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Ground beetle habitat templets and riverbank integrity

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Introduction

The appropriate application of ecological theories in the management of river systems, requires more knowledge of biological traits of riparian species (Barrat-Segretain, 1996). Where most river concepts focus on longitudinal patterns and gradients, the habitat templet theory is a useful approach for comparison and evaluation over and between river sections (Townsend et al., 1997). As organisms and communities in streambed landscapes respond to the type and spatial arrangement of habitat (Palmer et al., 2000, Eyre et al., 2001), the community responses of terrestrial riverine organisms are good predictors for river management impacts. River management has local effects on the spatial arrangement of habitats, but it can also generate downstream and upstream impacts on habitat integrity. Therefore, the sampling and analysis of biotic and abiotic parameters in river systems needs a hierarchic, scale-sensitive approach (Bovée, 1982, Frissell et al., 1986, Bauer, 1991, Gregory et al., 1991, Fawthrop, 1996, Petts & Bradley, 1997, Hansen et al. 1999).

The River Habitat Templet Theory (Townsend & Hildrew, 1994) offers a suitable approach to define indicators at river basin scale for habitat integrity and management. The use of habitat templets has benefits in defining responses and indicators in river systems with immediate relations to the physical conditions (Bornette et al., 1994, Townsend et al., 1997). Moreover ground beetles have been proposed as indicator group for river management (Sustek, 1994, Maiolini et al., 1998). Ground beetle assemblages have been recorded as responding to flood regimes (Bonn et al., 2002), riparian vegetation (Greenwood et al., 1995), riparian habitats (Boscaini et al., 1998, Plachter & Reich, 1998), riparian habitat heterogeneity and distribution (Eyre et al., 2001) and bank management (Gerken et al., 1991).

Ground beetles were chosen as bioindicators to assess the impact of flood protection strategies at Meuse riverbanks. The objective of this study was to identify responses of this species group to relevant parameters for the river management, to be integrated in an evaluation method for flood protection and river restoration. Carabid beetle assemblages were determined along the river's longitudinal gradient, and indicators for habitat integrity were derived from clustering and nestedness analysis of species assemblages. Further responses to river management related variables were identified with multivariate analysis. The important species traits for the templets were linked to habitat use and selection. Responses to specific river conditions of these templets are useful in the evaluation of river management and flood protection measures in particular.

Methods

Study area

The river Meuse is a rain-fed river, originating at an altitude of 409 m above sea level at the Plateau of Langres in the North of France and discharging into the North Sea some 900 km further downstream. The catchment's area is c. 33,000 km?, situated in France (9,000 km^2), Belgium (13,500 km^2), Germany (4,000 km?), Luxembourg (600 km^2) and the Netherlands (6,000 km^2). As the research focused large river's bank habitats, some 400km of the river's middle course were investigated. A detailed survey was executed in the unregulated middle course section (50 km) of the Common Meuse between the towns of Maastricht and Maaseik on the Flemish-Dutch border. The Common Meuse is a gravel river with a strong longitudinal gradient (0.45m/km). The discharge of this rain-fed river shows great fluctuations. Discharge levels for the Common Meuse range from 10 m^3/s during dry periods to 3,000 m^2/s in periods of heavy rainfall.

Studied species

Ground beetles have a wide range of ecological traits, related to habitat conditions of food supply, substrate and vegetation cover. Species traits of wing development, dorsal flattening, reproduction rhythms and phenology mean that ground beetles are very selective in terms of habitat affinities (Den Boer et al., 1979, Desender et al., 1994). Their potential use as bioindicators in surveys of riverbank communities along the Meuse and its main tributaries has been discussed previously (Baufays, 1994, Dufrêne & Legendre, 1997, Richir, 2000). Ground beetles are commonly referred to as a good indicator group as they exhibit habitat selection, varying dispersal capacity and colonising strategies (Stork, 1990). Moreover, the family is taxonomically well known and easily sampled. The combination of these abilities, together with the large number of river species, allows the distinction of indicator groups for environmental characteristics, habitat configuration and integrity in river systems (Zulka, 1994), and even for larger rivers in a global context (Boscaini et al., 1998).

Sampling

Data on the riparian carabid fauna and vegetation were collected during 3 consecutive years 1998-2000 along the river Meuse. The sampling at a catchment scale was executed in 2000 using 14 stations spread along the middle to lower course of the river Meuse (Figure 3.13). The reach scale sampling of the Common Meuse was carried out for two consecutive years 1998 and 1999 on 17 gravel bank stations sampled of the 50 km Common Meuse river reach. Each station consisted of two plots; one higher on the riverbank and one close to the waterline, giving 34 plots in total. Ground beetles were sampled using pitfall traps (filled with 5% formaldehyde preservative), three traps in a row at 1m intervals forming a plot. Samples from the 3 traps were pooled and species identified in the laboratory. The traps were sampled in two-weekly intervals for the period of May to October in both years. Although not without problems, pitfall sampling has been used extensively to compare species assemblages in larger geographical areas under river bank conditions (Dufrêne 1992, Spence & Niemelä, 1994, Desender & Maelfait, 1999, Eyre & Luff, 2002). However, abundance and especially size-abundance relationships require careful interpretation (Arneberg & Andersen, 2003).

