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Importance of variation in water-types for water beetle fauna (Coleoptera) in Korenburgerveen, a bog remnant in the Netherlands

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Effects of restoration of raised bogs on fauna are largely unknown. Here first results are presented concerning adult water beetles in Korenburgerveen, a Dutch bog remnant. A high water beetle diversity was found including rare and characteristic species. Variation in species composition and abundance could be linked to variation in water-types suggesting that for water beetles presence of variation in water quality is important. Species variation could be linked to acidity and alkalinity. It is discussed that these variables act both indirectly and directly on factors of importance for the completion of the life cycle, *e.g.* food and shelter. These findings are discussed in the light of restoration management. Well-considered phasing of small-scale measures are advocated, with monitoring programs as a necessary tool for evaluation.

Keywords: Coleoptera, water beetle, raised bog, restoration, fauna, diversity

Intact raised bog landscapes are complexes of one or more raised bog centres surrounded by more minerotrophic habitats and transitions in between. Raised bog centres receive water and nutrients mainly by precipitation (ombrotrophic) and consequently they are acidic and nutrient-poor and have a *Sphagnum*-dominated vegetation. Surrounding habitats (*e.g.* fens, rivers, mesotrophic lakes, and mineral soils) are influenced by minerotrophic, calcareous and/or more nutrient-rich ground or surface water. At a landscape level intact raised bog systems comprise variation in biotic and abiotic conditions, but also at a more detailed level heterogeneity is present within units of this landscape.

In the second half of the Middle Ages in The Netherlands about 250,000 hectares of intact raised bogs were present of which only a few thousand hectares remain today. There are no intact raised bog systems left and in bog remnants measures are taken to conserve and restore raised bogs (Van Wirdum, 1993). Restoration attempts are mainly focussed on creating conditions suitable for *Sphagnum*-recovery and success is mainly measured by the return of characteristic plants of ombrotrophic vegetations. Although vegetation is a very important aspect of an ecosystem, restoration of the flora does not necessarily imply restoration of the fauna (Schouwenaars *et al*., 1997). This is due to the fact that fauna species pose different demands to their surroundings in spatial use of the area, biotic and abiotic interactions and their dependence on resources like food and vegetation structure to complete their life cycles. As a consequence of these complex interactions little is known about fauna restoration (Bink *et al*., 1998). Regarding species number, fauna is of course a very important part of biodiversity of raised bog systems. For instance in the raised bog complex Fenn's and Whixall Mosses in Great Britain 1,688 invertebrate species have been recorded (Daniels, 1996).

Preliminary results of a comparative study on dragonflies of raised bog remnants under restoration suggest that variation in water quality as found in intact raised bog complexes, including transitional habitats, is important in the conservation and also restoration of faunistic biodiversity of raised bog landscapes (Van Duinen *et al*., 2000). These findings of course fit in common ecological knowledge, but are important to keep in mind when dealing with restoration management. The habitats of characteristic and threatened fauna species are of high conservation value. To avoid loss of populations of these species it is essential to assess what species are present at which sites before measures are carried out (Bosman *et al*., 2000).

This paper presents first results of a case study in the bog remnant Korenburgerveen, where restoration measures have been planned. Korenburgerveen has a high variation in water-types. Here raised bog vegetations are present as well as different types of more nutrient-rich and minerotrophic vegetations and transitions in between, making this bog remnant a valuable and vulnerable area. The aim of this case study is to get insight into the key-factors in the distribution of species within the area and to provide knowledge about the effects of restoration measures. This knowledge can provide thresholds for future restoration and management of bog systems. This paper focuses on adult water beetles (Coleoptera) serving as a first example in this study. Although adult water beetles are mobile and resistant to a number of factors, they are also an abundant and species rich group and more autecological knowledge exists on water beetles than on many other species groups. This paper deals with the following questions: 1) Are species characteristic of raised bog systems present in Korenburgerveen and where do they occur? 2) Which differences and similarities exist in species composition and abundance between different samples? 3) How can species variation be explained?

