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Morphometric differences in populations of *Nebria kratteri* Dejean & Boisduval, 1830 from two old forests in Calabria (Coleoptera, Carabidae)

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Abstract

In carabid beetles, several morphometric parameters may vary from one habitat to another. Body size is one of the most important traits in animals because it directly relates to fitness and changes across latitudinal and altitudinal gradients. In this paper, we compare two populations of *Nebria kratteri* (Coleoptera, Carabidae) sampled in two old forest sites of the Sila Mountain in Calabria. The specimens show significant differences in all morphometric parameters measured, the larger size at one site could be related to intraspecific competition.

Key words: morphometry, carabids, body size, intraspecific competition.

Introduction

Ground beetles (Coleoptera: Carabidae) are frequently used as bioindicators (Kotze et al. 2011). These beetles respond to abiotic and biotic variation, and to disturbances and management (e.g. Lövei & Sunderland 1996; Rainio & Niemelä 2003). These should reliably reflect particular environmental conditions. Although carabids have the potential to reflect soils, wetness and habitat-type variation (e.g. Thiele 1977; Lövei & Sunderland 1996), they cannot currently compete with plants as indicators of these factors. Several parameters, from physiological processes to environmental pressures, play a role in determining the body size and related morphological parameters in insects (Wheeler 1996; Angilletta 2003). Most of these factors may vary from one habitat to another; at a large geographic scale, clinal variation of morphological parameters within species from different taxa has been found (Hallas 2002; Blanckenhorn 2004). Strong relationships exist between body size and a variety of physiological and ecological features, including metabolic rate, production rate, survival probability and the likelihood of dispersal (Bommarco 1998). Body size is one of the most important traits in animals because it directly relates to fitness. Body size variation research clarifies morphoadaptation of organisms to the environment changes and intra- and interpopulations relations, which cannot be revealed by other methods and do not yield to the experimental check (Gelashvili et al. 2011; Talarico et al., 2007). Body size also changes across latitudinal and altitudinal gradients. However, in insect species, size does not vary regularly with elevation. Some species are larger at higher elevations (Stalker & Carson 1948, Miller 1991, Hawkins & Devries 1996, Krasnov et al. 1996), some smaller (Janes 1994; Hawkins & Devries 1996; Sota 1996; Blanckenhorn 1997; Krasnov et al. 1996), and some show no change at all (Hawkins & Devries 1996). Studies measuring body size, life-history characters, development, and population dynamics over a temperature gradient will assist in distinguishing the factors responsible for clinal variation among populations (Sukhodolskaya 2013, 2014). The aim of this work is to compare two populations of *Nebria kratteri* (Coleoptera, Carabidae) sampled in two old forest sites on the Sila Mountains: a) site "MO" (Macchia dell'Orso), fir dominated forest mixed with beech; b) site "S" (Spinalba Mount), beech forest mixed with silver fir. According to Magistretti (1965), in Calabria this species is found especially in mountain sites, including Sila and Pollino massifs. *Nebria kratteri* lives from the hills to the tree line, and has to be considered a purely forest species. The beetle represents a hygrophilic element, which concentrates at the edges of the waters, and is found up to 2000 m a.s.l., on dead leaves or wet parts of the forest. Diet of *Nebria* species includes collembola, small spiders and other invertebrates (Davies 1953).

Aim of this study is to clarify if body size and morphometric characteristics of an abundant forest species may vary also between two very similar although differently managed stands within a large forested landscape and what for factors may be responsible of the observed differences.

Materials and Methods

The study sites

The beetles samples have been collected in two forest sites of the inner part of the Sila National Park, both stands belong to the beech-silver fir mixed forest typical of the Southern Italian Apennine. Each site measured exactly one hectare and was carefully checked for structural and vegetation characteristics in the frame of the "Foreste Vetuste" project, an action plan promoted by the Italian Ministry for the Environment. The Spinalba forest was studied at 2017, Macchia dell'Orso during 2018, and in each site also ground beetles were sampled in four symmetrical subplots of the hectare. In all subplots two pitfall traps were active for an entire season (June/November), and the specimen counts are expressed in "annual activity density", i.e. individuals/trap in the standard period of ten days (mean values of the sampling period).

The most relevant features of the stands are summarized in Table 1, where also some characteristics of the carabid beetle community are reported.

