

photo-mosaics and TLS point clouds are required to estimate leaf coverage and flexural rigidity of the vegetation.

3D float tracking can be used to estimate the vegetation roughness under field conditions. At the same time it provides additional calibration data for hydrodynamic models to constrain parameter setting to realistic values. 3D float tracking could be further expanded using horizontal ADCP and small-footprint echo sounders to map the horizontal flow field and the vegetation structure of inundated floodplains.

The fusion of airborne spectral imagery with ALS data provides an effective source for mapping vegetation structural characteristics required to determine floodplain roughness. The method that was developed in this project provides more accurate determination of 3D floodplain vegetation structure than the current method of manual delineation and classification of floodplain ecotopes and, hence, of hydraulic roughness. Multi-temporal data analyses seems a promising way to optimize discriminate between herbaceous vegetation and meadows.

2.2 Influences of land use, flooding and metal contamination on biota in lowland Rhine River floodplains

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i. Problem

Floodplains of large rivers are among the most dynamic and diverse natural systems on earth. The large spatial diversity of site conditions, combined with the flooding-induced dynamics, yields a constantly changing habitat mosaic, which favors a high diversity of both aquatic and terrestrial plants and animals (Sparks, 1995; Tockner and Stanford, 2002; Ward et al., 2002). Apart from their biological richness, floodplains provide important resources to mankind, for example through the supply of fresh water, food and fertile soils (Costanza et al., 1997). Particularly in densely populated regions, large areas of natural floodplain have been reclaimed for agricultural, industrial and urban activities, thus modifying or simply eradicating natural floodplain habitats (Nienhuis and Leuven, 2001; Tockner and Stanford, 2002). Due to the profound human influences, floodplains are ranked among the most altered ecosystems worldwide (Millennium Ecosystem Assessment, 2005; Tockner and Stanford, 2002). The lowland floodplains of the Rhine River represent a clear example of such man-dominated and deteriorated systems (Nienhuis et al., 2002). These floodplains have a long history of reclamation and land use and received large loads of persistent contaminants, notably metals, during the past century (Lenders, 2003; Middelkoop, 2000; Nienhuis et al., 2002; Thonon, 2006).

Triggered by the extreme floods of 1993 and 1995, major reconstruction measures are to be performed in many floodplain sections along the Rhine River in The Netherlands, in order to enlarge the discharge capacity of the river corridor (Nienhuis et al., 2002; Van Stokkom et al., 2005). Possible measures include the creation of side channels, removal of minor embankments and lowering of the floodplain surface (Straatsma et al., 2009). These reconstruction measures

provide opportunities for ecological rehabilitation, as floodplain areas may be taken out of agricultural production and left to spontaneous vegetation succession (Nienhuis et al., 2002). In order to be successful, however, floodplain management and rehabilitation should be based on a solid scientific foundation, as insufficient consideration of floodplain natural dynamics and ecological processes may result in further loss rather than rehabilitation of biological integrity (Lake et al., 2007; Sparks, 1995; Stanford et al., 1996; Ward, 1998). Hence, a thorough understanding of floodplain properties and processes is needed, not only in pristine situations but also under anthropogenic influences (Arthington et al., 2010; Stanford et al., 1996; Ward, 1998; Wassen et al., 2002).

ii. Aim

To increase insight in lowland floodplain properties and processes, the present study aimed to assess the influences of flooding, land use and metal contamination on biota in the lowland floodplains of the Rhine River in The Netherlands. The influences of the three stressors were studied separately or concomitantly in various case studies comprising different groups of organisms, including plants, terrestrial arthropods and vertebrates (birds and mammals). The research took place from 2005 to 2010; field data were collected in 2005 and 2007-2008.

iii. Results

Plants and arthropods in relation to land use, flooding and soil metal contamination

