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Setting targets in strategies for river restoration

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Abstract

Since about 90% of the natural floodplain area of rivers in Europe has been reclaimed and now lacks river dynamics, nature rehabilitation along rivers is of crucial importance for the restoration of their natural function. Flood protection, self-purification of surface water, groundwater recharge, species protection and migration are all involved in this process. It is now generally recognised that rivers form natural arteries in Europe but are also of economic importance and are recognisable cultural landscape. Many examples are already available of successful small river restoration projects. Several species thought to be extinct have now reappeared and characteristic species have also expanded in recent years. This paper concentrates on the concept of setting targets for river restoration as exemplified by the Meuse River. A modelling exercise shows the restraints of current habitat configuration and the potential for habitat restoration along the river. A policy analysis, using a strategic approach, illustrates the influence of the decision making process on the targets for natural river development. River dynamics play a key factor in determining the potential for persistent populations of target animal species along the river, with the help of an expert system (LARCH, Landscape ecological Analysis and Rules for the Configuration of Habitat). The potentials for the increase of dispersion and biodiversity and the maximisation of ecological benefits at different scales, are also considered.

Introduction: declining biodiversity along rivers

Decreasing natural dynamics

Rivers have been symbols for the flow of thoughts and prosperity since the origin of man (Schama 1995). They also formed the primary network for exploration and development by man. Rivers are therefore highly modified and adapted to meet the needs of constantly changing societies (Billen et al. 1995; Galloway 2000). Major human activities have affected river systems and range from supra-catchment effects to local impacts (Boon 1992). The natural spatial dynamics of many rivers, as well as their temporal dynamics have therefore been altered.

In the lowland rivers of western Europe, engineering works have in general reduced the diversity in habitats and in patterns. The characteristics of flow, that used to be typical for these ecosystems, have now been converted to beneficial conditions for subsistence (Van de Ven 1993). The alluvial landscape is now uniform over large areas, and in many places is only recognisable by the presence of a canalised river, flood levees and a higher density of ditches in the river foreland (Havinga and Smits 2000). These engineering works are designed to control the dynamics of the river, and involve the loss of natural dynamics and of river-floodplain interactions, as well as the loss of flooding area and fragmentation of habitats.

The dynamics of flow velocity and discharge are key factors in the determination of the fluvial system, and are linked to the suitability of the river as a habitat for biota. Various concepts are used to describe this system, e.g. the river continuum (Vannote et al. 1980), the flood pulse (Junk et al. 1989; Bayley 1991) and hydraulic stream ecology (Statzner and Higler 1986).

From the perspective of the drainage basin and the integrating practice of landscape ecology, the river channel, the river margin and the river floodplain are interdependent and form a single system, referred to as the 'fluvial hydrosystem' (Amoros and Petts 1993; Petts and Amoros 1996). Conditioning processes in these complex fluvial landscapes are related to surface water – groundwater interactions that act in longitudinal, as well as in lateral and vertical directions. An undisturbed hydrology is the precondition for the maintenance of the habitats in their natural state. River bank constructions and flood levees prevent floods that normally lead to the disturbance of hydrology and therefore of habitats, and to changes in ecosystem development. Water management measures have divided the original complex fluvial hydrosystem into a number of distinct, and, almost independent, land units. The original state of interdependent patches has now therefore almost disappeared.

Flooding is the trigger for some of the most important characteristics of a living fluvial hydrosystem as is summarised by the flood pulse concept (Junk et al. 1989). For the river foreland, flooding is the key process determining the pattern and the development of the habitat mosaic. The floodplain therefore presents a lateral zonation regulated by the extent and duration of floods. During flooding, large quantities of water are built up in the alluvial plain. In this phase, energy is dissipated, decreasing the erosive and transporting capacity of the river and keeping the whole river system in a state of dynamic balance. As flood water recedes, so the rivers receive an input of nutrients, contributing substantially to the functioning of the lotic and riparian communities. Urbanisation and the control of water of floodplains for modern agriculture, however, have led to a dramatic decrease of the area available for uncontrolled flooding (Van der Kraats 1994). Furthermore, little of the original storage capacity of the floodplain is left, so that peak discharge control is now most of the time restricted to the river channel itself, compelling to a further impounding of the river (Petts 1990).

Fragmentation of the continuous river and riverine landscape system

With running water as the key factor, the river and the adjacent riverine landscape form one continuous fluvial hydrosystem. Engineering works have, however, fragmented this system to a large degree. Weirs, dams and dykes have divided the river into different sections, each functioning almost independently. Habitats in the river foreland are therefore deprived of the essential hydromorphic dynamics (Petts 1990).

The continuity of the hydrosystem is not only a precondition for its proper functioning, but also makes rivers play an important role in maintaining landscape coherence. From a biogeographical point of view, rivers form a network throughout the drainage basin and provide important pathways for the dispersal and migration of species (e.g., Forman 1995; Reijnen et al. 1995; Foppen and Reijnen 1998). Land use change and river management have destroyed many of the characteristic habitats of the fluvial landscape and hamper their recovery. For many species this means the loss of permanent habitats, temporary functional habitats or stepping stones. Other species are faced with unbridgeable barriers of different types. For example, for many aquatic species a weir is a barrier, whereas for rather mobile riverine species the absence of a patch of softwood in the floodplain within a 10 km stretch may be the problem. Unsustainable populations with numbers of individuals below the 'minimum viable population size' result, linked to impoverished habitats and uncolonisable patches (Chardon et al. 2000).

