IV.2

A CONSERVATION PARADOX FOR RIVER CORRIDOR PLANTS.

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Submitted to Biological Conservation

Abstract

We investigated grassland composition and diversity aspects for the alluvial plain of the River Meuse, one of the larger Northwest European streams, with special emphasis on the river corridor plants of dry river grasslands. In order to define a conservation strategy for the river corridor plants we examined isolation and fragmentation aspects and the role of flooding. A mapping and sampling of vegetation and soil conditions over the alluvial plain was executed, together with a recruitment analysis for the rare species of dry river grasslands. The central question for the study was whether preservation of relicts is a sufficient means to preserve riparian diversity. In the DCA ordination the rare river corridor plants were clearly restricted to the pioneer dry river grasslands of gravel or sandy deposits further from the river. A significant isolation of the river corridor plant relicts was revealed. As for the cause of this isolation, our analysis indicated recruitment limitation to be the major threat for survival of most of the river corridor plants. The recovery of populations depends strongly on flood contact and recruitment potential in the creation of new habitat. The withdrawal of the hypothesis that conservation outside the river dynamic influence is a necessity, shows that the construction of conservation and rehabilitation strategies for species at risk needs a good knowledge of key processes that determine the population dynamics at the regional scale. For the investigated River Meuse reach, the flood dynamics proved an essential habitat creation process, strongly determining population dynamic strategies and restoration potentials at the reach scale.

Introduction

Riparian zones are considered hot spots of species diversity (Gregory et al., 1991; Ward, 1998). Understanding the mechanisms which generate the plant species diversity in the riparian landscape is a challenge in the attempts to preserve these diversity hot spots (Zwick, 1992; Tockner et al., 1999).

The heterogeneity in abiotic conditions and the presence of strong gradients over the river corridor, together with the function as migration route, is put forward as explanation for the observed biodiversity (Nilsson et al., 1989; Petts & Bradley, 1997; Pollock et al., 1998; Ward et al., 1999). Also, a strong local-regional connection in species pools is thought to exist in river landscapes and

explains the high diversity (Naiman e.a., 1993, Mouw & Alaback, 2003).
A group of Central European plant species expanded their distribution range to the north along the large river's corridors. These river corridor species took advantage of the wide floodplains of the large rivers to reach the lowlands of Northwest Europe. The river corridor plants are a highly appreciated nature conservation asset of the River Meuse, the same as for most Northwest European streams (Burkart, 2001; Donath et al., 2003; Jongman, 1992). Emphasizing on this group and the factors limiting its distribution, is a possible way to develop conservation strategies for the floodplain diversity.

Human-induced changes to flow regime, flood contact and groundwater level cause a deterioration of the diversity of the riparian landscape (Petts, 1996; Ward, 1998). Together with the intensification of agricultural practices in the alluvial plain, this makes the dry river grasslands very fragmented and the characteristic river corridor species highly threatened in the present situation. Disruption from flood contact of large parts of the alluvial plain by the construction of winter dikes, is a further threat in this fragmentation problem (Leyer, 2005), as we already highlighted for floodplain forest diversity (Van Looy et al., 2003) for the highly regulated River Meuse.

Central question for our research was 'Is the preservation of relicts a sufficient mean to preserve riparian diversity'. At present, conservation efforts focus on the protection of relicts of these dry river grassland communities, in the designation of special protection zones within the Pan-European NATURA2000 network. In further attempts to define conservation strategies for these communities, river concepts like the shifting mosaics and the patch dynamics concept (Pickett and White, 1985; BarratSegretain and Amoros, 1996; Petts, 1996; Petts and Bradley, 1997) provide useful frameworks for the problem description and definition of spatial and management guidelines. With the described alterations to fluvial functioning by regulation, resulting in habitat deterioration and fragmentation, the dynamics of patches and populations received strong emphasis in our study. Starting from a mapping and diversity analysis of the grasslands in the alluvial plain of the River Meuse, we focussed further on specific habitat conditions and distribution of the dry river grasslands and their river corridor plant species. River corridor plants include a high proportion of threatened plant species with small populations, dispersed over a restricted number of patches alongside the river (Baumgärtel &

