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Habitat choice experiments with dung beetles (Coleoptera: Staphylinidae, Hydrophilidae, Scarabaeidae)

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Summary

A choice experiment was performed to test which kind of dung the dung-dwelling Coleoptera prefer. The dung of the three farm animals, sheep, cows and horses, were investigated for the two habitat situations, pasture and adjacent forest. A Randomized Block Design was selected for statistical analysis. . Two replicate blocks were exposed at each site for the two habitat situations, each having thirty feces pads of approximately 350 g wet weight of each kind of feces. The results showed that species richness was highest in sheep dung and lowest in cow dung, whereas no clearly significant differences were found between the forest and pasture habitats. However, significant differences between forest and pasture were exhibited for several species of Hydrophildae, Scarabeidae and Staphylinidae. On average, species of Hydrophilidae were more abundant on the pasture, and Scarabaeidae in the forest. In Staphylinidae, species preferring forest conditions and those preferring pasture conditions exist. Regarding single species, higher abundances were found in horse and sheep feces than in cow feces. None of the thirty species investigated were more abundant in cow feces than in horse or sheep feces.

Keywords: dung preference, species richness, habitat preference

Zusammenfassung

Habitatwahl Experinmente mit Dung bewohnenden Käfern (Coleoptera: Staphylinidae, Hydrophilidae, Scarabaeidae

Um Präferenzen von Dungkäfern zu studieren, wurde ein Wahlexperiment durchgeführt. Der Dung der drei Haustierarten, Schaf, Pferd und Kuh, wurde unter den zwei Habitatbedingungen, Weide oder angrenzender Wald, untersucht. Als Methode wurde das Randomisierte Block Diagramm gewählt, um anschließend statitisch signifikante Ergebnisse zu erzielen. Dazu wurden 30 Dunghaufen der drei Tierarten zu einem Blockdiagramm in jeder der beiden Habitatbedingungen zusammengestellt. Jeweils zwei Wiederholungen wurden durchgeführt. Jeder Dunghaufen betrug ungefähr 350 g Frischgewicht. Die Ergebnisse belegen, dass die Artenvielfalt im Schafdung am höchsten und im Kuhdung am niedrigsten war, während zwischen den beiden Habitatsituationen, Wald und Weide, keine eindeutigen Unterschiede gefunden wurden. Dagegen lagen signifikante

Unterschiede zwischen Wald und Weide für einzelne Arten der Hydrophilidae, Scarabaeidae und Staphylinidae vor. Im Durchschnitt waren Arten der Hydrophilidae auf der Weide häufiger als im Wald, Arten der Scarabaeidae im Wald häufiger als auf der Weide. Bei den Staphylinidae kamen beide Präferenzen vor. Die einzelnen Arten hatten höhere Abundanzen im Pferde- oder Schafdung als im Kuhdung. Keine der Art war im Kuhdung häufiger als im Pferde- oder Schafdung.

Schlüsselwörter: Dung Präferenz, Artenvielfalt, Habitatpräferenz

Introduction

Dung-heaps, such as cowpats, are micro-habitats with a narrow spatial and temporal restriction but are a high quality food source. These micro-habitats have a patchy distribution and undergo heavy changes in succession such as fungi, carrion, and decaying fruits (MOHR 1943, VALIELA 1974, IRMLER & LIPKOW in press).

Many dung-inhabiting animals are coprobiontic. Coprobiontic species feed and reproduce exclusively in dung, e.g. *Platysthetus arenarius* (Staphylinidae), *Geotrupes, Onthophagus, Aphodius* (Scarabaeidae), *Sphaeridium, Cercyon* (Hydrophilidae), dung-flies (Sphaeroceridae, Scatophagidae), and dung-midges (Scatopsidae). Coprophilous species are less restricted. They feed and reproduce in dung or in other decaying organic matter such as rotting plant matter, fungi, carrion, etc. Many Staphylinidae species, Sphaeridiinae (Hydrophilidae), Histeridae, Ptilidae, Diptera, and Gamasidae (mites) are coprophilous since they do not depend on dung as a food source (LIPKOW 2011, BOUKAL et. al. 2008). Most of the dung-inhabiting Staphylinidae species such as *Philonthus* and *Aleochara* are also found in other organic matter, which contain larvae of diptera (KOCH 1989).