Beetles and measurements

The samples consisted of 20 individuals of *Nebria kratteri* (ten males and ten females) for each sampling site. Specimens were collected in southern Italy (Calabria) from June 2017 to November 2018. For morphometric analyses, specimens stored in ethanol (70%), were measured. Photographs were taken with a Zeiss Stemi SV 11Apo stereoscope and acquired by Matrox PC-VCR software. Body length, head width and length, eyes distance, thorax width and length, abdomen width, elytra width and length (right and left) were measured for each specimen. Measurements were taken using Sigma Scan Pro 5 Software (SPSS® Inc.) and expressed as means ± standard error. Sexual dimorphism in each species and morphological differences among species was tested using the Kruskal-Wallis test.

Results and Discussion

N. kratteri presents significant differences in sexual dimorphism for all parameters in both of the sampling sites (Table 2; $p<0.001$). Significant differences have been found in body length, head length and width, eyes distance, abdomen length and width, elytra length and width, all values were larger in site S than in the site MO (Table 3; $p<0.001$). About weighted values, the right elytra is longer in samples from site S than in MO and thorax is longer in site MO than in S (Fig. 1). Morphometric data show that in the two sampled sites *N. kratteri* preserves its sexual dimorphism. This indicates a good site conservation condition. Specimens from the two sites show significant differences in some morphometric characteristics. In particular, the larger dimensions of of *N. kratteri* individuals from S

Table 1 – Main characteristics of the two forest stands.

Forest denomination	**Spinalba** (lat 39 104247 - long 16 653505)	**Macchia dell'Orso** (lat 39 130220 - long 16 645935)
Forest type	Beech/silver fir mixed forest (*Ranunculo-Fagetum*)	Beech/silver fir mixed forest (*Ranunculo-Fagetum*) with silver fir dominance in the canopy
Altitude	1700-1680 m	1640-1620 m
Aspect	SW-SSE	S-SW
Slope	5 - 10 - 20°	5 - 10 - 25°
Canopy covering	80 - 90 - 100%	85 - 90 - 95%
Leaf litter depth/covering	2-3 cm/100%	1-3cm/50-80-90%
Age of the silver fir	From > 200 y (scattered plants) to 20-40 y	80-90 y
Age of the beech	From 70-80 to 20-50 y	From 70 to 30-35 y
Necromass (% of dead wood on the soil)	20 - 30 - 40%, some old snags	20 - 30 %
Soil properties	Dystrudept, well drained	Dystrudept, humid
Nebria kratteri annual activity density (mean SE of four subplots)	4.225 ± 0.767	43.720 ± 9.244
Dominant carabid at the site	*Pterostichus bicolor amorei*	*Nebria kratteri*
N of carabid species at the site	14	11
Disturbance	Moderate grazing by cows	Sporadic grazing

Table 2 – Morphometric differences (means and standard error of the mean) in *N. kratteri* male and female by the sites. Kruskal-Wallis chi-squared results are shown. Statistical significant results are in bold.

