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# Suitability of different groups of terrestrial invertebrates for assessment of heterogeneity of terrestrial parts of lowland floodplains

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With 4 figures and 3 tables in the text

**Abstract:** In 2001 and 2002 a survey has been carried out on several taxonomic invertebrate groups in five floodplain areas along the river Waal in the Netherlands. Studied groups are: aculeate wasps (Hymenoptera: Chrysididae, Crabronidae, Tiphiidae, Pompilidae, Sphecidae, Vespidae), Apidae s.l. (Hymenoptera), Carabidae (Coleoptera), Mollusca (only terrestrial species), Odonata, Orthoptera, Syrphidae (Diptera). The study focused on sand dunes, high river banks, grasslands and marshes. The aim of the study was to compare the investigated invertebrate groups in terms of betadiversity to determine their sensitivity for heterogeneity of floodplain ecosystems. The results have been analysed in combination with the faunistic database of EIS (European Invertebrate Survey) – the Netherlands. Based on this database, species were selected of which at least 5 % of their distribution is situated in the Dutch Rhine branches ('preferential species'). Considering their high diversity in floodplain areas, both in absolute numbers and in betadiversity, and high number of preferential species in the Dutch Rhine branches, aculeate wasps, Apidae and Carabidae seem to be the most suitable of the studied groups for assessment of the heterogeneity of floodplain ecosystems. In aculeate wasps and Apidae, the highest diversity occurs in high parts of the floodplains. In Carabidae and Syrphidae with aquatic larvae, the highest diversity occurs in low parts of the floodplains.

Key words: biodiversity, terrestrial invertebrates, floodplains, ecological assessment, Coleoptera: Carabidae, Diptera: Syrphidae, Hymenoptera: Aculeata, Mollusca, Odonata, Orthoptera.

## Introduction

Nowadays, rehabilitation of floodplains along the lower Rhine is being linked to increasing the discharge capacity of the river during floods. The creation of secondary channels, oxbows, lakes and marshlands by lowering the floodplain has

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become a common measure in the Netherlands. The result is an increase of the safety level and rehabilitation of characteristic alluvial habitats. These habitats have historically been strongly reduced by normalization, to improve the opportunities for navigation and agriculture.

In order to be able to conduct the measures in an ecologically profitable way and to be able to evaluate the measures, it is necessary to design guidelines and assessment procedures. The concept of hydrological connectivity has proven to be useful in explaining the influence of river–floodplain interactions on biodiversity, especially in aquatic flora and fauna (Van den Brink 1994; Van de Geest et al. 2003; Van de Grift 2001; Tockner et al. 1999). So far, the terrestrial fauna of floodplains has received much less attention. No comparative analysis is available of the suitability of different terrestrial groups for ecological assessment of lowland floodplains. Most studies only deal with one or two different taxonomic groups or a specific habitat (van Looy & Jochems 2001; Wohlgemuth & Grube 1999; Zulka 1994).

In 2001 and 2002 a survey of several taxonomic groups of terrestrial invertebrates has been carried out in a river section of the river Waal in the Netherlands, comprising five different floodplain areas. The results have been used for a comparison between taxonomic groups in order to examine their suitability for developing evaluation strategies. This suitability strongly depends on the target of the rehabilitation measures, the reference condition, scale and possibilities for integration within design procedures and management programmes (Innis et al. 2000; Lenders et al. 2001).

In this study, the investigated groups are compared in terms of betadiversity to determine their sensitivity for heterogeneity of a landscape, and an attempt is made to identify indicator species for floodplain habitats.

## Material and methods

### Study areas

In this study, the Dutch Rhine branches are defined in 1 km squares, which comprise the floodplains of the branches Nederrijn, Waal and IJssel (Fig. 1). The total number of squares is 541, which amounts to 1.3 % of the total number of 1 km squares in the Netherlands.