Due to the spatially isolated distribution and unpredictable occurrence of dung heaps, dung-inhabiting animals must have a high mobility; they must either be able to fly, have high sensitive chemo-sensors, undergo a phoresis, or have short larval development.

Most of the coprobiontic and coprophilous Coleoptera are found in dung of herbivore mammals such as cows, horses, and sheep. They are found less often in dung of carnivore mammals (fox, dog), and are rarely found in the excrement of birds (FREUDE et al. 1964, 1969, 1971, 1974, 2012).

Some dung-inhabiting beetles are presumed to prefer dung of sheep, horses or cows. At present, it is not clear if these findings are based on accidental occurrences or if the species really are dependent upon the specific dung of herbivore mammals. We assume that the dung-inhabiting beetles also use the excrements of other herbivore mammals if their preferred specific dung is not available.

In this study, we aimed to answer the following questions using a Randomized Block Design for the statistical analysis of a choice experiment in the field of a common agrarian landscape with small forests and pastures): (1) Which habitat conditions (forest margin or open pasture) are favored by most of the species living in dung? (2) Which type of dung (sheep, horses or cows) is preferred? (3) How do the single species behave if they can choose between different dung types and different habitat conditions?

Sites and methods

The investigation was performed in Schleswig-Holstein (northern Germany) near Kiel. The climate can be characterized as moderate Atlantic humid climate; over the past 30 years, there has been an average of 782 mm annual rainfall and an average of 9.4 °C annual temperature. In 2012, the climate was slightly cooler and dryer, with a mean of 8.7°C and a total of 775 mm annual rainfall.

Two locations were selected: Klein Barkau (54°12.45′N, 10°07.24′E), approximately 10 km SSW of Kiel, and Blumenthal (54°14.20′N, 9°58.33′E), approximately 15 km WSW of Kiel. A pasture and a mixed deciduous forest were selected at each site. A Randomized Block Design experiment was installed at each site for each habitat. In each Randomized Block Design, a total of 30 pads were deposited, 10 each of cow, horse and sheep dung pads for a total of 120 pads altogether for the 2 sites and 2 habitats. Each pad had a wet weight of approximately 350 g. The experiment lasted from 25.4.2012 - 19.09.2012 in Klein Barkau and from 26.6.2012 - 21.9.2012 in Blumenthal. The fresh pads were initially investigated 3 days after exposure and then a second time 6 days after exposure. A few days after that, fresh pads were deposited for the next sampling period. Altogether, the pads were renewed 7 times in Klein Barkau and 5 times in Blumenthal.

In order to sample the beetles, the pads were transposed to a white dish. Subsequently, the beetles were sampled with an exhauster and identified in the laboratory. Nomenclature refers to ASSING & SCHÜLKE (2012) and FREUDE et al. (1974).

The statistical calculations were performed using the program Statistica version 6.1 (STATSOFT Inc. 2004). In case of parametric distribution, e.g. species richness values, ANOVA and Multi-factorial ANOVA were used. Abundances of species showed a non-parametric distribution. In this case, a Kruskal-Wallis ANOVA and a Multi-sample Median Test were used to compare the different types of pad. Although abundances had a non-parametrical distribution, mean values are given to avoid 0 values as medians. The U-test was used instead of ANOVA when comparing forest and pasture only.

Results

Species composition

A total of 3703 specimens were recorded that contributed to 47 species. Staphylinidae were the most frequent family with 2196 specimens and 29 species, whereas Scarabaeidae contributed to 522 specimens with 9 species and Hydrophylidae contributed to 985 specimens with 9 species (Table 1). 2013 specimens with 43 species were found in forests and 1615 specimens with 42 species were found in pastures. *Philonthus fimetarius* was the most frequent species, with 309 specimens. For both Hydrophilidae and Scarabaeidae respectively, *Cercyon lateralis* with 242 specimens and *Aphodius prodromus* with 123 specimens were most frequent.

