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MORPHOMETRY AND EYE MORPHOLOGY OF *HARPALUS (PROTEONUS*) *DISTINGUENDUS* (DUFTSCHMID, 1812) AND *H. (AMBLYSTUS) RUFIPALPIS* (STURM, 1818) (COLEOPTERA: CARABIDAE), TWO CONGENERS INHABITING ABANDONED CROPLANDS

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Morphometry and eye morphology of *Harpalus (Proteonus*) *distinguendus* (Duftschmid, 1812) and *H. (Amblystus) rufipalpis* (Sturm, 1818) (Coleoptera: Carabidae), two congeners inhabiting abandoned croplands. *Acta Biol. Univ. Daugavp*., *23(2): 153-161.*

Abstract

Physiological and behavioural characteristics reflect carabid beetle specific requirements for habitat. There is a strong correlation between body shape and habits in species with different lifestyle. In this study, I compare the morphometry and characteristics of compound eyes in two European congeners: *Harpalus rufipalpis* and *H. distinguendus*. Both are zoospermophagous species inhabiting open habitats.

Keywords: morphometry, beetle compound eye, carabid beetles, Harpalinae, zoospermophagous

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INTRODUCTION

Direct correlation exists in carabid beetles between body shape and habitat (their feeding, locomotion, burrowing and flying abilities). For instance, representatives of the tribe Carabini are generally heavier, bulkier and stronger than many other running ground beetles, but they are also relatively slow runners. The correlation is reflected mainly in size of hind body, notably hind body depth and prothorax depth. For example, carabids living in restricted or confined habitats, such as in fissures in the ground, tend to have slenderer body width and shallower in depth, with a prothorax similar in width to their hind body. It has been suggested that this type of body shape possibly minimizes frictions by causing less obstruction when moving through confined spaces (Forsythe 1987). At the first glance, most ground beetles, even of various body sizes, seems to have similar body shape, but there are species-specific differences and morphological peculiarities that reflect the demands of the specific niche (Erwin 1979, Forsythe 1981, Sharova 1975, Lovei & Sunderland 1996, Kotze et al. 2011, Kamenova et al. 2015).

It has been hypothesized that the size, bulkiness and strength of Carabini may help them overcome the environmental resistance (Heydemann 1957) in a wide variety of habitats and enable them to overcome larger, but comparatively slower prey such as terrestrial molluscs, worms, caterpillars and other slow-moving invertebrates (Forsythe 1991). Carabini obtains structural adaptations of their feeding apparatus indicative of their feeding habits (Forsythe 1982, Forsythe 1983, Evans & Forsythe 1985). Furthermore, morphological characteristics of the compound eyes in insects are known to reflect features of the lifestyle (Wehner 1981). Diurnal visual hunters share large, laterally protruding eyes with a large binocular overlapping area of visual fields. In nocturnal insects, which detect prey mostly through chemical signals and by mechanical means, eyes are known to be much smaller with comparatively fewer ommatidia (Bauer 1985). In the carabid beetle family visual hunters belong mainly to some tribes or subfamilies, such as Cicindelinae, Elaphrini, Notiophilini and some Bembidiini (Bauer 1981, Bauer 1985, Bauer & Kredler 1993, Bauer et al. 1998), but more detailed differences have been discovered in species from the same genera or in related subgenera.

In this study, I investigated two European species of the genus *Harpalus*: *H. distinguendus* and *H. rufipalpis*, in search of the correlation between body shape and morphometry of the compound eyes of adults in relation to the behavioral and ecological habits of the genus *Harpalus*.

MATERIAL AND METHODS

Samples

The samples consisted of 20 individuals of *Harpalus distinguendus* and *H. rufipalpis* (ten males and ten females of each species). Specimens were collected in abandoned croplands in southern Italy (Calabria Region) up to 1100 m altitude, from June 2007 to July 2008. The beetles were caught using pitfall traps.

