Hydromorphology controlling phytobenthos development and productivity along shorelines of a large river: an experimental approach

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Introduction

At the landscape scale, rivers with their adjacent areas such as floodplains, riparian and in-stream zones are hot spots for biogeochemical processes (McClain et al., 2003). These river ecosystems provide an intense turnover of organic matter, and control therefore transport, alteration and degradation of organic matter (Townsend-Small et al., 2005; Hedges et al. 2000). Key ecological processes as carbon and nutrient cycling are mainly influenced by the physical habitat heterogeneity and retention efficiency of subsystems within the riverine landscapes. Also, the mode of carbon and nutrient delivery influences the ecosystem functioning. Thorp and Delong (2002) hypothesized in the revision of the riverine productivity model (RPM), that the major source of organic matter, which is used by the food web, is derived from autochthonous autotrophic production in the river channel. Especially during low water periods the importance of shoreline zones for the in river productivity and therefore for the carbon supply increases along regulated rivers such as the Danube downstream Vienna (Hein et al., 2005). In regulated rivers, shoreline zones provide shallow areas with reduced flow, which is important for zooplankton, juvenile fish and also the development of phytoplankton and phytobenthos (Hein et al., 2005; Reckendorfer et al., 1999; Schiemer et al., 2001, Van der Nat et al., 2002).

The development of benthic algae in stream ecosystems depends on a variety of factors, including light availability, nutrient availability, temperature, water level fluctuations and water velocity (Stevenson, 1996) (Fig. 1). The lowering of the water level and desiccation of phytobenthos communities suppresses growth and increases mortality. The impact of this environmental condition depends on the community structure and the duration of the desiccation (Wetzel, 2001). Diatoms and cyanobacteria cope better with these conditions than desmids (Goldsborough and Robinson, 1996) and *Oscillatoria spp*. suppressed *Cladophora glomerata* at intermittent drying conditions (Benenati et al.,1998) Also, the rate at which drying proceeds is important for benthic algae to employ mechanisms to survive desiccation (Peterson, 1994). The filamentous green alga (*Klebsormidium rivulare*) for example increases cell wall thickness and changes its osmotic potential at the beginning of dryness (Morison and Sheath, 1985). This desiccation resistance is much higher if it exhibits gradually, so the physiological acclimation is time dependent (Hostetter and Hoshaw, 1970). Wave turbulence also has an effect on the phytobenthos community. Wave-induced turbidity reduces light availability, but can on the other hand increase nutrient availability. The latter result only appears if the turbidity is short-lived (Wetzel, 2001). In the Danube the ship induced waves

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are occurring frequently with short durations and are expected to have tremendous effects for biota (Hirzinger et al., 2004).

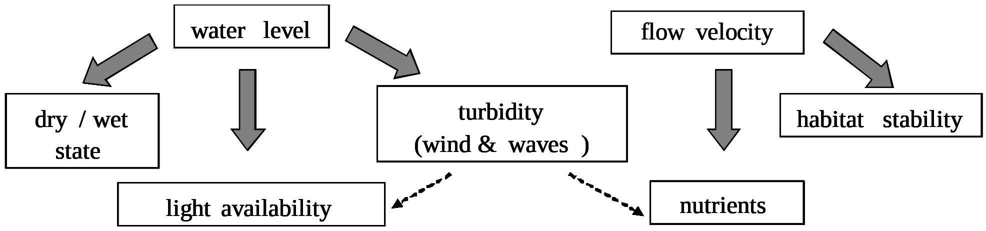

Fig. 1 Main factors affecting benthic river algae in shoreline zones

Therefore, in shoreline zones two factors control the development of benthic algae: Close to the water edge a better light availability is guaranteed, but also high risk of desiccation, while deeper structures have less light availability and higher flow velocity. We expect highest phytobenthos biomass development close to the water edge, especially during periods of constant water levels.

Objectives

For the Danube downstream Vienna an "Integrated River Engineering Project" (IREP) is developed which aims to improve both navigation and ecological conditions (Reckendorfer et al., 2005). One goal is to improve habitat quality of the inshore zone of the main channel by removal of embankments and resulting erosion. These measures restructure the shoreline, enlarge the habitat for benthic algae and alter the hydromorphological conditions. In consequence, the focus of the planned study is on water level fluctuations in shoreline zones and the effect of varying flow velocities in shorelines to describe the impact of the planned measures on benthic primary production. To understand the regulating factors for benthic primary production the following three aims will be pursued.

The first aim includes to show the impact of water level fluctuations on phytobenthos development, and to describe the spatial distribution of phytobenthos along a shoreline zone. In a following step, we intend to demonstrate the impact of ship induced waves on the phytobenthos community. The second aim deals with the impact of shoreline morphology on phytobenthos communities. Depending on the development of shallow or steep shoreline zones, it is likely that, due to different light availability, the phytobenthos shows different biomass quantities and productivity. The third aim deals with the effect that flow exposition regulates phytobenthos development. We want to test whether increasing flow velocity leads to higher uptake rates of nutrients and lower biomass development and how the change between phases of low and high velocities regulate the phytobenthos development.