River restoration principles to overcome ecological degradation

River restoration seeks to improve the natural functioning of the river and the riverine landscape as a diverse network of habitats, including its corridor function for the catchment. Boon (1992) describes five appropriate strategies for river conservation, in accordance with the state of the river. Where few natural or semi-natural systems with untouched hydrodynamics remain, their *preservation* is the task. This is rare in Europe, where all large rivers are more or less controlled. For rivers with a still high ecosystem quality and with ecological key factors functioning without major impediments, there the management option is for *limitation* of catchment development. When the quality is low, their *mitigation* becomes the case and the development of existing economic and recreational functions need to be accompanied by the implementation of measures that allow the survival of habitats and organisms. When rivers are degraded to a point that natural hydrodynamics are hardly recognisable and only scattered and small remnants of populations persist, there the emphasis shifts towards river *restoration*. With the help of well chosen restoration techniques and nature development projects, more suitable habitats need to be created, enhancing the recovery of the remaining populations and the establishment of new ones (Gore 1985). The final management option mentioned by Boon (1992), is for the worst case scenario where recovery is hopeless and *dereliction* is the only wise decision. In these cases, limited resources should not be allocated, but rather directed towards more promising restoration projects.

Biodiversity and river management

From the above discussion, it is evident that biodiversity in rivers and riverine landscapes depends largely on the unhampered hydrological and morphological dynamics of the river, functioning in the complex of the 'fluvial hydrosystem' (Amoros and Petts 1993; Petts and Amoros 1996). Fluxes of water, transported components and organisms between distinct environments and spatial units result in a mosaic of interdependent habitats each with characteristic hydraulic conditions, suitable for different species and communities. Any attempt to manage or restore rivers in favour of biodiversity, should focus on these preconditions.

Longitudinal river diversity

When determining the number of species in river systems and the potential for community recovery, it is necessary to assess the diversity, the quality and the distribution and configuration of the remaining habitats. The habitats in a river system differ gradually from source to mouth, as does the species distribution ('River Continuum Concept', Bayley 1991). Management and restoration measures should therefore take into account the geographical position of the project site within the river continuum. The selection of a feasible target for the conservation and restoration efforts is then assured as well as their proper adaptation to the prevailing hydrological and morphological dynamics. In most cases however, habitat restoration or development alone, is not enough to obtain environments suitable for sustainable populations. Habitats evolve and their qualities change. The proper qualities can be maintained by applying the appropriate management technique when the habitat is to be controlled by man. However, natural processes can be selected to sustain habitats. In river systems this is achieved when the habitats are still linked to the disturbing hydromorphic processes. Thus, natural succession is hampered or reversed, providing suitable conditions for a huge selection of pioneer species and for species of intermediate succession stages. The diversity and the pattern of habitats and consequently of species, reflect the regime of the current dominant disturbing processes, mainly flow velocity and flooding frequency and duration. These processes operate in a riverine landscape with a characteristic pattern of landforms formed during former phases of erosion and deposition. Features of the river basin such as bedrock type, slope, groundwater hydrology are also important. They determine to a large extent the size and the shape of the river valley and the contribution of groundwater to the total water budget at any site in the floodplain.

Requirements for persistent populations of animal species

A wide variety of habitats in a range of developing phases is not sufficient to sustain large numbers of species. The population controls of the species and the dynamics of the disturbing processes may indicate the number of comparable habitats needed, as well as their size, localisation and distance from each other. General guidelines for these features can not be given because they depend on the spatial aspects of the population biology of the species concerned (e.g. the area needed to hold a key population, minimal number and arrangement of small habitats to sustain a metapopulation, Verboom et al. 2001), on their dispersal capacity and on the way they use different habitats (Foppen and Reijnen 1998). The objective is to produce a river and an associated landscape, in which barriers and the accompanying isolation no longer put constraints on the free movement and dispersion of typical species. There must therefore be sufficient suitable habitat, also for colonisation. For species that depend on ephemeral ecosystems and for pioneer species of fast evolving habitats, it is therefore important that the specific habitat forming processes operate in a sufficiently extensive reach of the river and must be in accordance with the appropriate spatial and temporal scales.

River identity, basis for target setting

A description of the Upper Meuse in France (Figure 1) shows that traditional and recent values, such as recreation, of the Meuse are integrated to a considerable extent (Pedroli 1999). Such a situation could form a basis for comparison regarding the Common Meuse.

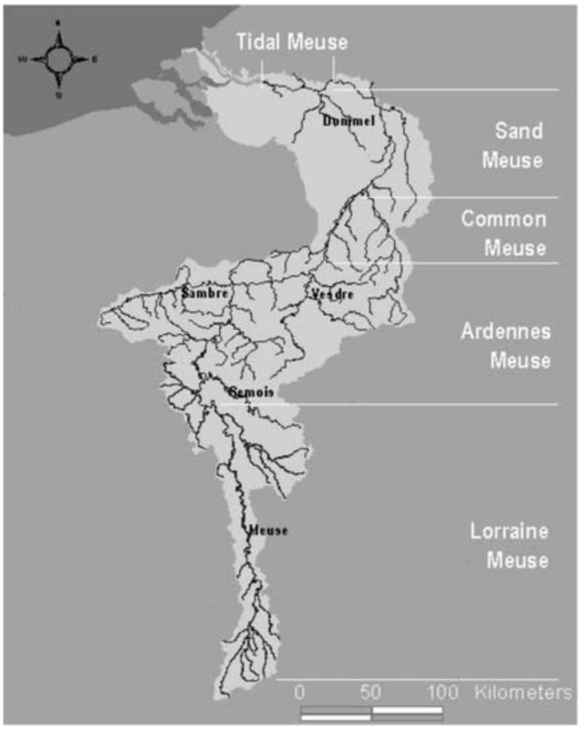

Figure 1. The catchment of the river Meuse.