Together with the biotic sampling, data on river bank and habitat characteristics were collected and stored as catchment and reach scale river variables (Table 3.9). This set of independent variables was retained from a broad range of variables, selected from relevant literature (Armitage et al., 2001, Growns & Growns, 2001, Bonn et al., 2002, Olden & Poff 2003). For the different gauging stations (Stenay, Lorraine Meuse / Ampsin-Neuville, Ardennes Meuse / Borgharen, Common Meuse / Venlo, Sand Meuse) data of 10 year average daily discharges were used to derive the hydrological indices at the catchment scale. For the Common Meuse, hourly flow data of the last 10 years were analysed. The selected hydrological indices are widely used in the description of flow modifications, especially in flow regulation assessment (Growns & Growns, 2001). The following definitions were used: baseflow index (BFI) = (lowest daily discharge/mean daily discharge) x 100, coefficient of variation (CV) = (standard deviation of monthly discharge/mean monthly discharge) x 100, peak frequency (PF) = number of discrete flood events, i.c. the peak fluxes (when discharges exceed the level of the riverbank dynamic habitats) during the summer period (may to October, the active period for the carabid fauna), peak velocity (PV) = the peak flux over hourly discharges, derived from the summer peak events over the longyear flow data, and the rising speed (RS) = the velocity of the water level rise, defined as the difference in water level (m) between 200 m^3/s and 10 m^3/s discharge as a measure for the hydrodynamics on the riverbank habitat.

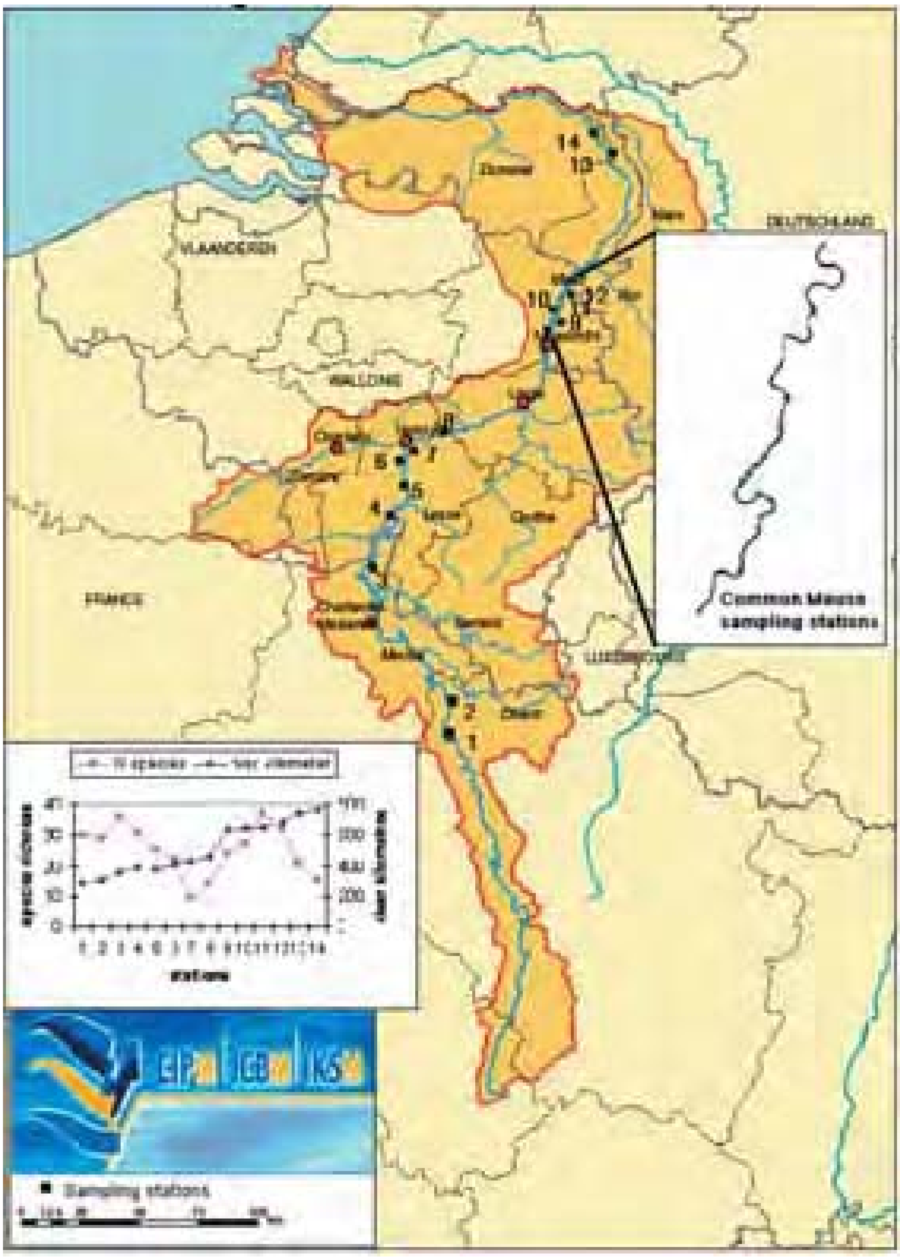

Figure 3.13 The Meuse river basin map of the International Meuse Commission with the Carabid sampling stations (with inset for reach level sampling of the Common Meuse stretch) and their richness in habitat templet indicator species in the inserted diagram.

