Importance of permanent and temporary water bodies for aquatic beetles in the raised bog remnant Wierdense Veld

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Wierdense Veld is a heavily degraded bog area, in which still various peat cutting pits are present. Restoration measures are proposed in order to reduce water table fluctuations, aiming at bog regeneration. Earlier research in other Dutch bog remnants showed that old peat cutting pits still harbour many rare and characteristic species of aquatic macrofauna, while rewetting has until now been beneficial to only a limited part of the species spectrum. To define the proper restoration strategy for the Wierdense Veld, the present-day situation is examined and compared to other bog areas. Relatively many characteristic species were found in the area, but at the same time the number of species and individuals per site was low. This may well indicate small population sizes. A substantial number of characteristic species showed a preference for temporary water bodies. Regarding restoration management, especially small populations of characteristic species might be sensitive to sudden changes in water table fluctuations. Measures might, however, be necessary to improve the habitat quality to reduce the risk of extinction. Understanding of bottle-necks in the life-cycles of the species is necessary to define the proper management strategy.

Keywords: Coleoptera, population size, raised bog, restoration, conservation

Raised bogs in The Netherlands are heavily degraded as a consequence of peat cutting, agricultural activities and drainage. Increased atmospheric nutrient deposition and mineralisation of drained peat have resulted in increased nutrient availability, enabling Birch (Betula sp.) and Purple moor grass (Molinia caerulea) to dominate the vegetation of raised bog remnants (Lamers et al. 2000, Limpens et al. 2003, Tomassen et al. 2003). To restore peat accumulating Sphagnum vegetation in these bog remnants rewetting measures are taken. Drainage ditches are blocked and dams are built to retain rain water. Although the main part of species diversity concerns fauna species, especially invertebrates, only little attention has been paid to effects of these rewetting measures on fauna (Kiel & Matzke 2002, Van Duinen et al. 2003a). Next, reference data on species assemblages and the important habitat characteristics in pristine bogs are hardly available (Smits et al. 2002). Since most restoration projects do not include a fauna monitoring programme, it is generally unknown whether the measures have had any effects on the fauna, either positive or negative. Also, generally little attention is being paid to fauna diversity in the planning of restoration measures.

In earlier research, the effects of bog restoration measures on aquatic invertebrates was assessed by comparison of micro- and macroinvertebrate species assemblages between water bodies created by restoration measures and water bodies which have not been subject to restoration measures, but are remnants of former hand peat cuttings and trenches used for buckwheat culture in the past (Van Duinen et al. 2003a,b). This comparison showed that the macroinvertebrate fauna seems to recover quickly after rewetting, but that this is not the case for macroinvertebrates. Until now rewetting measures resulted in a fairly similar macroinvertebrate species assemblage, including only a part of the species spectrum of an intact raised bog (Van Duinen et al. 2002). Remnant water bodies are inhabited by relatively high numbers of characteristic macroinvertebrate species, even when no characteristic raised bog vegetation is present. A considerable number of characteristic and rare fauna species is only found at the remnant sites. Thus, when planning restoration measures in bog remnants, it is recommended to protect relict populations of rare and characteristic species present in the area by phasing measures in time and space.

The raised bog remnant Wierdense Veld is heavily degraded by drainage and hand peat cutting, partly to the sandy subsoil. As a consequence the water table in the area fluctuates considerably and many water bodies are temporary. In summer only a limited number of hand peat cuttings contain water. Measures are proposed in order to minimize water table fluctuations, in order to stimulate bog regeneration. If rewetting measures are taken, many of the water bodies
temporary at present, may become permanent. This may have considerable effects on the macroinvertebrate species assemblages, including characteristic species. To assess the species diversity in the Wierdense Veld and the present-day importance of both temporary and permanent water bodies in the area, macroinvertebrates were sampled in permanent and temporary water bodies. Species diversity data were compared to data collected in remnant and restoration sites in seven other raised bog areas during previous research (see Van Duinen et al. 2003a). As aquatic beetles are a species rich group, including relatively many species known to be more or less characteristic for raised bog areas, this paper focuses on adult aquatic beetles.

MATERIAL AND METHODS
The Wierdense Veld is a remnant of the former large bog area between Wierden and Nijverdal in the province Overijssel, The Netherlands. The area is currently 400 ha and is managed by Stichting Landschap Overijssel. Macroinvertebrates were sampled between the 7th of April and the 15th of May 2003 at 32 sites in the various microhabitats present, using kitchen sieves and sorted in white trays in the field. Ten water bodies were permanent and 22 water bodies were temporary. Within both groups of sampling sites, water bodies differing in size, water and substrate quality, vegetation composition and structure were sampled, representing most of the habitat variation present in the Wierdense Veld.

