The importance of hydrodynamics for biodiversity: combining safety and nature

R.J.W. de Nooij[1], R.S.E.W. Leuven[1*], W.C.E.P. Verberk[1,2], H.J.R. Lenders[1] & P.H. Nienhuis[1]

[1]*Institute for Wetland and Water Research, Radboud University Nijmegen, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands;* [2] *Bargerveen Foundation. P.O. Box 9010, 6500 GL Nijmegen, The Netherlands;*
Correspondence: R.Leuven@science.ru.nl

Abstract
Large-scale reconstruction measures are being prepared and implemented in river basins of north-western Europe for the purpose of flood defence, ecological rehabilitation and infrastructural improvements. These measures will have far-reaching consequences for the physical structure, hydrodynamics, and hence for the ecological functioning and biodiversity of river-floodplain ecosystems. River managers are legally obliged to take protected species and their habitats into account in their effect assessments for spatial planning, physical reconstruction and management (e.g. Environmental Impact Assessments and Strategic Environmental Assessments). The relationship between protected and endangered riverine species and hydrodynamics in river-floodplain ecosystems are examined, linking the ecological significance of hydrodynamic conditions to the importance of species to policy and legislation. Hydrodynamic conditions along a lateral gradient were linked to various taxonomic groups. Our results show that (1) protected and endangered species require ecotopes along the entire hydrodynamic gradient; (2) each species and taxonomic group exhibits a specific distribution pattern along the hydrodynamic gradient; (3) low-dynamic parts are highly important for many species, and (4) species differ in their specificity for hydrodynamic conditions. River reconstruction and management should aim at increasing the spatial heterogeneity of hydrodynamic conditions, thus re-establishing the entire hydrodynamic gradient (including intermediate and low dynamic parts).

Introduction

Natural river-floodplain ecosystems exhibit a hydrodynamic gradient from the main channel to inundation-free areas. A wide variety of habitats exists along this gradient, in space and time, created by the dynamic interaction of water, sediment and biota, leading to high biodiversity. However, many riverine species have become rare and endangered in the Rhine and Meuse catchments, as a consequence of the dramatic changes in river-floodplain ecosystems (e.g. see figure 2). These modifications have greatly reduced the surface area and hydrodynamic conditions of the riverine landscape. Modifications mainly impact on the parts of intermediate dynamics, creating a situation with either extremely high dynamic parts or extremely low dynamic part (inundation free areas).

Large-scale reconstruction measures are being prepared and implemented in river basins of north-western Europe for the purpose of flood defence, ecological rehabilitation and infrastructural improvements. These measures will have far-reaching consequences for the ecological functioning of river-floodplain ecosystems. Maximizing ecological benefits of floodplain reconstruction and minimizing conflicts between river management and nature legislation (e.g. European Habitats and Birds Directives) require knowledge on the response of protected and endangered riverine species (PER-species) to river dynamics. The BIO-SAFE model integrates available knowledge about habitat demands of these species for the rivers Rhine and Meuse and their political and legal status (De Nooij et al., 2004; 2006). This model was used to answer the following questions:

- How important are different parts of the hydrodynamic gradient for PER-species of different taxonomic groups in river-floodplain ecosystems?
- How specifically do PER-species utilize the various parts of the hydrodynamic gradient?
- What are the implications of the response of PER-species to hydrodynamic conditions for river management?

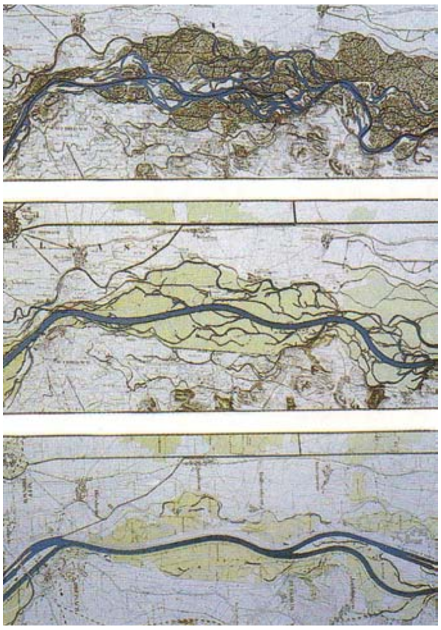

Figure 1: Effects of river regulation on spatial heterogeneity of a braided river-floodplain system.