Plant communities and terrestrial arthropod assemblages were investigated in relation to land use, flooding and metal contamination (As, Cd, Cr, Cu, Ni, Pb and Zn) in the “Ewijkse Plaat” floodplain and the “Wolfswaard” floodplain (Fig. A-2.5). This was done with multivariate statistical techniques designed to relate variation in taxonomic composition to multiple explaining variables. Plant species composition showed stronger relationships to flooding characteristics and land use (grazing) than to metal contamination levels (Schipper et al., 2010c; Fig. A-2.6). Nevertheless, the relationship to metal contamination was also significant, whereby plant species richness significantly decreased with increasing contamination levels. To check whether the soil metal concentrations in the study area were high enough to indeed induce toxic effects in plants, a tentative comparison was made with reference values for phytotoxicity reported in the literature (Schipper et al., 2010c). As these reference values are commonly expressed as plant tissue concentrations, soil metal concentrations (Cd, Cu, Ni, Pb and Zn) were translated to plant tissue metal concentrations using floodplain- and species-specific bioaccumulation factors (Schröder, 2005). Estimated plant tissue concentrations were generally well below levels critical for phytotoxic effects. Therefore, it was suggested that the negative relationship between plant species richness and soil metal concentrations might reflect additive effects of multiple stressors rather than impacts of single metals. Multiple stressors may include multiple contaminants or contamination combined with non-chemical stressors like flooding.

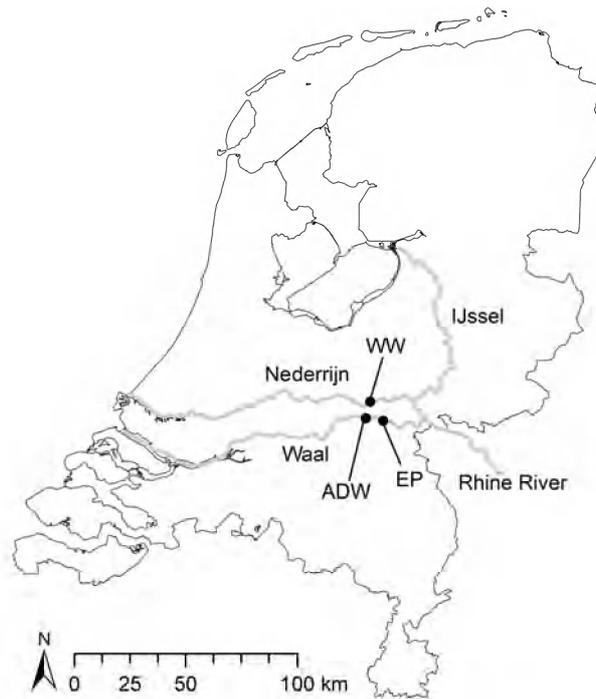


Fig. A-2.5: Main Rhine River distributaries in The Netherlands and study area locations. ADW = “Afferdensche en Deestsche Waarden”; EP = “Ewijkse Plaat”; WW = “Wolfswaard”.

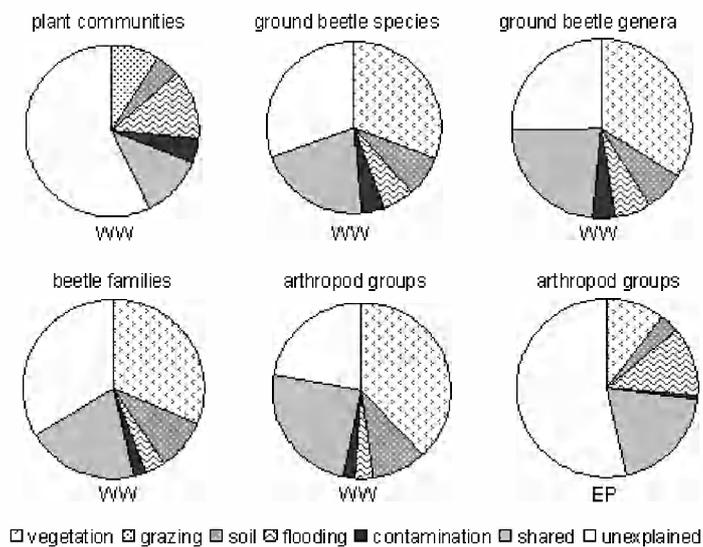


Fig. A-2.6: Relative importance of different environmental factors for explaining variation in plant communities or arthropod assemblages. Percentages were derived from variance partitioning analyses using canonical correspondence analysis (CCA; for plants) or redundancy analysis (RDA; for arthropods). WW = “Wolfswaard”; EP = “Ewijkse Plaat”.