To be able to compare data from the Wierdense Veld to those from the 19 remnant and 27 restoration sites sampled in spring 1999 (see Van Duinen et al. 2003a) also a standard sample was taken at 15 of the 32 sampling sites, using a 20 x 30 cm pond net with 0.5-mm mesh size. Most standard samples consisted of a 1 m sweep starting from the substrate and more or less open water into more dense vegetation near the shore. Standard samples were transported to the laboratory, washed over three sieves with 2, 1, and 0.5-mm mesh size, respectively, and sorted in white trays. In early June baited traps were used to collect large beetle species in the 17 sampling sites in which open water was present.

Beetle species were considered characteristic of raised bogs if they were listed as acidophilous, acidobiontic, tyrphophilous, tyrphobiontic or typical of raised bogs by Drost et al. (1992). Cumulative species richness curves were based on averages of 250 random sorts of the sampling sites using BioDiversityProfessional Beta 1 (McAleee 1997). Total and characteristic beetle species richness curves were made for the standard samples taken in the 27 restoration sites, 19 remnant sites, and 15 sites in the Wierdense Veld. Correspondence Analysis (CA) on species presence data of the 32 sampling sites in the Wierdense Veld was performed in Canoco for Windows version 4.0 (Ter Braak & Smilauer 1998). The preference of each of the characteristic species found in the Wierdense Veld was calculated as the frequency of occurrence in permanent and temporary sites, with the sum of these two frequencies converted to 1. Significance of differences in numbers of species and individuals per site between groups of sampling sites was tested using the Student T-test. This test was only performed on data of standard samples.

RESULTS
In the Wierdense Veld 53 aquatic beetle species were found in the 32 sites (Table 1). Twenty-one species were found in the 15 standard samples. For characteristic species these numbers were 21 and 12, respectively. In the Wierdense Veld 12 characteristic species were collected, that were not found in the restoration sites in previous research (Van Duinen et al. 2003a). The average numbers of species as well as individuals per site were significantly higher in remnant sites then in restoration and Wierdense Veld sites (p<0.05). The average numbers of characteristic species as well as individuals of characteristic species per site were also highest in the remnant sites, but these differences were only significant for restoration sites (p<0.05). These averages were not significantly different between Wierdense Veld and restoration sites. Regarding the cumulative species richness curves, the species numbers in the Wierdense Veld and restoration sites are both low compared to the remnant sites (Fig. 1). For characteristic species, however, the Wierdense Veld curve starts at an average species number fairly similar to restoration sites, but reaches a cumulative species number comparable to remnant sites at the end of the curve.
Table 1. Total and average (±sd) numbers of species, characteristic species, individuals, and individuals of characteristic species found in remnant, restoration and Wierdense Veld sites using standard samples and all sampling methods. * indicates significantly lower numbers then in remnant sites (p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Remnant standard samples</th>
<th>Restoration standard samples</th>
<th>Wierdense Veld standard samples</th>
<th>Wierdense Veld all sampling methods</th>
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<tbody>
<tr>
<td>Number of sites</td>
<td>19</td>
<td>27</td>
<td>15</td>
<td>32</td>
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<tr>
<td>Number of individuals</td>
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<td>177</td>
<td>2180</td>
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<td>76</td>
<td>118</td>
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<tr>
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<td>24</td>
<td>21</td>
<td>53</td>
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<tr>
<td>Characteristic species</td>
<td>14</td>
<td>10</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>Characteristic species not found in restoration sites</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Species number/site</td>
<td>7.3 ± 4.4</td>
<td>3.0 ± 2.4*</td>
<td>3.3 ± 2.8*</td>
<td>12.5 ± 4.7</td>
</tr>
<tr>
<td>Characteristic species/site</td>
<td>2.8 ± 2.3</td>
<td>1.3 ± 1.4*</td>
<td>1.7 ± 1.9</td>
<td>6.9 ± 2.7</td>
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<tr>
<td>Individuals/site</td>
<td>51 ± 70</td>
<td>7.6 ± 8.7*</td>
<td>12 ± 14*</td>
<td>-</td>
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<td>Charact. individuals /site</td>
<td>31 ± 62</td>
<td>2.8 ± 4.0*</td>
<td>7.9 ± 13</td>
<td>-</td>
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</tbody>
</table>

Figure 1. Cumulative species richness curves for all species (left) and characteristic species (right) in standard samples based on averages of 250 random sorts of sampling sites. Filled squares for remnant sites, open circles for restoration sites, and asterisks for Wierdense Veld sites.