The field study was carried out along a section of the river Waal (Fig. 1) near the town Zaltbommel, comprising the following floodplain areas: Breemwaard, Gamerense waard, Heesseltse waard, Hurwenense waard and Rijswaard. Together these floodplains occupy an area of 1110 ha. They are part of the European Nature 2000 framework. Table 1 gives the area and habitat composition of each study area. Descriptions of the recognized habitat types are given below:

- high river banks / sand dunes: high parts of floodplains with low herb vegetation and sandy soil, high morphodynamics during winter months;

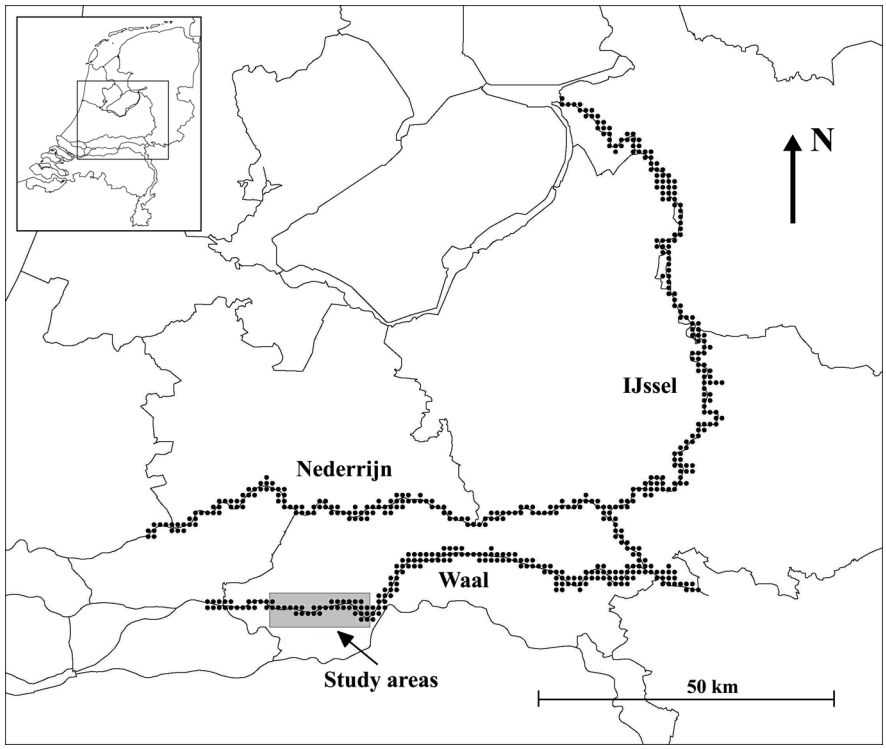


**Fig. 1.** The Rhine branches in the Netherlands, as defined in 1 x 1 km squares (black dots) according to Rijkswaterstaat. The total area comprises 543 $km^2$, of which 180 $km^2$ are situated in the area of the Rhine, 180 $km^2$ in the area of the IJssel and 165 $km^2$ in the area of the Waal. The study areas around Zaltbommel, indicated by the arrow and the grey rectangle, have a surface of approximately 33 $km^2$.

- grasslands: dry pasture, extensively grazed by horses, cows or sheep, flooded during winter months;
- marshes: herbaceous marshes along open water, only connected with the river during winter months;
- *Salix-/Populus* forest: alluvial softwood forest.

## Studied groups and sampling

The studied groups are: Aculeate wasps (Hymenoptera: Chrysididae, Crabronidae, Tiphiidae, Pompilidae, Sphecidae, Vespidae), Apidae s.l. (Hymenoptera), Carabidae (Coleoptera), Mollusca (only terrestrial species), Odonata (Zygoptera and Anisoptera), Orthoptera, Syrphidae (Diptera). These groups have been selected because enough information was available on their biology, ecology and their distribution in the Netherlands.

**Table 1.** Area and habitat composition of the five study areas.

| | Breemwaard | Gameren | Rijswaard | Hurwenen | Heesselt |
|---|---|---|---|---|---|
| **Total area (ha)** | **119** | **89** | **212** | **413** | **280** |
| Sand dunes/ high riverbanks (%) | 24 | 4 | 20 | 14 | 11 |
| Grassland (%) | 24 | 27 | 44 | 41 | 72 |
| Marshes (%) | 22 | 55 | 11 | 9 | 7 |
| *Salix-/Populus* forest (%) | 4 | 4 | 11 | 5 | 5 |
| Other (%) | 26 | 10 | 14 | 31 | 5 |