MATERIAL AND METHODS

Study area

Korenburgerveen is a bog remnant of 310 hectares in the eastern part of The Netherlands. The bog remnant is situated on the edge of a historical melt-water channel flowing from the north-east to the south-west. Due to the resulting flow of ground water and surface water and present soil types there is a large variation (including gradients) in water quality and vegetation composition (Biologische Station Zwillbrock, 1995; Fig. 1). The present heterogeneity in (a)biotic conditions is the result of both the natural situation and anthropogenic influence, like peat cuttings, drainage, and mowing as well as changed atmospheric deposition. A characteristic hummock-hollow vegetation has established on several floating rafts, especially in former peat cuttings in the western part, but also in the northern part. In the lower parts, mesotrophic forests and a fen vegetation are present with locally *Cladium mariscus*, as remnant of the former species rich fen vegetation (Biologische Station Zwillbrock, 1995). At the south-eastern border seeping-water-dependent nutrient-poor grasslands are present.

Data collection

In a selection of water-bodies in the various vegetation types quantitative samples (n=37; Fig. 1) of water macrofauna were taken in spring of the years 1999 (31-37) and 2000 (1-30) by means of a standard pond net of 30 x 20 cm and a mesh size of 0.5 mm. Average sample length was approximately 2 meters, resulting in a sample volume of 120 litres. By means of (baited) traps and hand sieves some additional data were obtained. For each sampling site 27 variables were determined, describing physical and chemical properties of the water-body and the vegetation in the water and on the bank. In the laboratory samples were washed over three sieves with a mesh size of 2, 1 and 0.5 mm. All macro-invertebrate groups were sorted in white trays and conserved. Adult water beetles were stored in 70% ethanol and identified to species level using Drost *et al*. (1992), Nilsson & Holmen (1995), Angus (1992), and Van Vondel (1997).

Statistics

A first classification was performed using TWINSPAN (Hill, 1979) on Preston transformed (Preston, 1962) invertebrate abundance data. To obtain a better isolation of clusters a subsequent classification was done with FLEXCLUS (Van Tongeren, 1986) using the output generated by TWINSPAN. Ordination was done using Canoco for Windows version 4.0 (Ter Braak & Smilauer, 1998). Significance of the canonical axes as well as each variable was determined by the magnitude of additional explained variation using stepwise forward selection, based on a Monte Carlo resampling procedure with 199 permutations (Ter Braak & Smilauer, 1998).