Morphometric analyses

The animals were stored in alcohol (70%). Images were taken using a stereoscope (Zeiss Stemi SV 11Apo) and acquired by Matrox PC-VCR software for Windows® 2000. For each individual of the two species, we measured body length, head width across compound eyes and head length, width and length of prothorax, width and length of each elytron (right and left), length of the antenna, cornea area, eye distance and number of ommatidia. All measures were compared with the body length of corresponding specimens. Visual parameters have been weighted against head width and body length. To determine the number of ommatidia and size of cornea, we relaxed the studied specimens in hot potash lye for a few minutes. The cornea was removed and fixed in the following way: distilled water, acetone, ethanol (70%), absolute ethanol and xylol. The samples were then mounted on microscope slides and were photographed. 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

A limited number of differences in sexual dimorphism in both sampling species have been uncovered (Tab. 1, Tab.2, $p<0.01$).

In *Harpalus distinguendus* significant differences have been found in visual parameters: eye surface, ommatidia density and weighted eye surface between female and male individuals (Fig. 1 A-D). In *H. rufipalpis*, significant differences were in head length and width, thorax width, antenna length, eyes distance and weighted ommatidia numbers between female and male individuals (Fig. 2 A-F).

Table 1. Differences in body and eye morphology (means and Standard Error of Means) in males and females of the studied *Harpalus distinguendus*. Kruskal–Wallis test results are shown. Statistically significant results are in bold.

Harpalus distinguendus	male		female				
	Media	SEM	Media	SEM	Chi-squared	df	p-value
Body length (mm)	10.01	0.18	10.18	0.15	0.69	1	0.41
Head width (mm)	2.31	0.04	2.38	0.02	2.90	1	0.09
Head length (mm)	1.43	0.04	1.46	0.05	0.12	1	0.73
Eye distance (mm)	1.47	0.02	1.54	0.04	1.65	1	0.20
Thorax width (mm)	3.20	0.04	3.29	0.04	1.85	1	0.17
Thorax length (mm)	2.18	0.03	2.23	0.03	0.57	1	0.45
Elytra dx width (mm)	2.01	0.04	2.06	0.04	0.69	1	0.41
Elytra sx width (mm)	1.85	0.05	1.94	0.03	1.46	1	0.23
Elytra dx length (mm)	5.37	0.13	5.55	0.04	0.97	1	0.33
Elytra sx length (mm)	5.32	0.11	5.60	0.04	2.77	1	0.10
Antenna length (mm)	3.71	0.20	3.59	0.19	<0.001	1	1.00
Head width/body length	0.23	<0.01	0.23	<0.01	0.37	1	0.55
Head length/body length	0.14	<0.01	0.14	<0.01	0.21	1	0.65
Thorax width/body length	0.32	<0.01	0.32	<0.01	0.206	1	0.65
Thorax length/body length	0.22	<0.01	0.22	<0.01	0.46	1	0.50
Elytra dx width/body length	0.20	0.01	0.20	<0.01	<0.01	1	0.94
Elytra dx length/body length	0.54	0.01	0.55	<0.01	0.46	1	0.50
Eye distance/body length	1.04	0.03	1.07	0.06	0.14	1	0.71
Eye distance/head width	350.47	0.01	0.65	0.02	0.28	1	0.60
Antenna length/body length	0.37	0.02	0.36	0.02	<0.01	1	0.94
Ommatidia numbers	709.50	50.24	704.80	39.441	<0.01	1	0.94
Eye surface (mm^2)	0.33	0.03	0.45	0.031	6.22	1	**0.01**
Ommatidia density	2264.29	166.03	1609.75	89.89	9.61	1	**<0.01**
√ommatidia number/body length	4.24	0.14	4.16	0.14	0.14	1	0.71
Ommatidia number/body length	113.21	7.23	110.95	6.42	0.09	1	0.76
Ommatidia number/head length	800.06	60.19	779.92	51.34	0.21	1	0.65
Eye surface/head length	0.37	0.03	0.50	0.04	5.49	1	**0.02**
Ommatidia number/head width	490.01	30.63	474.62	26.45	0.46	1	0.50
Eye surface/head width	0.23	0.02	0.30	0.02	6.22	1	**0.01**

Table 2. Differences in body and eye morphology (means and Standard Error of Means) of the studied *Harpalus rufipalpis*. Kruskal–Wallis test results are shown. Statistically significant results are in bold.

