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What do rove beetles (Coleoptera: Staphylinidae) indicate for site conditions?

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Summary

Although the rove beetle family is one of the most species rich insect families, it is ecologically rarely investigated. Little is known about the influence of environmental demands on the occurrence of the species. Thus, the present investigation aims to relate rove beetle assemblages and species to soil and forest parameters of Schleswig-Holstein (northern Germany). In the southernmost region of Schleswig-Holstein near Geesthacht, 65 sites were investigated by pitfall traps studying the relationship between the rove beetle fauna and the following environmental parameters: soil pH, organic matter content, habitat area and canopy cover. In total 265 rove beetle species have been recorded, and of these 69 are listed as endangered in Schleswig-Holstein. Four assemblages could be differentiated, but separation was weak. Wood area and canopy cover were significantly related with the rove beetle composition using a multivariate analysis. In particular, two assemblages of loosely wooded sites, or heath-like vegetation, were significantly differentiated from the densely forested assemblages by canopy cover and Corg-content of soil. Spearman analysis revealed significant results for only 30 species out of 80. Most of them were significantly related, generally to wooded sites or to humus-rich forests. Using rarefaction method, species richness was higher in the open sites or in forests loosely covered by trees. The number of endangered species increased from the wet forests to the open sites with bare soil surfaces. Evidently, rove beetle distributions are only weakly related to soil parameters and canopy cover. They depend more on the presence of small habitats, i.e. nests, specific succession status of dead wood etc.

Introduction

The species composition of ecosystems are, in many cases, evaluated to estimate the consequences of human impacts on the landscape or ecosystem processes. Usually, organisms are used that are easy to identify or have an emotional value, but it is often unknown if they really represent the biodiversity of the community. Therefore, it is necessary to re-evaluate and broaden the criterion of conservation decisions to include a higher number of species rich organism groups. In particular, beetles, and specifically rove beetles, with their rich species diversity, might be important indicators to represent the biodiversity of a community (DUELLI & OBRIST 2003).

From Schleswig-Holstein several investigations are available concerning the rove beetle family that originate from arable fields (HEYDEMANN 1956), salt marshes (HEYDEMANN 1962, 1967) or forests (IRMLER 1993), but little is known about the relationship between environmental parameters and the occurrence of rove beetle species or assemblages. As forests are the natural vegetation in northern Germany, the conservation of the forest community is of high importance for the wood poor country. The present comparing analysis of forests and adjacent open habitats, should particularly relate rove beetle assemblages and species to environmental parameters in order to differentiate forest types and the demands of rove beetle species on specific environmental factors.

The following questions should be answered: 1) Which assemblages of rove beetles can be differentiated in/between forests? 2) Which environmental parameters determine the composition of the assemblages? 3) Where are the most species rich assemblages with the highest number of endangered species?

Sites and methods

The investigated 65 sites are situated in and around the city of Geesthacht at the southern-most point of Schleswig-Holstein (northern Germany; between 53°27 N, 10°10 E and 53°22 N, 10°28 E) (Fig. 1). Because many sites are located on southerly exposed banks of the River Elbe, it was supposed that they would exhibit higher temperatures which would be reflected by a relatively high species richness in the cool northern country. The following climate data for the Geesthacht area are derived from the near by city of Luebeck that represent the long-term means: average annual temperature is 8.6°C, average temperature in January is 0.3°C, average temperature in July is 17.1 °C, and average annual rainfall is 658 mm.

The environmental parameters for this study were determined in 2004 and 2005. The canopy cover was estimated in the field and pH was determined by a WTW-electrode from a soil sample in 0.3 % $CaCl_2$–solution. Organic matter was measured by subtracting the ash weight, determined after combustion at 450°C for 5 h in a muffle furnace, from the dry weight of the soil sample which was dried at 105°C for 24 h. Determination of the forest area was performed from 1:25000 scaled maps using the computer program FUGAWI. For each site the area of the total forest was determined without referring to possible different habitat conditions within the individual forest. Thus, in several forests more than one site was located that differed in environmental conditions but not in forest area. A more precise determination of the area that also includes environmental conditions was not possible from the maps available.

Rove beetles were recorded by pitfall traps in the year 2000 from May 9 to September 5. Pitfall tarps were filled with a mixture of ethanol, water, glycerol, acetic acid and a detergent liquid. As usual, pitfall trap cups with an upper opening of 6.5 cm in diameter were used. A wire gauze with a mesh size of approximately 2 cm was installed at the opening to prevent catch of small mammals. At each site 5 replicate traps were installed, but subsequently aggregated to one sample. According to ASSING (1991) the indigenous species of a habitat are represented by at least a number of 5 samples. Change of pitfall traps was performed in 3 weeks intervals.

The program STATISTIKA (STATSOFT 1996) was used to perform statistical tests. For the ordination the identity of dominance between two sites was determined subsequently followed by an average-cluster-analysis. In the average-cluster-analysis unweighted pair group average was used as fusion rule and the percent concordance as measure of distance. The program CANOCO (TER BRAAK & SMILAUER 1998) was used to perform Detrended Correspondence Analysis (DCA). Both analyses were used to differentiate the rove beetle assemblages. The significance of environmental parameters on the composition of rove beetle assemblages was tested by the Canonical Correspondence Analysis using the Monte-Carlo permutation test. Furthermore, ANOVA, with 1 between factor, was subsequently performed after testing on normal distribution to test significant differences between assemblages in the single environmental parameters. A Least-Significant-Difference (LSD) post-hoc test finally followed.