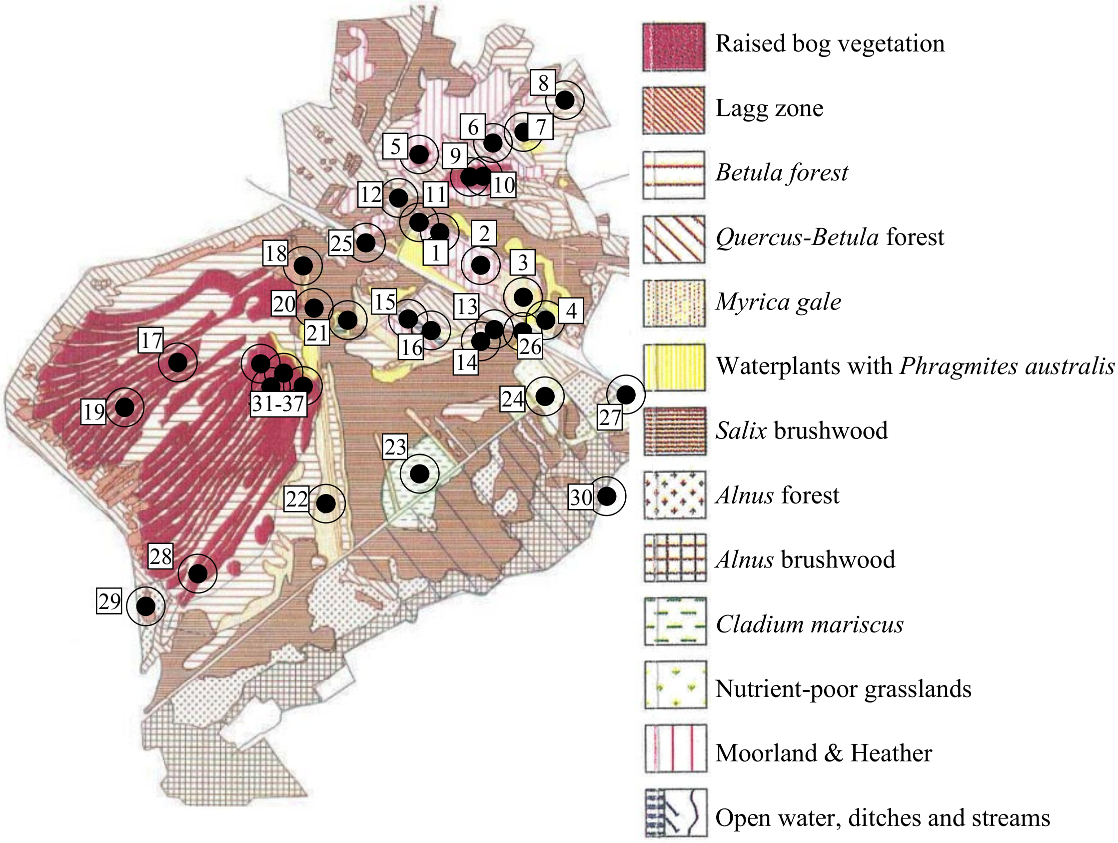

Figure 1. Map of Korenburgerveen, showing the variety in vegetation types and the location of the sampling sites (source: Biologische Station Zwillbrock, 1995)

RESULTS

Adult water beetles were found in 35 of the 37 samples and 1308 individuals belonging to 61 different species were captured. The captured water beetles belonged to the families Haliplidae, Dytiscidae, Noteridae, Hydraenidae, Hydrophylidae and Hydrochidae. Particular attention has to be paid to at least twelve of these beetle species as they are characteristic of raised bogs or threatened (Table 1). Most of these species were found at just one or few of the sampled sites. They were not found together in a single pool or one type of water-bodies, but in different types of water-bodies spread over the area (Table 2). Both tyrphobiontic species were captured in small pools in bog vegetation with a local water-flow resulting in a slightly calcareous and mesotrophic water quality. The seriously threatened species *Haliplus fulvicollis* was found in three pools with influence of seepage water and with floating *Potamogeton* vegetation and Reed (*Phragmites australis*). Concerning the tyrphophilous species, *Hydroporus umbrosus, Enochrus affinis*, and *Ilybius aenescens* were found in the most ombrotrophic bog pools, although the first two species also occurred in some more minerotrophic sites. *Agabus affinis* was only captured in two pools which can be considered as transitional habitats (lagg) close to raised bog conditions, but with some mineral influence and high cover of higher vegetation. *Acilius canaliculatus* occurred in several open water-bodies. Regarding the three sites where *Hydrochus brevis* was found, this species was most numerous in the *Cladium mariscus* vegetation. Additional capture methods revealed the presence of two other Red List species as well as three other individuals of *C. paykulli* (not included in statistical analysis).

Table 1. Species of special interest captured during this study. Frequency: number of samples in which the species was present. Tyrphophilous: species reach highest densities in bog vegetation, but not dependent on it. Tyrphobiontic: species dependant on bog vegetation. Red List categories: b: strongly threathened, c: threatened (based on Drost *et al*., 1992). [1]:species captured with a hand sieve. [2]:species captured with a baited trap

Species	Frequency	Tyrphophilous	Tyrphobiontic	RL category
Colymbetes paykuli	1 (3[1,2])		•	b
Rhantus suturellus	1		•	
Haliplus fulvicollis	3			b
Agabus affinis	2	•		c
Hydroporus scalesianus	3			c
Nartus grapii	3			c
Laccobius sinuatus	1			c
Ilybius aenescens	2	•		
Acilius canaliculatus	5	•		
Hydrochus brevis	3	•		
Hydroporus umbrosus	18	•		
Enochrus affinis	8	•		
Hydrophilus piceus	1[1]			c
Dytiscus dimidiatus	10[2]			c

Table 2. Species densities for each sample and variables describing the sampling sites. Samples are arranged in clusters according to classification results and species not mentioned in the text are not shown

Densities (# individuals / 5 metres (300 litres))
0 - 10
10 - 100
100 - 500
> 500

Size of habitat
. small <25 m^2
o medium 25-100 m^2
O large >100 m^2

Water vegetation
V Vertical watervegetation
F Floating vegetation
s *Sphagnum* present
S *Sphagnum* dominating