Harpalus rufipalpis	male		female				
	Media	SEM	Media	SEM	Chi-squared	df	p-value
Body length (mm)	9.94	0.15	10.20	0.20	0.09	1	0.76
Head width (mm)	2.28	0.04	2.26	0.04	0.21	1	0.65
Head length (mm)	1.51	0.05	1.73	0.09	2.52	1	0.11
Eye distance (mm)	1.59	0.05	1.52	0.02	0.82	1	0.36
Thorax width (mm)	3.47	0.11	3.37	0.06	0.46	1	0.50
Thorax length (mm)	2.37	0.11	2.30	0.06	0.09	1	0.76
Elytra dx width (mm)	2.06	0.04	2.14	0.05	1.65	1	0.20
Elytra sx width (mm)	1.98	0.06	1.91	0.05	1.12	1	0.30
Elytra dx length (mm)	5.61	0.09	5.63	0.08	<0.001	1	1.00
Elytra sx length (mm)	5.67	0.09	5.63	0.08	0.21	1	0.65
Antenna length (mm)	3.62	0.18	3.52	0.08	2.52	1	0.11
Head width/body length	0.23	<0.01	0.22	<0.01	4.17	1	**0.04**
Head length/body length	0.15	<0.01	0.17	<0.01	4.17	1	**0.04**
Thorax width/body length	0.35	<0.01	0.33	<0.01	3.86	1	**0.05**
Thorax length/body length	0.24	<0.01	0.23	<0.01	1.65	1	0.20
Elytra dx width/body length	0.21	<0.01	0.21	<0.01	0.28	1	0.60
Elytra dx length/body length	0.56	<0.01	0.55	<0.01	2.06	1	0.15
Eye distance/body length	1.06	0.03	0.90	0.04	6.22	1	**0.01**
Eye distance/head width	368.20	0.02	0.67	<0.01	2.29	1	0.13
Antenna length/body length	0.36	0.02	0.35	<0.01	5.49	1	**0.02**
Ommatidia numbers	749.70	48.97	648.13	50.71	1.90	1	0.17
Eye surface (mm^2)	0.33	0.03	0.34	0.04	<0.01	1	0.93
Ommatidia density	2393.65	179.20	2041.94	152.53	1.33	1	0.25
√ommatidia number/body length	4.39	0.14	4.01	0.18	2.85	1	0.09
Ommatidia number/body length	120.50	7.38	102.85	8.68	2.85	1	0.09
Ommatidia number/head length	797.01	47.82	620.72	52.68	4.55	1	**0.03**
Eye surface/head length	0.35	0.03	0.32	0.04	0.28	1	0.59
Ommatidia number/head width	526.24	32.53	462.58	39.31	1.55	1	0.21
Eye surface/head width	0.23	0.02	0.24	0.03	0.07	1	0.79