Apidae, aculeate wasps and Syrphidae were sampled using insect nets (53 sites, 20 days, Jun–Aug 2001 and Apr–Aug 2002). Most specimens were caught after they had been noticed by the eye of the observer, but each locality has also been sampled by 'sweeping' the net through the vegetation for 20 times. This is a suitable method for collecting small, inconspicuous species. Carabidae were sampled by pitfalls (26 sites, 5 pitfalls/site, Aug–Sep 2001 and May–Sep 2002). Mollusca were investigated by taking soil samples of approximately 1.5 liter (226 sites, Sep–Oct 2001 and Oct–Nov 2002). Odonata have been investigated by sight (210 sites, 20 days, Jun–Aug 2001 and Jun–Sep 2002) and Orthoptera mostly by ear (109 sites, 15 days, Jul–Aug 2001). The time needed for investigating each site depends on the weather (which determines the activity patterns of the species) and the species richness (the more species on a site, the more time is needed). For more details on the sampling methods we refer to De Bruyne et al. (2003), Van Helsdingen (2003), Kalkman (2002, 2003), Reemer (2003) and Turin et al. (2003).

## Faunistic databases

For the analyses involving the occurrence of invertebrate species in the total alluvial area of the Netherlands, the faunistic database of the European Invertebrate Survey – the Netherlands has been used. This database contains faunistic data of numerous taxonomic groups of invertebrates, collected by both amateur and professional biologists throughout the past 150 years. The numbers of records in the database are as follows: aculeate wasps 124,000; Apidae s.l. 116,000; Carabidae 110,000; Mollusca 38,000; Odonata 310,000; Orthoptera 90,000; Syrphidae 320,000.

Preferential species of the Dutch Rhine branches are defined as species of which at least 5 % of their range (measured in 1 km squares) in the Netherlands is situated

in the Dutch Rhine branches. This percentage is chosen more or less arbitrary, but it is important that it is considerably higher than the percentage of the area of the Netherlands occupied by the Dutch Rhine branches (1.3 %).

### Connection with the river

The river Waal is the largest free flowing branch of the river Rhine. There is no meandering due to the presence of groynes along the river. The hydrodynamics of the river Waal are rather strong, with peak discharges occurring in winter and spring. The inundation frequency, as defined by RADEMAKERS & WOLFERT (1994), is equal in all sample sites (2–20 days/year), so this is not a suitable measure for connectivity in this study.

The relative height can also be used as an indicator of hydrological connectivity. For the terrestrial part of floodplains, this is a rough indicator for the distance between the surface and the groundwater. The relative height of sample sites is calculated by subtracting the average water level of the river from the height of the site above N.A.P. ('Nieuw Amsterdams Peil', a standard measure for water levels in the Netherlands; these values are available for all floodplain locations in databases of Rijkswaterstaat, the Dutch governmental institution responsible for the management of rivers).

### Betadiversity and indicator species analysis

The betadiversity of each group has been assessed by calculating the average of the SÖRENSEN similarity coefficients (S) of the 10 possible combinations of the five study areas. This coefficient is calculated as (KREBS 1989): $S = 2n^{++}/(2n^{++} + n^{+-} + n^{-+})$, in which $n^{++}$ is the number of species found in both area A and B, $n^{+-}$ is the number of species found in A but not in B, and $n^{-+}$ is the number of species found in B but not in A (KREBS 1989).

For each investigated group of invertebrates, species preferences for different habitats have been determined using the indicator species analysis described by DUFRÊNE & LEGENDRE (1997). In this method, the indicator value is obtained by combining the relative abundance of a species with its relative frequency. When the indicator value of a species in a certain habitat is 100 %, the species is only found in that habitat and occurs in all investigated sites of that habitat.

The computer program IndVal version 2.0 (by M. DUFRÊNE, see http://mrw.wallonie.be/dgrne/sibw/outils/indval) was used for the calculations of indicator values. Significance of the obtained indicator values was tested with a rank-test (DUFRÊNE & LEGENDRE 1997). For Carabidae and Mollusca the analysis was based on numbers of observed specimens per locality, because the sampling method allowed for this. For the other groups the analysis was based on absence or presence in the localities, because no standardized method was used to assess the numbers. Odonata and Orthoptera were not included. The available data for these

groups were not suitable for this analysis, because they had been collected on a large number of point-localities, resulting in a very small number (often only one) of species per site.

## Results

### Preferential species of the Dutch Rhine branches

Fig. 2 gives the numbers and percentages of species known from the Dutch Rhine branches per taxonomic group, as well as the number of preferential species per taxonomic group.