Table 3.9 River variables of channel morphology, hydrology and bank characteristics as surveyed for the catchment and reach level sampling.

VARIABLE	DESCRIPTION	MEASUREMENT
River kilometre	Distance from river source (km)	Catchment/reach
Width/Depth–ratio	Dividing river width by mean river depth	Catchment/reach
Baseflow index	Dividing lowest flow by mean flow	Catchment
Coefficient of Variation	Dividing discharge variation by mean discharge	Catchment
Peak frequency (of summer peaks)	Number of relevant summer peaks in summer season	Catchment
Peak velocity	Hourly or daily maximum flow increment	Reach
Rising Speed	Velocity of water level rise	Reach
Habitat heterogeneity	Number of habitat types per station (within 20m around plots)	Catchment/reach
Texture	D50-value of substrate (mm)	Catchment/reach
Vegetation cover	Percentage soil covered by plants (%)	Catchment/reach

Some further variables, relevant in riverbank habitat description, were included: river kilometre, width/depth-ratio, habitat heterogeneity (# bank habitat types per station), texture of substrate and vegetation cover. Vegetation sampling occurred in a mapping of vegetation types in a range of 20 m around the plot and a 1 m? relevee at the plot site. These data were used for the definition of habitat heterogeneity of the stations, while the coverage of the relevees was used for the vegetation cover parameter.

Analyses

The habitat templets were derived from a clustering and ordination of species assemblages from the catchment level sampling set (Figure 3.14). The plot-species matrix was selected on species (>3 individuals), plots (>80 individuals per plot) and plots/species (>2 plots/species). 16 plots and 77 species were retained for the analysis at the catchment's scale, 29 plots and 84 species for the reach scale.

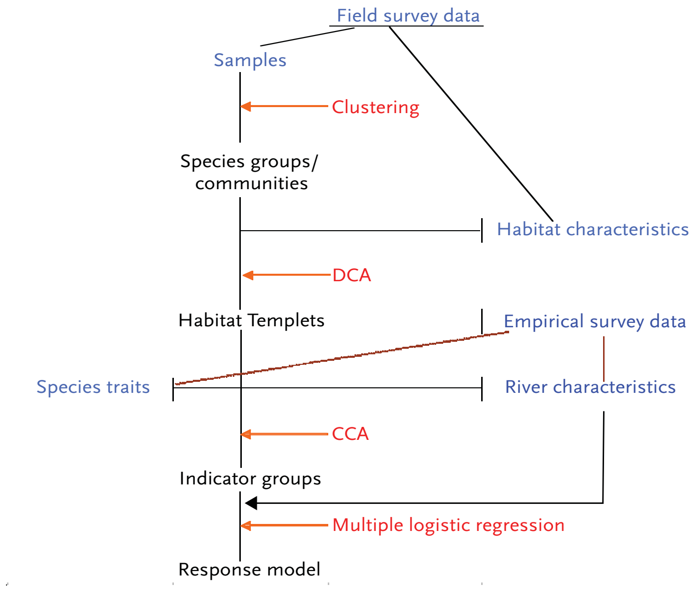

Figure 3.14 Flowchart of habitat templet approach.

For the classification of faunistic site sampling data, a non-hierarchical clustering method is the most appropriate (Dufrêne & Legendre, 1997). The k-means program (Legendre & Vaudor, 1991) is a least partitioning method that divides a collection of data into 'k' groups. The algorithm computes clusters and assigns each species to the nearest cluster at each level of k, in such a way as to maximize the between-cluster differences.
Before entering the clustering program, a principal coordinate analysis (PCoA) was run from the similarity matrix, using the Steinhaus coefficient (Legendre & Legendre, 1983), calculated on natural log-transformed data. The k-means method was applied to the plot coordinates on the first 12 PCoA axes of the Steinhaus similarity matrix, allowing the filtering of the ordination axes and the identification of a hierarchical structure in the data if present (Dufrêne & Legendre, 1997).

Together with the clustering, the identification of indicator species with the IndVal-method (Dufrêne & Legendre, 1997) computed indicator values at each level of 'k'. The INDVAL-index is maximal (100%) when all individuals of a species are observed in all sites of that site-group. The IndVal indicator value is not only a reliable measure in the proposed clustering method, but is a absolute measure, making comparisons across taxa, functional groups and communities robust to differences in abundance (McGeoch & Chown, 1998). Indicator species with high fidelity and specificity were selected for each habitat templet.

An ordination by DCA was computed in the CANOCO program (ter Braak, 1988). Based upon the length of the DCA gradient-value, a Canonical correspondence analysis (CCA) was performed with the environmental variables included. A first set of variables, relevant for ecological effect assessment of flow regulation (Growns & Growns, 2001), was determined at the catchment's scale-level (Table 3.9). Further analysis of the hydrological parameters was done at the reach scale to detect responses to hydrological regime (in-between years and reach plots) and management parameters.

