Large carabids (Coleoptera: Carabidae) prevail in ageing forests: Mean Individual Biomass and *Carabus* dominance as indicators of succession in North Rhine-Westphalian beech forests[1]

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Abstract: Successional processes as an important element of natural ecosystems not only proceed in a characteristic manner that is usually balanced, yet influenced by various site-dependent factors, but this balance is also necessary to protect especially anthropogenic forests from noxious influences, e.g. pest infestation. In successional processes the visual features of the habitat change along with its species composition.
Over the vegetation period 2009, we studied epigaeic ground beetle (Coleoptera: Carabidae) composition in 14 North Rhine-Westphalian beech stands of increasing age (1 – 165 years) and determined the Mean Individual Biomass (MIB) of carabids as a function over forest age. As a surrogate parameter the dominance of large carabids (genus *Carabus*) was also determined.
Large carabids (3,356 / 5,536 individuals trapped) were significantly dominant over other carabid species with increasing forest age, confirmed by a significant increase in MIB. Both MIB (156.88 mg – 733.63 mg) and *Carabus* dominance (12.24 % – 91.28 %) follow a similar, characteristic curve while MIB seems to more accurately reflect successional development.
In conclusion, MIB and *Carabus*-dominance functions were observed that characterize forest succession on rich North Rhine-Westphalian soil and may help foresters to identify areas of disturbed succession. More data from this region are needed to confirm these results.

1 Introduction

Beech forests are common in Germany and represent a landscape close to the situation before anthropogenic changes were made, although today's commercial forests are often monocultures with a uniform tree age. Whole forests thus undergo a successional process.

In the run of a succession not only the visual features of the habitat change, but also its productivity functions as seen, e.g., in the species composition (Neumann 1971, Schwerk & Szyszko 2006).

Since carabids (Coleoptera: Carabidae) colonize numerous different habitats and microhabitats they are excellent bioindicators for pedobiological as well as forest conditions and also the state of succession (Den Boer 1987, Müller-Motzfeld 1989, Szyszko 1990, Rainio & Niemelä 2003, Müller-Motzfeld 2004b, Schwerk et al. 2006).

Carabid species composition in successional processes has been extensively studied in Scots pine or spruce monocultures in the northern hemisphere (Szyszko 1990, Koivula & Niemelä 2002, Phillips et al. 2006, Pohl et al. 2007, Schwerk 2008). Here, the mean individual biomass of carabids (MIB) is a well-studied parameter that is closely related to the stage of forest succession (Serrano & Gallego 2004, Cárdenas & Hidalgo 2007, Schwerk & Szyszko 2007, Schwerk 2008, Schwerk & Szyszko 2009).

For the area presently studied data were elaborated showing a constant size distribution of *Carabus violaceus*, thus indicating a rather constant level of degradation (Schreiner et al. 2011). The large

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Site	Age (years)	Size (ha)	Byplants	Ordinance Survey Map	Carabid No.	Thereof Carabus spec.
1	1	0.5	Few larch & cherry	4609/1	744	91
2	1	0.9	5% cherry	4609/1	129	91
3	3	0.5	None	4510/3	163	49
4	4	0.4	None	4609/1	139	56
5	13	1.6	None	4510/3	125	65
6	20	0.8	None	4609/1	866	276
7	26	1.8	10% larch	4609/1	352	307
8	28	0.6	Few larch & cherry	4609/1	699	579
9*	52	2.2	10% larch	4609/1	277	256
10	78	2.5	10% oak	4609/1	477	344
11	146	1.0	10-year -old beech	4609/1	586	501
12	146	4.0	None	4609/1	442	375
13	152	3.5	10% oak	4609/1	273	125
14	165	3.1	None	4609/1	264	241
Total					5,536	3,356

Tab. 1: Study sites and carabid / *Carabus* spec. catching results over the vegetation period 2009 (beech).
*Vandalism

number of *C. violaceus* trapped was not unexpected due to the richness of loam soil in the Ruhr valley and adjacent hilly country. In the present paper data are presented on the numbers of carabid individuals as well as individuals of the genus *Carabus*, the resulting *Carabus* dominance and, finally, the carabid MIB. From the resulting figures, North Rhine-Westphalian foresters may be able, e.g., to detect areas of ecological imbalance, such as those with increased susceptibility to pest infestation, by comparing their own findings to the present data. The chance to define the outbreak probability for pest epidemics by relating MIB to the

