Strausz V, Janauer GA, Teubner K (2006) Predicted changes in macrophyte species composition induced by flooding in a Danube floodplain restoration area in Linz (Upper Austria). *In:* Proceedings of 36th International Conference IAD, Vienna:428-433.

Predicted changes in macrophyte species composition induced by flooding in a Danube floodplain restoration area in Linz (Upper Austria)

Veronika Strausz[1], Georg A. Janauer[1] and Katrin Teubner[1]

Keywords: oxbow lakes, current velocity, frequency distribution, flow, Natura 2000

Introduction

Flow is one of the key parameters in aquatic habitats that influences distribution and growth of water plants. The water flow affects macrophytes (i) directly by velocity pull, battering and abrasion and (ii) indirectly through its effects on the channel bed, such as erosion, sedimentation and anchorage of the plants (REMY 1993, CHAMBERS et al. 1991, HASLAM 1978). In turn, aquatic plants modify the flow patterns in streams due to their hydraulic resistance to flow (DODDS & BIGGS 2002, STEPHAN 2002, SAND-JENSEN & PEDERSEN 1999, SAND-JENSEN & MEBUS 1996, MACHATA-WENNINGER & JANAUER 1991). A detailed study on the relationship between flow resistance of macrophytes and water velocity was treated by SAND-JENSEN (2003) and initiated an intense discussion on methodical questions (SUKHODOLOV 2005, SAND-JENSEN 2005, GREEN 2005). Extreme events like floods represent disturbances in aquatic habitats. They usually generate turbulent flow of great force and velocity and relocate the bed sediments (HASLAM 1978, HENRY et al. 1996). Macrophyte response to disturbances and the role of connectivity in floodplain water bodies had been described in detail by different authors (BARRAT-SEGRETAIN & AMOROS 1995; HENRY et al. 1996; BORNETTE et al. 1998; BARRAT-SEGRETAIN et al. 1999; HEILER et al. 1995).

To predict species composition after natural or man-induced flooding, species composition before the disturbance, the ecological requirements of the species and their biological traits have to be known (HENRY et al. 1996). The restoration project in the Traun-Danube-floodplain in Linz (Upper Austria) focuses on the distribution of macrophyte species in habitats shaped by flow velocity, a key species trait described in HENRY et al. (1996). Artificial channels including oxbow lakes shall ameliorate the water supply in the area and changes in macrophyte diversity must be predicted in response to flooding with Danube surface water. Based on present flow conditions the effect of transforming still waters to flowing conditions is predicted for two scenarios: (i) permanent water flow at 0.2 $m\,s^{-1}$ and (ii) short-term flood-flow at 0.8 $m\,s^{-1}$ (JANAUER et al. 2001). Varying flow velocities and sediment types (STRAUSZ & JANAUER 2002) make the selected site “Mitterwasser” a good example to extend our knowledge on macrophyte structure changing along gradients of flow-velocity.

Materials and Methods

Study site: The study was carried out in “Mitterwasser”, a ground-water-fed former side-channel of the River Danube in Linz (Upper Austria), which is part of the Natura 2000-protected area “Traun-Donau-Auen”. Situated on the orographic right side of the River Danube (Danube River-km 2124-2117) it is connected to the main river channel only on its lower end. The levees of the hydroelectric power plant Abwinden-Asten separate the Danube floodplain from the main river channel, resulting in a chain of small, mainly lentic oxbow

[1] Department of Freshwater Ecology – Hydrobotany, University of Vienna, Althanstraße 14, A-1091 Vienna, Austria

lakes. A drain filled with ground water and river seepage parallels the levees on the outer side and meets the Mitterwasser at c. River-km 2122. Only flood-backflow enters the backwater system today. A connection with the Danube at the up-river end of the oxbow lake system shall ameliorate the hydrological conditions.

Flow velocity was measured in stands of 12 macrophyte species in the Mitterwasser, and the flow in the present seepage drain (up to 0.52 m s^{-2}). Measurement points were selected according to species growing in the oxbow lakes described in Table 1. Flow velocity was measured with a Höntzsch (Germany) propeller device, using a calibrated tube fitting to avoid interference with plant (MACHATA-WENNINGER and JANAUER 1991). At each site current velocity was measured in a vertical profile at discrete water depth every 5-20 cm (15 readings each). Frequency-distributions of depth integrated flow velocities are shown for the whole water column (m s^{-1}) in Figures 1a-k (Sigma Plot 9.0, SYSTAT Software). Taxonomy follows Fischer et al. (2005) and Krause (1997) for Characeae.