Zehm, 1999; Burkart, 2001; Bisschof, 2002; Jäkäläniemi et al., 2005). In order to preserve them, and in order to understand the mechanisms generating their distribution patterns, more has to be known about their population biology and dynamics (Malanson, 1993; Burkart, 2001; Lowe, 2002). We distinguished population dynamic strategies of the species at risk in order to determine applicable conceptual frameworks for the further planning of the restoration programme for this river reach. The strategies of the river corridor plants in the dry river grasslands are often remnant or metapopulation strategies, very sensitive to local extinctions as a consequence of their strong habitat selectivity. The paradox for conservation lies in their need for flooding processes for habitat creation and seed dispersal and on the other hand their sensitivity to flooding and the fact that relicts can be destroyed by erosion-sedimentation processes. The preservation of relicts outside the dynamic flooding zone is suggested to be a necessity for a sustainable protection of these species by several authors (Jongman, 1992; Hegland et al.., 2001; Donath et al., 2003; Eck et al., 2004; Lindborg and Eriksson, 2004). To test the hypothesis of relict conservation, a recruitment analysis was carried out for rare species with known distribution over the studied reach, and a population strategy testing for these species. To reinforce and argument their conservation, we investigated whether the river corridor plants are good indicators for well developed grassland communities and the overall riparian diversity.

Studied River Meuse reach

The study area is the Flemish side of the alluvial plain of the middle course section of the River Meuse between Maastricht and Maaseik (30 km) on the border between Belgium and the Netherlands, the so-called Common Meuse. Discharge levels for the Common Meuse range from 10 m^3/s during dry periods to 3,000 m^3/s in periods of heavy rainfall in the catchment area. The unregulated Common Meuse stretch is a typical gravel river with a strong longitudinal gradient (0.45 m/km). The Common Meuse valley consists of a gravel underground with a loamy alluvial cover. Local irregularities of levees and dikes are covered with more sandy sediments, the same as for dynamic overbank sedimentation zones. The floodplain traditionally was agriculturally used as meadows. Large parts of the alluvial plain have been excavated for gravel mining, leaving large gravel pits or lowered floodplain zones. The degradation of the floodplain natural heritage was the reason to start a river restoration programme and to start local pilot projects, mostly in abandoned gravel mining locations. The large-scale river restoration project is defined in a master plan for the alluvial plain (Pedroli et al. 2002). The concept of the restoration project is to restore hydrodynamics and morphodynamics and related ecological characteristics in a broadened river channel and in re-established secondary channels and backwaters. Planned measures comprise bed widening, bank lowering and side channel reconnection in a comprehensive approach for the river reach.

Sampling

The vegetation survey of the Meuse alluvial plain consisted of a vegetation mapping with sampling for every recorded patch. A minimum of 500 m? was chosen for the delineation of homogeneous vegetation patches in the field. For the mapping a topographic map basis was used. The parcels in intensive agricultural use were all integrated as rectangular patches in the map, for the natural managed areas, more irregular forms of patches arise. The 196 patches of grasslands under natural or extensive management were sampled in 1999 using 1 x 1m relevees. For the relevees, the Braun-Blanquet method of 1x1m quadrate sampling was used, as it was recorded useful for a biodiversity analysis at different scales (Pollock et al. 1998). All species within the sample plots were recorded. The grasslands cover a range from open pioneer to dense, tall vegetations. They were classified in 9 types according to management, elevation and river dynamics (Table 4.5). These types were assigned to a corresponding phytosociological association or order according to Schaminée et al. (1998).

Table 4.5 Classification of grassland patch types in the Meuse alluvial plain , with annotated phytosociological community (Schaminée et al. 1998).

Agricultural practice	B1 hayfields	Arrhenatherion elatioris
	B2 pastures	Cynosurion cristatus
	B3 fertilised meadows	Poö-lolietum perenne
Natural management		
Lower floodplain meadows	F7 long inundated meadows	Lolio-potentillion anserinae
	F9 floodplain meadows	Alopecurion pratensis
Higher floodplain meadows	L1 dry river grasslands	Medicagini-avenetum pubescens
	L4 xeric grasslands of open sand	Thero-airion caryophyllea
Overbank sedimentation zones	A1 gravel overbank sedimentation	Alysso-sedion albi
	A2 sand overbank sedimentation	Sedo-thymetum pulegioides

Environmental variables were gathered in the field survey or derived from available digital data on the flooding and from the mapping in GIS.