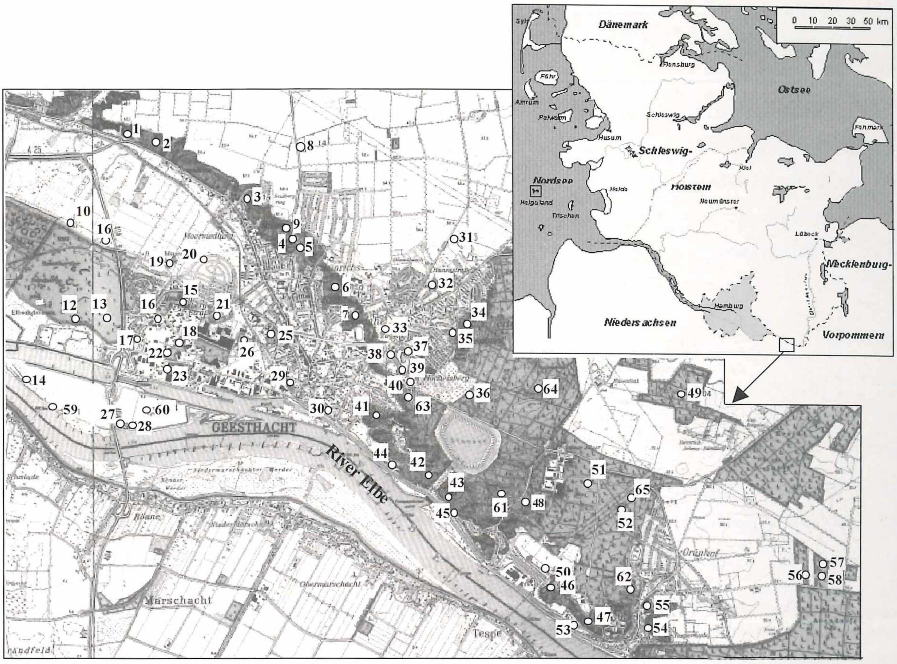

Fig. 1: Studied sites in the city of Geesthacht (Schleswig-Holstein).

To determine the species richness several different methods were used. To begin, species richness per 5 traps was counted. Using this method the highly different number of sites per assemblage combined with high differences in the number of specimens can lead to erroneous results. Thus, additionally the rarefaction method was used (SIMBERLOFF 1972). With this method species richness for a specific number of specimens could be calculated. When comparing two samples by the rarefaction method, the smallest number of specimens must be used. In the present investigation, species richness per 100 specimens was selected, although a lower number of specimens occurred at two sites. Theses two sites were omitted from the calculation. Rarefaction species richness was calculated using the program of KREBS (2002) for each individual site and the mean determined for each specific assemblage.

Table 1: Description and environmental parameters of sites (n.d.: not determined)

Nr.	Description of site	Tree cover (%)	pH	Corg (%)	area (ha)
1	Birch - oak wood	85	3.49	37.6	45.1
2	Beech - hornbeam slope wood	90	4.86	15.4	45.1
3	Beech - pine wood	60	4.23	32.3	34.1
4	Beech dominated deciduous wood	75	3.48	28.2	34.1
5	Line - Larch wood	60	2.98	40.5	34.1
6	Larch - pine wood	55	3.26	13.9	22.9
7	Beech - oak wood	70	3.77	7.3	22.9
8	Old fruit tree garden	65	5.08	7.7	1.7
9	Calluna-heath at wood margin	10	3.58	8.2	34.1
10	Alder wood in former floodplain	80	4.70	68.8	1.1
11	Birch - pine wood	65	4.07	6.6	2.1
12	Deciduous wood on sand	55	4.63	13.0	8.8
13	Sandy grassland near pine wood	2	6.14	0.6	122.5
14	Sandy pasture in floodplain	2	6.73	1.2	0.2
15	Pine wood	60	4.12	8.8	5.8
16	Pine - birch wood margin	15	5.36	1.4	0.4
17	Pine – deciduous wood	90	5.51	6.5	1.2
18	Sandy grassland near pine wood	65	5.59	9.5	1.7
19	Willow small grove	90	4.57	11.9	0.9
20	Birch – poplar grove	80	4.71	55.0	2.0
21	Pine – deciduous wood	65	5.20	11.2	3.1
22	Oak mixed wood	55	4.07	7.6	2.1
23	Pine – deciduous wood	50	4.33	36.9	2.1
24	Deciduous grove	n.d.	n.d.	n.d.	2.9
25	Pine wood	76	2.82	45.3	2.4
26	Pine – deciduous wood	10	4.24	2.3	2.9
27	Poplar grove in floodplain	90	5.82	8.6	0.4
28	Poplar grove in floodplain	80	3.88	14.9	0.5
29	Poplar grove	90	6.33	10.6	1.3
30	Oak mixed wood in floodplain	90	2.73	16.4	1.6
31	Mining site with birch – pine young trees	0	5.57	1.9	9.9
32	Beech deciduous wood	90	3.96	14.7	1.4
33	Mining site with birch – pine young trees	65	6.85	3.5	5.2
34	Pine – deciduous wood	80	3.49	50.9	225
35	Spruce – deciduous wood	50	3.56	18.1	225
36	Pine – deciduous wood	50	4.24	39.3	225
37	Pine wood	95	3.41	58.7	1.8
38	Pine – oak slope wood	92	3.77	12.1	80.2
39	Beech – alder slope wood	87	3.55	44.6	80.2

Nr.	Description of site	Tree cover (%)	pH	Corg (%)	area (ha)
40	Beech slope wood	100	3.76	11.3	80.2
41	Pine – deciduous wood	90	2.78	10.2	80.2
42	Oak wood	90	4.23	77.7	80.2
43	Oak – pine wood	90	3.75	69.2	70.5
44	Alder carr	100	4.89	9.9	80.2
45	Oak wood	75	4.14	21.8	70.5
46	Poplar slope wood	80	4.72	10.0	21.5
47	Beech – oak mixed wood	n.d.	n.d.	n.d.	21.5
48	Beech wood	90	3.72	17.8	70.5
49	Beech reforestation	50	4.02	5.3	40.1
50	Sandy grassland with broom grove	0	3.89	4.6	1.6
51	Small peat moor	n.d.	n.d.	n.d.	70.5
52	Alder wood	n.d.	n.d.	n.d.	91.5
53	Deciduous wood	n.d.	n.d.	n.d.	1.7
54	Beech slope wood	85	3.33	34.1	9.7
55	Spruce – deciduous wood	60	3.37	33.8	9.7
56	Oak – hazel wood	90	3.80	5.3	11
57	Birch wood	65	3.27	13.9	11.3
58	Beech – oak wood	90	3.44	32.4	11.3
59	Willow wood in floodplain	50	7.43	7.2	4.1
60	Sandy grassland in floodplain near wood	5	4.86	0.6	9.7
61	Pine – beech wood	100	3.43	66.0	70.5
62	Beech wood	n.d.	n.d.	n.d.	11.1
63	Pine – deciduous wood	70	3.32	12.9	80.2
64	Spruce young trees	85	3.70	12.4	225.0
65	Detonationsschutzwall	n.d.	n.d.	n.d.	91.5

