Spatial patchiness and similarity of macrophyte assemblages along a cut-off channel of the river Danube in Linz (Austria)

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Keywords: floodplain, stream, aquatic plants, species richness, Bray-Curtis similarity

1 Introduction

Aquatic macrophyte communities play a key role in aquatic ecosystems, structuring the water column, stabilising the substrate, providing microhabitats for other aquatic biota and contributing to the oxygen and carbon budget of the water body (Haslam 1978, Janauer & Dokulil 2006). They change in a more dynamic way than terrestrial vegetation as their habitats in lakes, rivers and wetlands are highly variable ecosystems. Extensive data collection on macrophyte distribution and floristic composition is indispensable for better understanding the factors mainly causing the variability among these aquatic plant assemblages. Several previous studies worldwide have focused on temporal changes in macrophyte assemblages (Kohler et al. 1994, Champion & Tanner 2000, Veit & Kohler 2003, Otahel'ová et al. 2007 and others). However, few studies exist on exact spatial changes in macrophyte communities and species composition in streams as exemplified by Kohler et al. (2003) and Tremp (2007). Among physical and chemical parameters, varying flow conditions associated with changing substrate types along the watercourse are seen as most influential abiotic factors shaping the structure of macrophyte assemblages (Baattrup-Pedersen & Riis 1999). This study aims to investigate the spatial distribution pattern of macrophyte communities along a lotic cut-off channel of the River Danube in Linz, Mitterwasser (Upper Austria). It represents one of the most precious aquatic habitats in Upper Austria and is part of the 'Natura 2000' protected area 'Traun-Donau-Auen' in Linz, despite the fact that the hydrology of the Traun-Danube floodplain and its watercourses was radically changed in the course of river regulation and power plant construction.

2 Study site, materials and methods

Study site: At the upstream end of the Mitterwasser, the "Weikerlsee" gravel pond feeds groundwater to the system (Fig. 1). Direct inflow of the Danube to the upper end of the floodplain was terminated by Danube river regulation and the construction of the hydroelectric power plant Abwinden Asten and its protective levee in the late 1970s. Thus, the Mitterwasser is mainly fed by groundwater and seepage water from the reservoir, which results in high water transparency. The field survey was conducted in the upper part of the Mitterwasser, which is located far from Danube backflow influence and hardly affected by even extreme flood events (Strausz & Janauer 2007).

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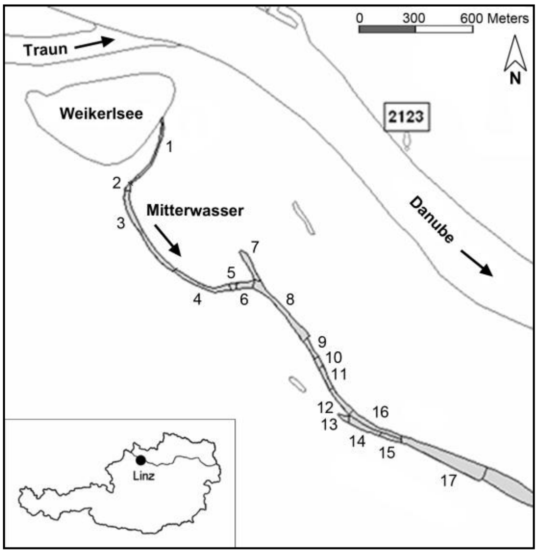

Figure 1. *Study site. The investigated part of the Mitterwasser is subdivided into contiguous survey units (labeled with numbers).*

Field survey: The aquatic plant survey including charophytes, aquatic bryophytes and vascular plants, was conducted four times a year during the vegetation periods of 2001 and 2002 (March to September) and followed the methodology of Kohler & Janauer (1995). This method is commonly applied in Europe for assessing the aquatic vegetation for EU-Water Framework Directive, and complies with the European Standard EN 14184 (European Council 2003). The investigated section of the Mitterwasser was subdivided into 17 contiguous and ecologically homogeneous individual survey units (SU, Fig. 1). For each SU, the abundance of macrophyte species was estimated using the 5-level estimator scale (Kohler Plant Mass Estimate values, PME), which comprises both the area and the vertical development of the plant stands. The ordinal measures of PME range from 1 (rare), 2 (occasional), 3 (frequent), 4 (abundant) to 5 (very abundant). Vegetation samples were taken with the aid of a small anchor and a rake with extendable handle, respectively. Macrophyte identification was based on Casper & Krausch (1980, 1981) and Fischer et al. (2005) for vascular plants, Frahm & Frey (1992) for bryophytes and Krause (1997) for charophytes. Survey unit lengths were derived from a GIS based map; substrate type, flow velocity and water temperature assessment had largely been described elsewhere (Strausz & Janauer 2002, Strausz et al. 2006, Strausz & Janauer 2006).