The latter currently mainly serves as a discharge channel for water. Recent flood events, however, have proved that the Meuse still is a living river, even threatening damage to newly built houses, enterprises and infrastructure. Currently, new guidelines are therefore being sought for river management and restoration.

The comparison between the two river sections solicits the question as how the river identity can be defined, since the Lorraine Meuse might readily be seen as the ideal reference for the Common Meuse. They are, however, only comparable to a certain degree because the identity of the river is multidimensional. The target images for nature rehabilitation need to consider this multidimensionality, that should be reduced to terms that can be understood by decision makers and politicians.

The described observations together give a firm, yet imprecise, personal impression of the river, which can be ordered by a systematic approach to the identity of the river, starting with appearance, moving into succession and the character as shown below in Figure 2.

Appearance: Spatial coherence

Interestingly, a river can not be described from a single point of view. It becomes an image as soon as the observer has combined in his mind the observations of the sites which make it up. The young islands with willow (*Salix spp.*) seedlings are inseparable from the eroded banks in the next bend whereas the pools and riffles downstream of weirs belong to the same system as the quiet standing water in the backswamps. Some parts of the same section may be sandy, others clayey or gravelly; with steep banks or with gentle slopes. Some flowers may be red and others yellow or green, adding to the image of the same section. These are the phenomena as they appear physically, together forming the spatial coherence. Just like a given tree may produce a richer image when observed from different angles, so the image of the river in spatial coherence is multifaceted.

Succession: Coherence in time

An other dimension is the coherence in time. The presence of plastic bags and straw in the trees along the river indicates that periods of high discharge have taken place. The age of the seedlings on gravel islands indicates past flooding events. The same upper Meuse exhibits many different faces during the day, the seasons, the years. The observed phenomena are continuously in transition like the water itself. It requires an active thinking effort to build up a conscious image of this unsteady but none the less characteristic picture.

Character: the combination of appearance and succession

The character of the river is formed by the combination of appearance aspects and features of succession, that are brought together to give an overall impression. For every section of the river this character is different, resulting in contrasting processes, plants and animals. Upper, middle and lower course can be distinguished, with distinctive plants and animals, water behaviour and banks and floodplains. The composition of these features makes up the recognisable character of a river. The inhabitants of the region can identify the difference between the Lorraine Meuse and the Ardennes Meuse because of the specific composition of their features.

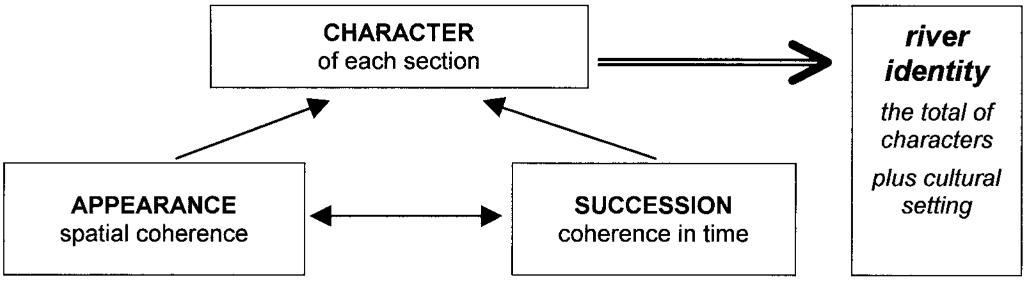

Figure 2. The relationship between appearance, succession and character as stages in the identification of river identity.

River identity

It is useful to compare the Meuse with another river such as the Marne in order to identify its principle distinctive features. Comparable physical phenomena and processes are present in both rivers. However, they differ in their overall profile. The Meuse flows through the plains of north-eastern France, before crossing the Ardennes, entering the lowlands and eventually reaching a delta near Rotterdam. In contrast, the Marne has its source in the same area as the Meuse, but then flows through the gentle Champagne hills towards the Paris Basin, where it joins the Seine, which in an estuarine exchange merges with the sea.

The cultural appreciation of a river also determines its individual identity. Whether the river has an influence on society, or vice versa, is subject for discussion (Schama 1995). The characteristics of the Champagne region and its gothic cathedrals undoubtedly give the Marne a different atmosphere than the Meuse which has meadows and fortified medieval churches. At the confluence of the Marne and the Seine, Paris has a major influence on the use of the river, because of its special status for the transport of grain and wine. The lower course of the Meuse is dominated by Liege and Maastricht, and eventually Rotterdam, but river traffic has always been hampered by the gravel shallows downstream of Maastricht. Moreover, the river Meuse flows through the three European states of France, Belgium and the Netherlands. By tradition, each of these countries has specific river management objectives, which have not encouraged integrated development of the river.