Macrophyte species	A	B	C	D
Callitriche hamulata Kütz ex W.D.J. Koch				■
Callitriche obtusangula Le Gall		■		
Ceratophyllum demersum L.	■			
Chara contraria A. Br. ex Kütz				
Chara globularis Thuill.				
Hippuris vulgaris L.				
Hottonia palustris L.				
Lemna minor L.				
Lemna trisulca L.				
Myriophyllum verticillatum L.	■			
Nitella opaca (Ag. ex Bruz.) Ag.				
Nuphar lutea (L.) J.E. Smith in Sibthorp et J. E. Smith	■			
Potamogeton berchtoldii Fieber	■			
Potamogeton friesii Rupr.	■			
Potamogeton lucens L.			■	
Potamogeton natans L.				
Potamogeton pectinatus L.	■			
Potamogeton pusillus L.			■	
Ranunculus circinatus Sibthorp			■	
Sagittaria sagittifolia L.		■		
Stratiotes aloides L.				
Utricularia vulgaris L.				

Table 1: Macrophytes occurring in all the lentic and lotic water bodies of the study site. Bold print indicates species which are common in both habitats (lotic "Mitterwasser" channel and seepage drain and the lentic oxbow lakes) and hence flow velocity measurements were carried out in "Mitterwasser" and seepage drain. Column A indicates species which are common over at a wide range of flow velocities (occurrence in at least 5 flow-velocity classes); other species are restricted to four (B), three (C) or two velocity classes (D) only.

Results

Macrophyte species found in the survey are presented in Table 1. More than half of the species occurred in both the lentic oxbow lakes and the lotic "Mitterwasser" channel and the seepage drain. The distribution of these species along the gradient of flow-velocities is shown in Fig. 1.

According to our empirical data set 17 velocity classes were statistically defined from zero to 0.52 ms^{-1} with a class width of 0.0327. Flow velocities showed two characteristic distribution patterns: *Ceratophyllum demersum, Nuphar lutea, Potamogeton berchtoldii, P. friesii* and *P. lucens* concentrated mainly at lower flow velocities (Fig. 1a-d), whereas *Potamogeton pectinatus, P. pusillus, Sagittaria sagittifolia, Myriophyllum verticillatum* and *Ranunculus circinatus* were more evenly distributed over all velocity-classes (Fig. 1e-i). *Callitriche obtusangula* showed an intermediate position (Fig. 1k). The species occurring in the highest velocity classes were *Ceratophyllum demersum* and *Potamogeton pectinatus* (until velocity class 12, 0.33-0.36 m s^{-1}), *Ranunculus circinatus* (until velocity class 14, 0.39-0.43 m s^{-1}) and *Myriophyllum verticillatum* (until velocity class 15, 0.43-0.46 m s^{-1}). *Callitriche hamulata* is found in only two velocity classes and not shown in Fig. 1.

Scenarios are based on two threshold velocities: 0.2 and 0.8 m s^{-1} (Fig.1). 0.8 m s^{-1} exceeds most of the flow velocities tolerated by macropyhtes in their natural habitats.

