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BRIEF COMMUNICATION

The effect of light intensity on the drift of young-of-the-year cyprinid fishes

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Density, but not body size, of drifting young-of-the-year cyprinid fishes was negatively correlated with light intensity. As an ability to resist the water current develops gradually with size, the results support the view that drift in cyprinid fishes is a behavioural decision, triggered by light level, rather than passive displacement of visually disoriented fishes.

Key words: larval drift; 0+ fish; dispersal; migration; illumination; timed behaviour.

Downstream drift of young-of-the-year (YOY) cyprinid fishes follows a distinct diel pattern, with most fishes drifting at night (Reichard *et al*., 2002). A nocturnal increase in the drift has been shown to be connected with visual acuity, and light intensity is clearly the key factor (Pavlov, 1994). Consequently, water turbidity can promote drifting during daylight (Reichard *et al*., 2001), whereas artificial illumination of a stream (Geen *et al*., 1966) and presence of visual landmarks (Bardonnet, 1993) can delay or suppress night-time drift. Cyprinid fishes <30 mm total length (L_T) orientate themselves visually (Pavlov *et al*., 1968), but the mechanism for how light levels affect individual fish and encourage them to enter and leave the current is not understood.

Drift in cyprinid fishes may be a passive process, whereby individuals are washed downstream if they lose orientation when visibility decreases below a threshold level (Manteifel *et al*., 1978; Brown & Armstrong, 1985). Alternatively, fishes may enter the water current to assist in their movement to locations where they can maximize their survival or energy gain, and drifting at night could reduce the risk of being detected by visual predators (Pavlov & Shtaf, 1981; Corbett & Powles, 1986; Harvey, 1991; Johnston, 1997). Thus, either visual disorientation or a behavioural response to darkness may be the causative factor promoting fishes to enter the current. Contrary to salmonid (Ali, 1959) and acipenserid (Pavlov *et al*., 1968) fishes, the ability to resist river currents develops gradually with size (Garner, 1999), and is related to visual acuity (Pavlov *et al*., 1968) across species in YOY cyprinids. Thus, if drift is passive, both drift density and body size of drifting fishes should increase with decreasing light intensity. In contrast, if drift is active, there should be a threshold value of light intensity when fishes start to enter the current. In the present study, these alternatives were tested.

The experiment was conducted in the River Morava (Danube Basin, Czech Republic) on 9–13 June 2000. The river was 60 m wide and river discharge varied from 18 to 24 $m^3 s^{-1}$ during the experiment. The shoreline comprised a boulder bank with a deposit of

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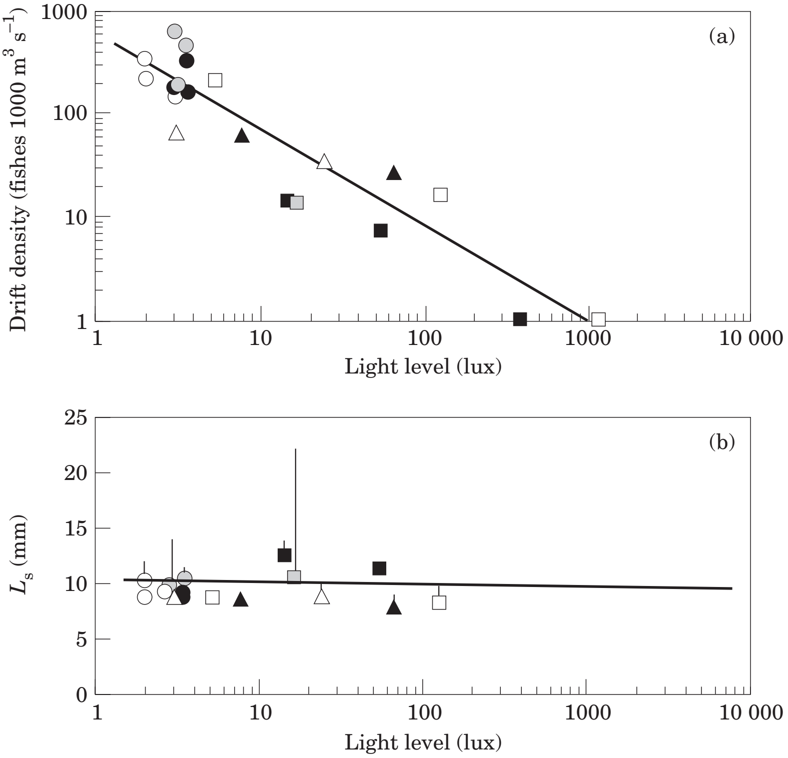