Man is inseparably associated with river landscapes. The target images for river restoration need to be realistic in relation to the natural physical processes, and their variation in time, and to the requirements of society has brought about, and which in most instances are irreversible. Even if some of the changes reversed, different situations could result, because of the changed structure of the river. The following section indicates how the above approach could be implemented.

The natural river target situation

It is necessary to clearly define objectives when strategies are being determined for the conservation or restoration of rivers for biodiversity. The clear definition of the goals will clarify the types and amount of resources that will be needed for a programme including biodiversity. The area involved in the actions, as well as the problems that have to be tackled and any constraints will determine the chances of success. Such an impact assessment will clarify the position of nature conservation in respect to other societal demands regarding the river. Thus for the proper understanding of the whole river system, an integrated assessment is required before any action is undertaken. Boon (1992) therefore argues that a fifth '*conceptual*' dimension should be added to the current four-dimensional description of rivers, comprising longitudinal, lateral, vertical and temporal components (Ward 1989). The definition of the natural river target situation is part of that conceptual dimension (Lenders et al. 1998). It is developed stepwise and is elaborated in the following successive phases.

The natural river base line situation

Much background information on hydrological dynamics and environmental characteristics of the valley is required to determine what developments can be expected. In the first place it is useful to assemble a vision of the more *natural reference* that can be adopted as a guideline when designing restoration measures in a particular river (Pedroli and Postma 1997; see Figure 3). In Germany this concept is referred to as

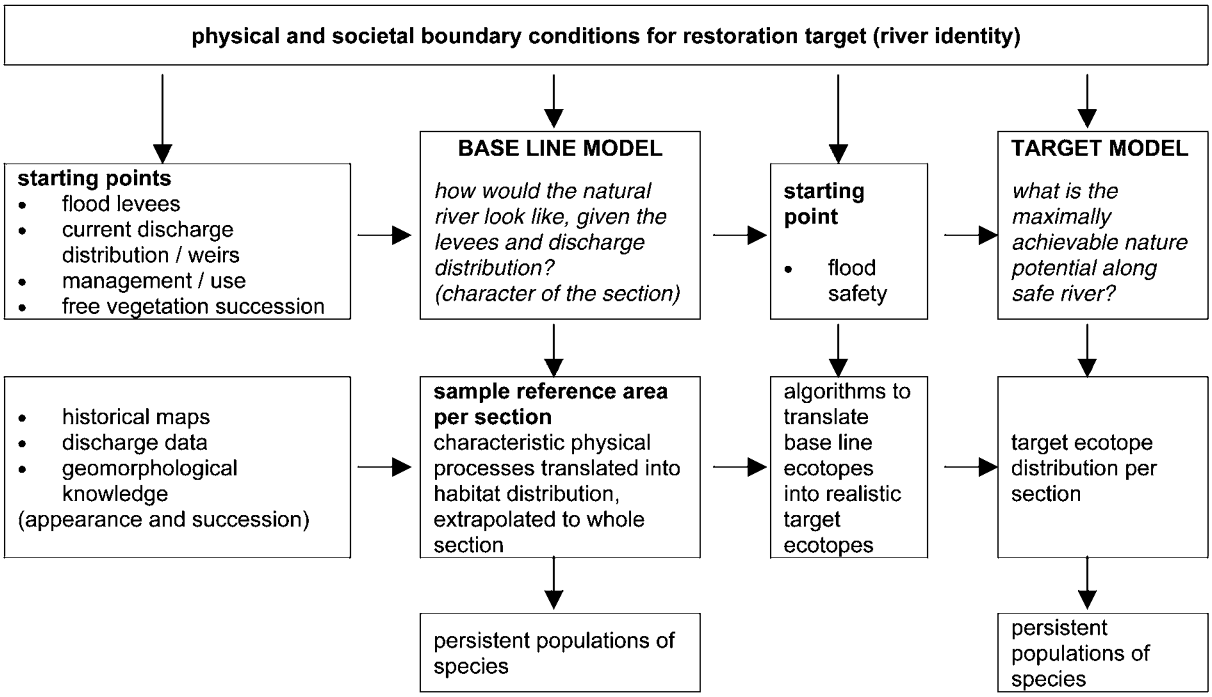

Figure 3. Approach of base line and target models for river nature rehabilitation (after Pedroli et al. 1996).

the '*Leitbild*' (see, e.g., Anonymous 1994). It is a description of the desirable stream properties regarding only the theoretical natural potential and not considering any of the economic or political aspects that influence the realisation of the scheme (Kern 1992). As such, it represents the potential for natural development, assuming that human activities in and along the river would cease. In this base line state, the hydrological and morphological dynamics, as well as the associated habitat mosaic, are included. These characteristics will therefore represent the pre-canalisation period from decades or centuries ago, which is mostly the case in European restoration projects. It may also refer to conditions prior to European settlement, as has been stated in the United States of America (Dahm et al. 1995). For the sake of realism, in most of the larger European rivers the presence of flood levees and of controlled discharges must be taken into account when elaborating the expected structure and the processes acting under more natural conditions. They represent irreversible changes in the abiotic environment but also ensure that river restoration, intensive land use outside the floodplain and navigation can go along hand in hand. The existing flood levees then put spatial limits to the restoration projects. The degree of control of the discharge determines the extent to which natural hydrodynamics can act as the driving forces for ecosystem development. Information on the original stream properties can be derived from old maps, photographs and field data and will serve for the definition and mapping of the corresponding habitats or ecotopes, defined as spatially determined habitat types. A hypothetical distribution map of these ecotopes is the result. Pedroli et al. (1996) give a method for this analysis, applied on larger Northwest-European rivers as is shown in Figure 3.

