IMPACTS OF RIVER BANK MORPHOLOGY AND TIME OF DAY ON DRIFT AND STRANDING OF EUROPEAN GRAYLING (*THYMALLUS THYMALLUS* L.) CAUSED BY HYDROPEAKING

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We analysed the effects of hydropeaking in terms of drift and stranding of juvenile graylings (*Thymallus thymallus* L.) with an average length of 53.3 mm. Single peak experiments were investigated in 2 outdoor flumes each of 20 m length with the main focus on time of day and gravel bank morphology (absence or presence of dewatering potholes). By daytime we observed low median drift rates of 15 % and median stranding rates below 5 % in dewatering potholes and on homogenous gravel bank during decreasing water level. Although, in the presence of dewatering potholes, the nighttime drift rates were about three times and stranding rates around seven times higher than on the homogenous gravel bank.

1 INTRODUCTION

Hydropeaking as the result of short-term energy demand has been identified as one of the key threads among hydromorphological impacts on fish populations in running waters [1].. Beside hydrologic parameters such as amplitude, magnitude, increasing/decreasing rate or prior flow conditions, also timing (seasonal and daytime), frequency and water temperature influence hydropeaking related impacts [1,2,3]. Consequences for fish can be stranding or lateral displacement due to decreasing water levels, downstream displacement and reduced spawning and rearing success due to redd dewatering and aggravated migration [3].
Life history strategies of aquatic species evolved in direct response to natural flow [4], so abnormal frequency and timing of anthropogenic water pulses can adversely affect fish due to atypical water flows at critical times during their life cycles [2]. For example, post-emerged graylings shift to dead zones [5] or slow flowing and shallow habitats, whereas exactly these habitats are susceptible for stranding [6]. Furthermore juveniles perform a diel habitat shift between feeding habitats during day and resting habitats during night, preferring shallow and flow reduced zones during night [5].

Although research outcome based on hydropeaking is growing, little is known about additional factors associated with stranding [7]. For instance we found contradicting results in literature regarding stranding risk during nighttime [8,9,10].

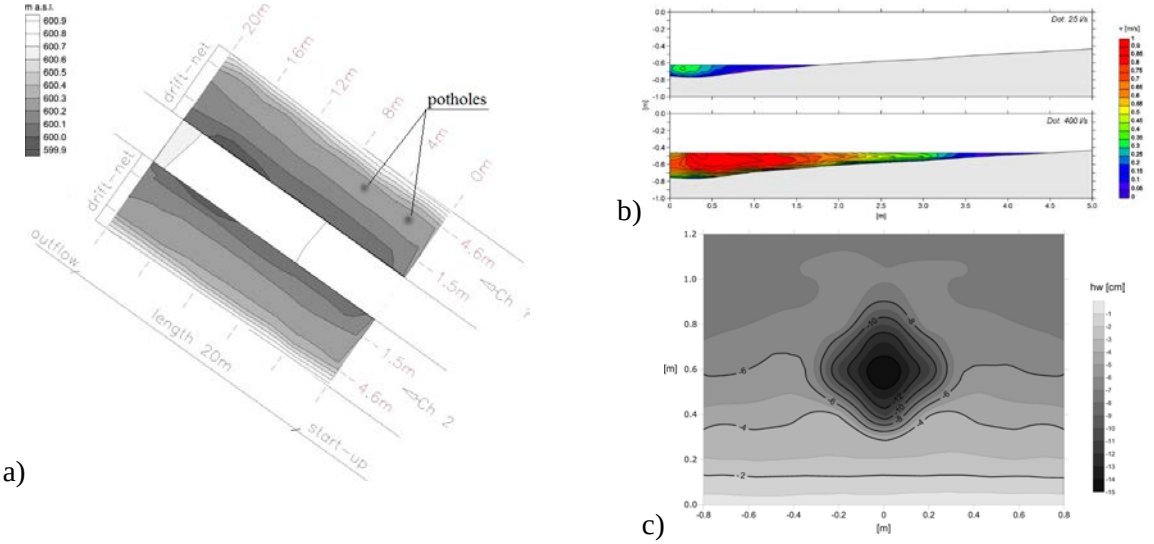
Heterogeneous river morphology can reduce negative effects of hydropeaking, but also comprises higher risks for stranding fish, for example in potholes [11]. In general, steeper lateral gravel bank slopes reduce the risk of stranding [11].

In this study we investigated the consequences of daylight and river bank morphology concerning drift and stranding risk of juvenile graylings using nature-like experimental channels.