Terrestrial arthropods showed stronger relationships to flooding and vegetation characteristics than to soil properties and metal contamination (Schipper et al., 2010b; Schipper et al., 2008b; Fig. A-2.6). These results were similar for four arthropod datasets of different taxonomic detail: ground beetle species, ground beetle genera, beetle families and arthropod groups at class-order level (Fig. A-2.6). This suggests that in strongly heterogeneous environments like floodplains relatively coarse taxonomic data can be used to assess the relative importance of different environmental factors for structuring biotic communities. Yet, the ground beetles showed a higher specificity for different vegetation types and a more distinct relation to soil contamination levels than the coarser arthropod taxa. This indicates that a higher level of taxonomic detail might be beneficial for detecting and quantifying more subtle effects of land use and contamination.

Exposure of wildlife to metal contamination

Potential health effects of metal contamination in floodplain soils were investigated for various vertebrate species, including six small mammals and four top predators. This was done by developing a spatially explicit wildlife exposure model that simulates dietary exposure to soil metal contamination via species-specific food chains. The model was parameterized for cadmium contamination in a floodplain area along the Waal River, the “Afferdensche en Deestsche Waarden” (Fig. A-2.5). Simulations were performed for 1000 individuals per species and revealed that the exposure concentrations were generally highest for worm-eating species: common shrew (*Sorex araneus*), European mole (*Talpa europaea*), little owl (*Athene noctua*) and badger (*Meles meles*). To check whether the predicted exposure concentrations might lead to potential adverse health effects, a comparison was made with dietary no-observed effect concentrations (NOECs) obtained from the literature (Schipper et al., 2008a). Because these NOECs typically originate from laboratory tests, they were corrected for differences in for example metabolic rate and food caloric content between laboratory and field conditions (Traas et al., 1996). Although toxicological hazards were difficult to assess because NOECs were not species-specific, tentative hazard estimates indicated that negative effects of floodplain metal contamination cannot be excluded for the four worm-eating species investigated (Fig. A-2.7).

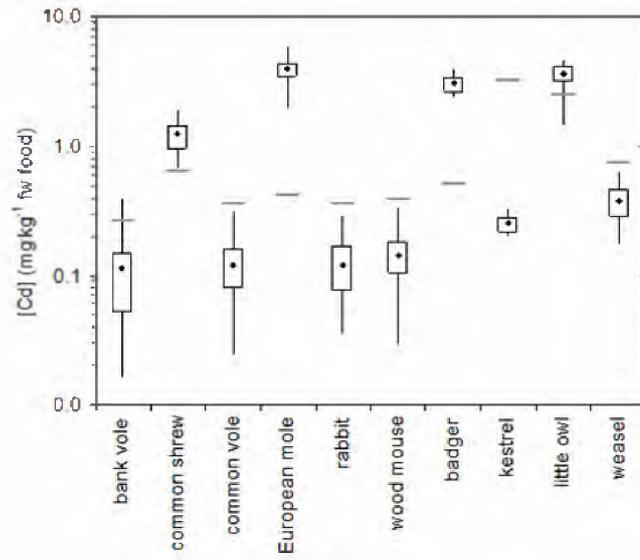


Fig. A-2.7: Predicted exposure concentrations (mg kg^{-1} fresh wt food) of cadmium for 10 vertebrate species in the study area "Afferdensch en Deetsche Waarden". Mean values are indicated by black diamonds; total range (minimum and maximum) are indicated by vertical lines; 10th and 90th percentiles are indicated by boxes; predicted no-effect concentrations (mg kg^{-1} fresh wt food) are represented by grey horizontal line marks.

