Analysis of flooding frequency and nutrient retention capacity of riparian wetlands along the river Elbe

S. Natho, M. Venohr

Leibniz-Institute of Freshwater Ecology and Inland Fisheries; Dept. of Lowland Rivers and Shallow Lakes; Müggelseedamm 310, 12587 Berlin, Germany; s.natho@igb-berlin.de; +049 (0) 30 6392 4088

Keywords: riparian wetland; flooding frequency; nutrient concentration

Background

The role of wetlands for nutrient retention is widely accepted (Trepel & Palmeri 2002, Verhoeven et al. 2006, Jansson et al. 1994, Woods Hole Group 2007). Politicians and planners regard riparian wetlands as cost effective measurements to reduce not only nutrient loads in rivers during and after floods but also diffuse nutrient emissions from agricultural areas which pass riparian wetlands as buffer strips between field and river (Jansson et al. 1994, Arheimer & Wittgren 1994, 2002, CIS 2003). Nitrate (NO_3-N) and phosphorus (here as TP) retention are subject to different retention processes during flood events; whereas denitrification is the most important process for NO_3-N on a yearly base (Venohr 2006, Trepel & Palmeri 2002, Saunders & Kalff 2001, Byström 1998, Spieles & Mitsch 2000), sedimentation is the most important process for TP retention (Behrendt & Opitz 2000, Verhoeven et al. 2006, Vougth 1994, Kronvang et al. 1999). The extent of nutrient retention in riparian wetlands during floods depends on wetland size, water temperature, retention time and depth of inundation (Arheimer & Wittgren 1994, 2002). Except of certain study wetlands, inundated areas of whole river basins are not known. Thus the BMU & BfN (2009) carried out a project to quantify the extent of recent riparian wetlands along German rivers with catchment sizes bigger than 1000 km². Nevertheless, it is not known, which parts of these riparian wetlands are inundated how often and how long.

Methods

In this study the extent of inundated riparian wetlands along the river Elbe from km 170 to km 500 were calculated with the software FLYS 2.1.3 (2011). The Federal Institute of Hydrology (BfG) has developed the River Hydrology Software FLYS as a water level information and analysis tool for German Federal Waterways. FLYS is not a hydraulic flow model but processes model results (1D) as well as basic and special geographic data. The software can derive water levels at any point of the course of the river on the basis of known discharges (for details see BfG 2009 or Busch et al. 2009). The module “Flood maps” (computation engine: WSPLGEN) is able to calculate the extent of the river water table at high floods also on the riparian wetland, based on a digital terrain model (DTM).

D270, D300, D320, D330, D340, D350, D360, as well as MNQ; MQ, HQ1 or 2 and HQ5[1] were calculated as long term means (in general from 1930 to 2006) for the sections of the seven gauging stations to learn when the Elbe starts overflowing. The actual frequency (1990-2005) of these discharges was calculated. For discharge events higher than D340 also inundation heights were calculated in 0.5 meter steps, as flooding heights are assumed to influence the denitrification rate (Arheimer & Wittgren 1994).

The data is then provided by FLYS 2.1.3 (2011) as GIS compatible file format. Detailed flooding maps for the above mentioned discharges were processed in ArcGIS. The inundation depths were considered in separate maps for each section.

[1] D270 refers to the German **D**auerlinie, meaning, that on 270 days per year there is less discharge; MNQ = mean low Q, MQ = mean Q and HQ 5 = Q with a frequency of once in five years.

To examine the influence of riparian wetlands on nutrient retention parameters from water quality stations (NO_3-N and TP as daily concentrations for 1996-2002) were taken into consideration. It is hypothesized that when the river overflows, loads will decrease. Whereas when floods are very high, concentrations increase again, because retention time is too low. As different discharge levels along the river Elbe are caused by the Q of tributaries, the relation of Q at the sample time of concentrations and MQ was applied.