In the Carabidae, both the number (154) and the proportion (41 %) of preferential species is the highest of all studied groups. Apidae are a good second with 62 preferential species (18 %) and aculeate wasps follow with 51 species and 15 %. In Orthoptera, the proportion of preferential species is high (16 %), but the number is low (7), because only 45 species of Orthoptera are known to occur in the Netherlands. The lowest values were found in Mollusca, Syrphidae and Odonata.

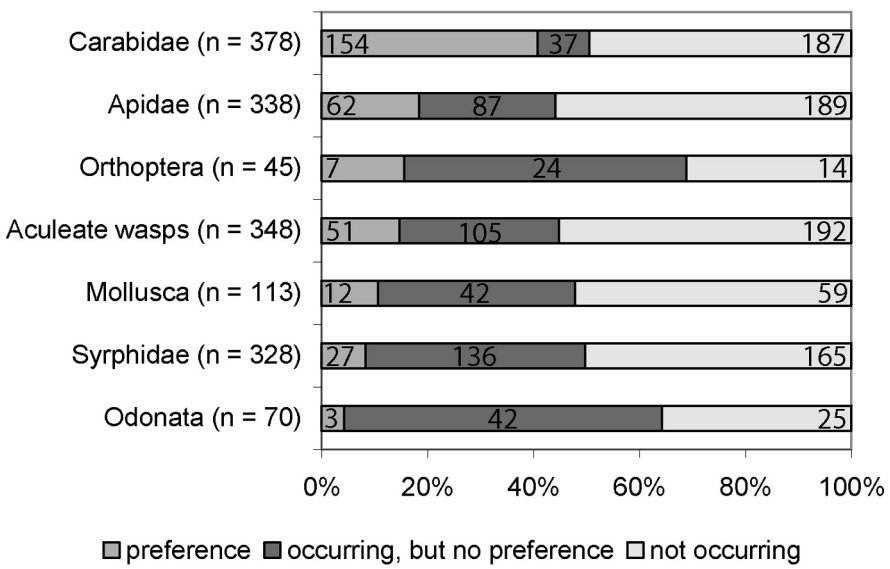


**Fig. 2.** Species numbers and proportions, expressed as percentages of the total number of species known from the Netherlands. Species numbers are indicated in the bars. Proportions are indicated on the x-axis: percentage of species with a preference for the Dutch Rhine branches (more than 5 % of their range in the Dutch Rhine branches), percentage of species occurring in the Dutch Rhine branches but without a preference and percentage of Dutch species not occurring in the Dutch Rhine branches.

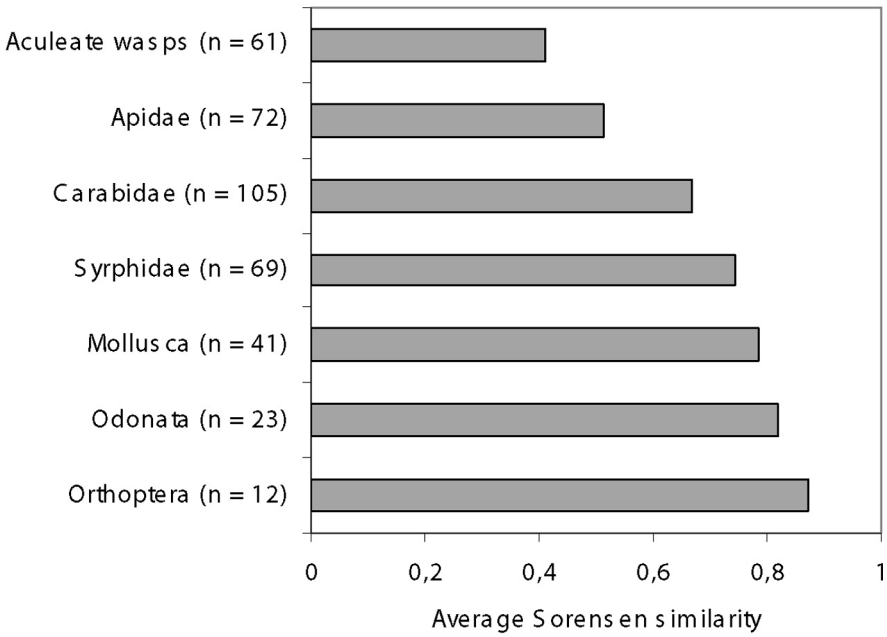


**Fig. 3.** Average SÖRENSEN similarity in species composition of the five study areas for each studied group of invertebrates (a measure of betadiversity). The numbers between brackets indicate the total number of species found in the study areas in 2001 and 2002.

