DO RESTORATION MEASURES HELP TO RESTORE DRAGONFLY COMMUNITIES IN RAISED BOG REMNANTS?

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Summary

Until now it is unknown whether restoration of raised bog remnants in The Netherlands result in the restoration of fauna communities characteristic of intact raised bog systems. Preliminary results of a comparative study in four different raised bog remnants under restoration show remarkable differences in dragonfly density and species composition. A main factor seems to be the presence or absence of variation in water quality, as found in intact raised bog complexes, including natural transitions to the surrounding landscape. Influence of atmospheric deposition, present spatial configuration of raised bog remnants, and hydrological interactions may hinder restoration efforts.

INTRODUCTION

Of the about 250,000 hectares of raised bogs present in The Netherlands in the second half of the Middle Ages just a few thousands of hectares remain, of which just ten hectares can be considered as living raised bog. This decline is due to peat industries, drainage and other kinds of land use. Apart from several small bogs no completely intact raised bog systems are present in The Netherlands anymore (Van Wirdum 1993, Schouten *et al.* 1998). In raised bog remnants and cut-over peatlands restoration measures are taken to create conditions suitable for recovery of *Sphagnum*-vegetations. In some cases these measures led to a characteristic hummock hollow vegetation. Until now it is unknown whether these measures also result in the restoration of fauna communities characteristic of intact raised bog systems, including natural transitions to the surrounding landscape.

In general, when studying effects of restoration measures on fauna, it is important to take into account the whole landscape or system the restored site is part from as many species depend on a combination of biotopes to complete their life cycles (Bink *et al.* 1998). Raised bogs are embedded in a wider landscape context and therefore an intact raised bog system is a complex consisting of one or more ombrotrophic centres, with dominance of *Sphagnum*-vegetation, surrounded by more minerotrophic and/or nutrient-rich habitats (e.g. laggs, rivers, mesotrophic lakes, and mineral soils), and transitions in between. So, when studying restoration of raised bog fauna communities attention has to be paid on the variation in water quality and type and structure of the vegetation in the bog system.

This paper deals with effects of raised bog restoration on dragonfly fauna. Our aim is getting an answer to the question whether characteristic dragonfly communities are (on the long run) being restored by rewetting measures and to get insight into key factors determining species composition and density of characteristic raised bog fauna. Extensive studies on dragonflies of Dutch raised bog remnants were, among others, performed by Beukeboom (1985) and De Groot (1997) in Fochteloërveen, by Wasscher (1992) in Bargerveen, and by Claessens (1989) in the Peel reserves. These studies yield important data, but thorough analyses of traits of the environment are necessary to get insight into key factors determining fauna composition. This paper presents preliminary results of a comparative study in four different Dutch raised bog remnants in which rewetting measures have been taken. We compared dragonfly density and species composition between these remnants and evaluate these data referring to dragonfly communities of intact raised bog systems.

MATERIAL AND METHODS

Study areas
All four study areas are remnants of formerly large raised bog complexes in which rewetting measures have been taken. Rewetting of cut-over peat fields in the Bargerveen reserve (2100 ha) by means of construction of peat dams created small to very large water bodies with acid water, submerse *Sphagnum cuspidatum* and several floating rafts, interspersed with small *Betula* forests and peat-meadows.
Fochteloërveen (1750 ha) has a very open landscape with dominance of *Molinia caerulea*, almost without *Betula* trees, partly surrounded by forests. Part of the reserve has never been dehydrated severely, but a large area has been used for buckwheat culture. Rewetting has stimulated growth of *Sphagnum* vegetations and created some open water bodies.
In the Haaksbergerveen reserve (500 ha) relatively small-scaled rewetting measures have been taken using sand dams. In the reserve variation in water quality and vegetation is present, due to groundwater flow and the presence of a forest on mineral soil. A characteristic hummock hollow vegetation has established on several floating rafts, but compartments with open water or dominance of *Phragmites australis* are also present.
The Peel area consists of different reserves of which Groote Peel (1350 ha), Deurnese Peel (650 ha) and Mariapeel (1100 ha) were studied. Small water-filled peat-cutting pits in different successional stages and larger flooded cut-over peatlands are present as well as *Betula* forests and *Molinia caerulea* dominated areas. Due to intensive agriculture close to the reserves the Peel area suffers highest atmospheric deposition (Schouwenaars *et al.* 1997).