Target setting for the ecological state of the river

As stated above, the base line gives a comprehensive but rather hypothetical view. To make it more applicable and suitable for the current planning purposes, it needs to be redefined as a clear *target situation for the ecological state of the river*; the 'optimal solution' under modified present land use and river use conditions. This target situation results from the combination of the hypothetical base line with the functions of river and riverine landscape that are desired in the future in conjunction with the constraints put on the system by society. In practice safety against flooding of particular parts of the foreland and the maintenance of the transport function of the stream, will frequently be requisites. As a consequence, the control of discharge

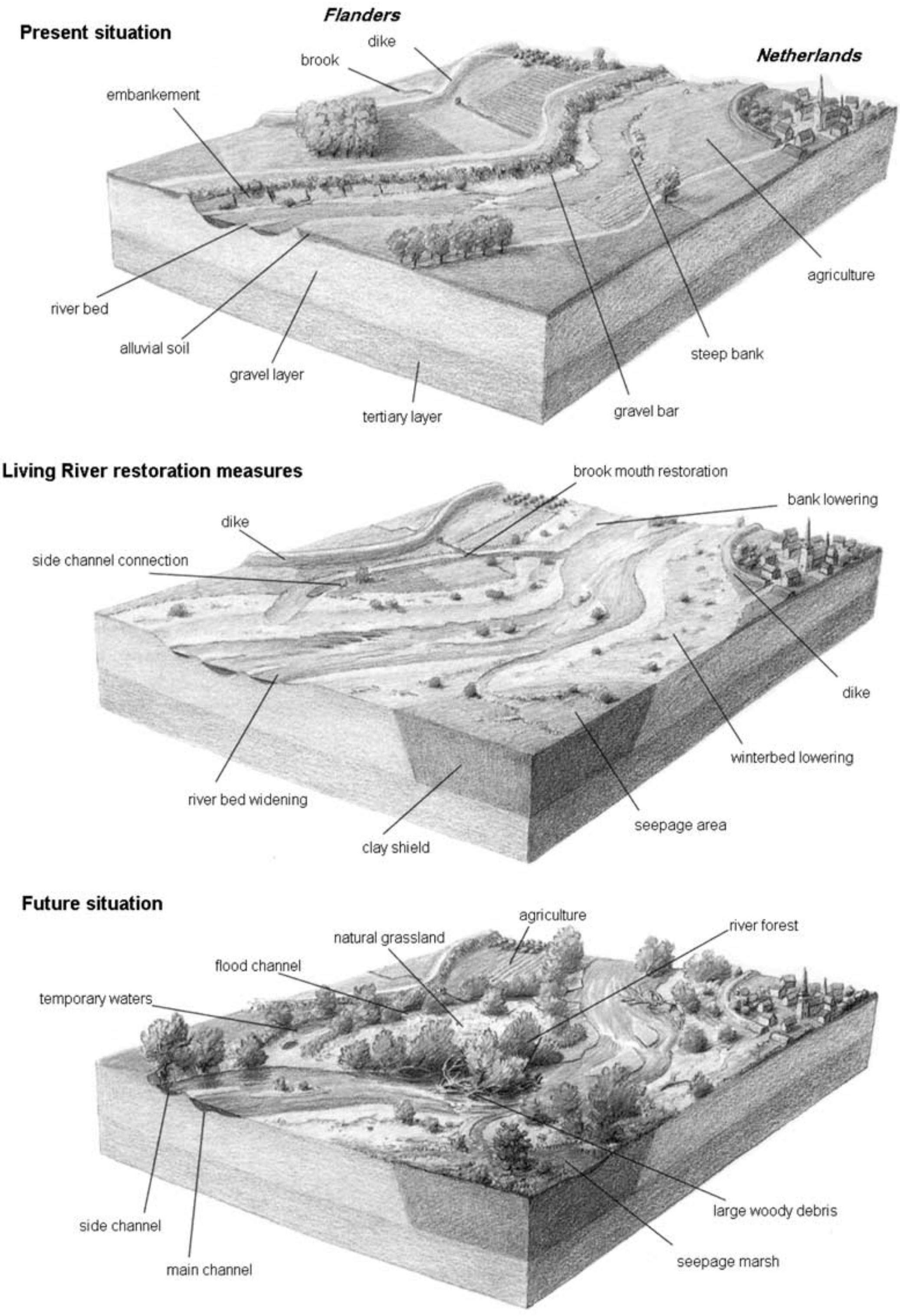

Figure 4. Presentation of the Living River strategy measures and result.

Table 1. Main river restoration measures for the three strategies of the Common Meuse floodplain.

Traditional river foreland	Living river	Free Meuse
■ Ecologically sound civil engineering in relation to bank protection and dyke construction	■ Bank lowering ■ Secondary channel connection	■ River bed widening ■ Floodplain lowering ■ Restoration tributaries
■ Implementation of extensive agricultural management	■ Implementation of extensive agricultural management	
■ Hedgerow restoration	■ Restoration tributary mouths	

Table 2. Estimation of ecotope distribution (in ha) in the Common Meuse valley in the three strategies.