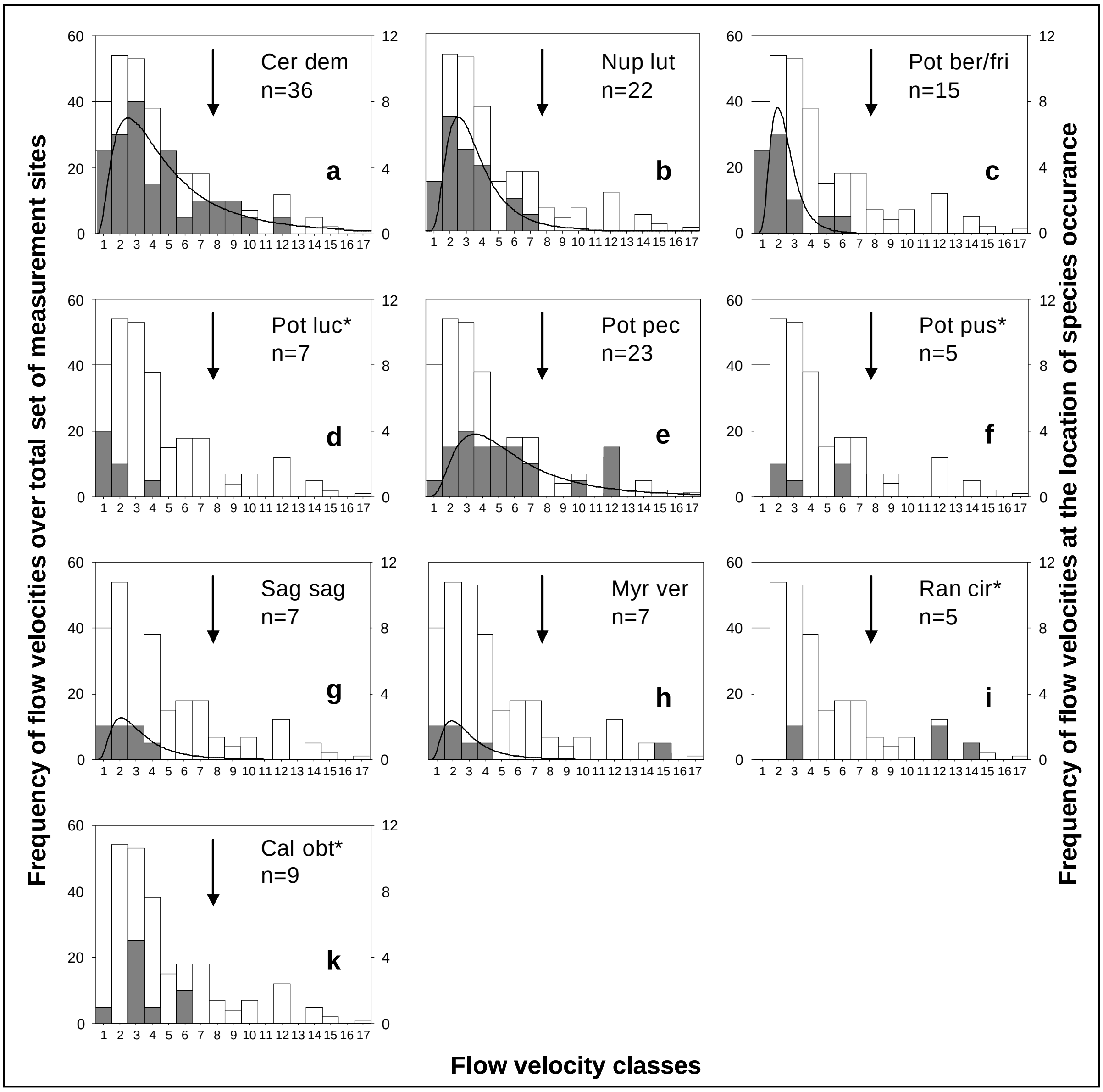

Figure1: Frequency distribution of flow velocities in the "Mitterwasser" and the seepage drain. Class width=0.0327; Flow velocity classes: 0 (class 1) to 0.52 m s^{-1} (class 17). White bars=total set of measurement sites. Grey bars=measurement at the location of species occurrence (regression curve fitting by log normal distribution); n=number of measuring sites per species. No regression curves were produced for species occuring at very few locations only (species marked by an asterisk). Black arrows indicate 0.2 m s^{-1} flow speed which is suggested for man-induced flooding. Abbreviations: Cal obt *(Callitriche obtusangula), Cer dem (Ceratophyllum demersum*), Myr ver (*Myriophyllum verticillatum*), Nup lut (*Nuphar lutea*), Pot ber/fri (*Potamogeton berchtoldii/friesii*), Pot luc (*P. lucens*), Pot pec (*P. pectinatus*), Pot pus (*P. pusillus*), Ran cir (*Ranununculus circinatus*), Sag sag (*Sagittaria sagittifolia*).

Discussion

Adaptation of macrophytes to current velocity and their resilience after disturbance play a key role in predicting species composition following re-connection of oxbow lakes to the main river. Our results are consistent with HASLAM (1978) and MIDCC (2005) which is shown in Tab.2.