Counting method
Dragonfly imagines were counted in two types of transects. There were shorter transects (75-150 m) to count Zygoptera species and the smaller Anisoptera species of the genera *Leucorrhinia*, *Libellula,* and *Sympetrum*, which are all present in relatively high densities. To count the larger dragonflies of the genera *Aeshna, Cordulia, Orthetrum,* and *Somatochlora*, which occur in lower numbers, longer transects (235-2400 m) were set out. In each study area at least one transect of both types was present. They were counted four to ten times between late May and early September 1996. Transects were set out along vegetation structures and water bodies resembling each other as much as possible in each of the study areas. All persons counted in a standard way by walking slowly along the transects and counting all individuals within a strip of five metres in width in the case of transects for small dragonflies and within the field of vision in the case of transects for large dragonflies.

Ecological interpretation
As a first step in the ecological interpretation of observed differences in dragonfly communities between remnants we made a simple division of observed species into ecological categories. Species are roughly characterised by the extent to which they inhabit the ombrotrophic raised bog centre, the more calcareous surrounding environment types, and the transitional habitats in between. This characterisation is based on the description of the habitats of the species as given in literature (Geijskes & Van Tol 1983, Schorr 1990, Sternberg & Buchwald 1999) and own observations in intact Estonian bog complexes. Species characteristic for the more ombrotrophic parts of the system were placed in the first two categories, whereas species mainly inhabiting surrounding

environment types were placed in the last two categories. Division of each of these two couples of two categories is based on the inhabitation of transitional habitats by the species. Dragonflies present in the whole range of the system were placed in category III (Table 1). Classification of *Orthetrum cancellatum* is difficult, as the species inhabits acid to calcareous water bodies partly surrounded by bare soil. Acid water is of course present in intact bog centres, but bare soil is usually absent.

Table 1. *Division of observed dragonfly species into ecological categories.*

I	ombrotrophic bog centre	*Aeshna subarctica*
II	bog centre and transitions to surrounding environment	*Aeshna juncea, Ceriagron tenellum, Coenagrion lunulatum, Leucorrhinia dubia, L. rubicunda, Sympetrum danae*
III	whole range of system	*Enallagma cyathigerum, Lestes sponsa, Libellula quadrimaculata, Orthetrum cancellatum*
IV	surrounding environment and transitions to bog centre	*Aeshna cyanea, A. grandis, A. mixta, Anax imperator, Coenagrion puella, C. pulchellum, Cordulia aenea, Lestes dryas, L. viridis, Pyrrhosoma nymphula, Somatochlora metallica, Sympetrum flaveolum, S. sanguineum, S. vulgatum*
V	surrounding environment types	*Calopteryx splendens, Erythromma spec., Gomphus pulchellus, Ischnura elegans, Platycnemis pennipes*

RESULTS

Maximum densities of larger dragonflies (Figure 1A) were highest in the Haaksbergerveen reserve (transects H1 and H2). As regards small dragonflies (Figure 1B), far highest density was observed in transect B1 in the Bargerveen reserve. Total numbers of individuals and species observed in each of the study areas during all countings in all transects are given in table 2. In Haaksbergerveen the highest number of dragonfly species was observed, whereas the total number of counted individuals was lowest in this area.

