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How ship-induced wave trains affect shoreline communities in regulated rivers

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Keywords

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Summary

Fluctuating water levels at different time scales and with varying amplitudes are common in riverine ecosystems. It can range from seasonal (low water level periods to flooding events) to daily changes, which can cause short-term desiccation phases (BONDAR-KUNZE et al., 2015). At navigable rivers, ship-induced wave trains are an additional stochastic disturbance affecting the littoral zone with a short but major impact for organisms living along the shore line zones (KILLGORE et al., 2001). They increase water turbulence via sediment suspensions and can induce dislocation (e.g. abrasion or drift) of organisms from the sediment. Maximum wave height within the train is expected to be the key variable and the magnitude of this impact depends on the ship type, speed, distance to the shore and shore morphology (LIEDERMANN et al., 2014; SCHLUDERMANN et al., 2014; GABEL et al., 2012). Especially shoreline communities such as periphyton (BONDAR-KUNZE et al, 2015), macroinvertebrates (BRUNKE et al., 2002; GABEL et al., 2012) and fish assemblages (ARLINGHAUS et al., 2002; WOLTER & ARLINGHAUS., 2003; SCHLUDERMANN et al., 2014) are effected by a pulsed increase in shear velocity, which can lead to a biomass decrease (BONDAR-KUNZE et al., 2016, CASHMAN et al., 2017) or increased drift densities of fish larvae. The aim of this study was to evaluate the effect of ship induced wave trains on periphyton communities and on the drift of early stages of fish by comparing two different shore line habitats (wave sheltered groyne field and gravel bar). For the periphyton investigations, we also disentangled the combined effect of wave action and desiccation stress, and therefore we sampled two sites in the wave sheltered groyne field (NWND = no wave action and no desiccation affected zone; DA = desiccation affected zone) and two sites on the gravel bar (WA = wave action affected zone; WADA = wave action and desiccation affected zone).

The first hypothesis was that wave impacted sites have a lower algal biomass due to a loss via abrasion, but a higher photosynthesis rate and enzyme activity to compensate the biomass loss. Furthermore the question was addressed, to which extend the settlement and drift rate of early stages of fish in two different nurseries habitats was affected by ship-induced waves. The hypothesis was that drift rates should be higher during time periods of wave impacts compared to periods with no or lower impacts. We applied a spatial design to understand in-situ effects of ship-induced wave actions on periphytic algal biomass, composition and activity. For fish drift the following ship-induced wave variables were analysed: wave height, frequency, swash, draw down and velocity. These were correlated with the drift density of early larval stages.

The results showed that up to 60 % of periphytic biomass can be potentially abraded after single ship-induced wave train events. Contrary to our first hypothesis, we found no significant lower periphyton biomass (expressed in chlorophyll-a) in the wave affected zones compared to the non-impacted ones. Reasons for this pattern could be a fast re-settlement of algal cells (REYNOLDS et al., 1990), high immigration rate of periphytic algae (PETERSON et al., 1990; ROBSON et al., 2008) and less grazing pressure (GABEL et al., 2011) in wave affected zones. Regarding the photosynthesis efficiency (measured as maximum quantum yield) after single ship-induced wave train events, a frequent damping effect of the maximum quantum yield of photochemical energy conversion was observed and thus, the photosynthetic efficiency was reduced.

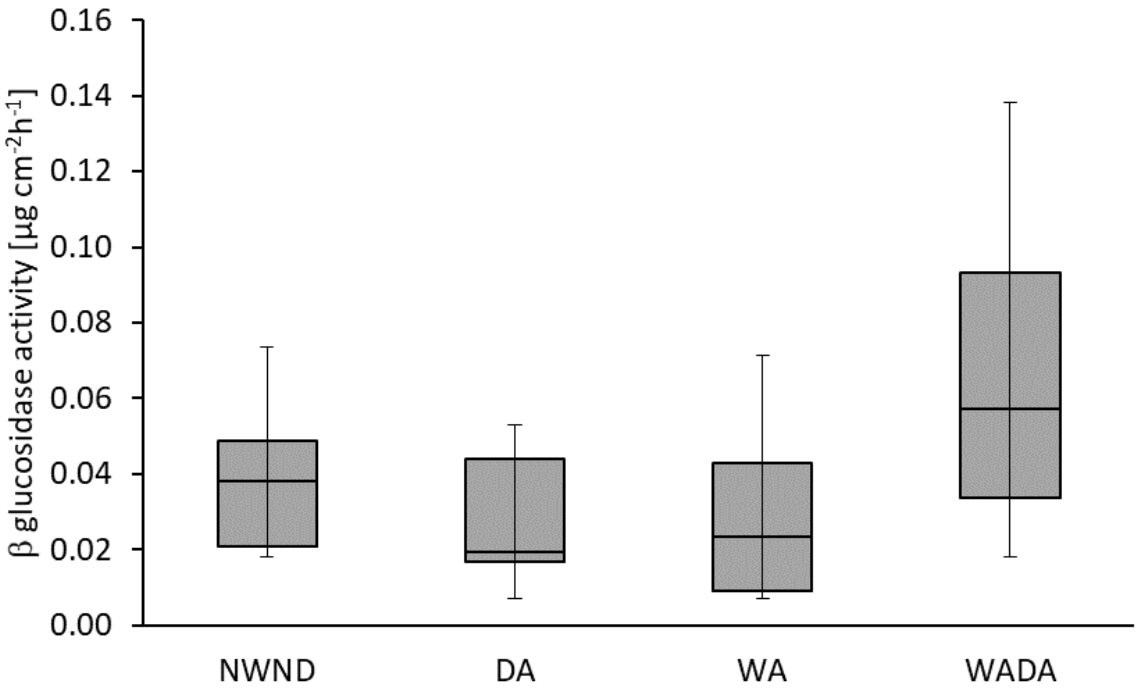

Figure 1: Periphytic β glucosidase activity at the four different zones after four weeks during low to mean water level. NWND = no wave action and no desiccation affected zone; DA = desiccation affected zone; WA = wave action affected zone; WADA = wave action and desiccation affected zone. N= 10 per group.

Looking at a heterotrophic process (enzymatic activity [here β glucosidase activity]) of the periphytic community, the results showed a decrease in activity at the desiccation and wave action affected sites (WADA) compared to the non-affected site (Fig. 1). The combined effect of wave action and desiccation stress led to a significant increase, which can be attributed on the one hand to an increase in dead algal material due to desiccation stress and on the other hand to an increased turbulence due to wave action and thus higher oxygen supply.

The drift of fish larvae showed strong diurnal fluctuations whereas the activity strongly increased during night. For minimizing this natural effect and for observing the influence of waves on young fish, further investigations were conducted during daytime. Continuous short-time samples during the day enabled the comparison of wave-impacted and non-impacted samples. The drift rates of these samples were compared and related to wave parameters by a correspondence analysis. The analyses revealed significant relations between wave oscillation, wave induced changes in flow velocities and the drift rates of fish larvae. Moreover, taxa specific differences were found. The highest drift densities were observed within the Cyprinidae (carps), followed by the Percidae (perchs) and the Gobiidae (gudgeons). Also fish stage specific differences regarding the effects of waves within the fish families of Cyprinidae as well as Percidae were observed.

Our results emphasise the need of river bank structures with shallow areas, protected from swash and draw down of ship-induced waves to maintain heterogeneous periphyton communities and serve as nursery habitat for several fish species in navigable regulated rivers.

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