Species richness and abundance of dung inhabiting beetles

The ANOVA shows that the species richness was highest in sheep dung and lowest in cow dung at the Klein Barkau (DF: 2, F=20.3, p<0.0001) and the Blumenthal (DF: 2, F=21.2, p<0.0001) experimental fields (Table 2). There was only a significant difference between the habitats at Klein Barkau, according to the U-test (Klein Barkau: DF: 58, t=2.6, p=0.01; Blumenthal: DF: 58, U=-0.9, p=0.38). The means for forests and pasture were similar. At Klein Barkau, the forest site showed the highest species richness; the pasture had more species at Blumenthal.

Table 1: Total abundance of species in the habitats and pad source

Species	Forest			Pasture		
	Horse	Sheep	Cow	Horse	Sheep	Cow
<u>Hydrophilidae</u>						
Cercyon haemorrhoidalis	13	10	4	17	29	2
Sphaeridium lunatum	6	8	6	17	31	15
Sphaeridium bipustulatum	6	.	.	15	17	8
Cercyon melanocephalus	35	46	18	28	26	10
Cercyon impressus	20	50	11	24	65	36
Cercyon lateralis	30	52	18	36	66	40
Cryptopleurum minutum	13	12	3	16	25	7
Cercyon pygmaeus	13	14	4	23	18	17
Sphaeridium scarabaeoides	.	.	.	1	4	.
<u>Scarabaeidae</u>						
Onthophagus coenobita	2	10	3	16	28	3
Aphodius prodomus	41	34	23	14	11	.
Aphodius sphacelatus	41	33	23	11	12	.
Aphodius depressus	10	18	7	4	13	1
Geotrupes stercorosus	8	24	2	.	1	.
Aphodius ater	7	15	.	10	11	9
Aphodius fossor	2	5	7	1	1	3
Aphodius rufipes	3	19	1	15	13	5
Aphodius foetens	1	1	.	.	.	.
<u>Staphylinidae</u>						
Philonthus splendens	17	26	13	26	32	15
Philonthus tenuicornis	12	12	11	21	14	2
Philonthus varians	11	9	4	28	40	9
Tachinus rufipes	47	44	24	20	37	11
Philonthus marginatus	4	.	3	12	7	2
Philonthus fimetarius	91	84	63	32	25	14
Oxytelus laqueatus	58	55	30	32	61	27
Anotylus tetracarinatus	36	31	31	33	48	30
Tachinus laticollis	50	52	31	8	25	17
Autalia rivularis	23	35	10	17	28	19
Megarthrus denticollis	8	14	6	17	13	4
Philonthus puella	3	3	4	7	1	.
Philonthus albipes	.	3	1	3	2	1
Megarthrus depressus	7	18	4	12	10	2
Philonthus cruentatus	.	.	.	2	3	2
Gyrohypnus punctulatus	3	14	2	2	8	1
Tachinus lignorum	18	17	15	9	9	6
Tachinus humeralis	15	14	6	1	2	.
Tachinus pallipes	28	26	14	2	2	7
Megasternum obsurum	3	6	2	10	6	5
Philonthus parvicornis	.	1	.	3	.	.
Platystethus arenarius	2	6	.	5	5	1
Ontholestes tesselatus	1	2	1	.	1	.
Tachinus proximus	4	10	7	.	.	.
Tachinus marginellus	4	20	1	5	8	.
Anotylus sculpturatus	14	12	3	5	13	1
Quedius scintillans	3	8	6	.	.	.
Quedius cinctus	15	10	7	.	.	.

The multi-factorial ANOVA using habitat type and dung type as independent variables showed that the most species were found in sheep dung at the Klein Barkau forest, whereas the most species were found in sheep dung at the pasture in Blumenthal (Table 3). Overall, dung type and habitat type significantly influenced the species number in the dung pats, with dung type having the greatest influence (Klein Barkau: total: DF: 1, F: 1948, $p < 0.001$; habitat: DF: 1:, F: 9.9, $p=0.003$, dung type: FG: 2, F: 30.4, $p<0.001$, Habitat*dung type: DF: 2, F: 5.8, $p=0.005$; Blumenthal: total: DF: 1, F: 569, $p < 0.001$; habitat: DF: 1:, F: 2.2, $p=0.14$, dung type: DF: 2, F: 27.0, $p<0.001$, habitat*dung type: DF: 2, F: 6.2, $p=0.004$).