Ecotope	Present	'Traditional River Foreland'	'Living River'	'Free Meuse'
Deep river bed	300	300	250	200
Shallow river bed and gravel bar	50	50	150	350
Secondary channel	0	0	50	0
Softwood forest	39	20	150	250
Hardwood forest	3	3	80	100
Marshland	5	5	105	200
Mosaics of grassland / tall herbs	220	120		
			800	900
Dynamic shrubland	83	60		
Floodplain ponds	595	650	440	300
Production grassland	710	765	260	15
Agricultural cropping	360	390	40	0

and of major shifts in the river-bed will continue and the vegetation developing in the floodplain will be managed in order to produce an optimal distribution of successional stages. These will correspond with the storage capacity that is necessary, as well as with the lateral flow characteristics of the floodplain needed to avoid problems elsewhere.

Within the limits set by the hydrological and morphological dynamics of the river stretch, the functions defined and the constraints put by society, there is still a choice of ecological target situations possible. Alternative ecological targets reflect different attitudes towards the role of natural river dynamics or of management activities as the controlling and driving force for nature rehabilitation. In a wider context, there is a problem concerning the human interference that should be allowed in nature rehabilitation projects. Today, this is a major issue in the debate on the practice of nature conservation and nature rehabilitation. This is especially the case in the intensively used and highly fragmented rural landscapes of Europe, where the ecosystems present are a result of the interaction between man and the environment (see, e.g., *Arbeitsgemeinschaft Renaturierung Hochrhein* 1996). Opinions differ widely and the major restoration projects therefore often start with designing different scenarios introduced in the public debate and presented to the authorities for final decision (Cals et al. 1998). A good example is the elaboration of three strategies for nature rehabilitation along part of the lower River Rhine, each with a specific spatial distribution of ecotopes related to differences in river dynamics and vegetation development control (Reijnen et al. 1995). Another example is the nature rehabilitation along the Common Meuse, as described in the following sections.

The River Meuse as an example

Policy analysis for river restoration

For the preparation of the river restoration project for the Belgian side of the Common Meuse in Flanders, three master plans were elaborated according to different views on the position and the functioning of

Table 3. Some results of the assessment of the spatial arrangement of habitat for selected species in the Living River strategy for part of the Common Meuse (– = negligeable; + = good; ++ = very good).

Species	Habitat requirements	Level of dispersal capacity	Potential for key population(s) in plain area	Potential for persistent population in plan area	Potential for persistent population in plan area and surrounding landscape
Barbel (*Barbus barbus*)	Secondary channels, shallow summer bed	Regional	Yes	–	+
Banded demoiselle (*Calopterix splendens*)	Shallow open water	Regional	Yes	++	++
Beaver (*Castor fiber*)	Transition of water and forest	Regional	No	–	–
Gravel spider (*Arctosa cinerea*)	Gravel and sand bars	Local	Yes	++	++
Blue winged grasshopper (*Oedipoda caerulescens*)	Gravel bars, grassland mosaics	Local	Yes	++	++
Kingfisher (*Alcedo atthis*)	Eroded steep banks	National	No	–	++
Common sand piper (*Actites hypoleucos*)	Transition of water and dynamic shrubland	National	No	–	++
Corn bunting (*Miliaria calandra*)	Grassland mosaics, production grasslands, crops	Regional	No	–	–
Wood chat (*Saxicola rubetra*)	Grassland mosaics, production grassland	Regional	No	–	–
Tree frog (*Hyla arborea*)	Floodplain water and transition to dynamic shrubland Local	Yes	–	–	
Night heron (*Nycticorax nycticorax*)	Combination of forest, water and marshes	National	Yes	+	++
Natterjack toad (*Bufo calamita*)	High levees with sandy patches (wintering habitat)	Local	No	–	–
Middle spotted woodpecker (*Dendrocopos medius*)	Hardwood forest	Regional	No	–	++