Data analysis: For statistical use, ordinal scaled PME values were transformed into quantitative data following Janauer & Heindl (1998). Plant species occurring in only one survey unit during the whole investigation period were removed from the data matrix as they produced only negligible biomass. The persistence in the macrophyte species composition and abundance was calculated as Bray-Curtis similarity between each pair of successive survey units using software package PRIMER 5 for Windows. For illustrating floristic changes along the Mitterwasser, species turnover rates were calculated as described for streams in the Rhine floodplain (Tremp 2007): the number of species only occurring in a survey unit was added to the number of species only occurring in the successive downstream survey unit; the sum was divided by total species number of both survey units. The resulting index is scaled between zero and one and indicates from floristic equality (zero) to no species in common (one).

3 Results

During the eight field surveys, altogether 54 aquatic plant species were recorded in the Mitterwasser. Of these, 9 rare species producing only negligible biomass were removed from the data matrix. The majority of the remaining 45 species grew submerged; *Iris pseudacorus* L., *Phalaris arundinacea* L. and *Phragmites australis* (Cav.) Trin. ex Steud. occurred as helophytes.

Highest species numbers were recorded downstream in SU17 with a mean of 24 species, followed by SU8 (15 species) and SU15 (14 species). Lowest species numbers were recorded upstream in SU1 (2 species, Fig. 2).

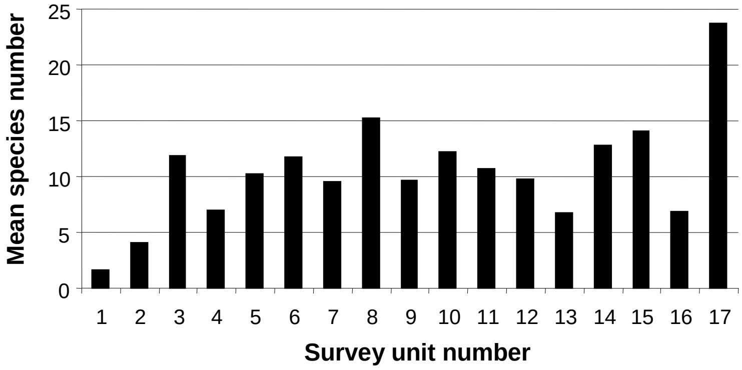

Figure 2. *Mean species numbers per survey unit in the Mitterwasser over the investigation period 2001 and 2002.*

Floristic heterogeneity was highest at the source of Mitterwasser (SU1-2: turnover 0.65), while floristic unification increased over the length of the stream course and slightly decreased downstream again (SU12-16: turnover 0.35, SU16-17: turnover 0.42; Fig. 3).

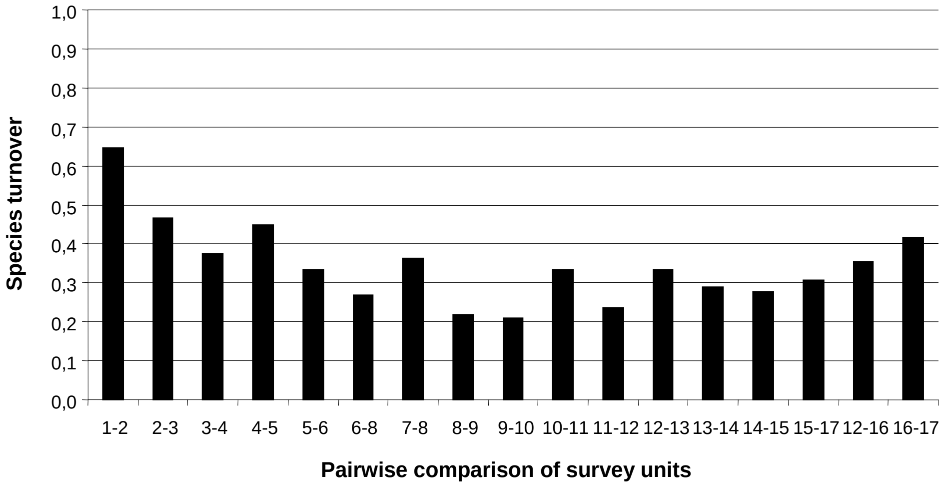

Figure 3. *Turnover rates of macrophyte species assemblages in consecutive survey units in the Mitterwasser over the investigation period 2001 and 2002 (1: the SU have no species in common, 0 = all species are identical).*

Average Bray-Curtis similarity between macrophyte assemblages in consecutive survey units showed four peaks and five minimum values (Fig. 4): Highest similarity values occurred mainly between SU with low flow velocities (<0.10 ms^{-1}) and fine sediment layer, as between SU3-4 (69%), SU6-8 (57%) and SU14-15 (59%) and refer to lower species turnover rates. Maximum similarity (74%) between SU11-12 represents an exception as SU11 was mainly dominated by gravel and mean flow velocities of 0.47 ms^{-1}, while SU12 was mainly dominated by finer sediments and flow velocities around 0.10 ms^{-1}.