## Similarity of the study areas

The average SÖRENSEN similarities between the five study areas is shown in Fig. 3 (in which the total numbers of species found in the study areas are indicated as well). The lowest similarities are found in aculeate wasps, Apidae and Carabidae. This suggests that these groups contain many species with specific preferences for certain habitats within floodplain ecosystems. The Syrphidae are the middle group, and Mollusca, Odonata and Orthoptera have the highest values, indicating that the species composition of these groups is very similar in the different study areas.

## Connection with the river

Table 2 gives the results of a linear regression analysis, assessing the correlation between species diversity of the investigated invertebrates and the relative height of the sample localities. The correlation is significant in aculeate wasps, Apidae, Carabidae and Syrphidae with (semi-)aquatic larvae. For these groups, the correlation is illustrated in Fig. 4. In aculeate wasps and bees, species diversity is the

**Table 2.** Correlation between species diversity and relative height of the sample localities, as calculated with linear regression analysis. n localities: number of sample localities used in analysis; $R^2$: correlation coefficient; p: significance (* = significant, n.s. = not significant); correlation factor: positive (+) or negative (–) correlation. For the groups with significant values, the correlations are illustrated in Fig. 4.

| | n localities | $R^2$ | p | correlation factor |
|---|---|---|---|---|
| aculeate wasps | 32 | 0.1455 | 0.031* | + 0.003 |
| Apidae s.l. | 32 | 0.2647 | 0.003* | + 0.045 |
| Carabidae | 24 | 0.2053 | 0.026* | – 0.040 |
| Mollusca | 212 | 0.0017 | 0.548 (n.s.) | – 0.001 |
| Syrphidae | 29 | 0.1160 | 0.071 (n.s.) | + 0.002 |
| Syrphidae aq. ** | 29 | 0.2202 | 0.010* | – 0.004 |

**: species of Syrphidae with aquatic larvae

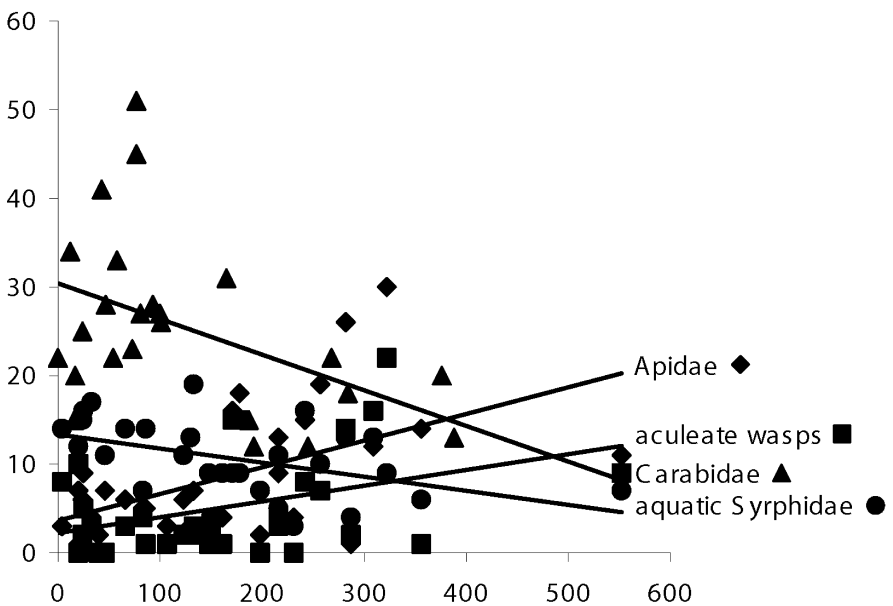


**Fig. 4.** Correlation between relative height of sample sites and species diversity in aculeate wasps, Apidae s.l., Carabidae and Syrphidae with aquatic larvae. For statistics see Table 2.