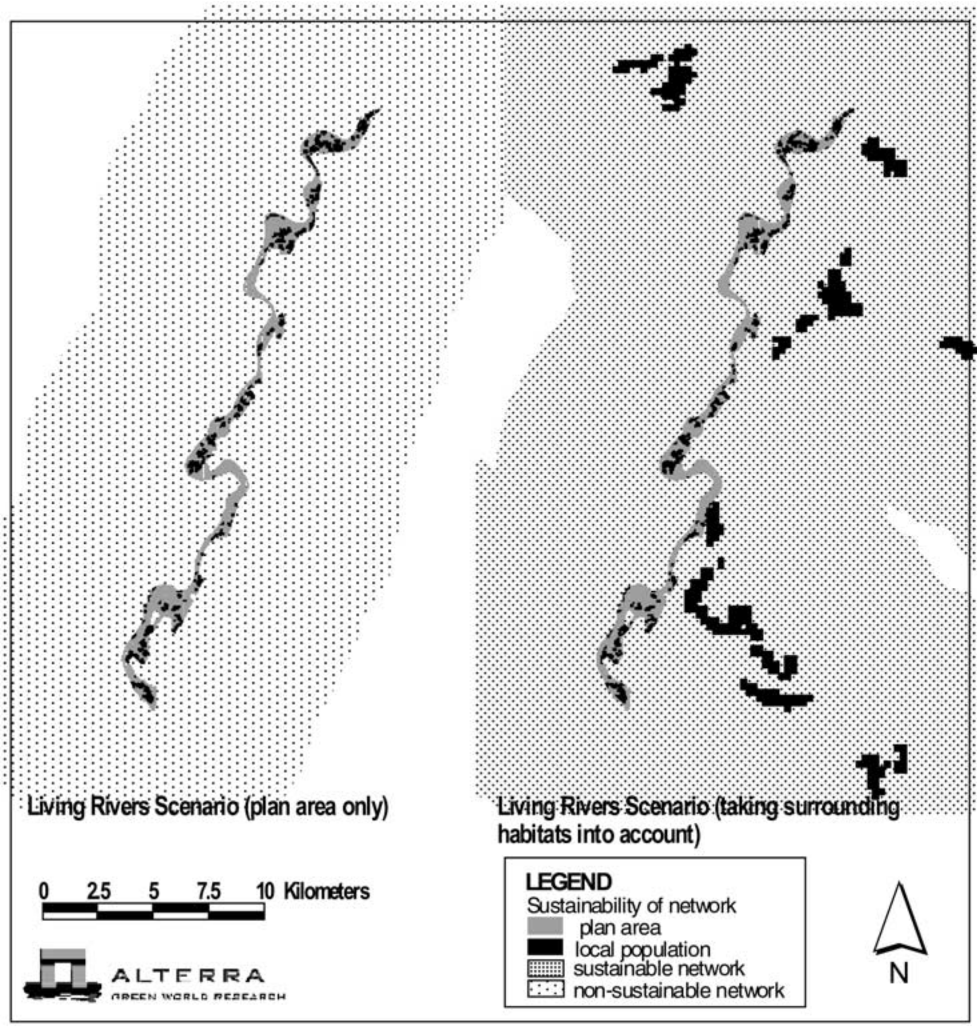

Figure 5. Habitat network of forest species with regional dispersal capacity ('middle spotted woodpecker') in the plan area along the Common Meuse (left) and in the plan area with surrounding landscape (right).

the natural river in relation to human interference (see Figure 4; Van Looy and De Blust 1995).

- In the first plan, termed *Traditional River Foreland*, the current distribution and variation of ecotopes is the starting point. Meadows and moderately fertilised pasture, old levees with thermophyllous vegetations, networks of hedgerows, are the significant ecotopes. They are elements in a 150-year-old cultural landscape, developed after the major impoundment of the river in the middle of the last century. Concern for the species and habitats of this landscape, maintained by low input agricultural management and recently developed recreation activities, restrict the possibilities to re-establish natural hydrological and morphological dynamics. Restoration of the river is for the greater part confined to the ecologically sound restructuring of river banks and gravel pits. Thus, in this view the river ecological functioning depends especially on the traditional use of the river and its foreland.
- In the second plan, termed the *Living River* strategy, the concept is to restore hydrodynamics and morphodynamics and related ecological characteristics in the primary river channel and in re-established secondary channels and backwaters. Ecotope development will take place mainly along these courses and will yield new habitats for riverine species. The land in between maintains its current functions. During flood periods, the river

can expand across the floodplain, penetrating the secondary channels.

- In the third strategy, termed the *Free Meuse*, the development and the distribution of habitats and species in the whole riverine landscape is considered to be determined by the dynamics of the River Meuse. Within the river foreland there are no restrictions and major human activities are withdrawn. Outside the floodplain and up and downstream of the restored river reach, flooding must be avoided.

At the beginning, the first plan was strongly supported by local nature conservation groups. They considered that it provides the best chance for maintaining the current biodiversity, whereas the other strategies still had to prove that they could produce high quality habitats. During the further development of the plans, opinions changed. Small scale demonstration projects showed the possibilities for a quick recovery of suitable habitats with characteristic pioneer species after disturbance or creation by the river dynamics. Furthermore, extensive grazing, as a way to maintain the pattern of heterogeneity during succession, turned out to be not only a valuable alternative for the traditional mowing, but also a way to create good germination conditions for the development of new microhabitats (Van Looy and Kurstjens 1997). Today, the river authorities and the government supported by conservation groups have adopted the *Living River* master plan as the guideline for further nature rehabilitation and river restoration in relation to discharge and flood control of the Common Meuse.

The strategies differ in restoration measure techniques and scale in relation to land use and river dynamics and their reciprocal influence on the development of nature. The most important measures to attain river restoration are channel widening, bank lowering and side arm connection, as shown in Table 1.

Table 2 gives an estimation of the extent of ecotope groups for the three strategies for the Common Meuse valley. Total area is based on the interpretation of land cover units according the Biological Valuation Map (De Blust et al. 1985) and an evaluation of the strategies (Van Looy and De Blust 1996).

From the transboundary master plan for the Common Meuse that treats the different strategies at length, the *Living River* strategy was selected by the international Co-ordination Commission as the starting point for future developments (Decision of 1/5/95). It was decided that this strategy, as presented in Figure 4, be assessed for its potential to support a region specific biodiversity.