Environmental variables were gathered in the field survey or derived from available digital data on the flooding and from the mapping in GIS. Flooding frequency of the samples ranges from more than once a year to less than once within a decade. It was derived from the two-dimensional hydraulic model developed for the restoration model and based on a high resolution DEM of the alluvial plain (See Van Looy et al., 2005). The frequencies were divided in flood frequency classes (>1/year, 1/year, 1/2-5year, 1/5-10year, < 1/10year). We also determined for each plot the distance in bird's-eye view to the river channel (m.). Isolation was recorded in categories, measured as the distance to the nearest same patch type, distances ranked in categories (1: <50m, 2: 50-500m, 3: 500-2000m, 4: >2000m). Management was classified as extensive meadows with haying and/or pastures (2), natural grazing (1) and no management (0). Soil humidity classes are wet (3), periodically wet with high fluctuation (2), moderately dry (1), extremely dry (0). The organic matter in the topsoil layer was categorised as a thick humus layer (2), present (1), absent (0). Soil texture in each sample plot was manually analysed and categorized in 9 classes, from clay (1), silt (2), loam (3), sandy loam (4), loamy sand (5), clayey sand (6), sand (7), gravel-sand (8) to coarse gravel (9). This texture classification was checked for 50 plots with a soil sample laboratory analysis for texture

(laser diffraction), acidity with Metrohm (titration, pH-carrousel), organic matter (Moffeloven destruction analysis) and conductivity (EC measured with conductance meter and translated to soil salinity).
Two consecutive exceptional floods in 1993 and 1995 showed the highest ever recorded peak levels. After these extreme peak events, a survey was done for the overbank sedimentation zones. Substrate texture was determined, floristic inventories carried out in the summer period and the zones were mapped. As these newly created habitats proved very important for the recruitment of river corridor species, this survey was repeated after the peak discharges of 2000 and 2002.

Ordination and diversity analysis
In a first stage we performed a data exploratory Detrended Correspondence Analysis (DCA) using the CANOCO 4.0 software (Gauch, 1982; ter Braak and Smilauer, 1997). Only species occurring in more than one plot were used for this analysis. In order to identify the abiotic drivers of the species composition gradients, DCA sample scores of the 196 sample plots were related with flood frequency class, isolation, soil humidity, organic matter and management using a one way Analysis of Variance (ANOVA) and with distance to river, flooding frequency and soil texture using a Spearman rank correlation coefficient.
For the diversity analysis we selected the rare species (≤ 5 plots) in the data set. Then we related species richness and diversity of the plots with rare species to the environmental parameters. We used a one way ANOVA. All statistical analyses were performed with Statistica (StatSoft Inc., 2001).

Population strategies

Freckleton & Watkinson (2002) defined population dynamic strategies explaining spatial dynamics of plants on a regional scale. They proposed a classification of large-scale spatial dynamics based on the relative importance of regional and local dynamics for the persistence of plant populations.
To classify the species dynamics in the Meuse river system, the Freckleton & Watkinson typology was translated into a scheme of species and patch criteria (Table 4.6). The strategies were appointed based on species frequency and abundance in the plot-species matrix and the vegetation mapping. The main distinction is between regional and local populations. In terms of the application of metapop-

ulation theory, regional populations are relying on colonization from upstream populations.

Table 4.6 Classification criteria for population dynamics types

Population dynamics type	Source population, immigration	Population frequency	Abundance within patch	Patch type selectivity	Patch frequency	Occupation of suitable habitat	Patch dynamics	Patch size, isolation
Meta-population	Upstream	Rare-occasional	Rare-occasional	high	frequent	partially	low	small, dispersed
Source-sink	Upstream	Rare-occasional	Rare-frequent	low	frequent	low	high	dispersed
Remnant population	Local	Rare-occasional	Rare-occasional	high	rare-occasional	partially	low-high	small, isolated
Shifting cloud	Local	Rare-frequent	Rare-frequent	low	frequent	low	high	-
Patchy population	Local	Rare-frequent	Occasional-frequent	high	occasional	high	medium-high	small, dispersed
Extended local population	Local	Frequent	Frequent	low-high	frequent	high	low	large

We classified the rare species (≤ 5 plots) in this population dynamics typology following Table 4.6. An indication to the dependence of upstream populations is the absence of strong local populations and the presence of occupied patches widespread along the river's axis. Species with only few and small local populations (abundance criterion: rare to occasional Tansley abundance values in the relevees and isolation criterion) were classified depending on colonization by upstream populations.