	Male		**Female**				
Measured	**Means**	**SEM**	**Means**	**SEM**	**Kruskal-Wallis chi-squared**	**df**	**p-value**
MO site							
Body length (mm)	8.219	0.108	8.654	0.134	5.1429	1	**0.02334**
Head width (mm)	1.668	0.018	1.714	0.030	0.75685	1	0.3843
Head length (mm)	1.313	0.063	1.529	0.044	6.6057	1	**0.01017**
Eyes distance(mm)	1.152	0.026	1.172	0.028	0.14286	1	0.7055
Thorax width (mm)	2.511	0.030	2.516	0.035	0.035741	1	0.8501
Thorax length (mm)	1.575	0.018	1.630	0.049	0.46321	1	0.4961
Abdomen width (mm)	3.294	0.047	3.520	0.039	10.08	1	**0.001499**
Elytra width (R) (mm)	1.548	0.039	1.675	0.035	4.8057	1	**0.02837**
Elytra width (L) (mm)	1.611	0.029	1.725	0.037	4.1657	1	**0.04125**
Elytra length (R) (mm)	4.796	0.075	5.203	0.078	9.3799	1	**0.002194**
Elytra length (L) (mm)	4.711	0.061	5.121	0.089	9.1429	1	**0.002497**
Head width/ Body length	0.203	0.002	0.198	0.002	4.1941	1	**0.04056**
Head length/Body length	0.159	0.006	0.176	0.003	5.1701	1	**0.02298**
Thorax width/ Body length	0.306	0.003	0.291	0.003	8.4891	1	**0.003573**
Thorax length/ Body length	0.192	0.003	0.188	0.004	0.75857	1	0.3838
Elytra width (R)/ Body length	0.188	0.004	0.194	0.004	1.2877	1	0.2565
Elytra length (L)/ Body length	0.583	0.005	0.601	0.003	5.1701	1	**0.02298**
Eyes distance/ Head length	0.893	0.041	0.770	0.023	4.48	1	**0.03429**
Eyes distance/Head width	0.692	0.020	0.686	0.021	0.24179	1	0.6229
S site							
Body length (mm)	8.438	0.133	9.303	0.094	11.063	1	**0.0008807**
Head width (mm)	1.735	0.025	1.832	0.018	6.2229	1	**0.01261**
Head length (mm)	1.498	0.051	1.662	0.039	4.4834	1	**0.03423**
Eyes distance(mm)	1.210	0.023	1.311	0.018	8.2576	1	**0.004058**
Thorax width (mm)	2.487	0.041	2.616	0.028	5.1545	1	**0.02319**
Thorax length (mm)	1.604	0.028	1.710	0.026	5.1429	1	**0.02334**
Abdomen width (mm)	3.380	0.057	3.684	0.047	10.08	1	**0.001499**
Elytra width (R) (mm)	1.804	0.030	1.959	0.031	7.2068	1	**0.007263**
Elytra width (L) (mm)	1.709	0.043	1.933	0.026	11.063	1	**0.0008807**
Elytra length (R) (mm)	5.049	0.064	5.428	0.081	7.8229	1	**0.005159**
Elytra length (L) (mm)	5.132	0.081	5.477	0.074	7.8229	1	**0.005159**
Head width/ Body length	0.206	0.001	0.197	0.001	11.598	1	**0.0006604**
Head length/Body length	0.177	0.005	0.179	0.003	0.051506	1	0.8205
Thorax width/ Body length	0.295	0.003	0.281	0.003	6.0539	1	**0.01388**
Thorax length/ Body length	0.190	0.002	0.184	0.003	3.5903	1	0.05812
Elytra width (R)/ Body length	0.214	0.002	0.211	0.003	0.0014405	1	0.9697
Elytra length (L)/ Body length	0.599	0.006	0.583	0.007	3.0274	1	0.08187
Eyes distance/ Head length	0.817	0.031	0.792	0.020	0.4639	1	0.4958
Eyes distance/Head width	0.699	0.014	0.716	0.008	1.2041	1	0.2725

Table 3 – Morphometric differences (means and standard error of the mean) in the species by the sites. Kruskal-Wallis chi-squared results are shown. Statistical significant results are in bold.

	MO site		S site				
Measured	**Media**	**SEM**	**Media**	**SEM**	**Kruskal-Wallis chi-squared**	**df**	**p-value**
Body length (mm)	8.448	0.068	9.416	0.080	25.587	1	**4.229e-07**
Head width (mm)	1.782	0.014	1.816	0.013	3.385	1	**0.06579**
Head length (mm)	1.326	0.031	1.981	0.030	29.271	1	**6.293e-08**
Eyes distance(mm)	1.231	0.023	1.213	0.013	0.40412	1	0.525
Thorax width (mm)	2.505	0.022	2.486	0.016	0.30753	1	0.5792
Thorax length (mm)	1.883	0.016	1.966	0.021	7.2448	1	**0.007111**
Abdomen width (mm)	3.128	0.020	3.153	0.022	0.61537	1	0.4328
Elytra width (R) (mm)	1.483	0.027	1.664	0.027	15.174	1	**9.804e-05**
Elytra width (L) (mm)	1.529	0.020	1.659	0.023	15.281	1	**9.264e-05**
Elytra length (R) (mm)	4.681	0.052	4.624	0.059	0.041166	1	0.8392
Elytra length (L) (mm)	4.590	0.052	4.635	0.061	1.3529	1	0.2448
Head width/ Body length	0.211	0.002	0.193	0.002	25.388	1	**4.688e-07**
Head length/Body length	0.157	0.003	0.210	0.003	29.307	1	**6.178e-08**
Thorax width/ Body length	0.297	0.002	0.264	0.002	27.99	1	**1.22e-07**
Thorax length/ Body length	0.223	0.002	0.209	0.002	13.381	1	**0.0002542**
Elytra width (R)/ Body length	0.175	0.003	0.177	0.003	1.1452	1	0.2846
Elytra length (L)/ Body length	0.554	0.005	0.492	0.007	28.694	1	**8.477e-08**
Eyes distance/ Head length	0.933	0.019	0.615	0.010	29.268	1	**6.302e-08**
Eyes distance/Head width	0.690	0.010	0.668	0.006	2.0955	1	0.1477

site compared with MO. Spinalba forest is a partially deciduous forest (beech forest) with scattered, very old silver fir giants, habitat conditions and trophic niches allow the presence of a higher number of carabid species. Macchia dell'Orso forest is largely dominated by fir and the soil is very humid and poor of understorey. The population density of *N. kratteri* in this second stand is extremely high; here *Nebria* dominates the community with a mean of 43.720 individuals/trap that is it shows a population density ten times higher than in Spinalba.