With the detected predictor variables for the riverbank carabid faunal composition, a covariance analysis was run for the templet indicator species. In the STATISTICA program, the datasets of the catchment and reach level sampling were analysed with non-parametric tests for 2 independent samples (Mann-Whitney and Wilcoxon). Covariance between the habitat templet indicator species and species richness of the plots was analysed (with Mann-Whitney test). Before entering this covariance analysis, a nestedness analysis was run, to detect matrix temperature and nested subsets with the Nestedness Temperature Calculator Program (Atmar & Patterson, 1995). Nestedness is a way to estimate the degree of hierarchy in species assemblages, which allows the distinction of indicators for species richness in hierarchic sets (Atmar & Patterson, 1993, Worthen, 1996, Gustafsson, 2000, Honnay et al., 1999). Strong covariance detects those templet indicator species that are good indicators for the biotic integrity of the riverbank. To conclude the correlation analysis, Mann-Whitney covariance testing was done on the datasets for the river management variables at the two dataset levels. The dependent (grouping) variables were the presence-absences of the indicator species, the species richness and the habitat heterogeneity respectively.
As the final step a multiple logistic regression was executed on the detected indicator species for the river management variables width/depth ratio, peak frequency and peak velocity. From this logistic regression a response and optimum range of the variables for the biological integrity, was assessed.

Results

The catchment sampling yielded 4,892 ground beetles extracted from the pitfalls and determined to species level (Table 3.10). Over 16,000 carabid beetles were sampled and determined from the 1998-1999 Common Meuse reach level sampling. The k-means clustering of the samples similarity coordinates gave the best fit for eight species groups (Figure 3.15). At each level below level 8 the species with the highest INDVAL-value are listed. At level 8 the cluster groups are shown with all species with INDVAL-values > 25 per group included. The clustering separates the sites closest to the waterline from the more elevated sites. The further differentiation accords to the present substrate and vegetation cover.

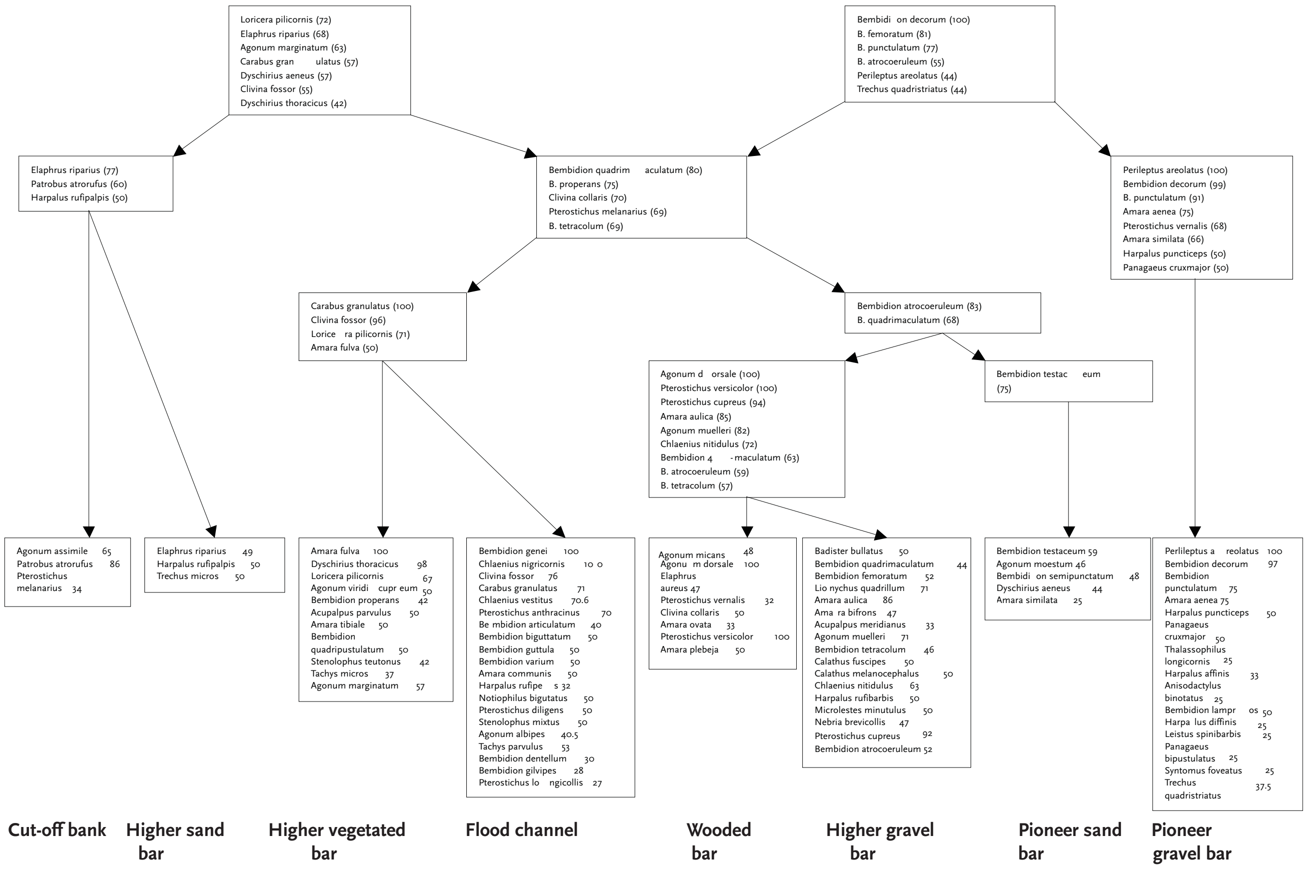

Figure 3.15 Site clusters with templet indicator species groups (INDVAL values > 25) obtained with the k-means method. For the hierarchic divisions the species associated INDVAL indicator values are given in parentheses