Table 2: Mean species richness of dung inhabiting beetles in the two habitats and the three dung types

		Klein Barkau		Blumenthal	
	n	Mean	S.D.	Mean	S.D.
Forest	30	24.6	5.2	12.0	5.9
Pasture	30	21.3	6.6	13.6	6.0
Cow	20	17.3	4.8	8.4	4.3
Horse	20	24.9	4.9	12.0	5.0
Sheep	20	26.7	4.1	17.9	4.3

Ecological preferences of species

A total of 30 species were analysed regarding their preferences to either the two habitat types as well as to one of the three dung types (Table 4). For 4 species, e.g. *Sphaeridium scarabaeoides, Aphodius fossor, Aphodius rufipes,* and *Anotylus tetracarinatus,* significant differences could be found, neither between the two habitat types nor between the three dung types. Nine species showed significant differences between only the two habitat types. *Sphaeridium lunatum, S. bipustulatum* and *Philonthus marginatus* were significantly more frequent in the pasture than in the forest, whereas *Aphodius prodromus, A. sphacelatus, Onthophagus coenobita, Tachinus lignorum, Tachinus pallipes,* and *Philonthus fimetarius* were more frequent in the forest than in the pasture.

Table 3: Species richness; same exponents indicate homogenous groups according to the Multi-factorial ANOVA

Farm animal	Kirchbarkau				Blumenthal			
	Forest		Pasture		Forest		Pasture	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Cow	^{c} 20.8	4.1	^{d} 13.8	2.1	^{d} 6.4	3.9	^{c} 10.3	3.9
Horse	^{bc} 24.1	4.6	^{ab} 25.6	5.4	^{bc} 13.9	4.8	^{c} 10.2	4.7
Sheep	^{a} 28.8	3.6	^{b} 24.5	3.6	^{b} 15.6	4.7	^{a} 20.2	2.4

Table 4: Means and Standard deviations of dung beetle species; underlined values differ significantly ($p<0.05$) according to U-test, dung type preferences differ significantly ($p < 0.05$) at different exponents according to the Kruskal-Wallis ANOVA