**Table 3.** Indicator species for four habitat categories per taxonomic group, with their indicator values in percentages. Species with a preference for the Dutch Rhine branches are marked with an asterisk (*).

| | high river banks & sand dunes | grassland | marshes | *Salix-* / *Populus* forest |
|---|---|---|---|---|
| aculeate wasps | *Cerceris rybyensis* (38%)<br>*Crossocerus wesmaeli* (45 %) | | | |
| Apidae s.l. | *Andrena chrysosceles** (47 %)<br>*Andrena wilkella* (29 %)<br>*Colletes daviesanus* (40 %)<br>*Colletes fodiens* (32 %)<br>*Lasioglossum quadrinotatulum* (43 %) | *Nomada fabriciana** (38 %) | | *Macropis europaea* (40 %) |
| Carabidae | *Amara spreta** (6 %)<br>*Bembidion femoratum** (65 %) | *Agonum muelleri** (56 %) | *Carabus granulatus* (65 %) | |
| Mollusca | *Balea biplicata* (14 %) | | *Vertigo antivertigo** (11 %)<br>*Zonitoides nitidus* (32 %) | *Carychium minimum* (27 %)<br>*Cochlicopa lubrica* (22 %)<br>*Discus rotundatus* (17 %)<br>*Pseudotrichia rubiginosa** (29 %)<br>*Vitrea crystallina* (6 %) |
| Syrphidae | | *Helophilus trivittatus* (43 %) | *Anasimyia interpuncta** (40 %)<br>*Eristalis nemorum** (47 %)<br>*Neoascia tenur* (67 %)<br>*Parhelophilus versicolor** (50 %)<br>*Platycheirus albimanus* (44 %) | |

highest in high parts of the floodplain, while in Carabidae and Syrphidae with aquatic larvae the highest diversity occurs in the low parts of the floodplain.

## Indicator species

Indicator species for the four recognized habitat categories have been identified using the indicator species analysis on aculeate wasps, Apidae, Carabidae, Mol-

lusca and Syrphidae (Table 3). The species with a preference for the Dutch Rhine branches (De Bruyne et al. 2003a; Kalkman 2003; Reemer 2003; Turin et al. 2003) are marked with an asterisk. These species are potential indicators for specific floodplain ecosystems.

For high river banks and sand dunes, aculeate wasps and bees show the largest number of indicator species, while marshes exhibit especially some characteristic hoverflies with aquatic larvae. In *Salix-/Populus* forest some characteristic terrestrial molluscs can be found.

## Discussion

### Aculeate wasps and Apidae (bees)

Aculeate wasps and bees are rich in species and the number of species which have their main distribution in the Netherlands in the area of the Dutch Rhine branches is also rather high. The similarity in species composition between the five study areas is the lowest of all investigated invertebrate groups, suggesting a high beta-diversity. Probably, these groups contain many specialized species which are restricted to particular parts of floodplain habitats. Aculeate wasps and bees predominantly occur in high parts of the floodplains, like sand dunes and high river banks. These habitats are sparsely vegetated and very diverse in microrelief of the soil and therefore they offer many suitable nesting sites. These habitats are desirable targets in ecological rehabilitation projects. This, in combination with the availability of a national red list of endangered bee species (Peeters & Reemer 2003), makes it possible to incorporate the results of a survey into the national biodiversity programme.

So aculeate wasps and bees seem to be suitable groups for assessing the heterogeneity of the terrestrial part of floodplains, especially of higher parts.

### Carabidae (ground beetles)

Carabidae are rich in species and a very large proportion (41 %) of these species has an important part of its distribution in the Dutch Rhine branches. The betadiversity in the study areas is lower than in aculeate wasps and Apidae, but nevertheless it is higher than in the other groups. Ground beetles, like aculeate wasps and bees, are insects of dynamic and open habitats. Unlike these two other groups, however, ground beetles show a clear preference for wetter places, as illustrated by the observed higher diversity in lower parts of the floodplains. Carabidae are a suitable and well-studied group for assessing terrestrial parts of floodplains at the level of (micro)habitats, especially low parts of floodplains, like grasslands and marshes. Besides, there have already been several studies on the effects of flooding on the species composition of Carabidae (Zulka 1994). This provides the opportunity to formulate reference conditions for habitats that are nowadays rare or

deteriorated, like alluvial forest and marshes with a high inundation frequency. No national red list of Carabidae is available for the Netherlands.

### Mollusca (terrestrial molluscs)

The Dutch Rhine branches have so far been poorly surveyed on molluscs, as illustrated by the relatively high number of species new to this area which were found during the study. The number of preferential species for the Dutch Rhine branches is low compared to the groups discussed above and so is the betadiversity in the study areas. The most characteristic species can be found in *Salix*-/*Populus*-forest. Possibly, Mollusca are a suitable group for ecological assessment of this type of forest. An additional tool for this could be the red list of Mollusca in the Netherlands (DE BRUYNE et al. 2003b).

