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SHORT COMMUNICATION

**Claudia Melis · Ivonne Teurlings · John D. C. Linnell
Reidar Andersen · Arnaldo Bordoni**

Influence of a deer carcass on Coleopteran diversity in a Scandinavian boreal forest: a preliminary study

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Abstract We tested the effect of a large ungulate carcass on boreal forest biodiversity by contrasting the local abundance and diversity of Coleoptera around a roe deer *Capreolus capreolus* carcass and in a control plot, between 8 August and 3 September 2003, in southern Norway. The two plots differed both in occurrence and richness of species, which were almost double at the carcass plot, although the diversity indices were similar. The higher evenness of the control plot compensated for its lower number of species, probably because the carcass plot was a disturbed area, colonized by many species, which were represented by few individuals. The number of beetles captured each day correlated positively with temperature at the control plot, but not at the carcass plot, indicating that the presence of an abundant and concentrated resource increased the local activity of Coleoptera. The carcass is likely to create a particular microclimate, which could partly buffer against extremes of air-temperature variation. These preliminary results indicate that ungulate carcasses have a significant ecological impact, which should be further investigated to improve the management and restoration of European boreal forest ecosystems.

Keywords Biodiversity · Beetles · *Capreolus capreolus* · Norway · Scavengers · Ungulates

Introduction

Ecosystem dynamics depend upon interactions between the macro- and micro-communities, which have historically received little attention in temperate and boreal forest systems (Thompson et al. 2001). Nevertheless, these interactions may play a pivotal role in community development and function, and their absence may be responsible for some failed attempts at community restoration (Wall Freckman et al.1997).

The carcasses of large herbivores that are left after a large carnivore has made a kill represent one of the most striking cases where some of the largest members of the community (e.g. wolves *Canis lupus* Linnaeus, 1758 and moose *Alces alces* Linnaeus, 1758) interact with the smallest members of the community. When a large carnivore kills an ungulate, part of the prey remains available for exploitation by a wide range of organisms. Some decomposers are specialists, like Coleoptera of the genus *Nicrophorus*, which can breed only in the presence of rodent carrion (e.g. Milne and Milne 1976; Meierhofer et al. 1999), while others are generalists that can both actively predate and scavenge a range of carcasses.

Carrion is expected to have a strong ecological impact as a specialized and ephemeral habitat (Putman 1983). The study of resource use and species distribution suggests that numerous successional changes should be observed as a result of the introduction of a large, rich, temporally limited food resource into a habitat (Sikes 1994; Finn 2001).

Recently, Towne (2000) investigated the impact of large ungulate carcasses on the vegetation and soil nutrient content in a grassland ecosystem and found that carcasses created a zone of disturbance varying with animal size and the season of the death. Five years after the death of the ungulate, the carrion plots remained

C. Melis (✉) · R. Andersen
Department of Biology,
Norwegian University of Science and Technology,
Realfagbygget, 7491 Trondheim, Norway
E-mail: claudia.melis@bio.ntnu.no
Tel.: +47-73596285

I. Teurlings
Resource Ecology Group,
Wageningen University, Wageningen,
The Netherlands

J. D. C. Linnell
Norwegian Institute for Nature Research (NINA),
Trondheim, Norway

A. Bordoni
Museo Zoologico “La Specola”,
sezione del Museo di Storia Naturale dell’ Università,
Florence, Italy

disturbed patches with vegetation differing both in composition and abundance from the surroundings. Likewise, the death of a muskox *Ovibos moschatus* (Zimmermann, 1780) has also been demonstrated to initiate a long chain of ecological processes in the tundra in which soil nutrients, chemical composition of plants, herbivores, and predators may all play a role (Danell et al. 2002).

The most basic approach to differentiate between carrion-associated and non-carrion associated taxa is the use of control measurements to evaluate the effect on the local biological community of introducing a large carrion resource into a habitat. The most broad and accurate study on how carrion resource modifies the communities was performed by Sikes (1994), by sampling Coleoptera around elk *Cervus elaphus* (Linnaeus, 1758) carcasses and in control plots in Yellowstone National Park, USA. He concluded that when a carcass is present, beetle abundance and species richness in a habitat increase significantly.