The second criterion number of populations was also used as criterion for the diversity analysis and is for our selection of course low (rare, <= 5, occasional <20). The extended local populations are out of the scope of our analysis of rare species as they are frequently present populations. For the abundance within the patches the Tansley cover in the relevees is used. Patch type selectivity refers to the determined grassland types of the mapping. Selectivity is low for generalist species present in >2 types. Patch frequency refers to the presence of the grassland type over the alluvial plain mapping (rare <=5, occasional <20). For the grassland types the species occur in, the occupation of suitable habitat describes the share of the patches of these types where the species are

present (low <10%, partially 10-50%). The patch dynamics for the specific situation of the floodplain and the river corridor plant strategies, are related to the river dynamics; high dynamic patches are regularly flooded with high river morphodynamics, patches with medium dynamics are regularly flooded and low dynamics means irregular flooding (< once/2year).
For the patch size criterion, small patches are in average <0,5ha. The isolation is measured in the distance between occupied patches. Isolated patches are >2000m apart.

Results

The mapping shows that over 50% of the alluvial plain is in intensive agricultural use (Figure 4.9). The dry river grasslands and the pioneer stage of overbank gravel and sand depositions, take only 4% of the alluvial plain. Natural riparian landscape units like sand-gravel bars, pioneer vegetation and overbank sediment zones have extremely low values, together they take only 1% of the surface.
The alluvial plain consists mainly of larger patches in agricultural use (arable land patches mean area 4,2ha). Some nature reserves and riverbanks show smaller vegetation patches.

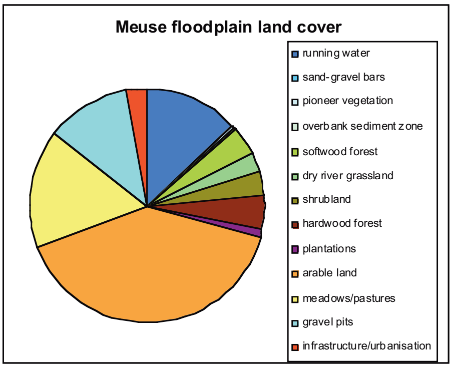

Figure 4.9 Pie chart of land cover units over the Common Meuse alluvial plain.

The vegetation survey yielded 329 species, 226 of them were present in more than 1 plot and retained for the ordination analysis. In the diversity analysis were entered the 46 species occurring in 2-5 plots (Table in annex). Species richness and patch area were plotted for the grassland types (Figure 3.5), indicating that the dry river grasslands (types A1, A2, L1 and L4) are the richest communities over the alluvial plain with the smallest patches. This indication is even stronger in the species-area plot (Figure 4.10), showing there is a strong concentration of rare species in the smallest and most species-rich patches.

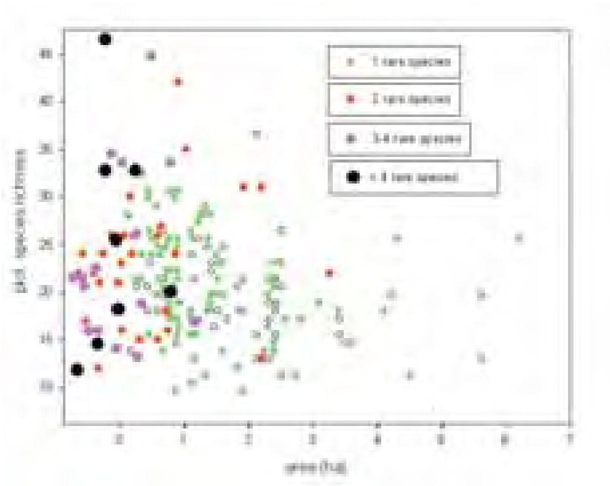

Figure 4.10 Species-area relationship for the sampling. Plots with no rare species are open circles, the larger dots indicate plots with more rare species.

More than half of the rare species are river corridor species (27/46) of the northern Central European streams (Burkart 2001). When we include the very rare species, in only one plot represented (which we omitted from the analysis) a majority of the Meuse river corridor plants is in this category.