Results

<u>Environmental parameters</u>

The sites 17, 27, 38, 73, 105, 144 and 47c were located in open habitats near a wood margin or in a clear-cut area (Table 1). Whereas most sites were situated on formerly heathland and were not older than 100 or 150 years, the sites 88b, 97a, 97b, 121 and 120 are located on old tree sites that are at least more than 250 years old. The open sites are located mostly on sandy soils with a canopy cover of maximum 15 %. Predominantly spruce forest is developed on sites 47, 80, 47b to 47e and O3. Mixed spruce and deciduous forests are found on sites 11c, 11d, O1 and O2. The remaining sites are covered by deciduous trees. Some of these are very small and surrounded by agricultural fields or within the downtown area of Geesthacht with high human impact.

The pH-values and the organic contents of the soils, too, reflect a high variance. Some alder woods are located on fen moor soils or on sandy soils with a thick layer of raw humus with high organic contents of more than 30 %.

The pH varied between 3 and 7.5. Some sites on the floodplain of the River Elbe exhibit sandy soils that reveal particularly high pH-values. This can be referred to the high calcium input from former inundations during flood events. In addition, the high calcium content in soils of a few sites can also be referred to the input from agricultural fields.

The rove beetle assemblages

A total of 265 rove beetle species were recorded including 69 species that are regarded as endangered according to the Red List of Schleswig-Holstein (see appendix). Using the cluster analysis and the DCA four assemblages could be differentiated, but most sites were placed in assemblage 2 (Fig. 2). According to the DCA, the eigenvalue of the 1st axis is relatively small with 0.49 which means the differences between the assemblages are only weakly developed. According to TER BRAAK (1987) a distinct ordination of assemblages can be expected at eigenvalues higher than 0.5. The four assemblages are ordered exclusively along the 1st axis.

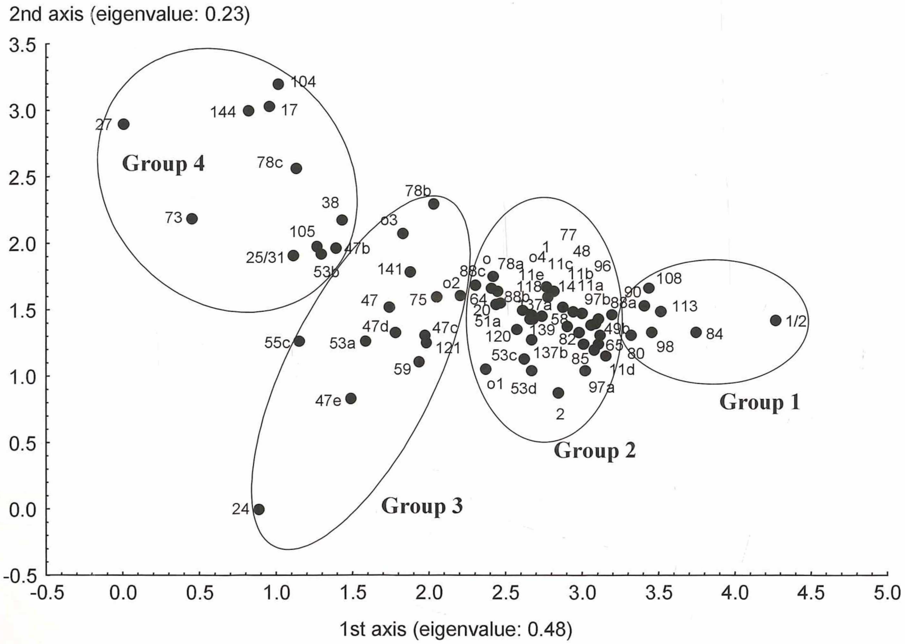

Fig. 2: Results of the Detrended Correspondence Analysis for the rove beetles of the 66 sites in the area of the city of Geesthacht.

Canonical Correspondence Analysis revealed significant influence by canopy cover (F = 3.7) and wood area (F = 1.6), while ANOVA significantly separated the four assemblages by the three parameters; canopy cover, wood area, and organic matter in soil (Table 2). Assemblages 3 and 4 were differentiated from assemblages 1 and 2 by more open canopy covers. Assemblage 3 is located on loosely covered wooded sites, whereas assemblage 4 can be found on open sites, at wood margins, or outside the woods. The low content of organic matter in the soil of assemblages 3 and 4 indicates sites on mineral soils with small humus layers and large areas of bare soil surface. Assemblages 1 and 2 can be differentiated according to the wood area. Assemblage 1 is located in large woods mostly dominated by alder trees, which usually characterise wetter conditions compared to sites of assemblage 2. Thus, the four assemblages might be also differentiated concerning a moisture gradient. The alder woods of assemblage 1 exhibited a low pH of 3.8 ± 0.6 which characterises sites that are not located near the groundwater level. In contrast, these sites seem to be placed in depressions on water-logged soils influenced by acid rain waters. They do not represent the typical alder carrs or alder-ash woods on calcium-rich soils located at lake margins.

Overall, the forest area has only a low influence on the composition of the rove beetle assemblages that can be seen by the high standard deviation of this parameter in each assemblage (Table 2). The pH-value revealed a gradient from acid to relatively calcium rich sites. This can be partly referred to the local situation where humus-poor sites were located in the floodplains of the River Elbe, or in mining areas with less decalcified sandy soils.