Bank vegetation
V vertical vegetation
r Reed
R Well developed Reed
O Other

Habitat
P Pool
D Ditch (broad)
d Ditch (narrow)
U Puddle
O Other

Depth
S Shallow 0-30 cm
I Intermediate 30-80 cm
D Deep >80 cm

Species type (based on Drost *et al.*, 1992)
ap acidophilous species
ab acidobiontic species
ap preference for acid water
tp tyrphophilic species
tb tyrphobiontic species
c common species
u uncommon species
i infrequently found species
[b] strongly threatened species
[c] threatened species

Species type		8	4	1									2						7												3		6		5	9
	Water vegetation	F	F	F	F	F	F	F	S	s	V	V	s	V	F	F	V	s	s	S	S	s	V	S	s	F	V	S	S	S	S	S	S	S	V	F
	Bank vegetation	r	V	r	V	R	V	O	V	V	V	V	V	r	R	R	V	r	V	V	V	V	V	V	V	r	r	V	V	V	V	V	V	V	V	V
	Habitat	P	P	P	d	D	P	O	P	P	P	D	P	P	P	d	U	P	U	P	P	P	P	P	U	P	U	P	U	U	U	U	P	U	U	S
	Size of habitat	O	.	O	.	o	O	O	.	.	o	O	o	o	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	o
	Depth	D	S	S	S	I	D	I	S	I	S	S	I	S	I	I	S	I	S	S	I	S	S	S	S	I	S	S	S	S	S	S	I	S	S	S
	pH	6,5	6,7	6,8	5,6	5,7	5,9	6,6	5,2	5,7	6,1	7,0	6,6	5,0	4,6	4,8	6,4	5,8	3,7	4,0	3,9	3,8	3,7	3,8	3,8	3,7	3,9	4,7	3,7	3,8	3,9	3,9	3,7	3,9	6,3	7,2
	Sample number	14	8	27	25	26	21	12	2	3	1	16	13	29	23	24	20	7	35	9	19	6	10	37	22	5	18	36	32	28	33	34	17	31	11	30
i	Porhydrus lineatus	15	-	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
i, [b]	Haliplus fulvicollis	-	-	-	-	3	-	-	-	-	-	-	-	-	20	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
i	Haliplus ruficollis	3	-	-	17	1	10	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
i	Noterus clavicornis	10	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
i	Ilybius ater	-	-	2	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-
i	Ilybius quadriguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	10
c	Noterus crassicornis	-	-	32	217	18	57	7	38	46	100	50	-	-	10	185	7	-	5	42	3	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-
c	Hygrotus inaequalis	-	-	6	-	3	13	33	2	-	3	-	10	-	-	-	7	32	-	-	-	-	-	-	-	-	2	10	-	-	-	-	-	-	-	-
c	Hygrotus decoratus	-	-	-	43	8	-	-	-	15	-	-	-	10	23	210	13	60	5	-	-	-	-	140	-	4	4	-	-	-	-	-	-	-	-	-
u	Hydrochus carinatus	-	3	2	-	-	-	-	-	-	-	-	3	-	17	5	7	24	-	-	-	3	-	-	-	12	-	-	-	-	-	-	-	-	-	-
ap	Anacaena lutescens	-	-	2	-	-	13	-	-	-	-	-	3	-	83	10	35	20	10	33	-	10	29	-	67	-	2	20	10	-	10	10	-	-	5	-
ap	Hydroporus erythrocephalus	-	-	-	43	-	-	-	8	15	13	-	-	-	-	5	-	4	10	17	-	-	43	10	7	8	4	10	10	40	-	-	-	-	-	-
ap	Enochrus ochropterus	-	-	-	-	-	-	-	14	-	-	-	-	-	-	5	-	-	-	92	-	-	-	-	-	4	-	-	-	-	-	-	5	20	3	-
ab	Hydroporus gyllenhalii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	17	-	73	29	10	33	-	2	-	-	90	-	-	-	-	-	-
ab	Hydroporus tristis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	92	70	25	-	80	27	2	2	90	10	710	20	20	28	10	-	-
ab	Hydroporus obscurus	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	20	-	20	-	60	-	-	-	133	12	-	30	50	730	80	10	10	30	-	3
tp	Hydroporus umbrosus	-	-	-	-	-	-	3	6	-	-	-	-	-	20	15	-	16	30	100	50	-	214	20	47	16	9	70	70	130	-	-	23	10	-	-
tp	Ilybius aenescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-
tpi, [c]	Agabus affinis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	2	-	-	-	-	-	-	-	-	-
tp	Enochrus affinis	-	-	-	-	-	3	-	-	-	-	-	-	-	7	-	-	8	-	-	-	-	-	-	-	-	-	-	10	10	-	-	3	100	3	-
tp	Acilius canaliculatus	5	-	-	-	-	-	-	-	15	-	10	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-
tp	Hydrochus brevis	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	3	-
[c]	Laccobius sinuatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
[c]	Nartus grapii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
[c]	Hydroporus scalesianus	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-
tb	Rhantus suturellus	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
tbi, [b]	Colymbetes paykulli	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	number of species not shown	**1**	**3**	**7**	**4**	**3**	**1**	**0**	**4**	**0**	**2**	**1**	**1**	**0**	**10**	**5**	**2**	**1**	**0**	**2**	**0**	**2**	**2**	**1**	**3**	**5**	**1**	**1**	**0**	**3**	**0**	**0**	**3**	**1**	**7**	**3**
	total number of species	**5**	**4**	**13**	**9**	**9**	**6**	**4**	**10**	**4**	**6**	**4**	**4**	**1**	**18**	**14**	**9**	**10**	**8**	**10**	**5**	**6**	**6**	**6**	**9**	**15**	**10**	**8**	**6**	**9**	**3**	**3**	**9**	**7**	**14**	**5**