N. kratteri is a non-specialist predator of small size prey that live on the surface of the leaf litter. The larval stages appear in late autumn and are active also in the less cold winter months, searching for prey on the leaf litter. They belong to the morphological type of the "surface runner" (Zetto Brandmayr et al., 1998), thus they are unable to search for prey in the soil depth and are forced to compete with conspecific larvae on the leaf litter surface. This could be a possible explanation of the larger body size of the Spinalba population, favoured by a remarkably lower intraspecific competition.

Other possible explanations should anyway be considered. Disturbance is sometimes thought to influence body size of carabids. Blake et al. (1994) concluded that disturbed habitats support a carabid fauna of smaller average body size than do less disturbed habitats. Though almost no published information seems to exist about the importance of beech forest soil types and related vascular plant richness to carabid abundance and species richness, effects of vegetation structure and diversity have often been recognised under other field conditions (Bortmann 1996). It seems likely that body size variability is caused by differences in food availability during the larval stage. It was demonstrated that variable host size had a major influence on the body size of adults in the parasitic carabid *Brachinus lateralis* Dejean (Juliano 1985). The great body size fluctuations, particularly in males, of species belonging to the Lucanidae (e.g., Mizunuma & Nagai 1994) are related both to differences in space and in nutrition during the long larval period. Indirect evidence of the importance of environmental conditions to the body size of imagines is the presence of very small-sized populations of some *Carabus* species, e.g. *C. violaceus*, in the far north of Europe, such as in montane and subarctic areas in northern Scandinavia (Sota et al. 2002). Carabids are mainly predators that feed on a wide variety of animals. Differenc-

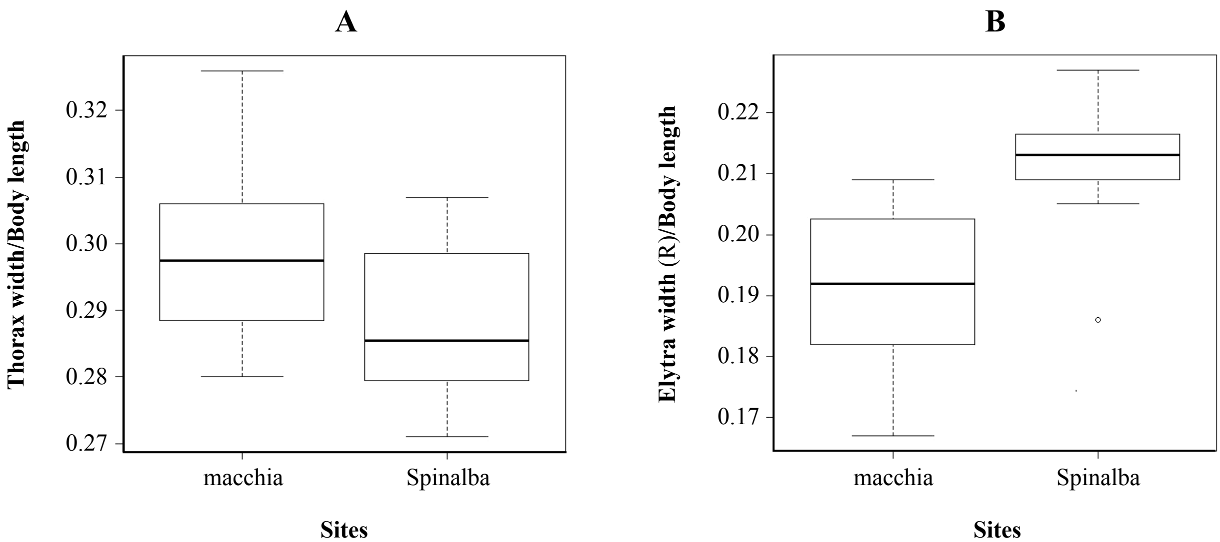

Fig. 1 – Measured traits: A) Thorax width/ Body length; B) Elytra width (R)/ Body length (mm) in the two species.

es in the composition, species richness, and other properties of the carabid beetle fauna between forests on contrasting soil types have little recognised. However, forests with canopies of the same dominating tree species, such as beech, may be characterized by widely differing properties, which is ought to exert to far-reaching influence on environmental conditions of importance to the carabid fauna (Tyler 2008). More investigations are needed but our results show remarkable differences in a carabid living in forest environments with different population density, different canopy and soil properties, and probable degrees of stability.

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