The five lowest Bray-Curtis similarity values between SU1-2 (7%), SU4-5 (27%), SU7-8 (25%), SU12-13 (29%) and SU16-17 (36%) correspond well with the higher species turnover rates in these pairs of survey units. Flow velocities and substrate types in successive survey units changed between SU1 (0.31 ms^{-1}, gravel) and SU2 (0.06 ms^{-1}, mud) as well as between SU4 (0.05 ms^{-1}, mud) and SU5 (0.46 ms^{-1}, gravel). The other mentioned survey units (SU7-8, SU12-13 and SU16-17) were all dominated by muddy sediment and very slow flow velocities (<0.10 ms^{-1}). SU7 and SU13 are shallow oxbows with stagnant water and higher mean water temperature. All in all, similarity increases over the whole investigation period (Fig. 4, trend line with R=0.25).

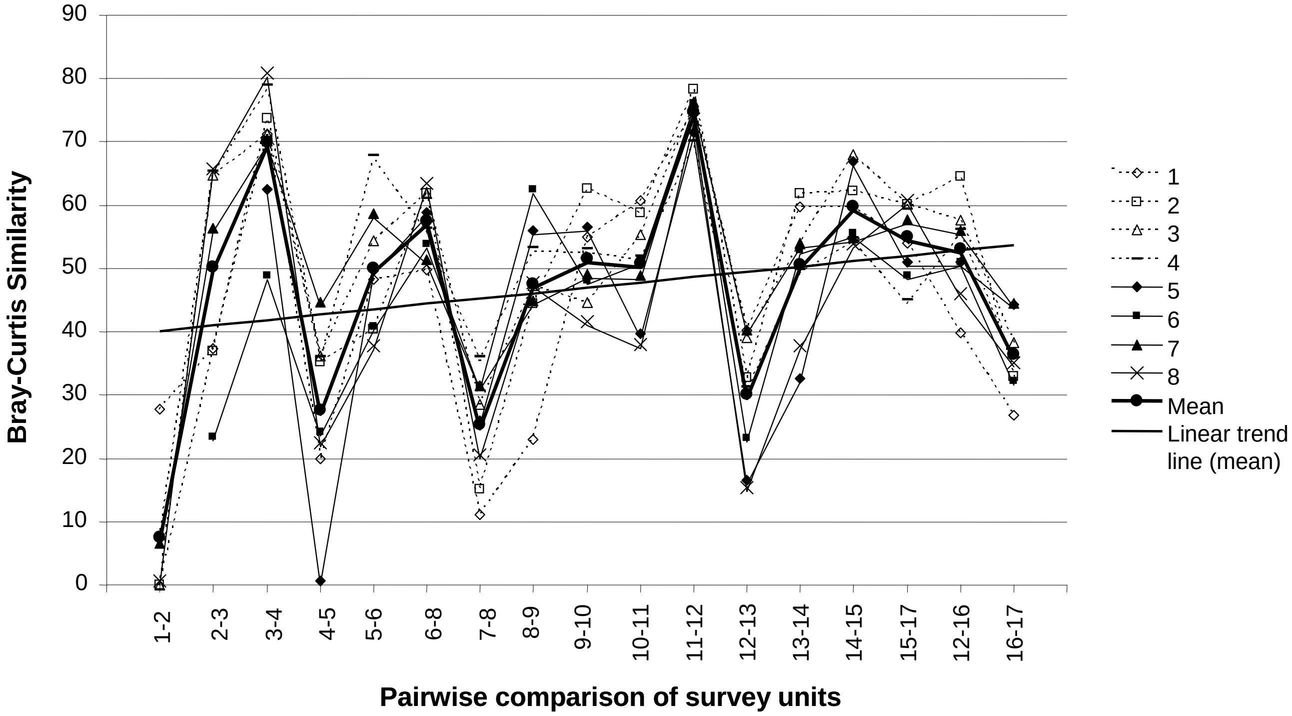

Figure 4. *Bray-Curtis similarity between consecutive survey units along the Mitterwasser over the investigation period 2001 and 2002 (eight surveys). Surveys 1-4 (2001), 5-8 (2002) and the average over the whole period are presented.*

The significant inverse relationship between similarity and species turnover illustrates that a high species turnover rate implies a high dissimilarity among the macrophyte assemblages of two consecutive survey units, while a low species turnover stands for the persistence of macrophyte structure (Fig. 5).