Classification resulted in 9 different clusters of samples (Table 2, Fig. 2). Four clusters consisted of only one sample. Species composition as well as the conditions at the sampling sites did not resemble that of other samples. Two samples comprising a single cluster each were taken in a stream (cluster 9) and a very shallow pool in the forest (cluster 5). Both sites were nutrient-rich and had a mud bottom. Here *Ilybius quadriguttatus* and *I. ater* occurred, which both prefer mud bottoms (Drost *et al.*, 1992). The sample comprising cluster 4 was taken in a small mineral rich clear water pool in a forest bordered by an agricultural field. The sample comprising cluster 8 was taken in a large pool and was influenced by seepage water. In these samples *Porhydrus lineatus* and *Noterus clavicornis* occured which are common in clean more nutrient-rich water.

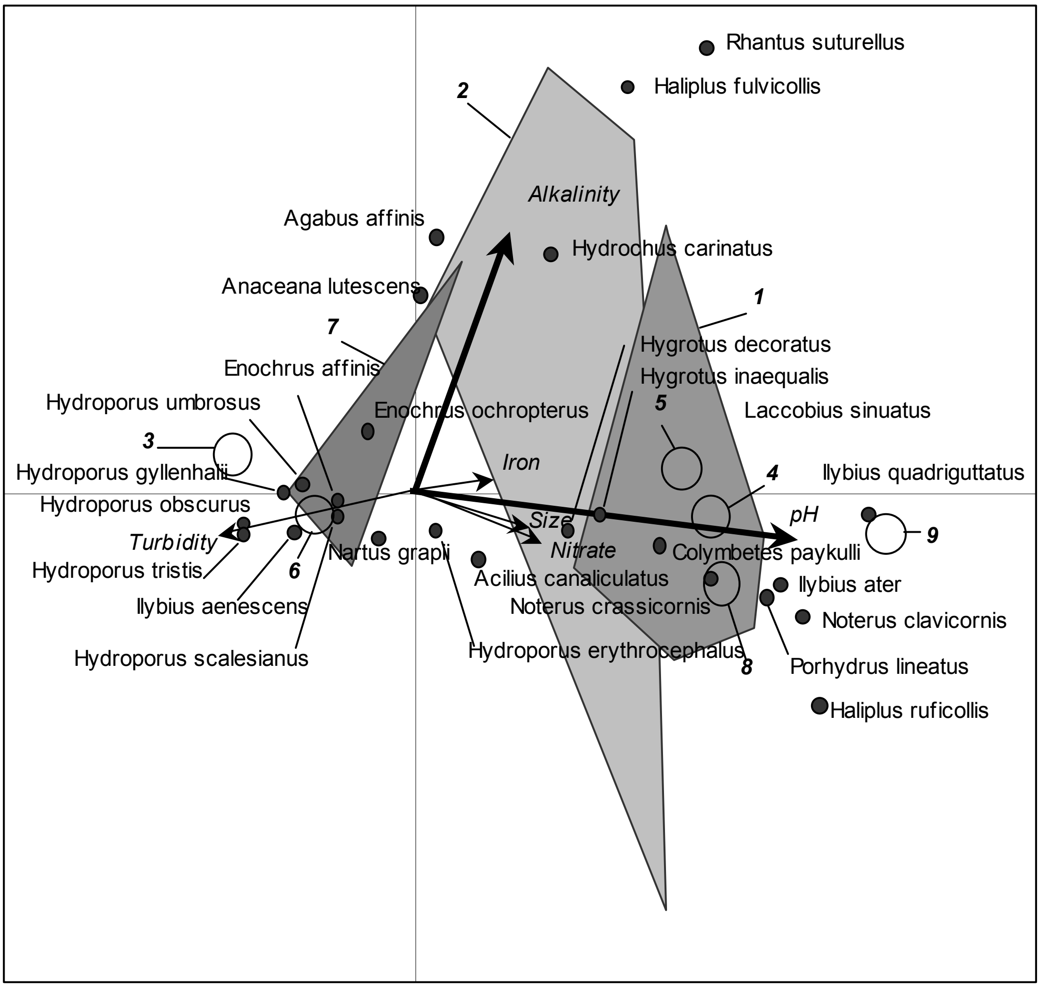

Figure 2. CCA plot showing species, samples and variables. Species not mentioned in the text are not shown. The six variables which explain most of the variation in species composition (enlarged by a factor of 2) are shown and significant variables are shown in **bold** (pH and alkalinity). Samples are encircled (small clusters) or arranged in polygons (large clusters)

Regarding the other five clusters of samples, cluster 1 and 2, containing samples taken in sites more or less influenced by minerotrophic water, were separated from cluster 7, 3 and 6, containing samples from more acid bog pools. Cluster 1 and 2 contain respectively 9 and 6 samples consisting of a wide range of water-types which are clustered together because common species with a wide ecological amplitude dominate these samples. This large variation is also reflected in the large size of the polygon in the CCA plot. Water-types falling into these clusters are pools in bog vegetation with some mineral influence, *Cladium mariscus* vegetation, large pools and water-bodies with Reed. Common species such as *Noterus crassicornis* and *Hygrotus inaequalis* dominate cluster 1. Samples in cluster 2 had a slightly lower value of pH and here common species with a preference for more acidic waters dominated such as *Hygrotes decoratus* and *Anacaena lutescens.*

