vulnerability to predation. Therefore, the dense vegetation acts as a shelter for predation.

Key words: spined loach, larval ecology, phototaxis, saltatory ontogeny

Introduction

The early life stages of fishes often represent the critical period for the development (Kamler 1992). In order to identify the critical environmental factors for a fish species, the ecology of the early life stages has to be understood. In a variety of fish species, ontogenetic niche shifts during the embryonic and larval phases have been observed (Schiemer et al. 1991). Balon (1990) postulated phototactic behaviour to be closely correlated to the ecology of the early life stages. For example, the free-embryos of the gravel spawning *Oncorhynchus* and *Phoxinus* are negatively phototactic in the beginning and hide in the interstitial (Bless 1992, Carey & Noakes 1981). After the onset of exogenous feeding, the young fish become positively phototactic and emerge from the substrate (Carey & Noakes 1981). In these examples, photobehavioural responses clearly determine the microhabitat used by the young fish.

Little information is available on the microhabitat use and the photobehavioural response of early life stages of loach fishes. Balon (1975) listed several species of *Cobitis*, *Misgurnus* and *Sabanejewia* to be “nonguarding phytophilous spawners”. The embryos of this guild were labelled as not photophobic, sticking to plants and avoiding contact with the bottom. Copp (1989) reported *Misgurnus fossilis* to be found at 0.5 and 1.0 m down in silty substratum of old oxbows of the Rhône. The only detailed analysis of habitats of *Cobitis* early life stages was carried out by Saitoh (1990). The early life stages of two ‘races’ of Japanese striated spined loach were found in shallow, vegetated areas, whereas the late larvae and juveniles entered more deep and more open water.

The present study reports the spontaneous mobility and the phototactic behaviour of embryos and young larvae of the spined loach, *Cobitis taenia* L. The microhabitat of the

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different developmental stages is described. To identify the advantage of shifts in microhabitat use, with respect to predation risk, tests were undertaken to assess the need and use of shelter.

Material and Method

Eggs of spined loach were obtained from a naturally spawning laboratory stock as described in B o h l e n (1999). Spontaneous mobility was estimated in 60×20 cm glass aquaria under weak indirect illumination. The aquarium was filled 10 cm high with well aerated water of 21°C and a conductivity of 350 to $400 \mu\text{S cm}^{-1}$. The position of 20 test specimens was estimated in 1 to 5 h interval during a period of 10 to 21 h from a 1 cm-scale at the front of the tank. Spontaneous mobility was calculated as the mean movement per individual per hour. Phototactic behaviour was estimated under the same set-up but under direct illumination from one side by a 60 W bulb (light gradient from 40 to $100 \mu\text{E}$ within the tank). Temperature measurements in different parts of the tank (to an accuracy of 0.1°C) revealed no temperature gradient established during the experiments. A group of 20 specimens was placed in the middle of the aquarium and the position of each individual was estimated from the front scale at the beginning of the experiment and after 3 h. Differences in the longitudinal distribution of the fish at beginning and end of the experiment were compared by analysis of variance ($n = 20$, at 95 %). The experiment was repeated with the bulb shining from the other side to exclude the impact of any spatial orientation. The mean change of position of fish in both repetitions were taken as the reaction per day. To follow the ontogenetic development of phototaxis, the reaction was estimated each day from the same group of specimens. The entire experiment was repeated three times with different specimens from different clutches. To test the ability of early life stages to avoid predation, a group of 20–50 eggs, embryos or larvae was placed into an aquarium ($39 \times 39 \times 20$ cm) with fine sand on the bottom. A group of potential predators was added and the number of surviving spined loach was counted after 48 h. Fish species tested as predators were: *Anguilla anguilla* (2 specimens, 90–99 mm TL); *Cobitis taenia* (5 specimens, 90–105 mm); *Gasterosteus aculeatus* (5 specimens, 56–65 mm); *Gobio gobio* (3 specimens, 54–65 mm); *Perca fluviatilis* (2 specimens, 94–98 mm). In the same manner, but in smaller aquaria ($20 \times 20 \times 5$ cm) the following invertebrates were used as predators: *Gammarus pulex* (20 specimens); *Orconectes limosus* (14 specimens); *Physella acuta* (10 specimens); *Limnaea stagnalis* (5 specimens); *Planorbis carinata* (10 specimens); *Radix* indet. (9 specimens); *Herpobdella octoculata* (3 specimens); *Orthretum cancellatum* larval (5 specimens). The survival rate in aquaria without predators was estimated as a reference.