Species	Habitats		Dung-type		
	Forest	Pasture	Cow	Sheep	Horse
Sphaeridium lunatum	0.3 ± 0.6	1.1 ± 1.2	0.5 ± 0.7	0.6 ± 0.8	1.0 ± 1.3
Sphaeridium bipustulatum	0.1 ± 0.4	0.7 ± 0.9	0.2 ± 0.5	0.5 ± 1.0	0.4 ± 0.7
Sphaeridium scarabaeoides	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0	0.1 ± 0.4	0.1 ± 0.2
Cercyon haemorhoidalis	0.5 ± 0.7	0.8 ± 0.9	[b] 0.2 ± 0.4	[a] 1.0 ± 0.9	[a] 0.8 ± 0.9
Cercyon melanocephalus	1.7 ± 1.5	1.1 ± 0.8	[b] 0.7 ± 0.8	[a] 1.8 ± 1.4	[a] 1.6 ± 1.1
Cercyon impressus	1.4 ± 1.5	2.1 ± 1.8	[b] 1.2 ± 1.3	[a] 2.9 ± 1.8	[b] 1.1 ± 1.2
Cercyon lateralis	1.7 ± 1.3	2.3 ± 1.6	[b] 1.5 ± 1.2	[a] 2.9 ± 1.5	[b] 1.6 ± 1.2
Cryptopleurum minutum	0.5 ± 0.5	0.8 ± 0.8	[b] 0.2 ± 0.5	[a] 0.9 ± 0.8	[a] 0.7 ± 0.7
Aphodius prodromus	1.6 ± 1.9	0.4 ± 1.6	0.6 ± 1.1	1.1 ± 1.6	1.4 ± 1.8
Aphodius sphacelatus	1.6 ± 1.9	0.4 ± 1.6	0.6 ± 1.1	1.1 ± 1.5	1.3 ± 1.8
Aphodius depressus	0.6 ± 0.9	0.3 ± 0.6	[b] 0.2 ± 0.5	[a] 0.8 ± 1.0	[ab] 0.4 ± 0.7
Aphodius ater	0.4 ± 0.6	0.5 ± 0.5	[b] 0.2 ± 0.4	[a] 0.6 ± 0.6	[ab] 0.4 ± 0.5
Aphodius fossor	0.2 ± 0.5	0.1 ± 0.3	0.2 ± 0.4	0.7 ± 0.6	0.4 ± 0.5
Aphodius rufipes	0.4 ± 0.6	0.6 ± 0.6	0.2 ± 0.4	0.5 ± 0.6	0.8 ± 0.6
Onthophagus coenobita	0.6 ± 1.0	0.1 ± 0.1	0.1 ± 0.2	0.6 ± 1.1	0.2 ± 0.6
Geotrupes stercorosus	0.8 ± 1.2	0.3 ± 0.6	[b] 0.2 ± 0.5	[a] 1.0 ± 1.3	[ab] 0.5 ± 0.9
Tachinus rufipes	1.9 ± 2.0	1.1 ± 1.1	[b] 0.9 ± 1.1	[a] 2.0 ± 1.8	[ab] 1.7 ± 1.7
Tachinus laticollis	2.2 ± 1.2	0.8 ± 0.8	[b] 1.2 ± 0.9	[a] 1.9 ± 1.2	[ab] 1.5 ± 1.4
Tachinus lignorum	0.8 ± 1.0	0.4 ± 0.5	0.5 ± 0.7	0.7 ± 0.9	0.7 ± 0.8
Tachinus pallipes	1.1 ± 0.7	0.2 ± 0.4	0.5 ± 0.6	0.8 ± 0.8	0.8 ± 0.9
Tachinus marginellus	0.4 ± 0.6	0.2 ± 0.5	[b] 0.1 ± 0.2	[a] 0.7 ± 0.7	[b] 0.2 ± 0.5
Philonthus splendens	0.9 ± 1.3	1.2 ± 1.0	[b] 0.7 ± 0.9	[a] 1.5 ± 1.2	[ab] 1.1 ± 1.3
Philonthus fimetarius	4.0 ± 1.7	1.2 ± 1.3	1.9 ± 1.7	2.7 ± 2.1	3.1 ± 2.2
Philonthus tenuicornis	0.6 ± 0.7	0.6 ± 0.9	[b] 0.3 ± 0.6	[ab] 0.7 ± 0.8	[a] 0.8 ± 0.9
Philonthus varians	0.4 ± 0.6	1.3 ± 1.3	[b] 0.3 ± 0.6	[a] 1.2 ± 1.1	[b] 1.0 ± 1.3
Philonthus marginatus	0.1 ± 0.4	0.4 ± 0.7	0.1 ± 0.3	0.2 ± 0.5	0.4 ± 0.7
Oxytelus laqueatus	2.4 ± 2.0	2.0 ± 1.3	[b] 1.4 ± 1.2	[a] 2.9 ± 1.9	[ab] 2.3 ± 1.8
Anotylus tetracarinatus	1.6 ± 1.3	1.9 ± 0.9	1.5 ± 1.1	2.0 ± 1.3	1.7 ± 0.9
Anotylus sculpturatus	0.5 ± 0.7	0.4 ± 0.7	[b] 0.1 ± 0.3	[a] 0.6 ± 0.9	[ab] 0.5 ± 0.6
Autalia rivularis	1.1 ± 1.0	1.4 ± 0.8	[b] 0.7 ± 0.7	[a] 1.6 ± 0.9	[ab] 1.0 ± 0.9

For 9 other species, only the comparison between the dung types showed significant results. All 9 species were more frequent in sheep and horse dung than in cow dung. Only *Tachinus marginellus* were found most frequently in sheep dung. *Cercyon melanocephalus* seemed to avoid cow dung; the abundance in both sheep and horse dung was significantly higher than in cow dung. For the remaining species, either horse or sheep dung was intermediate to cow dung. The remaining 8 species had significant differences between the habitat types and the dung types. Among these species, 6 species preferred the pasture habitat and 2 two species the forest habitat. Among the last group, the preference for the forest was weak in *Anotylus sculpturatus*. Thus, only *Tachinus lateralis* seem to clearly prefer the forest in combination with sheep and horse dung. *Cercyon impressus, C. lateralis,* and *Philonthus varians* preferred the pasture and the sheep dung, whereas *C. haemorhoidalis*, *Cryptopleurum minutum*, and *Geotrupes stercorosus* preferred the pasture in combination with sheep and horse dung.