The Detrended Correspondence Analysis (Figure 3.16) shows a strong influence of the river dynamics along axis 2, from the pioneer bars to the flood channel plots. The axis 1 division is related to the naturalness/modification of the riverbank, with the riverbank related species situated to the left, and the eurytope species to the right. The influence and inflow of species from adjacent fields dominates more to the right.

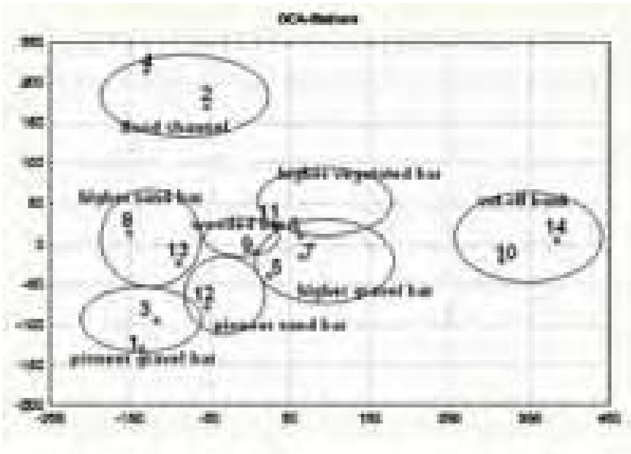

Figure 3.16 DCA-plot of the 16 sampling plots with the confidence ellipses for the 8 habitat templets.

In Figure 3.17 the triplot for the Canonical Correspondence Analysis (CCA) is given for the dataset of the catchment level sampling. The first axis in the CCA explained 36.8% of the total variance and coïncided for 91% with the variable width/depth-ratio, to a lesser extent with peak frequency. The second axis added 37.8% to the explanatory value, and was correlated for 80% with soil texture.
A high correlation with width/depth-ratio and peak frequency was observed for the 'pioneer gravel bar' indicator species. High habitat selectivity of this group was already shown in the INDVAL values of the indicator species (Bembidion punctulatum INDVAL 75.27, Bembidion decorum 96.82, Perileptus areolatus 100 and Amara aenea 75). This templet shows a negative correlation with vegetation-cover. The templets 'flood channel', 'pioneer sand bar' and 'higher vegetated bar' were correlated with sandy texture and high vegetation-cover. Species associated with the river kilometre variable were only few, restricted to the sampling of downstream (Patrobus atrorufus, Agonum assimile) or upstream (Bembidion dentellum and Harpalus puncticeps) stations.