This kind of study has never been performed with large carcasses in Europe. By using the methods described by Sikes (1994), we tested the null hypothesis that the local occurrence, richness and biodiversity of Coleoptera were not affected by the presence of a large herbivore carcass in comparison with an otherwise similar area lacking a large herbivore carcass.

Material and methods

On 7 August 2003, we placed a roe deer *Capreolus capreolus* (Linnaeus, 1758) carcass (weight 25 kg) in a medium-aged coniferous forest in Spydeberg, southern Norway (59°62′N, 11°09′E), inside a box made with an iron net (mesh diameter ca. 3 cm), which prevented access of large vertebrate scavengers. We sampled Coleoptera in six pit-fall traps [7.5 cm (diameter) × 9 cm (height)], placed around the carcass at 0.5, 1 and 2 m distance (two for each distance), and in a control plot 40 m away from the carcass plot. The relative distance between the traps was the same for the two plots, which also had the same vegetation type. In order to contrast Coleoptera diversity, we chose not to bait the traps with meat, to maintain the difference between control and experimental plot (i.e. absence/presence of carrion). Instead, we used a solution of vinegar, water and NaCl (respectively: 10, 90 and 0.02%; ca.100 ml per trap), which is commonly used to attract ground beetles (e.g. Koivula et al. 2003). We checked the traps daily between 8 August and 3 September 2003, starting 1 day after introduction of the carcass, with 2 days of pause every 7 days. Each collection day, we measured the air temperature ca. 1 m from the ground, at around 10:00 a.m., and weighed the carcass. We also collected Coleoptera by hand under the carcass during this operation. We killed the beetles with etilic ether, stored them in alcohol (80%) and identified them, when possible, to the species level.

We calculated, for the two plots, species richness (the cumulative number of species found) and Shannon's diversity index ($H' = -\Sigma p_i \log_c p_i$, where p_i denotes the proportion of individuals of the species, i). We used a Student's *t*-test assuming equal variance to compare the number of beetles collected daily in the two plots. We calculated the Pearson correlation coefficient to assess the relationship between the temperature and the number of beetles sampled day by day in the two plots. The significance value was $P < 0.05$. All statistical tests were two-tailed and conducted with SPSS for Windows 11.0 (2001) software (SPSS Inc., USA).

Results and discussion

We collected a total of 360 Coleoptera at the control plot and 547 at the carcass plot. The two sites differed also in species richness (Table 1), which was almost double at the carcass plot. Conversely, the diversity indices were similar (Table 1), because the higher evenness ($\Sigma p_i \log_c p_i / \log_c i$) of the control plot compensated for its lower number of species. In fact, the carcass plot was clearly a disturbed area, colonized by many species that exploited the carcass directly or fed on other scavenger invertebrates. Many species, represented by very few individuals, characterized the community of Coleoptera at the carcass plot, while the control plot looked more like a stable community in which each species had a more homogeneous number of individuals. Of the species collected at the carcass plot, 95% are reported to be specifically adapted to carrion or to consume any kind of decaying material (Putman 1983), whereas *Meligethes aeneus* (Fabricius, 1775), *Pocadius ferrugineus* (Fabricius, 1775) and *Otiorhynchus scaber* (Linnaeus, 1758) were most likely present by chance. The species reported to be specifically adapted to carrion, such as *Colobopterus fossor* Linnaeus, 1758, *Catops nigrita* Erichson, 1837, *Nicrophorus vespilloides* Herbst, 1784 and *Oiceoptoma thoracicum* (Linnaeus, 1758) were found only in the traps at a distance of 0.5 m from the carcass.