No.	Species	Sites													
		1	2	3	4	5	6	7	8	9*	10	11	12	13	14
1	*Cicindela campestris*	7	-	16	-	1	-	-	-	-	-	-	-	-	-
2	*Calosoma inquisitor*	-	-	-	-	-	-	-	-	1	1	1	-	-	-
3	*Carabus auratus*	-	1	-	1	-	-	-	-	-	-	-	-	-	-
4	*Carabus auronitens*	-	-	-	-	17	-	-	-	-	-	-	-	-	-
5	*Carabus cancellatus*	5	-	-	4	-	-	-	-	5	-	-	-	-	13
6	*Carabus coriaceus*	24	-	-	-	-	21	31	18	6	12	23	17	1	18
7	*Carabus monilis*	-	3	-	-	-	1	-	-	-	-	-	-	-	-
8	*Carabus nemoralis*	2	1	1	3	1	73	3	3	3	6	-	1	1	10
9	*Carabus problematicus*	8	13	11	1	1	8	85	33	13	6	121	9	4	6
10	*Carabus violaceus*	52	73	37	47	46	173	188	525	229	320	357	348	119	194
11	*Cychrus attenuatus*	-	-	-	-	5	-	-	-	-	-	-	-	-	-
12	*Leistus rufomarginatus*	-	1	-	-	-	1	1	13	1	-	4	12	1	1
13	*Nebria brevicollis*	23	1	1	-	-	90	-	2	-	2	-	-	3	-
14	*Nebria salina*	-	-	-	-	-	-	-	-	-	-	-	-	1	1
15	*Notiophilus biguttatus*	8	4	-	1	-	1	-	-	-	-	-	-	2	-
16	*Notiophilus palustris*	4	-	-	3	-	-	-	-	-	-	-	-	-	-
17	*Bembidion lampros*	19	3	-	-	-	-	1	-	-	-	-	-	-	-
18	*Stomis pumicatus*	1	-	-	-	-	-	-	-	1	2	1	1	-	-
19	*Poecilus cupreus*	1	-	-	-	-	-	-	-	-	-	-	-	-	-
20	*Poecilus versicolor*	261	11	47	5	1	-	-	-	-	-	-	-	-	-
21	*Pterostichus cristatus*	2	-	-	-	-	39	3	31	-	7	-	-	21	-
22	*Pterostichus niger*	-	-	10	-	50	-	-	-	-	-	-	-	-	-
23	*P. oblongopunctatus*	4	9	-	1	1	86	3	1	-	18	4	2	57	-
24	*Pterostichus strenuus*	-	-	1	1	-	-	-	-	-	-	-	-	-	-
25	*Pterostichus vernalis*	1	-	2	-	-	-	-	-	-	-	-	-	-	-
26	*Abax ovalis*	-	-	-	-	-	-	-	-	-	-	-	-	4	-
27	*Abax parallelepipedus*	5	7	1	55	1	97	36	72	18	101	71	49	59	21
28	*Abax parallelus*	-	-	-	13	-	256	-	-	-	-	-	-	-	-
29	*Limodromus assimilis*	-	-	-	-	-	19	-	1	-	-	-	-	-	-
30	*Agonum sexpunctatum*	275	1	-	-	-	-	-	-	-	-	-	-	-	-
31	*Calathus rotundicollis*	-	-	-	-	-	1	-	-	-	-	-	-	-	-
32	*Amara aulica*	-	-	9	-	-	-	-	-	-	-	-	-	-	-
33	*Amara convexior*	1	-	6	1	-	-	-	-	-	-	-	-	-	-
34	*Amara lunicollis*	1	1	-	3	-	-	-	-	-	-	-	-	-	-
35	*Amara ovata*	1	-	-	-	-	-	-	-	-	-	-	-	-	-
36	*Amara plebeja*	2	-	-	-	-	-	-	-	-	-	-	-	-	-
37	*Amara similata*	2	-	3	-	-	-	-	-	-	-	-	-	-	-
38	*Anisodactylus binotatus*	24	-	1	-	-	-	-	-	-	-	-	-	-	-
39	*Trichotichnus nitens*	-	-	-	-	-	-	-	-	-	2	4	2	-	-
40	*Harpalus laevipes*	-	-	-	-	1	-	-	-	-	-	-	1	-	-
41	*Harpalus rufipalpis*	1	-	-	-	-	-	-	-	-	-	-	-	-	-
42	*Harpalus rufipes*	10	-	17	-	-	-	-	-	-	-	-	-	-	-
	Total	744	129	163	139	125	866	352	699	277	477	586	442	273	264