Table 2. *Total numbers of individuals and species observed during all countings of the transects for small and larger dragonflies in each of the four study areas.*

	Bargerveen	Fochteloërveen	Haaksbergerveen	Peel
small dragonflies				
total transect length (m)	2400	2400	1500	1575
individuals	10830	1216	1112	1556
species	10	8	14	11
larger dragonflies				
total transect length (m)	12000	5400	5810	33750
individuals	91	13	53	184
species	8	4	7	5
total species number	18	12	21	16

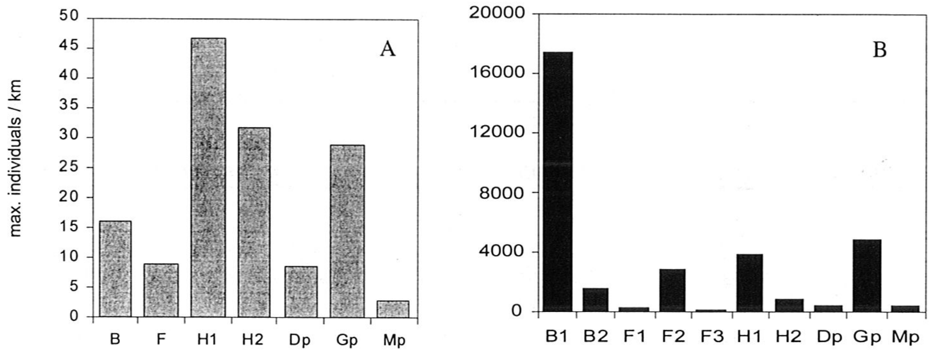

Figure 1. *Maximum dragonfly densities for all transects observed during the season, converted to individuals per kilometre. Figure A shows maximum densities observed in longer transects in which larger dragonflies were counted and figure B shows maximum densities in short transect in which small dragonflies were counted. B= Bargerveen, F= Fochteloërveen, H= Haaksbergerveen, Dp= Deurnese Peel, Gp= Groote Peel, Mp= Mariapeel. Numbers indicate different transects.*

Aeshna juncea was the most abundant larger dragonfly species in Bargerveen. In Haaksbergerveen both *Aeshna juncea* and *A. cyanea* were present in a high relative number (Figure 2A). In the transect for larger dragonflies in Fochteloërveen *Somatochlora metallica* was the most abundant species. Bargerveen, Fochteloërveen, and Haaksbergerveen have a quite high relative presence of *Sympetrum danae* in common (Figure 2B). In the Peel reserve *Enallagma cyathigerum* and *Orthetrum cancellatum* were dominant species.

Classification of all observed dragonflies into the ecological categories given in table 1 showed a large difference between the dragonfly fauna observed in the Peel area on the one hand and the dragonfly fauna of the other three areas on the other hand (Figure 3). In the Peel area dragonflies inhabiting water bodies in the whole range of ombrotrophic to calcareous environment types (Category III) were predominant, mainly due to dominance of *Enallagma cyathigerum* and *Orthetrum cancellatum.* As regards larger dragonflies, species of more calcareous habitats (Category IV) were most abundant in Fochteloërveen and Haaksbergerveen, whereas dragonflies of the more ombrotrophic parts of the raised bog system (Category II) were most abundant in Bargerveen. As regards small dragonflies, species inhabiting the more ombrotrophic parts of the system and species with a wide ecological amplitude (Categories II and III respectively) were present in about equal relative numbers in all areas, apart form the Peel reserve. In Haaksbergerveen the highest relative number of small dragonflies inhabiting the more calcareous habitats (Category IV) was present.

DISCUSSION

On the whole it can be concluded that dragonfly communities of both ombrotrophic raised bog centres and of gradients to more minerotrophic parts of the system are still not completely present in the studied raised bog remnants. Although several members of the bog centre community, like *Coenagrion lunulatum, Leucorrhinia rubicunda, Aeshna juncea,* and *Sympetrum danae* are present, the characteristic raised bog species *Somatochlora arctica* and *Aeshna subarctica* are still missing (although an individual of