We sampled six further species (Table 2) under the carcass, which were not found in the traps. In fact, many of the species which were found under the carcass are carrion-dependent, and their activity was probably more concentrated on the carcass itself, which they reached by flying directly on to it. Therefore, they were not attracted by the trap-bait, and their activity was not spread enough in the surroundings of the carcass to fall accidentally in the traps.

The number of beetles collected daily in the two plots was significantly different ($t_{28} = -2.1162$, $P = 0.043$) during the first 15 days of data collection. After day 15, the carcass was dehydrated and reduced to one-fifth of its original weight, which probably caused the decline in number of the beetles at the carcass plot (Fig. 1).

This difference between the two plots is emphasized by the fact that the number of beetles captured each day (Fig. 1) could be correlated positively with temperature

Table 1 Number of individuals sampled for each species of Coleoptera, by pit-fall traps, at control and carcass plots, between 8 August and 3 September 2003

Family	Species	Control	Carcass
Carabidae	*Epaphius secalis* (Paykull, 1790)	4	4
	Calathus micropterus (Duftschmid, 1812)	98	87
	Carabus hortensis Linnaeus, 1758	57	100
	Carabus violaceus Linnaeus, 1758	6	1
	Pterostichus melanarius Illiger, 1798	68	15
	Pterostichus niger (Schaller, 1783)	9	23
	Pterostichus oblongopunctatus (Fabricius, 1787)	18	10
	Catops nigrita Erichson, 1837	0	2
Silphidae	*Nicrophorus vespilloides* Herbst, 1784	0	2
	Oiceoptoma thoracicum (Linnaeus, 1758)	0	1
Staphylinidae	*Tachinus laticollis* Gravenhorst, 1802	3	1
	Quedius levicollis (Brullé, 1832) = *tristis* (Gravenhorst, 1802)	0	1
	Quedius mesomelinus (Marsham, 1802)	1	0
	Atheta sp. Thomson, 1858	0	1
	Ontholestes murinus (Linnaeus, 1758)	0	1
	Philonthus succicola Thomson, 1860	0	1
	Lorditon thoracicus (Fabricius,1777)	1	0
	Tachinus pallipes Gravenhorst, 1806	41	183
	Gyrohypnus fracticornis (Müller, 1776)	0	1
	Drusilla canaliculata (Fabricius, 1787)	0	1
Scarabaeidae	*Colobopterus fossor* Linnaeus, 1758	0	6
Geotrupidae	*Geotrupes stercorarius* Linnaeus, 1758	14	90
Nitidulidae	*Glischrochilus quadripunctatus* (Linnaeus, 1758)	39	12
	Meligethes aeneus (Fabricius, 1775)	0	1
	Nitidula bipunctata (Linnaeus, 1758)	0	1
	Pocadius ferrugineus (Fabricius, 1775)	1	1
Curculionidae	*Otiorhynchus scaber* (Linnaeus, 1758)	0	1
Sum		360	547
Species richness		14	25
Shannon-Wiener index		0.88	0.84
Evenness		0.77	0.60

at the control plot ($n = 21$, $r_p = 0.754$, $P = 0.001$), but at the carcass plot there was only a marginally significant tendency for such a correlation ($n = 21$, $r_p = 0.410$, $P = 0.065$). In fact, the presence of an abundant and concentrated resource (i.e. the carcass) probably increased the local activity of Coleoptera at the carcass plot, whereas the activity was more evidently limited by temperature at the control plot. Moreover, during the decay stage, the internal temperature of carrion increases significantly above the ambient temperature (Hewadikaram and Goff 1991), thus creating a microclimatic patch; this could be, in effect, partially buffered against ambient air temperature.