According to the environmental parameters the four assemblages can be characterised as follows: 1) moist alder woods on acid peat soils in large woods, 2) deciduous or coniferous woods on acid and humus-rich soils, 3) loosely wooded sites on relatively calcium rich mineral soils, and 4) open sites located near wood margins with relatively calcium rich mineral soils.

Assemblage 1 - alder wood on acid soils - is characterised by the high dominance and continuity of the species *Tachinus pallipes*, *Lesteva longoelytrata* and *Anotylus rugosus* (Table 2). The high moisture at these sites is underlined by the occurrence of these species that are typical for wet and moist habitats.

In the densely wooded sites of assemblages 1 and 2, *Philonthus decorus* occurred with high dominance and continuity. The species was found at nearly 100 % of the sites of the two assemblages. The ecological niches of *Omalium rivulare*, *Quedius fuliginosus*, and *Othius punctulatus* appear to be wider, as they were also frequently found in the loosely wooded sites of assemblage 3 with a continuity of up to 70 %. In assemblage 2 - woods on acid, humus-rich soils - *Placusa tachyporoides* and *Othius subuliformis* can be regarded as typical species in spite of their low abundance. However, their continuity was high in this assemblage.

Independent from canopy cover, the 8 species from *Atheta negligens* to *Platydracus fulvipes* are more frequent in the fresh to dry woods of assemblages 2 and 3 than in the moist alder woods of assemblage 1. Whereas the first four species avoid the loosely wooded sites on sandy soils, the last four species were abundantly found at all of these sites. Typical species for the sites of assemblage 3 are *Atheta gagatina*, *Zyras humeralis*, and *Ocypus brunnipes*. The last 5 species in table 2 characterise the open sites on sandy soils. In particular, the species *Xantholinus tricolor*, *Platydracus stercorarius*, *Aleochara binotata*, and *Othius angustatus* avoid even the loosely wooded sites of assemblage 3.

Table 2: Environmental parameters, species richness and most frequent species (%) of the four differentiated assemblages. For environmental parameters and species richness the means (M) and standard deviations (S.d.), for the species means (M) and continuity (C) are listed. A dominance below 0.1% is indicated with +, RL refers to the Red List of Schleswig-Holstein (ZIEGLER & SUIKAT 1994), different exponents indicate significant differences.

Assemblage	1		2		3		4	
Number of sites	7		33		15		11	
	M	S.d.	M	S.d.	M	S.d.	M	S.d.
Canopy cover	89	4	80	13	^{1}67	22	^{2}26	27
pH-value	3.8	0.6	4.0	0.7	4.6	1.3	4.7	1.0
Organic matter (%)	35	18	31	24	^{1}12	8	^{1}12	14
Area (ha)	^{1}63	31	34	45	40	81	42	70
Mean species richness/5 traps	47,5	14,9	40,7	11,9	40,1	13,6	33,7	10,3
Mean RL species richness/5 traps	7,7	3,0	6,7	2,1	6,9	3,0	6,5	6,5
Mean species richness/100 Ind.	20,0	6,4	23,4	3,5	^{1}26,0	3,2	^{1}25,5	5,8
Mean RL species richness/100 Ind.	2,3	0,9	^{1}3,7	1,0	^{2}4,3	1,3	^{3}5,0	1,8
Species	M	C	M	C	M	C	M	C
Tachinus pallipes	1.0	100	0.2	27	89.5			
Lesteva longoelytrata	15.7	57	+	6	0.1	13		
Anotylus rugosus	0.8	57	0.6	27	0.3	13		
Tachinus signatus	5.5	100	1.6	70	0.5	40	0.2	27
Philonthus decorus	42.8	100	30.8	97	4.5	80	0.4	9
Omalium rivulare	4.6	86	3.9	79	3.5	87	0.1	27
Quedius fuliginosus	3.7	100	2.7	73	2.3	73	0.6	27
Othius punctulatus	1.9	86	4.3	91	3.1	93	0.9	36
Placusa tachyporoides	0.2	57	1.1	85	0.5	73	0.7	45
Othius subuliformis	0.1	29	1.7	79	0.7	67	0.6	36
Atheta negligens	1.0	71	4.4	79	6.1	93	0.6	45
Quedius mesomelinus	0.6	14	2.2	88	1.1	73	0.3	27
Aleochara sparsa	2.3	100	9.1	97	9.1	93	6.8	91
Rugilus rufipes	1.3	100	2.6	85	2.2	80	1.5	36
Atheta fungi	1.2	86	2.0	79	2.4	73	2.5	73
Xantholinus linearis	0.9	86	3.7	94	5.7	93	3.7	82
Ocypus compressus	0.9	86	1.4	70	1.9	87	2.1	27
Platydracus fulvipes	0.6	71	1.9	64	1.2	27	1.3	36
Drusilla canaliculata	0.8	29	1.0	33	6.4	87	17.8	82
Atheta euryptera	0.4	57	3.0	91	9.4	87	4.9	64
Atheta gagatina	0.5	43	0.5	48	3.9	47	0.9	45
Zyras humeralis	0.1	14	1.0	39	7.7	53	1.4	9
Ocypus brunnipes	0.5	57	0.6	61	2.1	80	1.6	36
Zyras limbatus			0.4	9	2.7	33	7.8	64
Stenus clavicornis			0.1	21	1.2	80	3.8	73

Species	M	C	M	C	M	C	M	C
Xantholinus tricolor			0.1	21	0.2	40	2.6	64
Platydracus stercorarius			0.1	6			1.1	36
Aleochara binotata							2.4	9
Othius angustus	+	14	+	6	+	7	0.6	36

The mean total species richness in the four assemblages varied between 48 and 35 species per 5 traps with relatively high deviation, whereas the mean species richness of endangered species was between 6.5 and 7.7 per 5 traps. ANOVA revealed no significant differences between the assemblages, neither for total species richness nor richness of endangered species. The lowest species richness occurred in a pine wood on sandy soils of assemblage 3, with 19 species/5traps, while the highest species richness was found in a moist mixed deciduous wood of assemblage 1, with 74 species/5 traps. In contrast to species richness per site, rarefaction species richness revealed significant results between the assemblages. On average, the species richness/100 ind. was 3 to 6 species higher at assemblages 3 and 4 than at assemblages 1 and 2. This is distinctly more pronounced if the endangered species are regarded. Species richness of endangered species/100 ind. continuously increased from assemblage 1 to assemblage 4. On average, it is twice as high in assemblage 4 than in assemblage 1. It was also tested if the 15 sites located in the centre of the city have a lower species richness than the 48 sites outside the centre, but no significant results were found neither for all species nor for endangered species.