### Odonata (dragonflies and damselflies)

The dragonfly fauna in the Dutch Rhine branches is neither very specific nor very diverse. The species compositions of the five study areas are very similar, and the same species can be found almost anywhere in the Dutch Rhine branches. Dragonflies are part of the national biodiversity programme. A national red list of endangered species is available (WASSCHER 1999).

In contrast to the other groups the dragonfly fauna of the alluvial habitats at the beginning of the 20$^{th}$ century is well documented. Many species that used to occur are now absent in these areas (KALKMAN 2003; NVL 2002). The main causes for this are deterioration of water quality and habitat loss, especially oxbow lakes with seepage water. When water quality and specific floodplain elements are rehabilitated, it is possible that this situation will return. This possibility could serve as an 'end-point' for river rehabilitation on a large scale, but at this moment dragonflies are not suitable for assessing floodplains in the Netherlands at a regional or small spatial scale.

### Orthoptera (grasshoppers)

As in dragonflies, only a small number of species is characteristic for the Dutch Rhine branches and the species compositions of the five study areas are very similar. The few characteristic species can be found almost anywhere in the Dutch Rhine branches and they are not very critical in terms of habitat choice, so their occurrence does not provide valuable information for assessing the heterogeneity of floodplains.

### Syrphidae (hoverflies)

The proportion of hoverfly species with a preference for the Dutch Rhine branches is low compared to other groups, but because of the large number of hoverfly

species occurring in the Netherlands, the absolute number of preferential species is quite high (27). Compared to the other groups, the betadiversity of hoverflies in these areas is neither high nor low.

While a large proportion of the total hoverfly fauna of the Netherlands consists of woodland species, the fauna of the investigated floodplains contains many species of open and wet habitats. This is illustrated by the large proportion of species with (semi-) aquatic larvae (Reemer 2003). This group of species is most diverse in the low parts of the floodplains and contains some species which can serve as indicator species for floodplain marshes. In larger floodplains, in which some areas are rarely flooded, the hoverfly fauna can be very interesting, especially in marshes and alluvial forests (Reemer 2000). However, large floodplain areas and alluvial forests are still rare in the Netherlands.

So, as a whole the Syrphidae do not seem to be very suitable for assessing floodplain ecosystems, but when considering the group of species with aquatic larvae they seem to be useful at the level of habitats.

## Indicator groups for heterogeneity

Because of their high betadiversity in floodplains and high proportion of characteristic species in the Dutch Rhine branches, aculeate wasps, Apidae and Carabidae seem to be suitable groups for assessing the heterogeneity of floodplains. The diversity of aculeate wasps and Apidae can provide information on higher parts of the floodplain, while Carabidae proved to be suitable especially for lower parts.

Methods like those of BIO-SAFE (Lenders et al. 2001; de Nooij et al. 2004) could be used to correlate numbers of characteristic floodplain species to heterogeneity of the landscape. However, BIO-SAFE bases its methods on (inter)national directives, legislation and red lists. Since these are not (yet) available for most groups of invertebrates, an important part of biodiversity does not play a role in the assessment of floodplains when using BIO-SAFE. This is especially true for fauna, because the major part of the species with 'relevance for policy' is occupied by higher plants. So either more invertebrate groups should be incorporated in directives, legislation and red lists, or a methodology should be developed to include these groups in assessment procedures without being dependent on the – often slow and political – choices that are made in the compilation of such (inter)national lists and treaties. For many taxonomic groups (like the groups studied here) large national databases with distributional data are available, making it possible to calculate rarity and trend of species without having to wait for the interest of governmental institutions.

## Indicator species

The calculated indicator values for the species in Table 3 are not very high. This means that the species also occur in other habitats and that they are not exclusively

characteristic for the recognized habitat categories. A possible explanation for this is the mobility of several species, especially aculeate wasps, Apidae and Syrphidae. For their reproduction, these insects are more or less restricted to specific habitats, but they can often be found in other habitats for their food supply (visiting flowers). Many bee species are even dependent on the existence of two different habitat types close to each other (Westrich 1996).

The species in Table 3 are all relatively common in the Netherlands and, although some of them have a preference for the Dutch Rhine branches, they are by no means restricted to this area. Probably, some of the other species found in the study areas are more indicative for the quality of specific floodplain habitats (see for example Reemer 2003). However, these species were present in too low numbers to draw conclusions.

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