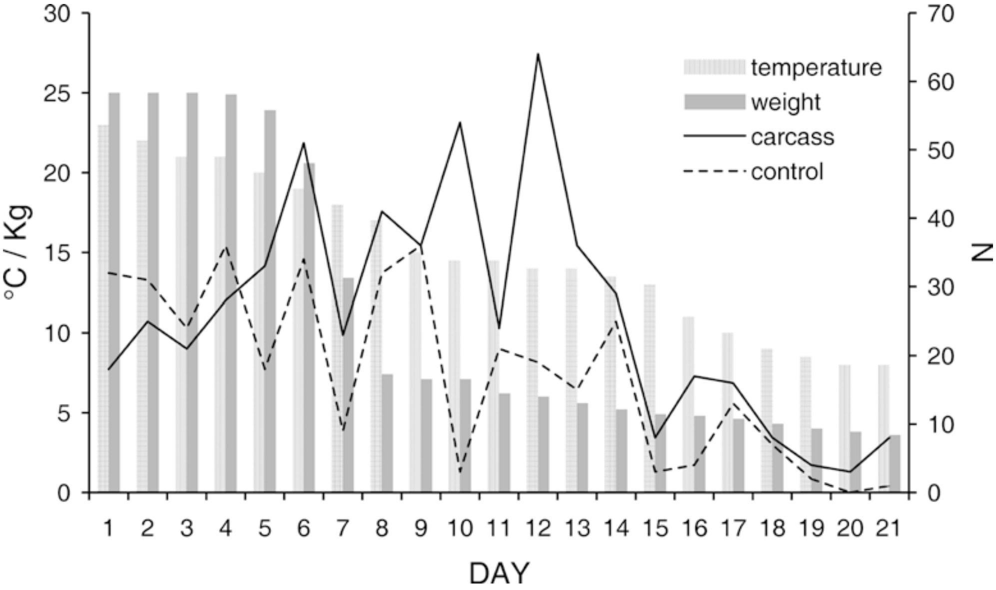
Table 2 Species of Coleoptera sampled by hand under the roe deer carcass, between 8 August and 3 September 2003. * Not found in traps

Family	Species
Carabidae	*Pterostichus niger* (Schaller, 1783)
Histeridae	*Hister cadaverinus* Hoffman, 1803*
Staphylinidae	*Creophilus maxillosus* (Linnaeus, 1758)*
	Lordithon lunulatus (Linnaeus, 1761)*
	Othius sabuliformis Stephens 1833*
	Ontholestes murinus (Linnaeus, 1758)
	Tachinus pallipes Gravenhorst, 1806
	Tachinus proximus Kraatz, 1855*
Silphidae	*Nicrophorus vespilloides* Herbst, 1784
	Oiceoptoma thoracicum (Linnaeus, 1758)
	Nicrophorus humator (Gleditsch, 1767)*
Scarabaeidae	*Colobopterus fossor* Linnaeus, 1758
Geotrupidae	*Geotrupes stercorarius* Linnaeus, 1758

For a better understanding of the ecological role of ungulate carcasses in the European boreal forest, the experiment should be repeated with a higher number of control and carcass plots, considering different types of habitat, seasonality, size (and therefore species) of the carcass and by using different types of traps and/or baits. However, our results seem to indicate that the presence of a large vertebrate carcass affects the local species richness and biodiversity in European boreal forest ecosystems.

Moreover, in Norway as in other parts of Europe, large carnivores are slowly expanding their distribution, implying that carrion from large ungulates again will be a natural part of several ecosystems in the future. In Norway, most wild ungulate mortality is due to human hunting. The quantitative and temporal difference between large carnivore kills and human hunting remains is obvious, and it is likely to affect the biodiversity in totally different ways. For example, these differences include: *seasonality*—carnivores kill all year-round, while hunters kill mainly in autumn when temperatures are too cold for most insect activity and *composition*—carnivores leave meat, bones and rumens, whereas hunters usually leave only rumens. These differences are also worthy of further investigation. Moreover, when human hunters are called to replace the role of large carnivores, such a study could help in producing

Fig. 1 Air temperature (measured in °C), weight of the carcass (measured in kg) and number of Coleoptera collected each day at the carcass and at the control plots, between 8 August and 3 September 2003



guidelines about the amount of carcass that should be left in the forest to better simulate a natural environment.

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