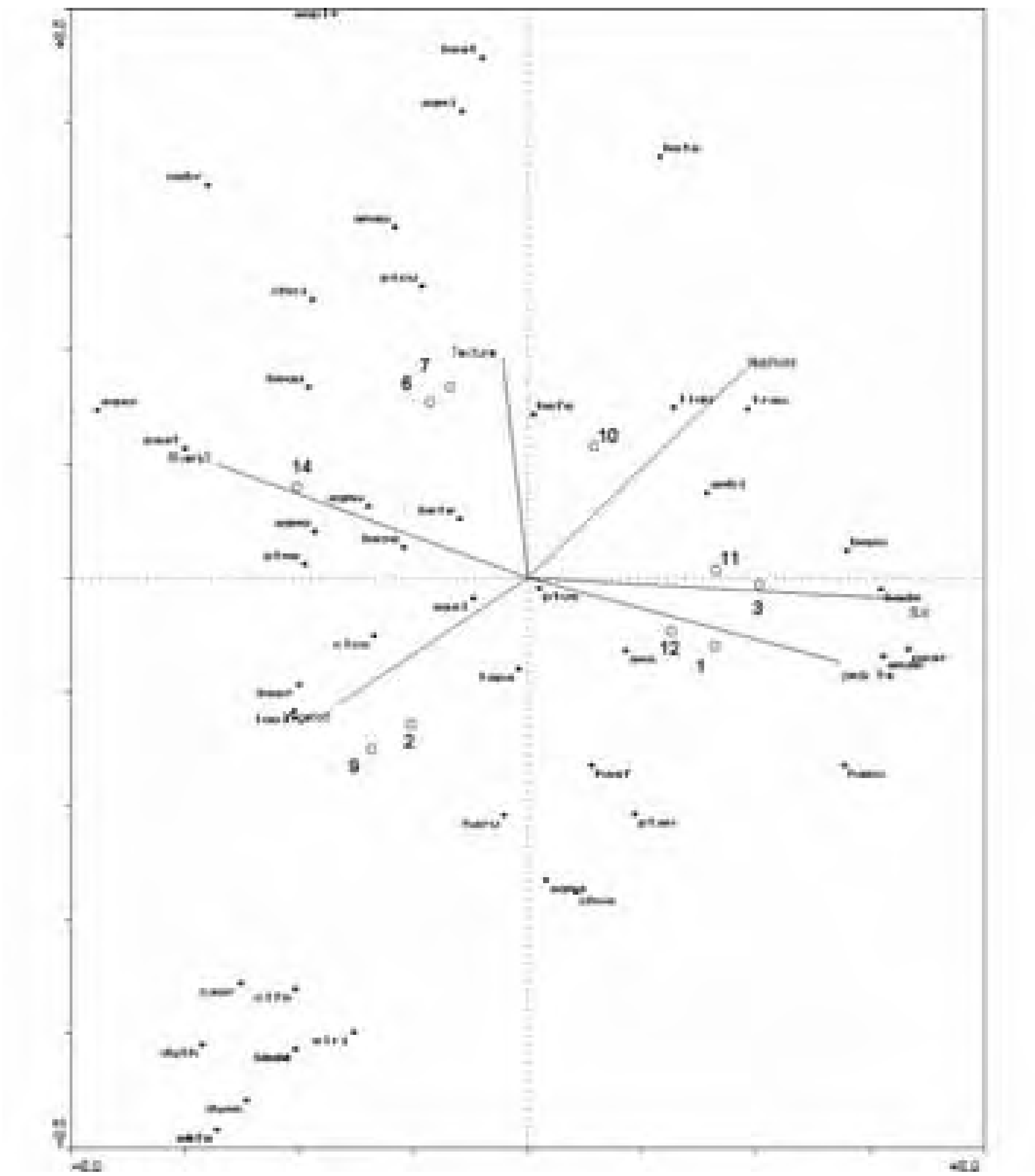

Figure 3.17 Canonical correspondence analysis (CCA) triplot of carabid species, sampling stations and environmental variables along 600km of the river Meuse (sampling 2000).

Figure 3.18 Canonical correspondence analysis (CCA) biplot of carabid species (1998-1999 sampling) and 4 environmental variables

Figure 3.18 shows the result of the correspondence analysis at the reach level. The strongest correlations were detected with the peak velocity (with the first axis 82%), and to a lesser extent rising speed (for the fourth axis 81%). Width/depth ratio showed a high correlation with the higher elevation habitat templets (higher vegetated bar and higher gravel bar). Highest habitat heterogeneity was observed for the 'flood channel' and 'wooded bar' templets, as they are only present in the most natural stations.

Response analysis

The INDVAL determined habitat templet indicator species were entered in the analysis for riverbank integrity indicator species. Indicators for the habitat

integrity of the riverbank as a whole were detected in the nestedness analysis. A significant covariance (Wilcoxon p value 0.00019) was first detected between species richness and habitat heterogeneity. The assembly of ground beetles at the catchment as well as at the reach scale had a significantly nested structure. For the reach sampling, the data set temperature of 10.64° deviated significantly ($p < 0.001$) from the simulated set temperature of 39.5°. For the catchment's data, the matrix temperature was 32.27°, indicating the wider spreading of the species data, but still significantly deviating ($p<0.001$) from the Monte Carlo simulation run in the Temperature Calculation Program.
So, Mann-Whitney covariance testing allowed detection of indicators for the biotic integrity of the Meuse riverbanks. Overall Meuse riverbank bioindicators (Bembidion tetracolum, Chlaenius nitidulus, Pterostichus vernalis, Amara similata and Harpalus affinis) were detected in the correlation with species richness (Table 3.10).

Indicator species and river management variables

For the species richness, significant correlations were detected with peak velocity (explained beta-variation: 0.36) at the reach level, and with peak frequency at the catchment level (explained beta-variation: 0.47). The W/d ratio covariance was significant for 21 habitat templet indicator species. The species with the strongest significant covariance and CCA correspondence values preferred the broader stretches with W/d ratios above 25.
The indicator species with the strongest covariance for the peak frequency are Perileptus areolatus (chi^2: 11.4, $p=0.0007$) and Amara aenea (chi^2: 7.9, $p=0.004$). For the indicator species, optimum peak frequency lies in the observed maximum of 9 summer peaks.
The indicator species for the peak velocity (Harpalus affinis $chi^2= 25.9$, $p<0.0000004$ and Bembidion decorum $chi^2= 22.1$, $p<0.0000026$), showed an optimum below 30 in the logistic regression.