When focussing on individual species the clusters can be further subdivided into different water-types. This is also apparent from the CCA plot where species that are dominant in the same cluster are not necessarily plotted close to each other. For example *Hydroporus erythrocephalus*, having a preference for more acidic waters, as well as both the tyrphobiontic species were found in bog pools of cluster 1 which had a local water-flow through the vegetation. Haliplidae including the seriously threatened species *Haliplus fulvicollis* were abundant in mesotrophic waters with pH around 6, floating leaves and a well developed bank vegetation containing Reed.

Cluster 7, 3 and 6 contain respectively 12, 2 and 2 samples, which were all taken in small acidic non-calcareous pools, except for one pool which can be considered as lagg (sample 18: pH

4.7). *Sphagnum cuspidatum* occurred in nearly every pool. Species dominating these clusters belonged to the genus *Hydroporus*, in particular the acidobiontic *H. tristis* and *H. obscurus* and the tyrphophilous *H. umbrosus* were abundant. These three clusters can be further divided when focusing on individual species. *Enochrus affinis* and *Enochrus ochropterus* are species that live near the bank and these species were predominantly found at sites with a well-developed bank vegetation such as those of cluster 6. Small crawling water beetles such as *Anaceana lutescens* and *Hydroporus* spp. were found in cluster 3 containing two samples taken in very small and shallow hollows between *Sphagnum*-hummocks.

Fig. 2 shows a canonical correspondence analysis plot with species, locations and variables plotted. Axis 1 and 2 together explained 41.0% of the relationship between the species and the environmental variables. Two variables were significantly correlated to variation in species data; pH (P=0.005) and alkalinity (P=0.04).