FIG. 1. The relationship between light intensity and (a) drift density and (b) body size of drifting cyprinid fishes in the River Morava at sunset (squares), night (circles) and sunrise (triangles) on 9–10 (□, ○ and △), 10–11 (■, ● and ▲) and 12–13 (▨, ◍ and ◭) June 2000. Body length corresponds to the median (± interquartile range) L_S for particular samples. (a) The line was fitted from: $y=2{\cdot}745-0{\cdot}928x$. (b) The line is non-significant.

silt. Woody debris and overhanging emergent vegetation provided shelter for YOY fishes (Reichard *et al.*, 2002). Drifting fishes were sampled using a drift net (opening of 1 m wide × 0·6 m deep; 2 m long; mesh size 0·5 mm) positioned 1 m from the shoreline for 15 min (S.E. = 36 s). The net covered the whole water column. Light intensity (lx) was measured at the beginning and end of each drift sampling to the nearest 1 lx using a digital LX 103 Lutron light meter. Later laboratory calibrations with a LX 105 Lutron light meter, however, showed that the measurements were not accurate for values <3 lx. Thus, these very low light levels are referred to as <3 lx. Field light intensity measurements were taken at the water surface. As light is quickly absorbed in water, light intensity measured at the water surface does not exactly correspond with light intensity perceived by a fish beneath the surface. Consequently, the light levels measured at the water surface serve only as an index of light level and do not represent the real threshold value for drifting.

Water temperature (mean ± S.E. = 23·4 ± 0·3° C), dissolved oxygen (mean ± S.E. = 10·0 ± 0·5 mg l^{-1}) and current velocity in the centre of net opening (mean ± S.E. = 0·33 ± 0·0 m s^{-1}) were measured during each sampling. Sunset occurred at 2055 hours [civil twilight (illumination sufficient for terrestrial objects to be clearly distinguished) ended at 2141 hours] and sunrise occurred at 0449 hours (civil twilight started at 0407 hours) of Central European summer time (U.S. Naval Observatory, 2002). In total, nine night samples (at 2200, 2400 and 0200 hours each sampling date; light intensity <3 lx), seven sunset samples (from 2030 to 2145 hours; 3–1617 lx) and four sunrise samples (from 0345 to 0435 hours; 3–105 lx) were taken.

All YOY fishes captured in the drift net were preserved in 4% formaldehyde and, in the laboratory, identified to species and measured for standard length (L_S, to the nearest 0·01 mm). The total catch consisted of 528 fishes belonging to 11 species dominated by bitterling *Rhodeus sericeus* (Pallas) ($n=346$, 66%) and bleak *Alburnus alburnus* (L.) ($n=104$, 20%). Drift density (fishes *per* 1000 m^{-3} of filtered water) was calculated for each sampling occasion (Reichard *et al.* (2002)).

No difference between sunset and sunrise drift densities was detected (t-test on log transformed data $t=0{\cdot}31$, d.f.$=9$, $P=0{\cdot}76$). Drift rate was negatively correlated with light intensity (Pearson correlation on log transformed data, $r=-0{\cdot}924$, $P<0{\cdot}001$, $n=20$; Fig. 1) and mean night-time drift density (289 ± 54 fishes 1000 m^{-3}) was more than sixfold higher than drift density at twilight (45 ± 19 fishes 1000 m^{-3}). Body size of drifting fishes did not differ between night, sunset and sunrise (time of the day effect in main effect GLM ANOVA, $P=0{\cdot}23$). Indeed, no correlation between body size and light intensity was found (Pearson correlation, $P=0{\cdot}87$; Fig. 1). The same pattern was obtained for bitterling and bleak analysed separately.

In contrast to the findings in the present study, Pavlov (1966) reported that smaller bream *Abramis brama* (L.) and silver bream *Blicca bjoerkna* (L.) started to drift earlier (i.e. during higher light levels) than larger conspecifics. Since visual acuity (Pavlov *et al.*, 1968; Pavlov, 1989) and swimming ability (Harvey, 1987; Garner 1999) develop with size, he concluded that fishes were passively washed-out by the water current as they became visually disoriented at night. Notably, he did not find such a relationship for roach *Rutilus rutilus* (L.) (Pavlov, 1966). Similarly, no correlation between the body size of drifting cyprinid fishes and time of the day was found in the River Rhône (Peňáz *et al.*, 1992) and the River Dyje (Reichard, 2002). Moreover, Fraser *et al.* (1994) failed to find any relationship between light intensity and age at the time of emergence from the redd in Atlantic salmon *Salmo salar* L., though, quantitatively, significantly fewer Atlantic salmon emerged during light nights.

The present results show that, even though fishes entered and left the river current gradually (with a change in the light intensity), fishes drifting at twilight were not smaller than fishes drifting at night. It suggests that, even if there is variation among individuals in the threshold level of light intensity encouraging fishes to drift, this variation is not related to fish body size. This supports the view that drift in cyprinid fishes is a temporally sensitive behavioural decision rather than passive displacement.

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