Relation of species to environmental parameters

In the present study 80 species occurred with more than 20 specimens. A Spearman analysis was performed to relate the occurrence of these 80 species with the environmental conditions. This analysis showed that 30 species revealed significant correlations (table 3). Most of the species can be regarded as euryecious in woods as they were positively correlated with canopy cover. This ecological group included 7 species, e.g. *Othius punctulatus* and *Atheta negligens*, two of these appeared to prefer large woods. Preferences seem to be more specific in some species that were more frequently found in humus-rich woods, e.g. *Lathrimaeum atrocephalum* and *Philonthus decorus*. These species were positively correlated with a high content of organic matter in soil and dense canopy cover. Three species were also positively correlated with wood area indicating that they were more frequently found in large woods.

The remaining species are either species of open habitats or show little or no correlation with canopy cover, but are negatively correlated with wood area. Among the species that are negatively correlated with canopy cover, particularly *Zyras limbatus* was found on open, humus-poor soils indicating that this species is typical for sites with bare sandy soils without vegetation cover.

Discussion

According to the results of the ordination analyses only weak differences between the four assemblages of rove beetles were found. The low eigenvalue of 0.49 for the first canonical axis reflects that the species composition of the studied sites is similar. Although the four environmental parameters; soil pH, content of organic matter, canopy cover, and wood area, exhibited strong differences, a weak, but significant influence on the separation of the assemblages was found only between canopy cover and wood area. Additionally, ANOVA results showed a significant effect of organic matter in the soil. This low separation of the assemblages by the environmental parameters reflects their weak influence on the species composition. Furthermore, the Spearman analysis revealed relatively few significant correlations, particularly if the high number of species found at the studied sites is considered. Thus, only few species can be regarded as typical for wooded sites and their specific soil conditions.

Table 3: Results of Spearman Rank correlation analysis with classification of species to ecological groups with similar correlation results. Rank correlation coefficients are listed for pH, content of organic matter (Corg), canopy cover, and wood area.

Species	pH	Corg	Canopy cover	Area	Ecological group
Atheta euryptera	0.38			-0.62	Species on limy soils
Ocypus brunnipes	0.45				
Zyras humeralis	0.31	-0.37			Species on limy, humus-rich soils
Oxypoda opaca	-0.29				Species on acid soils
Ilyobates bennettii		0.43			Species on humus-rich soils
Lathrobium brunnipes		0.35			
Aleochara bilineata		-0.39			Species on humus-poor soils
Plataraea brunnea		-0.29		-0.39	
Lathrimaeum atrocephalum		0.31	0.42		Species of humus-rich woods
Philonthus decorus		0.34	0.57		
Platydracus fulvipes		0.34	0.32	0.56	
Quedius fuliginosus		0.46	0.39	0.31	
Tachinus pallipes		0.32	0.33	0.35	
Phloeostiba plana[1]			0.30	0.34	Euryecious species of large woods
Rugilus rufipes			0.28	0.44	
Atheta negligens			0.33		Euyrecious species of woods
Othius punctulatus			0.45		
Oxypoda alternans			0.40		
Quedius cruentus			0.44		
Tachinus signatus			0.33		
Zyras limbatus		-0.35	-0.33	-0.27	Species on open, humus-poor soils
Quedius molochinus			-0.31		Species of open habitats
Stenus clavicornis			-0.32		
Tachyporus hypnorum			-0.28		
Liogluta alpestris				-0.40	
Gabrius osseticus				-0.36	
Gyrohypnus angustatus				-0.31	
Tachinus corticinus				-0.32	
Mycetoporus baudueri				-0.37	
Aleochara bilineata				-0.31	

[1] species living under bark

In a detailed study on a variety of forest, grassland and dune ecosystems on the German North Sea islands, ROSE (2001) also found low eigenvalues of 0.41 in spite of the strongly different habitat types. In his investigation, leaf litter type and canopy cover were the most important factors, while salt content, moisture and soil pH were of lower importance. STEINMEYER & TIETZE (1982) investigated 30 pine forest sites of different age in central Germany. They also found a high similarity in the rove beetle composition and emphasised the eurytopic behaviour of the species. Only clear cut sites differed more distinctly from the remaining pine wood sites. On clear cut sites *Xantholinus linearis* was found to be a characteristic that corresponds with the findings in Geesthacht. In Scandinavian investigations, too, the distribution of rove beetles was found to be independently developed from plant assemblages (ANDERSEN et al. 1990). However, it was still more related to plant cover than spider assemblages, which was referred to the high mobility of spiders by ballooning (PALMGREN & BISTRÖM 1979). In contrast, ground beetles (Carabidae) showed a strong relationship to soil parameters and a distinctly stronger separation of assemblages than rove beetles and spiders (IRMLER 2000). VOGEL & UHLIG (1982), too, emphasised the mainly eurytopic behaviour of rove beetles for urban habitats.

In investigations of Luxembourgian rove beetles, soil pH and the annual number of warm days were significantly relevant for their distribution (DRUGMAND 1993), but both environmental parameters were strongly correlated with each other. Both organic matter and soil moisture had no influence on the composition of the rove beetle fauna. The high influence of the soil pH on the Luxembourgian rove beetle assemblages was referred to the wide pH gradient, as limy sites on lacustrine limestone were included in the investigation. The lime content of soils seems to be also important for the rove beetles in woods of Schleswig-Holstein which can be seen by significant changes after fertilisation with limestone (IRMLER 1993). Although in the present study soil pH did not significantly separate the assemblages, an obvious gradient existed from assemblage 1 to assemblage 4 that might also reveal an influence of soil pH on the occurrence of species.