Ordination results

The first three axes of the DCA explained a cumulative percentage of the variance of the species data of 19%, with gradient lengths > 6, expressing the heterogeneous character of the vegetation in the sample plots. The first DCA-axis shows a wet-dry gradient. There are only a few wet meadow patches present. For the most part of the alluvial plain summer groundwater levels are about 3-5 meter below ground as a consequence of the river bed incision of the last century. The significant relation between DCA1 sample scores and flooding frequency and soil characteristics of texture, soil humidity and organic matter expresses the river influence in the floodplain environmental conditions. DCA2 sample scores showed significant covariance with soil parameters and management conditions and also with isolation and distance to the river (Table 4.7). For this axis the management and soil texture are the most explanatory abiotic characteristics, showing a gradient of densely vegetated floodplain meadows to open, sandy pioneer grasslands. Hayfield species and nutriphilous species have low values, whereas sand- and calcareous, xerophilic species have high DCA2 values. For the third axis, flooding frequency and distance to the river show strong covariance.

Table 4.7 Covariance test results for stand conditions and ordination axes.

	distance river	texture	flood frequency	isolation	humidity	organic matter	flood frequency	class management
DCA1	0,18*	0,33**	-0,4**	1,11	37,5**	32,9**	32,6**	4,9*
DCA2	-0,27**	0,45**	0,04	8,3**	6,7**	17,5**	0,5	10,1**
DCA3	0,38**	0,02	-0,38**	0,42	0,81	0,74	6,7**	1,2
DCA4	0,2*	0,089	0,07	2,3	2,5	0,8	1,2	0,99
Spp richness	0,14	0,16	-0,22*	2,1	3	5,22*	3,08*	0,9

Distance to river, substrate texture and flood frequency are Spearman rank correlation coefficients, for the other variables ANOVA F-values are given. **: significant correlation ($p < 0{,}001$), *: little significant ($0{,}001 < p < 0{,}01$)

In the ordination the rare river corridor plants are clearly grouped together with the pioneer grasslands of the dry river grasslands on gravel or sandy deposits further from the river and irregularly flooded (Figure 4.11). The rare species of the dry river grasslands show strong correlation with the third axis (Rare species-DCA3 z:5.74, $p<0.001$, Figure 4.12), indicating the isolated position of the river corridor plant relicts situated farther from the river and seldom flooded.

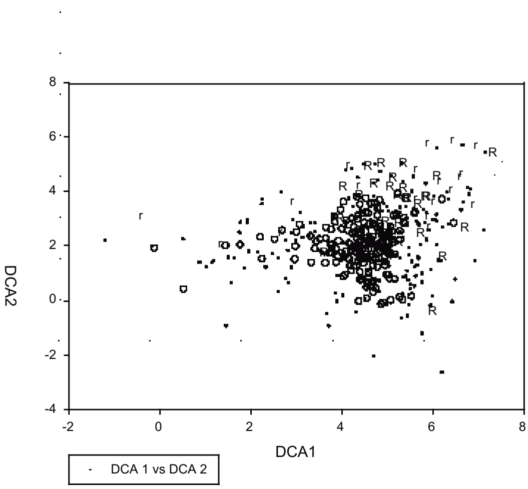

Figure 4.11 Plots-species biplot over the first two DCA axes; with circles: plots, dots: species and r: rare species, R: rare river corridor species

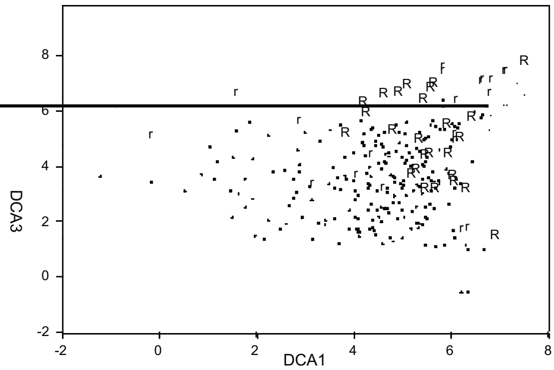

Figure 4.12 Species biplot over the DCA axes 1 and 3; with r: rare species, R: rare river corridor species

Diversity analysis

The number of rare species shows significant covariance with the species richness of the plot (F: 3.6, $p<0.001$). This marks the rare species as good indicator species for the well developed grassland patches of the alluvial plain. Higher rates of rare species are restricted to the plots with gravel and sand soils (F:4.6, $p<0.001$). This shows their faith to the dry river grasslands, as the gravel-sandy soils are only present at levees and overbank sedimentation plots, the stand conditions for the dry river grasslands.