Material and methods

BIO-SAFE is a valuation model which links ecotopes to riverine target species listed in the European Habitats Directive, the European Birds Directive, the Conventions of Bern and Bonn and Red Lists (De Nooij et al., 2004). To each species, values were assigned on the basis of its policy and legislation status. Through the linkage of species to ecotopes, values were assigned to ecotopes as well. The ecotopes were classified into seven different hydrodynamic classes along the hydrodynamic gradient (De Nooij et al., 2006). The biodiversity potential of a hydrodynamic class was quantified, based on the values assigned to species, the linkage of species to ecotopes and the relation between hydrodynamics and development of ecotopes (Hydroclass Importance; De Nooij et al., 2006).

Results

When all taxonomic groups of target species are combined, the biodiversity potential shows an increase with decreasing hydrodynamics, until class 6, where an optimum is reached (Figure 2). In this class highest number of protected and endangered species occurs. The contribution of the different taxonomic groups to the potential differs markedly along the hydrodynamic gradient. Many species of higher plants, fish and butterflies have a narrow range for hydrodynamics and many species of birds and mammals use ecotopes along the entire gradient (data not shown).

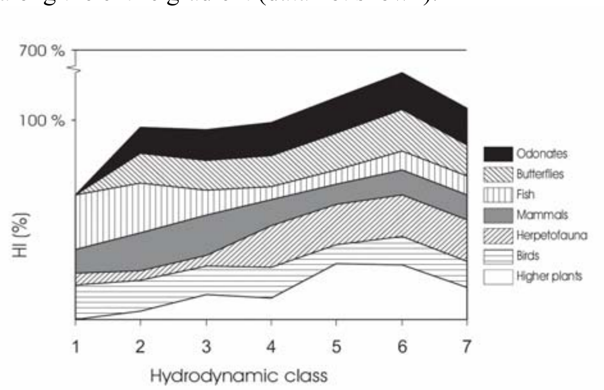

Figure 2: Hydroclass Importance (HI), for all species groups combined, along the hydrodynamic gradient. The contribution of each taxonomic group was set at 100%. 1: highest degree of hydrodynamics (e.g. main channel); 7: lowest degree of hydrodynamics (e.g. natural levees).

Discussion and conclusions

River managers today are faced with highly modified river-floodplain ecosystems, with large numbers of species that are nowadays protected and/or endangered and therefore require special attention. The challenge in the near future is to reconstruct and manage these river-floodplain ecosystems in a way that reconciles flood risk management, infrastructural works and economic development with ecological rehabilitation, within legal boundaries imposed by nature conservation legislation.

PER-species occur along the entire gradient and the potential for these species increases gradually with decreasing dynamics and reaches an optimum when the inundation frequency is between 0 and 20 days per year (class 6). In addition, each taxonomic group shows a different and characteristic distribution pattern along the gradient. For some groups (e.g., rheophilous fish), it is the high-dynamic parts that are more important, while for other groups (e.g. higher plants, herpetofauna, butterflies), the most important parts are those with low dynamics. Many species of birds, mammals and odonates predominantly use the entire gradient, while most plant species and – to a lesser extent – butterflies and fish are specifically bound to one or two hydrodynamic classes. These results are in accordance with studies dealing with total species richness of various aquatic taxonomic groups in river-floodplain ecosystems along the Rhine, Meuse and Danube (De Nooij et al, 2006). This strongly indicates that many more riverine species can benefit from measures only focussing on suitable conditions for PER-species. The results also mean that goals of ecological rehabilitation and nature conservation legislation correspond on the ecosystem level.

Increasing the opportunities for target species requires enlargement of the winter bed (i.e., more space for the gradient to develop), a prerequisite running counter to current reconstruction plans. Because space is scarce, river managers are looking for room for water discharge in the vertical dimension, by riverbed deepening and floodplain lowering. This causes higher levels of hydrodynamics, and thus results in an extensive loss of parts with intermediate and low dynamics (creation of 'bathtub' situation). River reconstruction and management should aim at increasing the spatial heterogeneity, thus re-establishing the entire hydrodynamic gradient, including parts of intermediate and low dynamics. Because strong spatial limits are set to the winter beds of rivers in the Netherlands, this requires tailor-made designs.

References

De Nooij, R.J.W., R.S.E.W. Leuven, H.J.R. Lenders, G. de Blust, N. Geilen, B. Goldschmidt, S. Muller, P.H. Nienhuis & I. Poudevigne, 2004. BIO-SAFE: assessing the impact of physical reconstruction on protected and endangered species. River Research and Applications 20: 299-313.

De Nooij, R.J.W., W.C.E.P. Verberk, H.J.R. Lenders, R.S.E.W. Leuven & P.H. Nienhuis, 2006. Importance of hydrodynamics for protected and endangered biodiversity of lowland rivers. Hydrobiologia (in press).