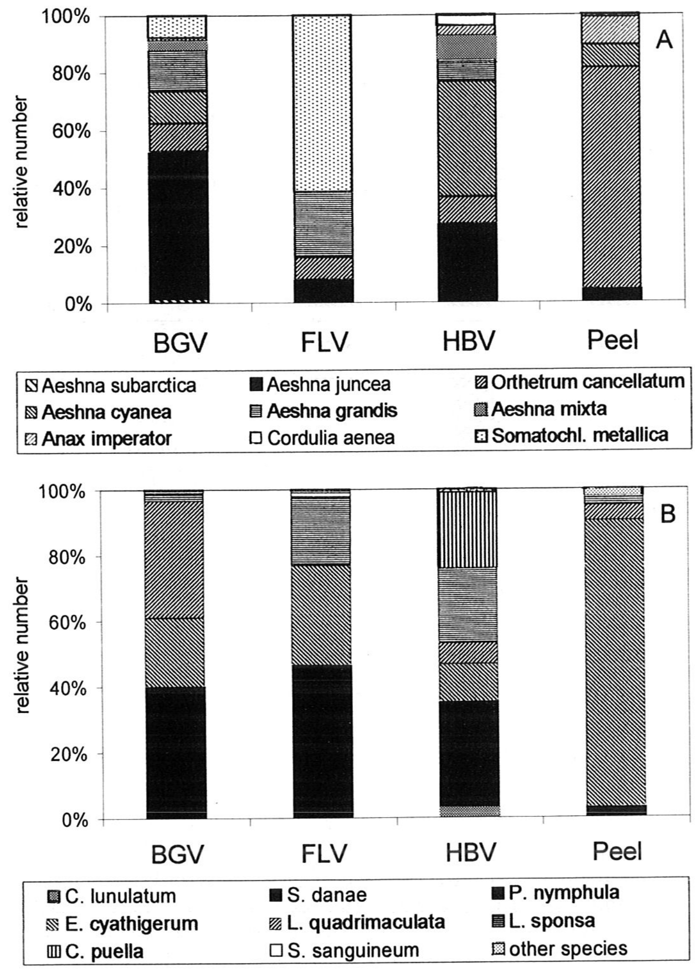

Figure 2. *Relative numbers of most abundant dragonfly species in the four study areas. Figure A shows relative numbers of larger dragonflies and figure B of small dragonflies. BGV= Bargerveen, FLV= Fochteloërveen, and HBV= Haaksbergerveen.*

the latter species was observed in Bargerveen in 1996). Absence of dragonflies highly specific for ombrotrophic (nutrient poor) bog water might be a consequence of high nutrient loads due to atmospheric deposition or dehydration of peat and consequent mineralisation. This influence of high nutrient loads is probably important in the Peel reserve, where the dragonfly fauna is dominated by species with a wide ecological amplitude, but it could also have effects in the other areas.

Another reason for the absence of characteristic species in raised bog remnants might be lack of specific vegetation structures required for egg-laying or lack of a specific water quality essential for larval development. *Somatochlora arctica* does not reproduce in any ombrotrophic water in raised bogs, but demands some water flow at least in spring, little open water and close *Sphagnum*-vegetation with perpendicular stems or leaves of plants like *Menyanthes trifoliata, Carex* and *Eriophorum* spp. (Schorr 1990). Such conditions can be found on the slope between the raised bog centre and the edge of the bog. The dragonfly species *Coenagrion hastulatum* does not occur in ombrotrophic pools, but in the transition to mesotrophic or eutrophic water (Sternberg & Buchwald 1999).