The strongest covariance is between the rare species (F: 20.6, $p<0.001$) and the isolation. Together with the observed restriction to the smallest patches, this indicates that fragmentation of habitat is a major threat for the rare (river corridor) species. The number of rare species clearly increases with the degree of isolation (Figure 3.9). The graph shows there's a group of isolated relict sites, harbouring a list of specific rare species. The observed isolation does not necessary imply that disconnection of river contact is the problem. Fragmentation of habitat, by loss of habitat through land use changes can cause isolation as well. Species truly suffering from isolation have lost their dispersal abilities and colonization potential. The inventory of newly created habitat patches after the floods of 1993, 1995, 2001 and 2002 proves the opposite. The rare species of the dry river grasslands show a high colonization potential (Table S4 in annex). In 21 newly created patches (ranging from 50m? - 2ha) of overbank gravel-sand deposition over this investigated period, most rare species show recruitment of the new habitat. The recruitment of river corridor plants of the dry river grasslands was only successful over the investigation period (between 1993 and 2002) in the extensively managed areas, as the sediment zones under intensive agricultural use are reworked (evened/ploughed) after each flood event with destruction of the newly created habitat.

The population dynamic strategies were appointed (Table S4 in annex) based on species frequency and abundance in the plot-species matrix and mapping. We derived a recruitment rate for the different species strategies, by analyzing the recruitment over the strategy groups (Table 4.8). Mean values for the groups give a good approximation of a recruitment rate for the metapopulation, remnant and patchy population dynamic strategies. Especially the patchy population strategists are very successful in colonizing suitable habitat patches. The recruitment of newly created habitat is mostly an immediate process (seeds provided with flooding) covering most of the rare species in the immediate surroundings.

Table 4.8 Surveyed recruitment of river corridor plants within the population strategies.

Strategy	**Remnant**	**Patchy**	**Metapopulation**	Source sink	Shifting cloud
Number of species	12	28	8	1	2
Recruitment	13	116	11	4	12
Median + SD	1 + 1	4 + 1.2	1 + 0.8	-	-
Mean	1.08	4.14	1.38	4	6
Recruitment rate	1,1	4,1	1,4	4	6

Species showing no recruitment do have a dispersal limitation, this can be due to disruption from flooding or to a regeneration limitation in unfavourable relict conditions. For some remnant species, e.g. Potentilla argentea and Sedum telephium, the contact with the river is lacking, and no recruitment was observed. To this list can also be added a list of species restricted to one plot in our analysis: Potentilla neumanniana, Carex caryophyllea, Briza media, species that are disconnected from river contact by the construction of dikes. Other remnant species like Eryngium campestre, Ononis spinosa, Plantago media and Tragopogon pratensis show only limited recruitment due to a lack of regerenation under actual unfavourable stand conditions of changed agricultural practices.

Discussion

Burkart (2001) described the distribution pattern of the river corridor plants of the large northern Central European rivers (Vistula, Elbe, Oder and Weser) of which 48 of the 129 are also present in the Meuse corridor. Some of the here identified rare river corridor plants (Sedum sexangulare, Vulpia myuros and Trifolium campestre), are also distinguished by Baumgärtel and Zehm (1999) as characteristic species of the Rhine system sandy deposit mosaics. These authors tried to derive explanations for their threatened status and potential restoration guidelines from their remarkable distribution. The ordination and diversity analysis together with the recruitment and population strategy assessment proved a successful method to analyse the postulated conservation paradox, as they revealed the patterns and threats in the actual distribution of river corridor plants along the Meuse. There was a clear segregation of rare (river corridor) species in the ordination, showing the specific status of the dry river grasslands rich in river corridor plants. The rare river corridor plants seem good indicators of diversity and fragmentation aspects at river reach scale, as the rare species correlated significantly to species richness and isolation. The identified correlation with isolation of the dry river grasslands, proves their threatened status and need for restoration.