Discussion

Coprobiontic dung beetles are highly specialized regarding their food preferences. They are adapted to consume herbivore dung and play a key role in the nutrient cycles of pastures (HANSKI & CAMBEFORT 1991, GITTINGS et al. 1994). They have similar ecological requirements as thousands of species with which they are in competition for the dung food resource (HORGAN 2005, SCHOLTZ at al. 2009). The dung-dwellers dominate in northern temperate regions, whereas the tunneling and rolling Scarabaeidae are rare (HANSKI & CAMBEFORT 1991). The dung remains on the surface of the pasture and the dung beetles break it into small pieces. Therefore, succession patterns within the dung heap are observed since coprophagous and predatory insects have time to migrate into the dung (KOSKELA & HANSKI 1977). The succession pattern of sheep dung differs strongly from that of cow and horse dung. Because of its smaller size, lower water content and larger surface, sheep dung dries out more quickly and insects can not use it as long as they can use cow dung. In Mediterranean or tropical regions, dung is buried or rolled away within a few hours. Thus, a long-term succession does not exist (HIRSCHBERGER & BAUER 1994). Specialization can occur as a result of competition and scarcity of dung resources (HANSKI 1989). Previous research indicates that dung beetles differ in their preference for the dung type (ESTRADA et al. 1993), the composition of dung (DOUBE 1987), and the odor of dung (DORMONT et al. 2004).

We found no differences in species richness between the three types of dung. This may be the result of the lower number of species in Middle Europe. The dung beetle communities were studied using bait traps for 9 different kinds of wild and domesticate vertebrates in the National Park Coto Donana (South Spain). Undifferentiated attraction to different herbivore feces was noted. Feces of the domesticate ungulates had a richer fauna than that of the wild herbivores (MARTIN-PIERA & LOBBO 1996). DAVIS & SCHOLTZ (2001) suggested that there are two principal factors influencing the global patterns of species richness in dung beetles, namely climate and the diversity of dung types. The latter varies among biogeographic regions due to dissimilar past and present mammalian fauna. Mammal droppings have different sizes, fiber and moisture contents as well as other physical-chemical properties depending on the diet, type of digestion and body size of the mammals (VILJANEN et al. 2010).

Our results show that most species of Scarabeidae, Hydrophilidae and Staphylinidae prefer dung of sheep, whereas dung of horse and cow are preferred less. No species investigated had a significantly higher abundance in cow than in horse or sheep dung. More than 50 % of the species investigated were significantly more abundant in sheep than in cow dung, whereas horse dung had an intermediate position. In all, there are only a few investigations about the preferences of dung types for Scarabaeidae, Hydrophilidae and Staphylinidae. WHIPPLE & HOBACK (2012) used bait traps with dung of various native and exotic herbivorous, omnivorous and carnivorous mammals in Nebraska (USA). According to their results on *Onthophagus* species, dung of omnivorous mammals (Chimpanzee and human) was much more attractive than that of pig, tiger, lion, zebra, mus, donkey and bison. They assumed that the difference in attractiveness may be attributed to the odor of the excrement because the dung of omnivorous mammals is more odorous than that of herbivorous mammals. The influence of dung odors as a selection parameter for dung beetles was studied using bait traps and labor experiments. Cow dung attracted more Scarabaeidae than horse feces (DORMONT et al. 2004). The behavioural responses of 7 scarab beetles to volatile compounds emitted by cow or horse dung were compared in laboratory olfactometer bioassays. 3 species (*Aphodius erraticus, A. scrutator, Onthophagus vacca*) were more attracted to volatile compounds from cow dung; two others (*Euonthophagus amyntas, Bubas bubalus*) showed a preference for horse dung volatiles (DORMONT et al. 2004). In olfactory bioassays, scarab beetles orientated preferentially towards the dung volatiles from the dung type they preferred in the field. *Trypocopris pyrenaeus, Anoplotrupes stercorosus, Aphodius rufipes* were more attracted to volatile compounds from sheep dung, *Onthophagus fracticornis* significantly preferred horse dung volatiles, *Aphodius haemorrhoidalis* responded positively to deer dung odors (DORMONT et al 2007).