Tab. 2: Catching results by carabid species on individual study sites (beech).
*Vandalism

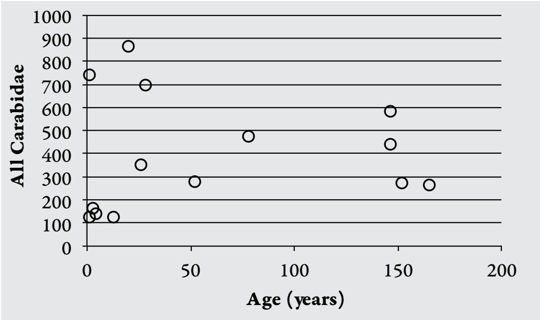

Fig. 1: Relationship between age of the stands and number of carabid individuals; r = 0.181, n.s.

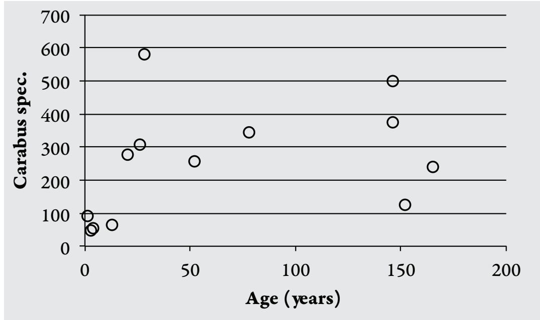

Fig. 2: Relationship between age of the stands and number of *Carabus* individuals; r = 0.589, p < 0.05.

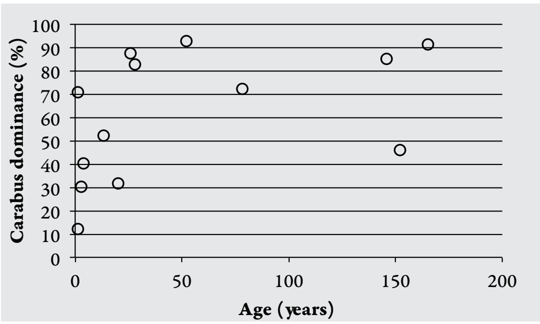

Fig. 3: Relationship between age of the stands and *Carabus* dominance (%); r = 0.639, p < 0.05.

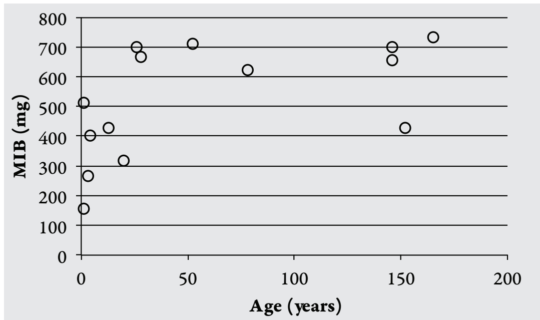

Fig. 4: Relationship between age of the stands and mean individual biomass of carabids (mg); r = 0.665, p < 0.01.

age of the habitat has already been described for commercial forests in Poland (Szyszko 1990).