The dispersal limitation of the river corridor plants in remnant populations

along the Rhine was recorded as most important limiting factor for restoration success (Donath et al., 2003). Therefore the preservation of the relicts was put forward as the most crucial together with the provision of sufficient habitat adjacent to these sites. Hegland et al. (2001) came to the same conclusion based on the same method of population analysis for a river corridor plant (Salvia pratensis) along the River Waal in the Netherlands. This preservation strategy was also put forward by other authors (Jongman, 1992; Eck et al., 2004). Bischoff (2002) observed strong dispersal limitation in a floodplain with little flood dynamics (very low flow velocity). These observations contrast strongly with our observations for the River Meuse of strong flood related dispersal capacity and recolonization potential for most river corridor species. Our analysis indicated recruitment limitation to be the major threat for survival of most river corridor plants of the dry river grasslands. Wolfert et al. (2002), Boedeltje et al. (2004) and Baumgärtel and Zehm (1999) also pointed at the necessary stand dynamics and flood pulse based on the study of abiotic conditions of dry river grasslands with characteristic river corridor plants. Eck et al. (2005) documented also recruitment limitation along disturbance gradients as structuring distribution patterns in river floodplains.
In our Meuse dataset, the communities with rare river corridor plants were restricted to overbank deposition zones, linked to the periodic habitat creating process of overbank deposition of gravel and sand sediments. The recruitment analysis showed the potential to colonize newly created habitat for most of the threatened species. Recruitment limitation proves the major cause of threat for most of the river corridor species. Species showing limited recruitment, indicated a dispersal limitation due to disconnection of flooding contact. As we were interested in the impact of fragmentation of habitats to the conservation strategy, in the recruitment analysis, we revealed the impact of the recent dike construction to the distracted relicts, as we already documented the strong impact of this disconnection to floodplain forest diversity (Van Looy et al., 2004). Other authors also described the importance of water dispersal (Johannson et al., 1996; Nilsson et al., 1989; Andersson et al., 2000b) and the barrier effects of dikes (Andersson et al., 2000a; Leyer, 2005) for floodplain grassland species.

But furthermore, we revealed the necessity of dynamics for the conservation of these species, as we observed that only dynamic habitats, with species in more dynamic strategies, show potentials to recruitment and restoration in general. For

most species, the population strategy assessment explained these patterns. The Freckleton and Watkinson population strategy classification differentiates between spatial scales of population structure, enabling conclusions towards aspects of the river continuity. Main distinction is between regional and local populations, for the river system regional populations in terms of the application of metapopulation theory are relying on colonization from upstream populations. The species were assigned to one of these strategies without the evidence of a lengthy population study and no reference is made to current discussion on the distinction of metapopulations in non-continuous habitats and the evidence for extinctions and discrete habitat patch use (Gouyon et al., 1987; Ouborg, 1993; Eriksson, 1996; Freckleton & Watkinson, 2003).
Nevertheless this generalized strategy interpretation offers interesting opportunities to analyze aspects of species dispersal at a regional scale (Freckleton & Watkinson, 2002).

Population dynamic strategies of the species at risk, explaining the regional persistence and patterns in populations, can be guiding in the delineation of biodiversity conservation strategies (Miles, 1979; Tilman, 1988; Tabacchi et al. 1996; Hansen et al., 1999; Freckleton and Watkinson, 2003). The Freckleton & Watkinson typology provides a framework for the distinction of regional components of population dynamics, by integrating the key processes that determine the population dynamics (Eriksson, 1996; Hanski & Gilpin, 1997). It is a useful tool in determining how populations persist at the regional scale and important for the construction of conservation and rehabilitation strategies for species at risk (Freckleton & Watkinson, 2003; Jäkäläniemi et al., 2005). Population structure and spatial dynamics are recorded in many studies for their conservation implications for riparian vegetation communities and endangered species (Van Treuren et al., 1993; Brys et al., 2003; Tero et al., 2003).
The population strategies assessment allowed the evaluation of the isolation threat risks, whereas we can conclude to the general importance of the relict conservation, as well as include conclusions of this analysis in the restoration programme. Patchy populations of species colonizing each newly generated habitat near to even far downstream, show an optimal recruitment as was observed for some extremely rare river corridor species, like Medicago falcata, Anthyllis vulneraria and Salvia pratensis. For the metapopulation and remnant

population strategists, upstream sources are of major importance and the management and conservation of present relicts is primordial, but these are by far a minority. Survival of the metapopulation and remnant species' populations is critical under the identified threats. The opportunities for these species lie in the ability of upstream populations to recolonize the Common Meuse reach, but have to be regarded in the scope of declining populations at river basin scale. For some of them, the optimisation of management practices of the relicts, might be sufficient to strengthen the local population and its dispersal and recruitment ability.