Discussion

The use of single species or taxonomic groups as indicators for the integrity or quality of ecosystems has been criticized (Landres et al., 1988; Niemi et al., 1997;

Prendergast et al., 1993) because the effectiveness of the concept has often been assumed, but only rarely tested (Andersen, 1999, McGeoch & Chown, 1998). Furthermore, the selection of bioindicators for river health assessment needs a scale-sensitive survey and analysis of distribution and selection of habitat (Fairweather, 1999, Karr 1999, Norris & Thoms 1999, Hansen et al., 1999, Pedroli et al., 2002). The broad range of species traits and habitat adaptations makes ground beetles a good candidate indicator group for habitat integrity and river health assessment in general. The habitat selectivity is reflected in the species traits as the smallest, flattest, flying species are best adapted to the most dynamic riverbank habitats (Desender, 1989, Eyre & Luff, 2001). Larger, slower species of the genus Carabus or Pterostichus are restricted to the higher, less dynamic zones. The clear segregation of habitats in the riverbank, caused by sharp boundaries of substrate and vegetation cover, contributes to the high INDVAL-values for the habitat indicator species.
The relevance of carabid beetles as bioindicators for hydromorphological processes and riverbank habitat integrity was already tested in local as well as global river management context, using the same sampling method (Boscaini et al. 1998, Maiolini et al., 1998, Kleinwächter et al. 2003). The identified habitat templets include a large number of riverbank species with high INDVAL-values. These are valuable bioindicators for the riparian habitats, as the INDVAL method selects species more or less unique to the habitat (high specificity) as well as widespread within it (high fidelity). So these indicator species have not only high information content, but also a high probability of being sampled during monitoring and assessment. This habitat specificity does not imply that the identified indicator species in our riverbank survey are restricted to riparian habitats. Several generalists of open and disturbed ground were attributed to specific riparian habitats. The same observation can be made for the use of the riparian zone in other organism groups.
The presence of many habitat specialists in this organism group for the riparian zone, contrasts with Meuse macroinvertebrate surveys. In a macroinvertebrate sampling of the littoral zone of the Common Meuse, only 1% of the sampled individuals was habitat specialist (Smit & Gardeniers, 1986). This distortion was attributed to the strong anthropogenic disturbances in the habitat conditions related to flow regime and mainly water quality. As many carabid species inhabit the summer bed in low flow conditions, anthropogenic changes

to the river system are also reflected in changes in species composition. Indeed in our dataset, the assemblages of highly modified banks contain the smallest number of indicator species, while more undisturbed stations have more templet indicator species. Nevertheless, with more than 90% of the individuals belonging to riverbank habitat templet indicator species, the abundance of riparian habitat specialists in our sampling set was spectacular. So, where dramatic changes in aquatic organism groups were caused by anthropogenic disturbances, terrestrial riverbed habitats still preserved characteristic communities allowing river health assessment for the hydromorphic aspects.

The significant correlation between the habitat heterogeneity and the species diversity is important for the habitat integrity assessment. The heterogeneity in riverbank habitats yields more potential ecological niches to be filled at the same location (Sadler et al., 2004). The richness of templet indicator species over the pitfall sampling stations along the Meuse shows the lower integrity in the Ardennes Meuse and Sand Meuse stations (inset in Figure 1). The heavily regulated Belgian and Dutch Meuse reaches show a drastic decline of stream integrity, with a strong recovery in the un-navigable Common Meuse reach. Stream canalisation efforts for navigation in the Ardennes and Sand Meuse, with embankments and groins, reduced the available riparian habitats for terrestrial as well as aquatic macroinvertebrate communities dramatically (Usseglio-Polatera & Beisel, 2002).

No clear shift in communities along the river was observed for the ground beetles in contrast with the longitudinal changes in macroinvertebrate assemblages and alleged problems for the coordinated assessment of the biological integrity for the whole river Meuse (Usseglio-Polatera & Beisel, 2002). So, with the defined habitat templets, we can work out an unbiased catchment's scale 'river health' bioassessment.

The need for quantification of physical and biological responses remains a main issue for the evaluation of river management and flood protection measures (Van Kalken & Havno, 1992, Large & Petts, 1996, Pedroli et al., 2002). To adequately describe the main aspects of the flow regime and relevant biological consequences, the use of different hydrological indices is required (Olden & Poff , 2003). Also the need for multi-scale approaches in river ecology and restoration is stressed (Wiens, 1989, Hansen et al., 1999, Rabeni & Sowa, 2000). Gathering the necessary data requires extensive work and the same counts for the data screening and detection of significant correlations and responses.

The determining variables in the clustering and ordination identified here are generally applicable flood regime and riverbank management parameters, and can serve as predictor variables over reaches and even in-between rivers. Surveys of major German rivers (Bonn et al., 2002) and exposed riverine sediments in Scotland and England (Eyre & Luff, 2002, Sadler et al., 2004) showed separations based on differences in flooding regime and habitat conditions similar to our conclusions. The important key predictor variables were width-depth ratio and peak frequency/velocity and both are widely used variables in the description of river dynamic character and river management. The responses of the ground beetle community to river management practices can be successfully evaluated based on our results. The main explanatory variables of bed profile and habitat heterogeneity indicate the responses to management practices of riverbed widening and bank lowering in a positive sense, and encroachment and embankments in a more negative way. Although the strongest determining parameters are associated with the spatial facets of habitat availability, the indices of flow regime added a complementary set of explanatory variables for the ground beetle communities. Hence, the hydrological management on the river basin level is a trigger factor for the riparian biota and regulation activities, weir management and retention strategies have impact on the biological integrity of riverbanks throughout the whole river basin.