Study area

The Danube east of Vienna has a catchment of 101,700 km^2, is of 9th order with a mean discharge of 1,900 $m^3\ s^{-1}$ and an annual flood discharge of 5,500 $m^3\ s^{-1}$ with a strong seasonality controlled by the regime of its alpine catchment (Tockner et al., 1999). The river stretch was originally an anabranched section (Nanson & Knighton 1996) consisting of a main stem and a channel-network of numerous small and large branches as well as extended riverine woodlands. The total anabranching zone extended over an average width of 2 km. The side arms originally presented lotic conditions almost all the year round. Areas with low flow velocities existed only in bays, abandoned arms and in side arms far away from the main stem. The river was close to a state of dynamic equilibrium.

After the major regulation scheme of 1875, long term development lead to reduced hydrologic connectivity and dramatic loss of riverine habitats. The still existing high nature value and potential for restoring key ecological processes led to the declaration of a national park in 1996. The biogeochemical dynamics in the Danube at present are affected by the reduced quality and quantity of inshore zones and the limited lateral integration of former side-arms. Efforts are now being taken to improve the geomorphologic, hydrologic and ecologic conditions in response to the present situation (Reckendorfer et al., 2005). The setting of restoration activities going on in this area allows designing experimental set-ups to test the proposed hypotheses.

Methods

Benthic algal primary production is determined with the light/dark bottle method and assimilated carbon is measured using the ^{14}C technique (Steemann-Nielsen, 1974; Strickland and Parsons, 1972). Artificial substrate (etched glass slides) for benthic primary production will be incubated in test tubes under different light conditions to simulate a light gradient. Photosynthetic capacity (P_{max}) and the gradient of the curve α_k are defined according to (Jassby and Platt 1976),.

Vertical profiles of light intensity are measured regularly to calculate light attenuations coefficients of the water column and model a daily light climate for the groyne field. Also the flow velocity is recorded at each sampling date.

Determination of algal biomass using pigment extraction (Talling and Driver, 1961*;* Jeffrey and Humphrey, 1975) and alternatively in-vitro fluorescence will be measured of benthic and suspended algal cells in field using a novel fluorescence probe (Benthofluor, Moldaenke Corp. Germany). To find out whether there is a shift in the algal community regular identification of the taxonomy is applied.

DOC concentrations are analyzed with a Shimadzu TOC-5000 C-analyzer. The dry mass and the ash-free dry mass of the total suspended matter are measured according to APHA (1992). Samples for particulate organic carbon and nitrogen (POC, PON) are dried at 60 °C for 24 h and fumed over concentrated HCl for 2-4 hours according to the carbonate content present and prepared for elemental analysis (Cifuentes et al., 1996).

Phosphorus and nitrogen fractions in the water column and the sediment are measured according to standard methods (Golterman et al., 1978; Parsons et al., 1984; Ruban et al., 2001) to quantify nutrient availability for primary producers.

Experimental setting and expected results

To understand the effect of each factor on the development an in-situ experimental design will be used. Basically, the incubation of racks with artificial substrata (etched glass slides) according to Ivorra et al. (1999) and natural substrata will be performed for maximum of one month. Sampling will take place at five dates within that month between June and September 2006. Pre-tests include detailed measurements of the effect of these artificial substrata in comparison to natural substrata (cleaned and sterilized coarse gravel in the size range of 2-7cm) on colonization patterns (Schagerl & Donabaum, 1998).

To test the impact of water level fluctuations, estimation of phytobenthos biomass development will be performed along the expected water level range. For one month, sets of etched glass plates will be exposed along a water level gradient to investigate the development of the community. A second approach is to show the development of the algae community with or without ship induced waves (in areas which are less affected by wave actions). Our expected result is that the maximum phytobenthos development occurs along the summer mean water levels. We also hypothesise that waves have a more negative effect on the phytobenthos communities due to increased turbidity and rapid sedimentation than a stimulating one by enhanced nutrient availability (Wetzel, 2001).

To understand the importance of the shoreline morphology, sets of glass slides will be exposed at different water levels at two different sites, a shallow and a steep one. In a second step, to get a more detailed picture of the potential of benthic algae, measurements of benthic productivity will be established. We hypothesise a characteristic zonation along the shorelines, whereas a low gradient exhibit a higher potential for benthic production than steep shore lines.

A similar strategy will be used to show the effect of different flow velocities. Sets of glass slides will be exposed at different current velocity situations. Additional the benthic primary production will be measured. We expect a higher algae biomass in flow reduced areas, although the nutrient uptake might be lower.

The understanding of the regulating processes of benthic algae will provide a scientific support for management decisions in future, especially regarding the WFD and river ecosystem management in a large river.

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