2 MATERIALS & METHODS

The HyTEC facility (Hydromorphological and Temperature Experimental Channel; http://hydropeaking.boku.ac.at/hytec.htm) is located in Lower Austria, below Lake Lunz and next to the lake outflow. It consists of 2 identical channels in which hydropeaking of up to 600 l/s can be simulated. Water is taken from Lake Lunz at 2 different water depths to allow adjustment of water temperature (Figure 1a). At the facility water is mixed before release into the experimental channels. All experiments were carried out in the lower 20 m of the 40 m long and 6 m wide channel. Longitudinal channel slope was approx. 0.5 % and lateral bank slope was 5 % within the range of low and high water (Figure 1b). Substratum was dominated by coarse

gravel (d_{90}=21-29 mm). Experiments with heterogeneously structured gravel bank included two approximately 15 cm deep and 60 cm wide circular synclinal depressions, i.e. potholes (Figure 1c).



a) b) c)

Figure 1: a) top view of the 2 experimental channels with contour lines and water levels at 25 l/s (wetted width 1.5 m) and 400 l/s (wetted width 4.6 m); b) lateral flow velocity at 25 and 400 l/s; c) schematic contour view of a pothole

Grayling spawners were retrieved from the River Ybbs near the experimental facility. Fish were bred at a local fish farm, kept in circular tanks on-site with constant water temperature and were fed with plankton from the upstream lake. Two sets of fish were used: experiment 1 had an age of 98-105 days, a mean length of 51.3±1.16 mm, and a mean weight of 0.98±0.01 g. For experimental setup 2 we used fish with an age of 115-126 days, a mean length of 54.5±2.23 mm and a mean weight of 1.19±0.14 g.

For each experiment 50 fish per segment were stocked using buckets at low flow conditions (25 l/s), whereby an upstream ramp hindered fish to swim to the upper part of the channel. Discharge remained unchanged during 30 min adaption time. After an upramping phase of 5 min duration (corresponding upramping rate: 3.7 cm/min) maximum discharge of 400 l/s lasted 15 min followed by a downramping phase for 5 min (corresponding downramping rate: -3.0 cm/min) (Table 1). Drifted individuals were collected and removed from driftnets at the very end of the channel and were recorded during upramping, peak flow and downramping separately. After downramping phase was finished, gravel banks were surveyed for possibly stranded individuals and fish which remained in the still watered part of the channel were caught by electrofishing device and hand nets.

For experiment 1 (homogenous gravel bank) we stocked 250 fish, with equal distribution of 50 individuals in each 4 m segment along the 20 m long downstream part of the channel. Experiment 2 (heterogenous gravel bank) comprised identical hydrological parameters but featured a gravel bank including 2 potholes (approx. 60 cm in diameter and 15 cm deep (Figure 1c) implemented at the first two of the 4 m segments. We again stocked 50 fish per segment but only within the first two so fish density for the two uppermost segments were identical at the beginning of the experiment.

Table 1: Overview of experiments and parameters

Experiment no.	Daytime	Morphology	Replicates	Water temperature	Stocked fish	Initial flow	Adaption time	Upramping rate	Peak flow	Peak duration	Downramping rate	Final flow
1	Day	homo-	11	14.1±1.6°C	250	25 l/sec	30 min	3,7 cm/min	400 l/s	15 min	-3,0 cm/min	25 l/s
	Night	genous	10	14.7±0.7°C								
2	Day	hetero-	7	12.9±0.9°C	100							
	Night	genous	8	12.7±1.0°C								

For adequate comparison within each phase of the experiments we calculated drift rates by observing the amount of drifted fish related to the amount of fish inside of the channel at the beginning of individual phases (Table 2). Stranding rates were calculated indirectly as the percentage of fish that did not drift and were not found in the channel after the experiment in relation to fish present in the channel before downramping (Table 2).

Table 2: **R**: amount of fish after adaption time; **D_ur**: amount of fish drifted out during upramping phase; **D_p**: amount of fish drifted out during peak phase; **C**: residing fish removed after experimental trial; **ΣD_x**: amount of fish drifted out during experimental phase

Metric	Phase	Index	Calculation	
Drift	upramping	D_ur	**D_ur_rel**[%] = **D_ur/R*100**	Eq. (1)
	peak	D_p	**D_p_rel**[%] = **D_p/(R–D_ur)*100**	Eq. (2)
	downramping	D_dr	**D_dr_rel**[%] = **D_dr/(R–D_ur–D_p)*100**	Eq. (3)
	total	D_tot	**D_tot_rel**[%] = **D_x/R*100**	Eq. (4)
Stranding	downramping	Str_calc_rel	**Str_calc**[%] = ((**R**–(**ΣD_x**+**C**)/(**R**–(**D_ur**+**D_p**))***100**	Eq. (5)