Soil moisture was the most important parameter in Polish woods (SZUJECKI 1966), which was also confirmed for woods of Schleswig-Holstein (IRMLER 1993). As in the investigations at Geesthacht, soil moisture was not measured and there is no evidence for the importance of this parameter on the studied sites. However, in the investigation of three woods by IRMLER (1993) and the woods at Geesthacht, the separation of assemblages was weak which supports the low influence of soil moisture on the composition of rove beetle assemblages.

Rove beetles appear to be influenced considerably more by the presence of microhabitats (biochores in the sense of TISCHLER 1993) than by large-scale soil or microclimatic conditions. Many forest dwelling species demand dead wood as habitat (GEILER & BELLMANN 1974) as they occupy the different stages of wood decay (IRMLER et al. 1997). Characteristic soil dwelling species, e.g. *Othius punctulatus*, *O. subuliformis* and *Philonthus decorus*, are either unable to fly, or fly reluctantly. Thus, *Othius punctulatus* was never found by flight intercept traps that were installed only 1.5 m above the ground (IRMLER 1998). According to ASSING (1993) wings are usually developed by the species, but muscles for flying are rarely sufficiently developed. Reluctant flying seems to be also true for *Philonthus decorus* which was frequently found in flight intercept traps. However, it was less frequently found than *P. rotundicollis* and *P. cognatus* which were rarely recorded on the ground. Most rove beetles, e.g. *Quedius xanthopus* and *P. subuliformis,* that are dead wood or nest dwelling species, are good flyers and were detected even in 30 m high flight intercept traps.

Even landuse seems to be of low importance as shown by the low percentage of typical species of wooded habitats. Nevertheless, some species exist that prefer specific edaphic conditions, e.g. *Philonthus decorus*, *Platydracus fulvipes* or *Lathrimaeum atrocephalum*, that were predominantly found in humus-rich woods.

The eurytopic ecological behaviour complicates the indication of habitat or ecosystem conditions by rove beetle species in relation to conservation demands. The inappropriate use for these demands, seem to be reinforced by the difficulties with identification. However, the specific catching method by pitfall traps has to be reconsidered, particularly in the wood ecosystem, where many species live in tree bark, in tree holes or in nests and are not recorded by this method. Thus, the low influence of canopy density or soil conditions only refer to soil dwelling rove beetle species. Rove beetles may be appropriate indicators for the total habitat biodiversity, because they represent the different scales from micro- to macro-habitats in an ecosystem (BOHAC 1999), but precise research on this field of ecology is lacking for forests. In wet grassland, the demands of several rove beetle species in tussocks are well documented and reflect a seasonally dependent preference for a complex pattern of micro- and macro-habitats (MEISSNER 1997).

Comparing the four assemblages concerning their species richness, distinct differences are found only by the rarefaction method, while species richness per traps revealed no significant differences. This might be referred to the distinctly lower amount of specimens in assemblages 3 and 4 compared to assemblages 1 and 2, although the species richness was more or less similar in all four assemblages. However, this fact can not explain the significantly higher richness of endangered species in assemblages 2 and 3 compared to assemblage 1. This difference reflects the overall higher endangerment of species occurring on oligotrophic, open habitats with warm microclimate conditions in Schleswig-Holstein. With reference to the rarefaction species richness in assemblage 4 with bare, sandy soils 5% of specimens were endangered, while it was only 2.3% of specimens in assemblage 1 on wooded humus-rich soils.

Zusammenfassung

Welchen Zeigerwert haben Kurzflügelkäfer (Coleoptera: Staphylinidae) für Standortfaktoren?

Obwohl die Kurzflügelkäfer zu den artenreichsten Familien auf der Erde zählen, sind sie bisher ökologisch selten untersucht worden. In der vorliegenden Untersuchung sollten die Gemeinschaften der Kurzflügelkäfer im südlichen Schleswig-Holstein differenziert und die Beziehungen zu Boden- bzw. Waldparametern festgestellt werden. In der südlichsten Region Schleswig-Holsteins bei Geesthacht wurden 65 Standorte mit Bodenfallen im Jahr 2000 untersucht und sowohl die Kurzflügelkäfer als auch später die Bodenparameter, Boden pH und Corg-Gehalt des Bodens, sowie die Fläche der Wälder als auch die Baumdeckung bestimmt. Insgesamt wurden 275 Arten erfaßt, von denen 69 auf der Roten Liste Schleswig-Holsteins stehen. Vier Gemeinschaften wurden getrennt, die aber nur eine schwache Differenzierung und hohe Ähnlichkeit zeigten. Die Baumdeckung und die Flächengröße erwiesen sich als signifikant nach der multivariaten Methode. Zwei Gemeinschaft in locker bewaldeten oder offenen Bereichen wurden durch die Baumdeckung und den Corg-Gehalt des Bodens signifikant von den dicht bewaldeten Bereichen getrennt. Die Spearman Analyse ergab nur für 20 Arten eine signifikante Beziehung zu den Umweltparametern. Die meisten Arten können als euryöke Waldarten oder als Arten humusreicher Wälder angespro-

chen werden. Nach der Rarefaction Methode war die Artenzahl in den locker bewaldeten und offenen Bereichen höher als in den dicht bewaldeten. Die Zahl gefährdeter Arten stieg von den bewaldeten zu den offenen Habitaten an. Offensichtlich weisen die Kurzflügelkäfer nur eine geringe Beziehung zu Bodenparametern und der Baumdeckung auf. Sie scheinen dagegen mehr von dem Vorhandensein von Biochoren, wie Nestern, spezifischen Sukzessionsstadien bei der Holzzersetzung und anderen kleinen Habitaten, abzuhängen.