2 Materials and Methods

Fourteen beech-forest sites in the North Rhine-Westphalian Ruhr valley were studied over the complete vegetation period 2009 (Tab. 1). Carabids (Coleoptera: Carabidae) were collected by ground traps (Barber 1931), and determined to the species. Three traps were placed in each site, keeping a distance of 5-10 m between individual traps. Boundary effects were avoided by placing the traps at least 20 m away from the sites' edges (Den Boer 1977).

Collected carabids were stored in commercial EtOH 70 % v/v before determination.

In addition to counting the individuals trapped, the dominance of the genus *Carabus* as percentage of the catches of each study site was determined. The individual biomass was obtained by using values from Szyszko (1990) or applying the mathematical term according to Szyszko (1983) to length data by Müller-Motzfeld (2004a).

Correlations between the parameters determined and age of the stands were tested using the Spearman rank correlation coefficient (Sachs 1984).

3 Results

A total of 5,536 carabid beetles were trapped on 14 beech stands in 2009 (Tab. 1). Due to vandalism on site No. 9 the number of individuals may not reflect the full carabid yield of this site. Of all carabids trapped, 60.62 % (3,356 individuals) belonged to the genus *Carabus* (Tab. 1). Differences in the species composition of the tested sites occurred but were negligible for the analyses presented. The complete list of species detected in the beech stands analyzed is given in Tab. 2.

While the total number of carabids remained almost constant (r = 0.181, n.s.) with increasing forest age (Fig. 1), with regard to the number of *Carabus* individuals a significant increase (r = 0.589, p < 0.05) was observed as beech stands grew older (Fig. 2). As is depicted in Fig. 3, the *Carabus* dominance shows an increase over time (12.24 % – 91.28 %) which is more pronounced (r = 0.639, $p < 0.05$) as it delineates a hypothetical curve similar to a horizontal parabola. Finally, MIB values (156.88 mg – 733.63 mg) deviate from the parabola shape even less (Fig. 4) and also reveal the highest Spearman r = 0.665, which is again statistically significant ($p < 0.01$).

4 Discussion

Studying the mean individual biomass (MIB) of Carabidae and comparing the data to previous findings (Serrano & Gallego 2004, Cárdenas & Hidalgo 2007, Schwerk & Szyszko 2006, Schwerk & Szyszko 2007, Schwerk 2008) reveals similarities and differences. For instance, the increase in MIB until reaching a plateau value (representing the ecological "capacity" of a study site) is similar to previous findings while the rapid onset and high baseline MIB (low level of initial site degradation) are rather untypical for forests on sandy soil in Western Poland (Schwerk 2008, Schwerk & Szyszko 2008). However, the present data suffer from the short observation period of one year. Since succession could not be followed in one particular forest stand through the years, different stands of variable age were used. These may differ in terms of certain geological or botanical prerequisites, although the species composition appears to be comparable. The number of large-size carabid individuals (genus *Carabus*) increases over the run of succession according to a host of previous data (e.g. Magura et al. 2002). In the highly populated area studied, data on *Carabus* numbers thus reflect the literature findings, although occasional catches were affected by vandalism. When looking at the figures for the *Carabus* dominance and MIB (cf. Fig. 3 and 4), both appearing as a part of a logistic growth function, it seems that the MIB values do not deviate from an "ideal curve" (the true function of succession development) as much as the *Carabus*-dominance values. This is perfectly understandable as MIB – with biomass data for all carabid species detected – contains a lot more information than dominance data for only one carabid genus (that could even be missing on very poor soils, for example, Schwerk 2008, Schwerk & Szyszko 2008). Yet, both methods lead to a similar curve that can be used as a standard for comparison to local catching results in order to e.g. possibly predict pest attacks (Szyszko 1990). In cases where carabids cannot be caught alive and weighed (Pgl Lasy Państwowy 2004), it will be easier for foresters to identify and count *Carabus* individuals and divide by the total carabid catching result than to determine every trapped ground beetle to the species. In order to further specify these curves more data (more sites or prolonged observation time) are necessary.

5 Conclusion

On rich North Rhine-Westphalian soil MIB and *Carabus* dominance characterize forest succession and may help foresters to identify areas where succession is disturbed. More data from the Ruhr valley are needed to confirm these results.

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