3 RESULTS

3.1 Drift

We found a slight increase of drift rates aggregated over all experimental phases (D_tot_rel) during nighttime compared to daytime experiments on the homogenous gravel bank (Figure 2a)(Median test p=0.086; Mann-Whitney-U-test p=0.197; Kolmogorov-Smirnov-test p=0.294) and a significant increase for experiments on a heterogenous gravel bank (=potholes) (Median test p=0.001; Mann-Whitney-U-test p=0.004; Kolmogorov-Smirnov-test p=0.007). Comparing both morphologies we could not find differences of D_tot_rel during daytime experiments, but a significant alteration of D_tot_rel during nighttime experiments with potholes (Median test p=0.015; Mann-Whitney-U-test p=0.012; Kolmogorov-Smirnov-test p=0.010). We split up D_tot_rel into the underlying, single phases (D_ur_rel, D_p_rel, D_dp_rel) and we could find similar tendencies for D_ur_rel and D_p_rel: slight increase of driftrates during nighttime experiments on the homogenous gravel bank, significant increase during nighttime experiments on the heterogenous gravel bank (potholes), no different drift rates based on morphological distinction during day, but significant alteration of driftrates during night. Drift during the downramping phase (D_dr_rel) was lowest for all experiments without significant differences.

3.2 Stranding

Relative stranding rates were low for all daytime experiments without differences between homogeneous and heterogeneous gravel banks (Figure 2b) (Median test p=1.000; Mann-Whitney-U-test p=0.791; Kolmogorov-Smirnov-test p=0.714). Stranding increased significant during night, both on homogenous (Median test p=0.000; Mann-Whitney-U-test p=0.000; Kolmogorov-Smirnov-test p=0.002) and heterogenous structured gravel bank (Median test p=0.001; Mann-Whitney-U-test p=0.001; Kolmogorov-Smirnov-test p=0.007) (see 2b). Moreover we identified a sevenfold higher stranding risk during nighttime experiments with heterogenously structured gravelbank compared to a homogenous structure (Median test p=0.015; Mann-Whitney-U-test p=0.000; Kolmogorov-Smirnov-test p=0.002).

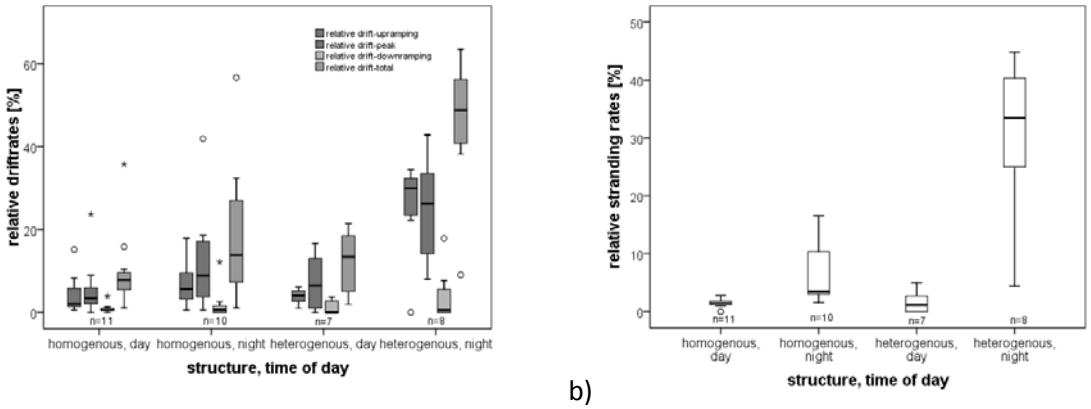


Figure 2: relative drift (a) and stranding (b) rates depending on gravel bank structure and time of day

4 CONCLUSIONS

Using gravel banks as one of their favorite habitats, juvenile graylings run the risk t of becoming stranded due to hydropeaking. Due to diurnal habitat shifts, they are more susceptible for drifting or become stranded during nighttime. These risks increase in dewatering potholes which function like traps. The results of our study underline the importance of considering hydropeaking produced at night for a comprehensive evaluation of the

possible ecological consequences. For effective restoration measures, we suggest the use of more narrowly defined hydrological threshold values for reducing hydropeaking events during nighttime including lower downramping velocities (for stranding reduction) as well as lower upramping velocities and peaks (for drift reduction). Furthermore, suitable habitats and shelters like permalinked backwaters or other morphological structures should be provided to reduce negative impacts due to hydropeaking.

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