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Appendix

List of rove beetle species recorded in the investigated sites of Geesthacht

Acidota cruentata (Mannh., 1830)
Acrotona aterrima (Grav., 1802)
Acrotona exigua (Er., 1837)
Acrotona parens (Muls.Rey, 1852)
Acrotona silvicola (Kr., 1856)
Aleochara bilineata Gyll., 1810
Aleochara binotata Kr., 1856
Aleochara brevipennis Grav., 1806
Aleochara ruficornis Grav., 1802
Aleochara sparsa Heer, 1839
Aloconota gregaria (Er., 1839)
Amischa analis (Grav., 1802)
Amischa decipiens (Shp., 1869)
Anotylus insecatus (Grav., 1806)
Anotylus mutator (Lohse, 1963)
Anotylus rugosus (F., 1775)
Anotylus sculpturatus (Grav., 1806)
Anotylus tetracarinatus (Block, 1799)
Aploderus caelatus (Grav., 1802)
Astenus procerus (Grav., 1806)
Atheta amicula (Steph., 1832)
Atheta britanniae Bernh.Scheerp., 1926
Atheta cadaverina (Bris., 1860)
Atheta celata Brundin, 1948
Atheta crassicornis (F., 1792)
Atheta elongatula (Grav., 1802)
Atheta euryptera (Steph., 1832)
Atheta fungi (Grav., 1806)
Atheta gagatina (Baudi, 1848)
Atheta graminicola (Grav., 1806)
Atheta gyllenhali (Thoms., 1856)
Atheta harwoodi Will., 1930
Atheta laticollis (Steph., 1832)
Atheta longicornis (Grav., 1802)
Atheta macrocera (Thoms., 1856)
Atheta malleus Joy, 1913
Atheta melanocera (Thoms., 1856)
Atheta negligens (Muls.Rey, 1873)
Atheta nigra (Kr., 1856)
Atheta nigricornis (Thoms., 1852)
Atheta oblita (Er., 1839)
Atheta orbata (Er., 1837)
Atheta palustris (Kiesw., 1844)
Atheta ravilla (Er., 1839)
Atheta sodalis (Er., 1837)
Atheta tmolosensis Bernh., 1940
Atheta triangulum (Kr., 1856)
Atheta trinotata (Kr., 1856)
Autalia rivularis (Grav., 1802)
Bledius erraticus Er., 1839
Bledius femoralis (Gyll., 1827)
Bledius gallicus (Grav., 1806)
Bledius occidentalis Bondr., 1907
Bledius opacus (Block, 1799)
Bledius pallipes (Grav., 1806)
Bolitobius castaneus (Steph., 1832)
Bolitobius cingulatus (Mannh., 1830)
Bolitobius inclinans (Grav., 1806)
Bolitochara mulsanti Shp., 1875
Bryophacis crassicornis (Maekl., 1847)
Callicerus obscurus Grav., 1802
Calodera aethiops (Grav., 1802)
Calodera nigrita Mannh., 1830
Carpelimus corticinus (Grav., 1806)
Carpelimus pusillus (Grav., 1802)
Carpelimus subtilis (Er., 1839)
Coenonica puncticollis Kr., 1857
Coprophilus striatulus (F., 1792)
Cordalia obscura (Grav., 1802)
Cypha longicornis (Payk., 1800)
Deinopsis erosa (Steph., 1832)
Diglotta mersa (Hal., 1837)
Dinaraea aequata (Er., 1837)
Dinaraea angustula (Gyll., 1810)
Dinarda maerkelii Kiesw., 1843
Drusilla canaliculata (F., 1787)
Enalodroma hepatica (Er., 1839)
Euaesthetus bipunctatus (Ljungh, 1804)
Euryporus picipes (Payk., 1800)
Eusphalerum sorbi (Gyll., 1810)
Falagrioma thoracica (Curt., 1833)
Gabrius breviventer (Sperk, 1835)
Gabrius osseticus (Kol., 1846)
Gabrius splendidulus (Grav., 1802)
Geostiba circellaris (Grav., 1806)
Gyrohypnus angustatus Steph., 1833
Gyrohypnus liebei Scheerp., 1926
Gyrophaena affinis Mannh., 1830
Habrocerus capillaricorne (Grav., 1806)
Heterothops dissimilis (Grav., 1802)
Ilyobates bennettii Donishorpe, 1914
Ilyobates nigricollis (Payk., 1800)
Ischnosoma longicornis Maekl., 1847
Ischnosoma splendidum (Grav., 1806)