Although sheep dung was preferred most in our experiment, the results also show that dung beetles are generalists concerning their food resource as none of the species was restricted to a single dung type. These results are supported by a number of other investigations (SCHOLTZ et al. 2009, BOUKAL et al. 2008, LIPKOW 2011, RATCLIFF & PAULSEN 2008). GROTH et al. (2011) investigated the colonisation of boar, red deer, roe deer, fallow deer dung and the domestic sheep and cow in the same region as the present investigation and also found no preference for any one dung type. They also noticed that cow dung had the lowest abundances compared to the other 5 mammals. The wide range of food utilisation has also been found by investigations made by LUZZETTO et al. (1997), who reported that *Tetraechma tarsalis* (Scrabaeidae: Canthoninae) in Central Argentina feeds on vizcacca dung pellets as well as on dung from cows that European immigrants imported to South America. Nevertheless, our experiment proved that if beetles can select between different types, a certain dung type is preferred.

We assume that the low preference of dung beetles for cow dung is referred to the high moisture content. Nearly all cow droppings used in our experiment were mushy and pasty. However, if only cow dung is available, moist dung seems to be more attractive than dry dung. BARTH et al. (1995) used fresh cow droppings and investigated the fauna colonization and the rate of degradation. Their results indicate that small differences in moisture content of 1 – 2 % which is not distinguishable by visual inspection, may have an impact on the development of Diptera and Coleoptera. In contrast to our results, BARTH et al. (1995) found that Hydrophilidae preferred pads with high moisture. An increase of 1 % of dung moisture induced 15 % increase of the number of Hydrophilidae larvae within 63 days. A rapid encrustation of the dung surface delays the pellet evaporation.

Aside from moisture, the composition of solid particles may also play a role in the attractiveness of dung. GITTING & GILLER (1998) examined the degree of resource selectivity of 5 types of dung which all have significant physical and chemical differences. Quality of cow and sheep dung differs from horse dung. The particles in cow and sheep dung were smaller than those in horse dung. In agreement with our findings, GITTING & GILLER (1998) and FINN & GILLER (2002) found highest abundances of *Aphodius* and *Geotrupes* in sheep dung, intermediate in horse and lowest in cow dung. In contrast to our results, *Sphaeridium* showed a higher abundance in cow dung than in horse or sheep dung (FINN & GILLER 2002). Although differences in nutrient contents existed among dung types, no trends in preference appear to be correlated with the nutritional value, e.g. Corg, Phosphorous, Potassium, Calcium, Magnesium, Sodium and pH (WHIPPLE & HOBACK 2012).

The size of dung pads may be also a parameter for the colonization of dung. LIPKOW (2011) reported that the large species *Philonthus splendens* prefers large dung pads of cows and horses, whereas the smaller *P. varians* prefers smaller dung pads. Since our pad had an equal size of 350 g each, this may have influenced our results. In the field, horse and cow pads weigh more than 1000 g and sheep pads weigh less than 200 g. The effect of pad size was also found by OLECHOWICZ (1974). According to FINN & GILLER (2000) the density of dung beetles increased in experimental dung pads that ranged from 0.25 to 1.5 l.

We found that more than 50 % of the species investigated preferred either pasture or forest. These results are in agreement with the findings of GROTH et al. (2011), who found significant differences between forest, bog, and different grassland habitats. This is in contrast to the statement give by KOCH (1989), who classified most of the species investigated in our experiment as ubiquistic or eurytopic. Corresponding to our findings, KOCH (1989) found that *Sphaeridium bipustulatum*, S. scarabaeoides, and S. *lunatum* preferred pastures, whereas *Tachinus humeralis, T. pallipes, T. proximus*, and *Othophagus coenobita* preferred forests. SLACHTER et al. (2008) collected beetles in bait traps with 1.5 l fresh cow dung on montane pastures and forests. Although the species composition of Scarabaeoidea and Hydrophilidae was similar among samples of both habitats, substantially more beetles of most species were found in pastures than in forests. Only 2 species were more abundant in forest samples than in pasture samples, i.e. *Anoplotrupes* (*Geotrupes*) *stercorosus* and *Aphodius distinctus*.

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