Restoration projects in general aim at mitigating the effects of regulation works by rehabilitating geomorphological processes, to promote the recovery of degraded biota and the floodplain benefits from the river (Tockner and Schiemer, 1997). However, the hydrological, geomorphological and biological heterogeneity and variability of river-floodplain systems, both temporally and spatially, can complicate the restoration schemes (Amoros et al., 1987). The role of gradients in hydrological and soil nutrient conditions, determined by the flood regime, together with aspects of spatial and temporal disturbance and connectivity patterns in the river system was already documented for the floodplain grassland biodiversity conservation of the River Meuse (Grévilliot et al., 1999; Grévilliot and Muller, 2002; Vécrin et al. 2002; Geilen et al., 2004). Although the river corridor plants benefit from floods, flooding also bears the risk of local destruction of habitat and populations. So, enhancing flooding can seem a sure restoration strategy for threatened metapopulation strategists, depending on upstream sources for new recruitment. True remnant populations on the other hand first have to be strengthened and/or expanded locally before dynamic restoration can be the best option. The preservation of relicts is also important as upstream populations for many species are strongly decreased and threatened as well as local populations.

As the process of habitat creation does not annually occur, the spatial conclusions of the recruitment analysis also need a temporal interpretation. Therefore we can project the habitat creating process over a broader range of potential locations, with of course the restriction that existing habitat will be put back in succession, as local stands will be overdeposited or eroded, or become temporarily unfavourable due to longer inundation (Vervuren et al., 2003). So, flooding allows propagule dispersion but also local extinctions. River corridor plants are very well susceptive to develop metapopulations in their river reach dispersion (Ouborg, 1993). For the conservation of these metapopulations, a sufficient number of dynamic populations is needed (Hegland et al., 2001). So, the observed isolation and fragmentation has a spatial but especially a temporal dimension, important for conclusions on conservation and restoration.

Restrictions in land use and management practices cannot stop gradual succession from pioneer to grassland communities, as these are governed by soil processes. So, the pioneer communities rich in river corridor species only survive under the benefit of flooding events with deposition of new sediments. Therefore, the rehabilitation of fluvial processes is a necessity. The rehabilitation of fluvial processes does not only mean that land use practices need to be changed to allow sediment zones to develop naturally, it also means that the river must transport enough coarse sediment. For this morphological criterion, sediment supply from eroding banks and gravel and sand bars in the river bed is a necessity. As these processes operate on a larger scale in time and space, a restoration approach at reach scale must be tailored to the shifting mosaics and patch dynamics of the dry river grassland habitat, with measures in the river bed as well as in the floodplain to assure the generation and rehabilitation of suitable habitat for the river corridor plants.
So, the identification of the recruitment limitation and the knowledge of habitat creation processes allows the design of measures in the river restoration programme. For effective conservation efforts for the endangered species, further knowledge of population biology and metapopulation dynamics are indispensable elements (Lowe, 2002), whereas the river corridor plants are a promising subject for metapopulation studies (Burkart, 2001; Menges, 1990). Research on several Meuse river corridor species for the metapopulation functioning and genetics has been initiated in 2003. First results (Jacquemyn et al., in Press) already confirm our observations of long distance dispersal and colonization with exceptional peak flow events for species with no adaptations to water propagation.

Conclusions

The river corridor plants are a good flagship species group for the protection and restoration efforts for larger Northwest European streams, as they cover a lot of information on the characteristic habitats and indicate well developed vegetations of the floodplain.
We detected the alterations to the floodplain dynamics as major threat for the river corridor plants in the present situation. Relicts isolated from the river flooding dynamics show no restoration potential, in contrast to relicts with high dynamics. The species that are cut off from flood contact by dikes, have the most serious isolation problem. Although we found the hypothesis on the conservation by preservation of relicts to be unsatisfactory, the protection of present relicts and newly generated habitat does need priority. The high recruitment potential of this endangered species group nevertheless tips the balance in favour of river dynamics restoration measures as most effective conservation approach. Habitat creation can be restored by changed river management and land use in the floodplain.