Results

Spontaneous mobility of early stages of spined loach was very low. During the eleutheroembryonic phase, until pigmentation of the eye, the mean movement of every fish was 0.3 cm h^{-1} . From pigmentation of the eye until beginning of exogenous feeding, mobility was 0.6 cm h^{-1} . During the first week of larval phase, spontaneous mobility increased from 1.0 cm h^{-1} to about 10 cm h^{-1} . Mobility became dependent on starvation of the fish. During the entire study, movements occurred at the bottom of the tank. Spined loach did not demonstrate a free swimming phase or any other mechanism of dispersal.

When placed into a light gradient, the mobility of the fish was dependent on developmental stage. During the first two days after hatching, the embryos did show neither a significant increase of activity nor a direction of movements (Fig. 1). From the third day, when the

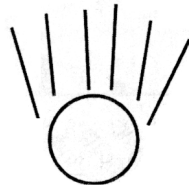
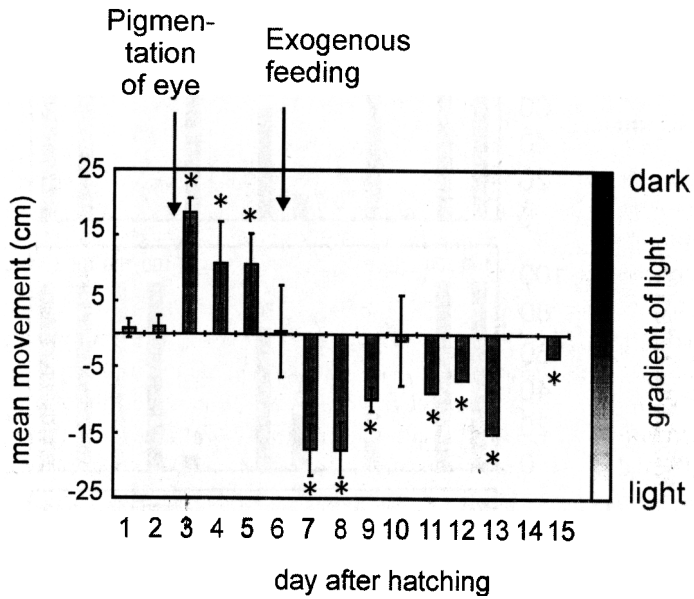


Fig. 1. Phototactic behaviour of young spined loach during the 15 days after hatching. Significant changes of the mean position of the test animals are indicated by asterisks.

pigmentation of the eye was nearly finished, the presence of a light gradient initiated a strong mobility. The embryos showed a well expressed negative phototaxis. Together with the beginning of exogenous feeding, phototactic behaviour changed to strong positive phototaxis. The strength of the phototactic reaction decreased during the larval period, whereas the spontaneous mobility increased. Consequently, the impact of light direction on the movements of the larvae became more and more negligible.

Early life stages of spined loach were highly vulnerable to predation by fish as well as by invertebrate predators (Fig. 2). Embryos and larvae did not show any avoidance or escape behaviour. There was no evidence for morphological structures (e.g. spines) or a chemical cues (e.g. bad taste) that may have put off predators.

Discussion

The early life stages of spined loach showed a strong phototactic response, their behaviour matching the phototactic reaction described for salmonids (Carey & Noakes 1981). A reaction to heat rays from the bulb is unlikely, since in previous experiments the embryos reacted also to a light screen on one side of the experimental tank. Under natural conditions light is frequently accompanied by heat, therefore the framework of the conclusions would not change.