Corncrake occurrence in relation to land use

Breeding site locations of the corncrake (*Crex crex*), a floodplain-specific bird species, were related to land use characteristics in the floodplains along the three main Rhine River distributaries in the Netherlands: the IJssel River, the Nederrijn River and the Waal River (Fig. A-2.5). Records of corncrake breeding sites obtained in 2001-2007 were related to landscape characteristics pertaining to area, shape, texture and diversity with logistic regression models. Landscape characteristics were determined at three spatial scales: distinct floodplain units ("floodplain scale"), circular zones around individual observations ("home range scale"), and individual patches ("patch scale"). The probability of corncrake occurrence showed a significant increase with patch area and with the area of potential habitat, i.e., herbaceous vegetation and grasslands, at the home range scale (Fig. A-2.8). In addition, significant positive relationships were found with the area of nature reserves (i.e., areas where mowing is delayed). The median potential habitat patch size associated with corncrake occurrence was 11.3 ha; 90 % of the corncrakes were associated with patches of at least 2.2 ha. These results indicate that the corncrake is an area-sensitive species, possibly governed by the males' tendency to reside near other males while maintaining distinct territories (Schipper et al., 2010a).

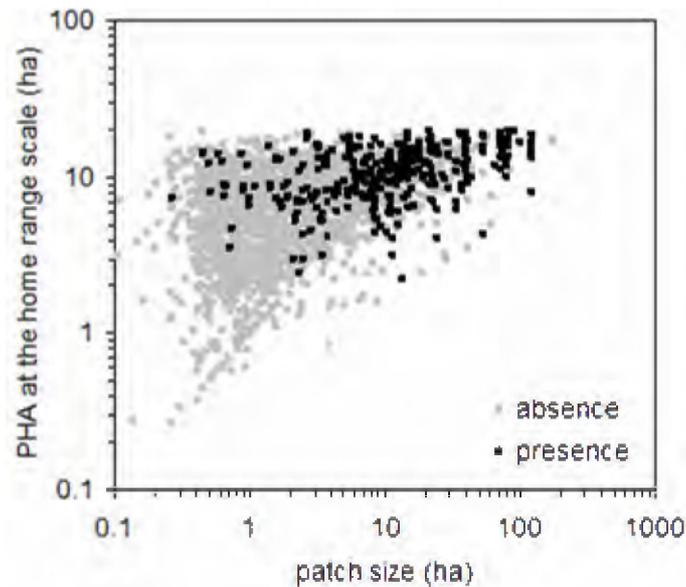


Fig. A-2.8: Corncrake presence and absence in relation to patch area and potential habitat area (PHA) at the home range scale.

iv. Conclusions and recommendations

The results from this research project give rise to some conclusions and recommendations which may be useful to consider in present and future floodplain management:

For plant communities, terrestrial arthropod assemblages and various vertebrate species in the present-day lowland Rhine River floodplains, effects of metal contamination are likely limited or subordinate to influences of other environmental factors. However, species with specific traits (e.g., feeding on earthworms, relatively long generation time, permanent residence) may be more susceptible to adverse impacts of metal contamination. This may warrant attention particularly in case of endangered, protected or key-stone species like the little owl.

Results of the case study on floodplain vegetation communities indicated that the concomitant influence of other stressors, notably flooding, may increase the vulnerability of biota to adverse effects of metal contamination. This implies that an integral approach is required to assess multiple stressor impacts in floodplain ecosystems.

In strongly heterogeneous environments like floodplains, the relative importance of different environmental factors for structuring biotic communities can be assessed based on relatively coarse taxonomic data. However, more taxonomic detail will be beneficial for detecting more subtle effects of, for instance, land use and contamination.

A floodplain-specific bird species like the corncrake, which relies on present-day land use and management practices, is unlikely to benefit from reconstruction and rehabilitation measures that yield wetter habitats and much denser vegetation.

Habitat conservation schemes for the corncrake should focus on the preservation of sufficient potential habitat area. Existing corncrake habitat management measures, like delayed mowing, should be implemented in relatively large, preferably contiguous areas.