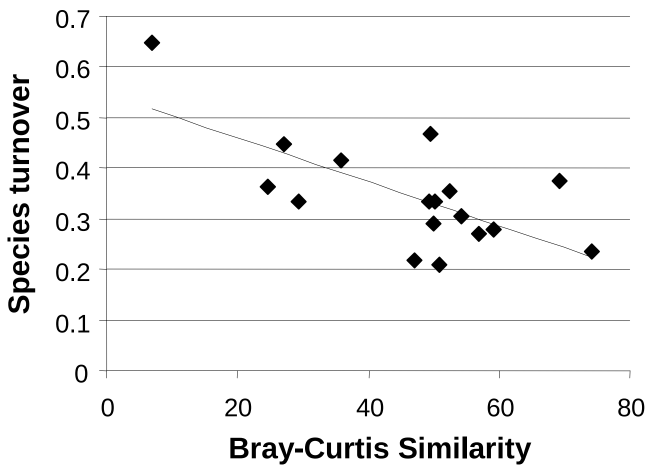

Figure 5. *Regression of Bray-Curtis similarity versus macrophyte species turnover of successive survey units in the Mitterwasser for both survey years 2001 and 2002 (R=-0.68, p<0.01).*

The highest species turnover and lowest similarity was found at the source of the Mitterwasser while inverse values of both measures commonly occurred at the downstream stretches (Figs. 3 and 4).

Similarity values were associated with trends of abiotic parameters. While the increase of persistence of macrophyte community structure was positively related with ‘survey unit length’ and ‘water temperature’ we found an inverse relationship for the parameters 'substrate type' and 'flow velocity'. All these trends, however, were statistically not significant and are therefore not illustrated in detail.

4 Discussion

The macrophyte species composition in the Mitterwasser corresponds well with numerous studies conducted in the Danube floodplain in Austria and its neighboring countries (Janauer & Pall 1999, Ráth et al. 2003, Otahel'ova et al. 2007, Barta & al. 2009 and others). Alterations of species within assemblages were studied for various biota groups as phytoplankton (Teubner et al. 2003), zooplankton (Sonntag et al. 2006) and macroinvertebrates (Heino et al. 2007) on temporal and spatial scales. The similarity of plankton assemblages between successive samples, measured by Bray-Curtis index, did not exceed values of 90% for phytoplankton and 85% for ciliate zooplankton although at the same time the total biomass of the respective plankton group was constant (biomass net change rate = 0; Teubner et al. 2003, Sonntag et al. 2006). In the present macrophyte study the similarity index on spatial gradients did not exceed values of 80%. This illustrates the spatial patchiness of macrophyte species distribution along the stream bed. In other words, at least a 20% change occurred between aquatic plant assemblages in consecutive survey units. In contrast to temporal species succession in aquatic plankton, the spatial similarity between macrophyte assemblages was even lower than 10%. This low persistence of macrophyte communities resulting in maximum species turnover rates occurred at the source of Mitterwasser. In this shallow most upstream stretch, the groundwater fed outflow of lake Weikerlsee, environmental factors like high flow velocities and coarse substrate determined species composition. Easily erodable amphiphytes with partly high regenerating abilities from fragments prevailed and produced only a low biomass. These species were likely to be uprooted from litoral habitats of Weikerlsee, transported downstream and rooted again at sheltered sites in the Mitterwasser. Strausz & Janauer (2007) showed a similar effect on amphiphytes in downstream parts of Mitterwasser during the 2002 flood. Subsequently downstream of the above mentioned near-source stretch, successive survey units were characterised by floated-leafed and submerged macrophyte communities related to lower flow velocities and finer substrate due to increased water depth.

This alteration in hydrological and environmental conditions recurred along the Mitterwasser and caused – to a great extent – alterations in aquatic species assemblages. However, endogenous ecological processes like transport of plant fragments and propagules to downstream, structurally different sections, can promote the establishment of floristically similar plant communities in physically different survey units (Tremp 2007, Riis & Sand-Jensen 2006). This is related to low turnover rates between some structurally different successive Mitterwasser sections.

To conclude, Mitterwasser can be considered as a hydrologically stable stream in the sense of Riis & Biggs (2003) as it is protected from natural flooding by damming. Local hydraulic factors such as water velocity, substrate type and depth are likely to primarily determine the establishment of macrophyte assemblages in streams with low disturbance frequencies (Riis & Biggs 2003). Environmental heterogeneity at relatively small scales allows species with differing demands to coexist by niche separation (Santamaria 2002) resulting in spatial patchiness of macrophyte communities along the stream course.

Acknowledgements

We thank Harald Zechmeister and Brigitte Schmidt for providing assistance with bryophyte identification. This study was partly supported by the provincial government of Upper Austria and the Dr. Heinrich Jörg-Foundation (Graz), Austria.

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