Conclusion

Research and evaluation tools in flood protection and river restoration projects focus mainly on hydrological relationships, only recently the geomorphic aspect has gained attention. The presented habitat templet approach envisages the hydromorphological impact on the riverbank, based on habitat and species group traits. Apart from water level effect prediction, a set of parameters describing peak characteristics and morphodynamics should at least be estimated in evaluation methods. Responses to a set of hydrological and morphological parameters were identified that allow riverbank habitat integrity assessment. From the presented analysis, an evaluation tool was elaborated (Geilen et al., 2001) that is not solely focused on the intrinsic quality of riverbank habitat, but at the same time allows qualitative assessment of impacts, on the spot as well as downstream and upstream by responses to hydromorphological parameters.

Abstract

The habitat templet approach was used in a scale-sensitive bioindicator assessment for the ecological integrity of riverbanks and for specific responses to river management. Ground beetle habitat templets were derived from a catchment scale sampling, integrating the overall variety of bank types. This coarse-filter analysis was integrated in the reach scale fine-filtering approaches of community responses to habitat integrity and river management impacts. Higher species diversity was associated with the higher heterogeneity in bank habitats of the unnavigable river reaches. The abundant presence of habitat specialists in the riverbank zone, allows a habitat integrity assessment based on the habitat templet indicator species. Significant responses were detected for channel morphology in the width/depth ratio and for hydrological regime in peak frequency and peak velocity, enabling the development of evaluation methods for the impact assessment of river management and flood protection strategies.

Acknowledgements

The assessment of riverbank habitat integrity was embedded in the European Commission funded international research program on flood protection measures for the Rhine and the Meuse, the IRMA-SPONGE Intermeuse project (Geilen et al. 2001). The selection and inter-correlation of the predictive variables with their critical ranges resulted in an evaluation method for flood protection strategies. The information of the gauging stations was provided for the analysis in this ecological assessment, with the permission of the management authorities, the Directorate Limburg for the Netherlands, the Administration of waterways and sea, DIHO for Flanders and the Direction Regional Lorraine for France.

Table 3.10 Mann-Whittney test for covariance with species richness, habitat heterogeneity and width/depth ratio of the plots, ** significant p<0,05, * 0,05<p<0,1.

species		Agonum albipes	Agonum assimile	Agonum dorsale	Agonum margina	Agonum micans	Agonum moestu	Agonum muelleri	Amara aenea	Amara aulica	Amara bifrons
total:		69	68	30	269	27	7	105	5	5	4
stations:		6	4	2	12	3	4	5	3	4	2
	species richness	0,81	0,63	0,43	0,39	0,9	0,67	0,62	0,34	0,3	0,77
habitat hetero-geneity	0,000197**	0,28	0,75	0,57	0,16	0,44	0,49	0,92	0,09*	0,7	0,57
W/d ratio	0,57	0,63	0,45	0,39	0,42	0,95	0,079	0,45	0,009**	0,8	0,26

species	chlaenius nigricornis	Chlaen nitidulus	Chlaen vestitus	Clivina collaris	Clivina fossor	Dyschir aeneus	Dyschir thoracic	Elaphr riparius	Harpa affinis	Harpa punctic	Harpa rufipes
Total:	16	7	10	26	33	7	57	21	96	4	38
stations:	2	4	5	7	6	4	4	6	7	2	6
species richness	1	0,06*	0,65	0,38	0,17	0,52	0,79	0,63	0,05*	0,36	0,13
habitat hetero-geneity	1	0,39	0,84	0,41	0,96	0,12	0,42	0,26	0,18	0,57	0,7
W/d ratio	0,16	0,2	0,55	0,12	0,39	0,26	0,75	0,77	0,36	0,09*	0,92

Amara fulva	**Amara similata**	**Bembid articulat**	**Bembid atrocoer**	**Bembid decoru**	**Bembid femorat**	**Bembid propera**	**Bembid punctul**	**Bembid quadrim**	**Bembid semipu**	**Bembidtetr acolum**	**Bemb tes-tac**	**Carabu granulatu**
5	9	5	19	1818	313	91	866	47	7	244	46	15
2	8	2	5	9	14	11	9	10	5	14	3	5
0,09*	0,05*	1	0,96	0,42	0,6	0,71	0,69	0,65	0,96	0,06*	0,85	0,32
1	0,006**	1	0,34	0,56	0,26	0,89	0,12	0,72	0,37	0,59	0,28	0,88
0,6	0,029**	0,16	0,21	0,17	0,49	0,44	0,03**	0,18	0,16	0,95	0,63	0,19

Lionych quadrill	**Loricer pil-icorni**	**Nebria brevicol**	**Patrob atrorufu**	**Perilep areolatu**	**Pterost anthrac**	**Pterost cupreus**	**Ptero melanar**	**Pterost vernalis**	**Pterost versicol**	**Tachys parvulus**	**Stenol teuton**	**Trechu quadristr**
5	55	36	41	32	13	69	116	18	19	9	6	34
3	14	4	8	4	5	9	13	11	2	5	2	5
0,4	0,67	0,36	0,75	0,36	0,43	0,72	0,11	0,04**	0,43	0,49	0,77	0,76
0,81	0,04	0,26	0,53	0,08*	0,16	0,89	0,88	0,03**	0,57	0,84	1	0,76
0,05*	0,009	0,79	0,37	0,002**	0,23	0,72	0,21	0,61	0,39	0,55	0,16	0,12