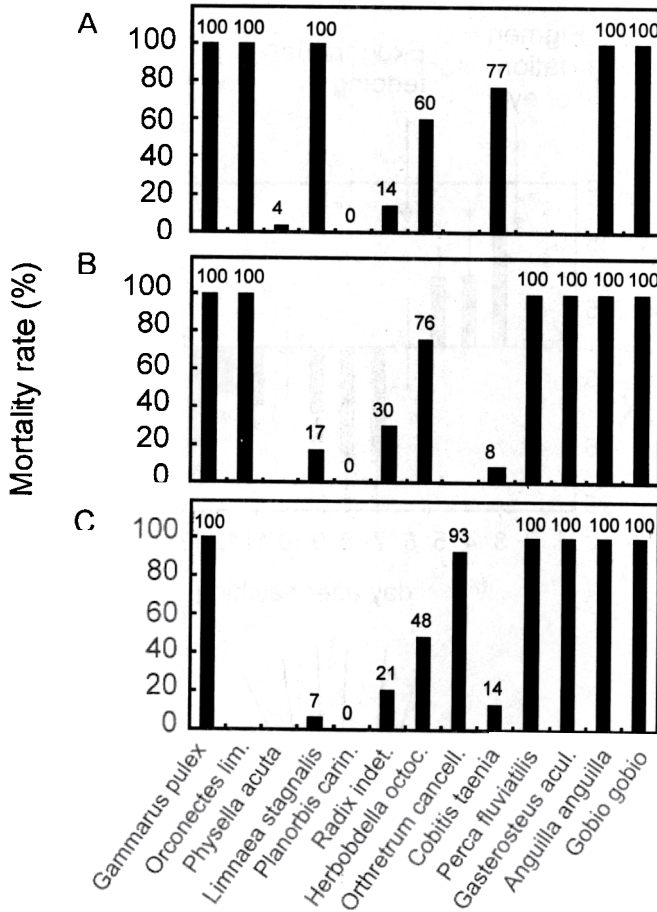


Fig. 2. Mortality rate of eggs (A), eleutheroembryos (B) and larvae (C) of spined loach when exposed to potential predator species.

The adult spined loach place their eggs into the most dense vegetation (B o h l e n 1999), thus the microhabitat for egg development is the inside of such dense vegetation structures. The early eleutheroembryos do not show any mobility, therefore their microhabitat is also the inside of the dense vegetation. Little or no water movement occurs inside this structure, so eggs and free-embryos will not drift away unless they are actively moved from the microhabitat. After the onset of negative phototaxis, the free-embryos will accumulate at the darkest point in the surrounding, i.e. the bottom beneath the centre part of the vegetation. The most remarkable environmental feature of this microhabitat is the muddy bottom with possible low oxygen concentrations (Table 1). Spined loach embryos bear several morphological features to enhance uptake of oxygen (K r y z a n o v s k y 1934) and are able to develop under constantly low oxygen concentrations (B o h l e n , unpubl. data). With the beginning of exogenous feeding, the positive phototaxis leads the larvae from the dark centre of the vegetation to the lighter marginal areas. In these areas, the bottom is not as muddy as beneath the centre of the vegetation, and the larvae are able to carry out their feeding behaviour. Later in the larval period, the impact of phototaxis declines, whereas the impact of food stimuli increases.

Table 1. The microhabitat, the main environmental features of the microhabitats and the main adaptations of early life stages of spined loach to these environmental features. Division into four phases as described in the text.

	Eggs and eleuteroembryo before eye pigmentation	Eleuteroembryo after eye pigmentation	Larvae from exogenous feeding	Juvenile
Microhabitat inhabited	inside dense vegetation	beneath dense vegetation	beneath edge of vegetation	open sandy bottom
Environmental conditions	- no water movements - fluctuating oxygen	- no water movements - low oxygen	- small water movements - medium oxygen	- high water movements - high oxygen
Behavioural characteristics	no movements	negative phototactic	positive phototactic	
	no attachment to substrate, no free swimming, low spontaneous mobility			
Morphological adaptations for additional oxygen uptake	- large egg surface area - early hatching	- external gill filaments - large Ductus Cuvieri - rich finfold vascularisation	- rich finfold vascularisation	none

During its early ontogeny, spined loach undergoes ontogenetic habitat shifts and phototactic behaviour is the mechanism that leads the animals into the next habitat. The rapid change between the microhabitats may correspond to the transition between different steps in the theory of saltatory ontogeny (Balon 1990). At least four such steps or phases may be distinguishable in spined loach (Table 1). The first phase includes the development until eye pigmentation. The second phase covers the time until exogenous feeding. The larval period, i.e. after onset of exogenous feeding provides the third phase in life history, gradually changing into the fourth phase at the onset of the juvenile period. Since qualitative differences between the ecology of adult and juvenile spined loach have been indicated (Saitoh 1990, Slavík & Ráb 1995), the adult fish probably represent another phase.

If not disturbed, then young spined loach demonstrate very low mobility. Such low mobility has the advantage to save energy for anabolism (Rombough 1988), but on the other hand makes the young fish very vulnerable to predation, which brings them into need of shelter for predation. Dense vegetation is a shelter from optically orientated predators. The impact of this gain became obvious in Lake Müggelsee at Berlin, when a collapse of filamentous algae during July 1996 lead to the loss of an entire year class of spined loach. Prior to this collapse, spined loach eggs could be collected among the algae like in other years, but afterwards no 0+ spined loach could be found (Bohlen, unpubl. results). In this case, the critical period for the recruitment of spined loach clearly was during the early life stages.

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