Figure 2. Correspondence Analysis (CA) plot of 32 sites sampled in the Wierdense Veld. Filled circles for permanent water bodies and open triangles for temporary water bodies.
Figure 3. Preference of the 21 characteristic species found in the Wierdense Veld for temporary or permanent sites. The numbers of sampling sites in which the species were found are given between brackets.

Permanent and temporary water bodies in the Wierdense Veld were clearly separated on the first CA-axis, which explained 13.1% of the variation in species data (Fig. 2). Two temporary water bodies were plotted in the upper-right quadrant of the CA-plot. These sites are situated at the edges of the area and are completely dry in summer. In spring, however, they consist of large open water, like most permanent water bodies. Several species frequently found in the other temporary sites were not found in these two sites (*e.g.*, *Agabus labiatus*, *Helophorus* spp., *Hydroporus pubescens*, and *Hydroporus gyllenhalii*), whereas some species were present, which are next to these two sites or exclusively found in permanent water bodies (*e.g.*, *Dytiscus marginalis*, *Graphoderus cinereus*, and *Acilius sulcatus*). Figure 3 shows that some characteristic species were mainly found in permanent water bodies. All other characteristic species either did not differ in frequency between permanent and temporary water bodies or had a preference for temporary water bodies.

**DISCUSSION**

Total species richness of aquatic beetles and numbers of species and individuals per site appear to be low in the Wierdense Veld compared to water bodies sampled in other raised bog remnants and which are also not (yet) influenced by restoration measures. However, concerning the characteristic species, the cumulative number of species is comparable to other remnant sites, whereas the numbers of species and individuals per site are lower. The latter differences were not statistically significant (p=0.12 and p=0.07, respectively). About half of the characteristic species
present in the Wierdense Veld (and other remnant sites as well) are not found in water bodies created or influenced by restoration measures.

Regarding these comparisons, it has to be noted that by means of standard samples just a fraction of the beetle species present in a water body was collected. In the Wierdense Veld all sampling methods together – especially putting effort in sampling the different microhabitats with the kitchen sieves – yielded about four times as many species per site as the standard samples. Still, the comparison of the species richness and abundance data between remnant, restoration, and Wierdense Veld may well reflect the real situation in the raised bog areas, as the data are obtained by means of the same sampling method and effort.

In the Wierdense Veld species assemblages in temporary water bodies are clearly different from those in permanent water bodies. A substantial number of characteristic species shows, at least in spring, a preference for temporary water bodies. For several of these species this preference found corresponds with the description by Drost et al. (1992). The differences in species occurrence between permanent and temporary water bodies are well known and described by many authors (e.g. Galewski 1971, Wiggins et al. 1982). The presence of both temporary and various types of permanent water bodies offers opportunities for many species to survive in an area, e.g. in case of extreme drought (Verberk et al. 2001, 2002, Moller Pillot 2003).

Now, the implications of the results have to be elucidated, regarding the aim to reduce water table fluctuations in the Wierdense Veld. Clearly, both permanent and temporary water bodies have to be conserved within the area. The presence of many characteristic species and at the same time the relatively low number of species and individuals per site found in the area may well indicate relatively small population sizes. In this case, these populations might be sensitive to sudden changes in water table fluctuations, resulting from restoration measures. On the other hand, measures might be necessary to improve habitat quality to reduce the risk of extinction of these small populations in the area. In order to be able to define a proper management strategy, understanding of bottle-necks in the various stages in the life-cycles of aquatic beetle species as well as of species of other invertebrate groups is necessary. This requires a further, more detailed study of the life-cycles and the distribution of life-stages of the species within and in the vicinity of the area in the dry and wet seasons.

Acknowledgements We are indebted to Loekie van Tweel, Gerrit Pastink, and Gerrit Braakman for enabling us to perform this study in their management area and to Bas Drost, Theo Peeters, Wilco Verberk, Jan Kuper, Ankie Brock, Marten-Jan Vonk, Mirjam Kollenaar, Jorge Candeias, and Hein van Kleef for help during fieldwork, sorting the samples, identification of the collected beetles, and/or helpful comments on the data analysis and manuscript. This research is performed by order of Stichting Landschap Overijssel in the framework of the national programme ‘Overlevingsplan Bos en Natuur’ of the Dutch Ministry of Agriculture, Nature and Food Quality.

REFERENCES