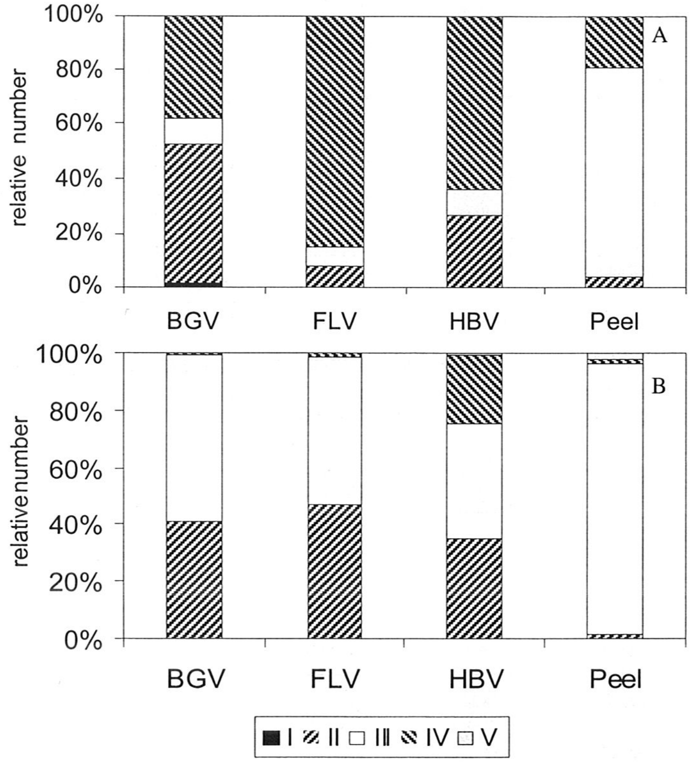

Figure 3. Relative numbers of ecological categories as given in table 1 in the four study areas. Figure A shows relative numbers of the larger dragonflies and figure B of the smaller dragonflies. BGV= Bargerveen, FLV= Fochteloërveen, and HBV= Haaksbergerveen.

Haaksbergerveen is the only of the four study areas in which a population of this species is present (outside our transects in 1996). In the Dutch raised bog remnant Korenburgerveen *C. hastulatum* is also present (Van de Wetering 1995). Both Haaksbergerveen and Korenburgerveen have a relatively high variation in water quality. This high variation in water quality can be causal for the presence of the highest number of dragonfly species in this study in the Haaksbergerveen reserve (Table 2). Other examples of species inhabiting habitats occurring in transitions from raised bog centres to surrounding environment types are *Leucorrhinia albifrons* and *L. caudalis* (Geijskes & Van Tol 1983, Schorr 1990). Both species are (almost) extinct in The Netherlands (Wasscher *et al.* 1998).

Besides presence and absence of species, density is another aspect of the composition of fauna communities. The very high density of adult dragonflies in transect B1 in Bargerveen (Figure 1B) may partly be explained by the shelter given by bushes and small trees in this transect, as the surrounding area consists of open large-scale rewetted cut-over peat fields. But as transects were set out along vegetation structures and water bodies resembling each other as much as possible in each of the study areas, presence of shelter can not completely explain this very high density. Highest densities of dragonfly larvae within seven Dutch raised bog remnants were found in Bargerveen (unpublished data Bargerveen Foundation), which surely might contribute to the high density of adults. These high densities are no fact by itself, but act upon the foodweb. The presence of large breeding populations of the bird species *Lanius collurio* and *Chlidonias niger* in the Bargerveen reserve after rewetting, is likely partly due to the high dragonfly densities, as

a substantial part of their diets consists of dragonflies (Esselink *et al.* 1995, Bruijnzeels *et al.* in prep.).
Restoration efforts in raised bog remnants are mainly focused on the creation of ombrotrophic conditions in large parts of the area. It is important to be very careful when hydrological measures are going to be carried out. Schorr (1990) pointed out that flooding in aid of bog regeneration can threaten populations of *Somatochlora arctica*, as inundation can destroy present habitats suitable for reproduction. Variation and transitions in water quality and vegetation, whether naturally present or in an artificial configuration, have to be saved, otherwise a variety of specific habitats for dragonfly species and surely also other kinds of animals will be lost.
As the spatial configuration and hydrological situation of raised bog remnants has been affected severely, restoration of more or less complete raised bog landscapes, including transitional habitats, will be very difficult or even impossible in many remnants. Lamers *et al.* (1999) showed that influence of groundwater is important in the restoration of raised bog vegetations, besides the influence of atmospheric input. Groundwater and surface water are also of importance in the conservation and restoration of habitats of raised bog fauna, both directly in water quality and indirectly in the formation of vegetation types and structures. Where restoration of parts of the raised bog system is impossible in raised bog remnants, alternative developments may result in interesting species compositions, whereas prospects for development of transitional habitats of raised bog systems could be regarded in minerotrophic peatland areas.

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