Ceratophyllum demersum, *Sagittaria sagittifolia* and *Lemna minor* agg. are species best "correlated with negligible flow" (HASLAM 1978: 29), which is confirmed by our measurements (Fig.1a, g). *Nuphar lutea* and *Potamogeton pectinatus* mainly occur in "slow flow" also shown by our data (Fig.1b, e). The latter often grows in moderate flow as well, also shown by three of our *P. pectinatus*-sites (flow class 12, 0.33-0.36 m s^{-1}, Fig.1e). *Ranunculus circinatus* occurred in class 3, 12 and 14 (>0.39-0.43 m s^{-1}). Hence, our results confirm HASLAM'S study who stated that larger *Ranunculus*-populations are more frequent in fast flow whereas *Ranunculus circinatus* also occurs in negligible flow.

Table 2: Flow-categories after HASLAM (1978), MIDCC and the authors.

HASLAM (1978)	MIDCC (2005)	STRAUSZ, JANAUER & TEUBNER (2006)
	1) no flow, stagnant	
1) negligible flow	2) low flow, from just visible (>0 – <0.30 m s^{-1})	velocity class 1-10 (0 – 0.30 m s^{-1})
2) slow flow		
3) moderate flow	3) medium flow (0.35 – 0.65 m s^{-1})	velocity class 11-17 (>0.30 – 0.52 m s^{-1})
4) fast flow	4) high flow (>0.70 m s^{-1})	

Regarding resilience some species tolerate disturbance better than others because of stronger regeneration and colonisation potential (BARRAT-SEGRETAIN et al. 1999). *Ceratophyllum demersum* has high abilities, while *Hippuris vulgaris*, *Potamogeton pusillus*, *P. lucens* and *Utricularia vulgaris* are susceptible as shown in experiments by BARRAT-SEGRETAIN et al. (1999). Timing of disturbance influences species composition as well: *Sagittaria sagittifolia* regenerates quickly after summer floods while *Potamogeton pusillus* recovers easily after disturbance in winter. *Ranunculus circinatus* and *P. pusillus* are both temporarily affected by summer floods (BARRAT-SEGRETAIN & AMOROS 1995).
Our study in the Danube floodplain area confirms that current velocity determines macropyhte diversity and abundance in running waters. A flooding with 0.2 m s^{-1} is likely to be tolerated by *Ceratophyllum demersum* and *Potamogeton pectinatus* as these species occur over a wide range of flow velocities. *Ranunculus circinatus* and *Myriophyllum verticillatum* both occur in flow velocities up to 0.43 and 0.46 m s^{-1}. Nevertheless, predicting the effects of permanent higher water flow on these species, a larger set of flow measurements would be desirable. As *Potamogeton berchtoldii*, *P. friesii*, *P. lucens*, *P. pusillus*, *Sagittaria sagittifolia* and *Callitriche obtusangula* occur in velocity classes below 0.2 m s^{-1} we assume that these species will decrease in abundance within short time. *Nuphar lutea* tolerates just about 0.2 m s^{-1} and will probably decrease, too – as also all the species not given in bold letters in Table 1 –, as even a modest increase in current velocity is capable of reducing aquatic plant abundance (CHAMBERS et al. 1991, JANAUER & PALL 1999). A short-term flood-flow at 0.8 m s^{-1} exceeds most of the flow velocities tolerated by macropyhtes in their natural habitats and will probably flush away all species present.

Summary

The backwater system of the Danube in Linz (Upper Austria) is cut off from inundations by damming and impoundment and receives only backflow from the main river channel. Several mainly lentic water bodies remain as part of the local backwater system and house a number of endangered aquatic species. This study predicts the long-term change in macrophyte species composition and abundance due to proposed artificial flooding to ameliorate the surface and ground water conditions in the Danube floodplain area. Flow velocity measurements in stands of 12 macrophyte species in a former river channel and a seepage

drain in the Danube floodplain showed that *Potamogeton berchtoldii*, *P. friesii*, *P. lucens*, *P. pusillus*, *Sagittaria sagittifolia*, *Callitriche obtusangula* and *Nuphar lutea* occur in velocity classes below 0.2 $m\,s^{-1}$. In consequence of a man-induced flooding with 0.2 $m\,s^{-1}$ these species will most probably decrease in abundance within short time. *Ceratophyllum demersum* and *Potamogeton pectinatus* occur over a wide range of flow velocities, thus, a flooding is likely to be tolerated. A flooding by 0.8 $m\,s^{-1}$ will completely dislodge all the species present in the lentic water bodies.

Acknowledgements

This study was partly supported by the provincial government of Upper Austria and the Dr. Heinrich Jörg-Foundation (Graz).

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