DISCUSSION

With 61 species about twenty percent of the total water beetle diversity in the Netherlands is found in the raised bog remnant Korenburgerveen. This is a relatively high diversity, considering that large beetles are undersampled (but were captured in high numbers with baited traps, unpublished data Bargerveen Foundation), larvae are not yet included, and only samples taken in spring were analysed. A number of characteristic and threatened species were captured in different sites and different habitats spread over the area. These findings stress the importance of the whole area and the different habitats of Korenburgerveen for water beetles. The occurring water-types are predominantly waters with low value of pH such as oligotrophic pools and mesotrophic waters, which are important habitat types for threatened species of water beetles (Cuppen, 1994).

The total species variation is significantly correlated with alkalinity and value of pH. These factors are related to each other and may act both directly and indirectly on the occurrence of water beetles. Although adult beetles are quite resistant (Richoux, 1994), tolerance is not absolute, since most eurytopic species dominating cluster 1 and 2, were scarcely found in acid pools. Preference for acid waters is noted for many of the observed *Hydroporus* species (Drost *et al*., 1992). Indirect effects of pH and alkalinity on species composition are most likely, acting on vegetation structure and food as is also supposed by Galewski (1971). Many potential prey species are intolerant to low pH. Results show that *Hydroporus* species reach high densities in *Sphagnum* vegetations and many *Hydroporus* species are mentioned as tyrphophilous or tyrphobiontic in literature (Hebauer, 1974). *Sphagnum* species are strongly associated with low pH and the dense and structure-rich vegetation provide an ecological niche for these small water beetles. Galewski (1971) assumes the rich humus and detritus layers in peaty waters serve good conditions for Hydroporinae larvae to hide and to search for food, whereas adults can deposit their eggs between leaves and stems of the mosses.

High alkalinity enhances decomposition by preventing the formation of organic acids, resulting in a higher nutrient availability and the dominance of a floating vegetation (*e.g. Potamogeton*) (Bloemendaal & Roelofs, 1988). Haliplidae occur in these mesotrophic waters with floating vegetation and a well-developed bank vegetation. Haliplidae are small beetles living mainly near the bank. The larvae feed on filamentous algae and adults are omnivorous. Haliplidae deposit their eggs on plant stems, *Chara* spp. or in filamentous algae. *Haliplus fulvicollis* is more demanding and inhabits slightly calcareous mesotrophic water with little growth of algae (Drost *et al.*, 1992), which can be affected by eutrophication and acidification and may explain why the species is strongly threatened.

In short, pH and alkalinity affect factors that are important for the completion of the life cycle such as food, shelter and substrate for egg deposition. In the studied bog reserve Korenburgerveen, a rich water beetle fauna is present. Very acidic water-types such as bog pools could be separated from more minerotrophic water-types on the basis of common species. It is apparent that each of the less common, characteristic or threatened species pose a specific set of demands on their habitat in order to complete their life cycles and occur in a limited number of sites. This provides a strong indication that the high variation in water-types present in Korenburgerveen allows for a high diversity of water beetles including species characteristic of raised bogs, transitional habitats and rare species. Further research with other groups, but also on the larvae of water beetles, which are less mobile and are more strictly bound to their habitat may provide more direct evidence for this conclusion.

In light of these findings recommendations can be made for restoration management. The variation in water-types in Korenburgerveen is the result of the natural streaming pattern of ground and surface water and arrangement of soil types, combined with antropogenic influence. This has resulted in today's mosaic arrangement of the different landscape ecological units. Results show that common, rare and characteristic species have established themselves in this mosaic pattern according to their habitat demands. Measures which are taken now, but aimed at recovery of raised bog in the long term, will lead to a loss of parts of this mosaic pattern of variation in water-types. This may result in the extinction of populations of rare water beetle species in the area. Recolonisation must then come from other nature reserves. Many beetle species have well developed flight capacity, however, especially for rare species it may prove difficult to reach isolated waters on the short term (Cuppen, 1994).

Loss of variation can be minimised by small-scale measures. Well-considered phasing of measures allows for restoring parts of the reserve one at a time. This allows for recolonisation from other parts within the nature reserve, which will be restored later. The present distribution of species in the mosaic pattern in Korenburgerveen deviates from that of an intact raised bog system. Therefore restoration measures must provide a gradual shift of the different landscape ecological units to the place where they occur in a natural situation. In this way the different water beetle species may shift along with the landscape ecological units. A good monitoring program before and after (partial) restoration measures are taken is a necessary tool, providing data on the occurrence and speed of recovery and how to proceed with further restoration measures.

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