Assessment of the potentials for biodiversity

Theoretical and empirical studies have shown that the spatial pattern of a fragmented landscape determines the persistence of natural populations (Vos et al. 2001). In fragmented landscapes, any method for assessment of population persistence or potentials for biodiversity should therefore take metapopulation theory into account (Verboom et al. 2001) and focus on ecological networks. Ecological networks describe the spatial configuration of habitats.

Verboom et al. (2001) propose an approach for assessing ecological networks in which at least one patch (key patch) is relatively large. Based on this assumption and on indices and standards for dispersal capacity of species and population related minimal spatial conditions, an expert system has been developed (LARCH, Landscape ecological Analysis and Rules for the Configuration of Habitat) (Chardon et al. 2000). This system allows the assessment of the persistence of metapopulations in a fragmented landscape and hence can be used to compare strategies that lead to the formation of different landscape and habitat patterns.

For a set of 13 selected species representing certain aspects of natural rives, habitat spatial cohesion was assessed with LARCH for the *Living River* strategy of the Dutch side of the Common Meuse. The middle spotted woodpecker (*Dendrocopos medius*), for example, is a model for forest birds with a regional dispersal capacity. For all species, the network of suitable habitats in the flood plain, as well as the habitat network extending into the surrounding areas was assessed on its ability to sustain persistent populations.

The analysis shows that the river restoration strategy indeed offers opportunities for persistent populations of many species, especially for those typical of dynamic river habitats and river foreland, as shown in Table 3. Those species with a regional and national dispersal capacity have their requirements fulfilled regarding habitat cohesion once the restoration measures are put into practice. In addition, the interconnections with habitats up and downstream of the Common Meuse and outside the floodplain, result in a robust habitat network. The model thus stresses the importance of designing nature development projects in both upstream and downstream sections of the river to produce conditions suitable for persistent populations of many riverine species that function on this large scale. Examples of such species are the middle spotted woodpecker, shown in Figure 5, and the kingfisher. A similar application of LARCH on the Flemish part of the Common Meuse revealed that habitat requirements are met for the beaver (*Castor castor*), absent in the catchment at the moment, to establish three local populations. The tree frog (*Hyla arborea*), a species currently under threat, could also develop a core population (Vanacker et al. 1998).

Perspectives

Biodiversity: A matter of habitat cohesion

Strategies designed for a large reach of the river and the associated alluvial plain, are rather inaccurate when a precise prediction of the development of a particular site is required. As a consequence, the identification of a specific site of interest, or the exact locations where ecotopes would develop, can seldom be determined. This represents a practical problem because today, in regions with scarce and highly fragmented ecosystems, almost all initiatives and measures to protect and enhance biodiversity are directed towards individual sites. So in order to agree with current policy, it remains necessary in most cases to define the nature conservation values and the ecological functions of the site and to discuss the desired development. Although it makes no sense from a landscape ecological point of view, a particular site, such as an ecotope, is in this respect often appreciated as an isolated entity, which if it is dependent upon the surrounding landscape can cause management problems. The biodiversity present and the possibilities to optimise management activities are necessary criteria for assessment of such sites. Results available from surveys, empirical studies and modelling exercises however, have demonstrated that ecotopes and habitats must be seen as functional parts in ecological networks (Verboom et al. 2001). This is especially true for river corridors (Foppen and Reijnen 1998). The running water itself is an ideal pathway for active and passive dispersion of plant and animal species. The whole riverine system functions as an ecological network, with longitudinal and transversal transfer of water, sediments and nutrients (Petts and Bradley 1997). Migrating animals, especially birds, often use rivers to move through the landscape, where they can also find food and resting places. The considerations presented here, and the Common Meuse example, suggests the potential of further development of habitat network assessment methodology in river restoration studies. Research currently being carried out on the ecology of the whole Meuse will expand these concepts further and will be subject of subsequent publications.

Design with nature...

The Common Meuse example shows that relatively simple data such as land cover maps and defined criteria of habitat configurations for typical species, can lead to strategies for the development of land use along the river and indicate consequences for natural processes and elements, indicated by animal species. The methodology to define targets for spatial configuration of habitat types, or ecotopes, appeared to be very useful in this context. Instead of concentrating on single habitats, the concept of connectivity is used as a natural guideline to design strategies for nature rehabilitation, because of the interdependence of many landscape elements.

Planning cohesive networks is more effective than conserving species habitats

There are several reasons for changing the species oriented conservation policy into a landscape oriented policy focussing on pro-active strategies:
(1) Landscapes are the arena for human activities where biodiversity is situated. However, they include many species and habitats combination with different functions, of which nature conservation in only one.
(2) Many species need different habitats and contrasting spatial conditions. It is therefore not feasible to integrate all species requirements into a single landscape plan. There is a need for integrated planning guidelines for spatial landscape networks.
(3) The conservation of single species – whether considered as a representative or indicator of other groups – will never be a successful instrument in biodiversity policy when their associated habitats are not considered in their context and configuration in the landscape. Both plant and animal species depend on spatial dispersal – and animal species also on migration – for the long term viability of their populations. Biodiversity planning therefore needs to take account of landscape networks.

These considerations would lead to a policy directed to conservation and development of habitat networks rather than of species or isolated habitats.

Specific groups of species should be selected having comparable requirements in the sense of dispersal, migration ranges and barriers. These groups of species may be represented by an idealised key species, for which then sustainable habitat networks can be determined.

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