Ityocara rubens (Er., 1837)
Lamprinodes saginatus (Grav., 1806)
Lathrimaeum atrocephalum (Gyll., 1827)
Lathrimaeum unicolor (Marsh., 1802)
Lathrobium brunnipes (F., 1792)
Lathrobium fovulum Steph., 1833
Lathrobium fulvipenne (Grav., 1806)
Lathrobium impressum Heer, 1841
Lathrobium longulum Grav., 1802
Lathrobium pallidipenne Hochh., 1851
Lathrobium pallidum Nordm., 1837
Lathrobium volgense Hochh., 1851
Leptusa fumida (Er., 1839)
Leptusa pulchella (Mannh., 1830)
Leptusa ruficollis (Er., 1839)
Lesteva longoelytrata (Goeze, 1777)
Liogluta alpestris (Heer, 1839)
Liogluta granigera (Kiesw., 1850)
Liogluta longiuscula (Grav., 1802)
Liogluta microptera (Thoms., 1867)
Liogluta oblongiuscula (Shp., 1869)
Liogluta pagana (Er., 1839)
Lomechusa emarginata (Payk., 1789)
Lomechusa paradoxa Grav., 1806
Lordithon exoletus(Er., 1839)
Lordithon lunulatus (L., 1761)
Lordithon thoracicus (F., 1777)
Lordithon trinotatus (Er., 1839)
Manda mandibularis (Gyll., 1827)
Medon piceus (Kr., 1858)
Metopsia similis Zerche, 1998
Mniusa incrassata (Muls.Rey, 1852)
Mycetoporus baudueri Muls.Rey, 1875
Mycetoporus bimaculatus Kr., 1857
Mycetoporus clavicornis (Steph., 1832)
Mycetoporus despectus Strand, 1969
Mycetoporus eppelsheimia Fagel, 1965
Mycetoporus erichsonanus Fagel, 1965
Mycetoporus lepidus (Grav., 1802)
Mycetoporus mulsanti Ganglb., 1895
Mycetoporus punctus (Gyll., 1810)
Mycetoporus rufescens (Steph., 1832)
Myllaena minuta (Grav., 1806)
Myrmecocephalus concinna (Er., 1839)
Neobisnius procerulus (Grav., 1806)
Ocalea badia Er., 1837
Ocalea picata (Steph., 1832)
Ocypus ater (Grav., 1802)
Ocypus brunnipes (F., 1781)
Ocypus compressus (Marsh., 1802)
Ocypus melanarius (Heer, 1839)
Ocypus nero (Fald., 1835)
Ocypus olens (Müll., 1764)
Ocypus ophthalmicus (Scop., 1763)
Ocyusa maura (Er., 1837)
Oligota pumilio Kiesw., 1858
Oligota pusillima (Grav., 1806)
Olophrum piceum (Gyll., 1810)
Omalium caesum Grav., 1806
Omalium rivulare (Payk., 1789)
Omalium rugatum Muls.Rey, 1880
Ontholestes murinus (L., 1758)
Othius angustus Stephens, 1832
Othius punctulatus (Goeze, 1777)
Othius subuliformis Stephens, 1832
Ousipalia caesula (Er., 1839)
Oxypoda abdominalis (Mannh., 1830)
Oxypoda acuminata (Steph., 1832)
Oxypoda alternans (Grav., 1802)
Oxypoda annularis Mannh., 1830
Oxypoda brachyptera (Steph., 1832)
Oxypoda brevicornis (Steph., 1832)
Oxypoda exoleta Er., 1839
Oxypoda formosa Kr., 1856
Oxypoda opaca (Grav., 1802)
Oxypoda procerula Mannh., 1830
Oxypoda spectabilis Märk., 1844
Oxypoda vittata Märk., 1842
Oxytelus fulvipes Er., 1839
Philonthus carbonarius (Grav., 1810)
Philonthus cognatus Steph., 1832
Philonthus decorus (Grav., 1802)
Philonthus fimetarius (Grav., 1802)
Philonthus fumarius (Grav., 1806)
Philonthus laminatus (Creutz., 1799)
Philonthus mannerheimi Fauv., 1869
Philonthus marginatus (Ström, 1768)
Philonthus nitidulus (Grav., 1802)
Philonthus politus (L., 1758)
Philonthus rotundicollis (Menetr., 1832)
Philonthus sordidus (Grav., 1802)
Philonthus succicola Thoms., 1860
Philonthus tenuicornis Rey, 1853
Phloeocharis subtilissima Mannh., 1830
Phloeonomus punctipennis Thoms., 1867
Phloeonomus pusillus (Grav., 1806)
Phloeostiba lapponica (Zett., 1838)
Phloeostiba plana (Payk., 1792)
Phyllodrepa ioptera (Steph., 1834)
Placusa tachyporoides (Waltl, 1838)

Plataraea brunnea (F., 1798)
Platydracus fulvipes (Scop., 1763)
Platydracus latebricola (Grav., 1806)
Platydracus stercorarius (Ol., 1795)
Platystethus arenarius (Fourcr., 1785)
Proteinus brachypterus (F., 1792)
Proteinus ovalis Steph., 1834
Quedius aridulus Janss., 1939
Quedius assimilis(Nordm., 1837)
Quedius boops (Grav., 1802)
Quedius cinctus (Payk., 1790)
Quedius cruentus (Ol., 1795)
Quedius fuliginosus (Grav., 1802)
Quedius fumatus (Steph., 1833)
Quedius lateralis (Grav., 1802)
Quedius limbatoides Coiff., 1963
Quedius limbatus (Heer, 1834)
Quedius lucidulus Er., 1839
Quedius maurus (Sahlb., 1830)
Quedius mesomelinus (Marsh., 1802)
Quedius molochinus (Grav., 1806)
Quedius nemoralis Baudi, 1848
Quedius nigriceps Kr., 1857
Quedius nitipennis (Steph., 1833)
Quedius picipes (Mannh., 1830)
Quedius tristis (Grav., 1802)
Quedius umbrinus Er., 1839
Quedius xanthopus Er., 1839
Rugilus rufipes (Germ., 1836)
Scopaeus sulcicollis (Steph., 1833)
Sepedophilus immaculatus (Steph., 1832)
Sepedophilus marshami (Steph., 1832)
Sepedophilus pedicularius (Grav., 1802)
Sepedophilus testaceus (F., 1792)
Staphylinus erythropterus L., 1758
Stenus bimaculatus Gyll., 1810
Stenus boops Ljungh, 1804
Stenus carbonarius Gyll., 1827
Stenus clavicornis (Scop., 1763)
Stenus europaeus Puthz, 1966
Stenus geniculatus Grav., 1806
Stenus humilis Er., 1839
Stenus impressus Germ., 1824
Tachinus corticinus Grav., 1802
Tachinus fimetarius Grav., 1802
Tachinus humeralis Grav., 1802
Tachinus laticollis Grav., 1802
Tachinus marginellus (F., 1781)
Tachinus pallipes Grav., 1806
Tachinus signatus Grav., 1802
Tachinus subterraneus (L., 1758)
Tachyporus atriceps Steph., 1832
Tachyporus dispar (Payk., 1789)
Tachyporus hypnorum (F., 1775)
Tachyporus nitidulus (F., 1781)
Tachyporus obtusus (L., 1767)
Tachyporus quadriscopulatus Pand., 1869
Tachyporus solutus Er., 1839
Thamiaraea cinnamommea (Grav., 1802)
Thiasophila angulata (Er., 1837)
Thinonoma atra (Grav., 1806)
Xantholinus laevigatus Jac., 1847
Xantholinus linearis (Ol., 1795)
Xantholinus longiventris Heer, 1839
Xantholinus tricolor (F., 1787)
Zyras cognatus (Märk., 1842)
Zyras funestus (Grav., 1806)
Zyras haworthi (Steph., 1832)
Zyras humeralis (Grav., 1802)
Zyras laticollis (Märk., 1844)
Zyras limbatus (Payk., 1789)