Results

Inundation frequency and size of riparian wetlands differ at the sections along the river Elbe. Not only the total size of riparian wetlands varies from 10 to 80 km², but more important also the extent of riparian wetlands which is flooded for a certain time per year. Also the relation of size of riparian wetland to flow length of river section varies from 0.4 to 2.2. Considering different flooding levels it can be shown that around gauge Wittenberge app. 60% of the riparian wetland (equals about 41 km²) are flooded on more than 55 days a year (longterm mean between 1990 and 2005). In wet years discharges can be high enough to produce floods on more than 160 days on these areas. It should be noted, that after such floods, parts of riparian wetlands normally stay inundated even longer. Whereas for NO_3-N no clear trend of retention could be observed, TP was shown to be retained during floods.

Acknowledgments

The authors greatly thank the FLYS team J. Graf, M. Hammer, M. Hatz, N. Busch and D. Meißner from the BfG who provided the software FLYS 2.1.3 and always found time to help if questions occurred.

References

Arheimer, B., Wittgren, H. Ba. (1994) Modelling Effects of Wetlands on Regional Nitrogen Transport; Ambio Vol. **23**, No. 6, 378-386; special issue: Wetlands and Lakes as Nitrogen Traps.

Arheimer, B., Wittgren, H. B. (2002) Modelling nitrogen removal in potential wetlands at the catchment scale; Ecological Engineering **19**, 63-80.

Busch, N., Meißner, D., Hammer, M., Hatz, M. & M. Graf (2009) Flusshydrologische Software Version 2.1.3; brochure of The Federal Institute of Hydrology (in German only), 17 pages.

BfG (2009): Wasserstandsinformationsdienste der BfG für Bundeswasserstraßen. Kolloquium am 24. März 2009 in Koblenz. Bundesanstalt für Gewässerkunde, Koblenz

Byström, O. (1998) Analysis - The nitrogen abatement cost in wetlands; Ecological Economics **26**, 321-331.

CIS (2003) Horizontal Guidance Document on the Role of Wetlands in the Water Framework Directive, Final Draft Version 8.0, 7th November 2003

Jansson, M., Andersson, R., Berggren, H., Leonardson, L. (1994) Wetlands and Lakes as Nitrogen Traps; Ambio Vol. **23**, No. 6, 320-325; special issue: Wetlands and Lakes as Nitrogen Traps.

Kronvang, B., Hoffmann, C. C., Svendsen, L. M., Windolf, J., Jensen, J. P., Dørge, J. 1999 Retention of nutrients in river basins; aquatic Ecology **33**; 29-40.

Trepel, M. and Palmeri, L. (2002) Quantifying nitrogen retention in surface flow wetlands for environmental planning at the landscape-scale; Ecological Engineering **19**, 127-140.

Saunders, D. L., Kalff, J. (2001) Nitrogen retention in wetlands, lakes and rivers; Hydrobiologia **443**: 205-212.

Spieles, D. J. & Mitsch, W. J. (2000) The effects of season und hydrologic und chemical loading on nitrate retention in constructed wetlands: a comparison of low- und high-nutrient riverine systems. - Ecological Engineering **14,** 77-91.

Venohr, M. (2006): Modellierung der Einflüsse von Temperatur, Abfluss und Hydromorphologie auf die Stickstoffretention in Flusssystemen. Berliner Beiträge zur Ökologie 14, Weißensee Verlag, Berlin, 193 S.

Verhoeven, J. T.A., Arheimer, B., Yin, C. and Hefting, M. M.(2006) Regional and global concerns over wetlands and water quality; Trends in Ecology and Evolution Vol.**21** No.2; 96-103

Vought, L.B.-M., Dahl, J., R., Pedersen, C. L., Lacoursière, J. O. (1994) Nutrient Retention in Riparian Ecotones; Ambio Vol. **23**, No. 6, 342-348; special issue: Wetlands and Lakes as Nitrogen Traps.

Woods Hole Group (2007) Natural attenuation of nitrogen in wetlands and waterbodies; Final report; MassDEP/USEPA funded study