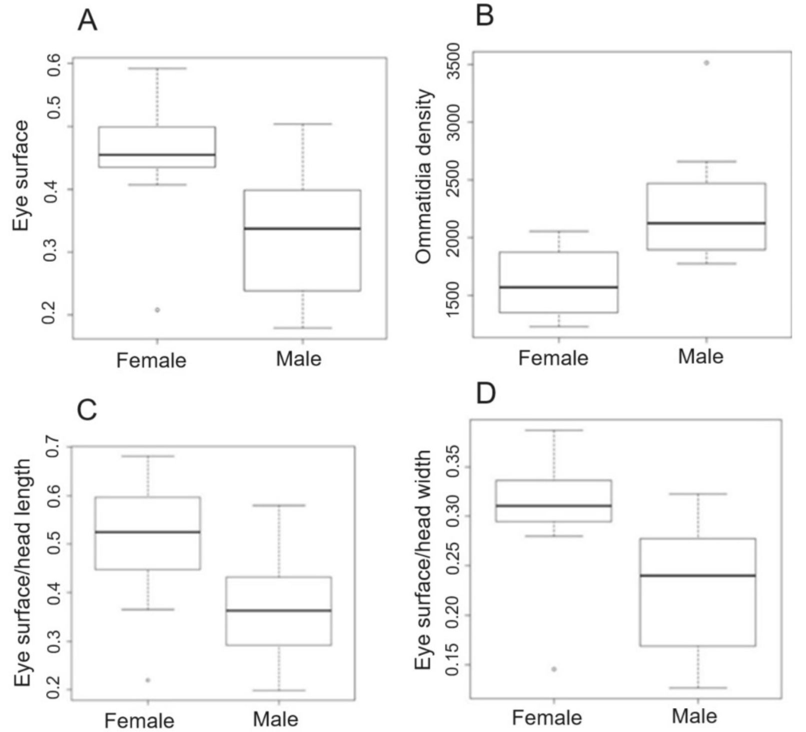

Figure 1. Measured traits of *Harpalus distinguendus* female and male individuals. Trait units in table 1.

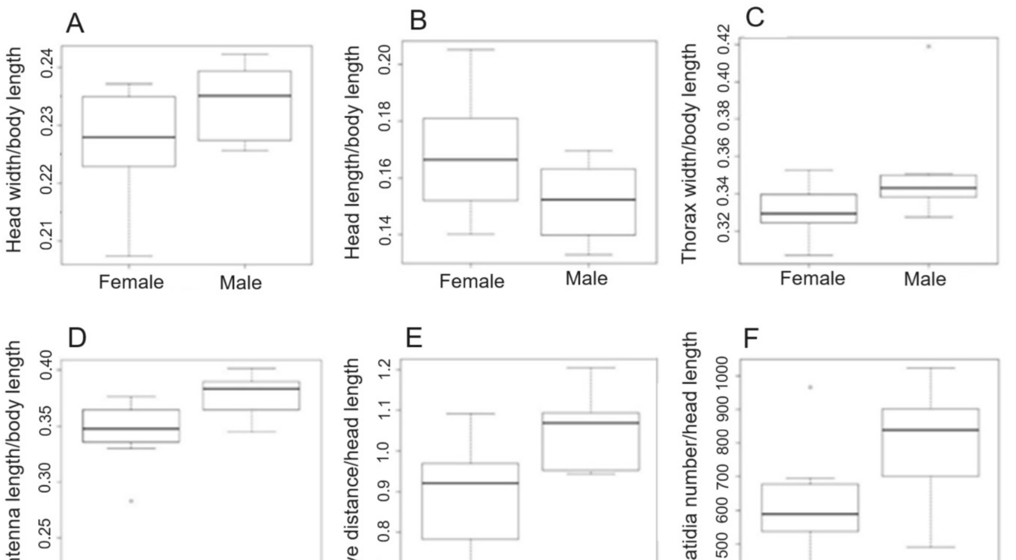

Figure 2. Measured traits of *Harpalus rufipalpis* female and male individuals. Trait units in table 2.

Specimens of the two species show significant differences in some morphometric characteristics (Tab. 3). Significant differences were found in head length and width, prothorax width and ommatidia density. In terms of weighted values, there are significant differences in head length, thorax width and length, elytra dx length, eye distance and eye surface.

Table 3. Inter-specific differences in morphological characteristics (means and standard error of the mean) in *Harpalus distinguendus* and *H. rufipalpis*. Kruskal–Wallis test results are shown. Statistically significant results are in bold.

	Harpalus distinguendus		*Harpalus rufipalpis*				
	Media	SEM	Media	SEM	Chi-squared	df	p-value
Body length (mm)	10.09	0.12	10.07	0.13	<0.01	1	0.96
Head width (mm)	2.34	0.02	2.27	0.03	4.57	1	**0.03**
Head length (mm)	1.45	0.03	1.62	0.06	5.67	1	**0.02**
Eye distance (mm)	1.51	0.02	1.55	0.03	1.62	1	0.20
Thorax width (mm)	3.25	0.03	3.42	0.06	6.19	1	**0.01**
Thorax length (mm)	2.21	0.02	2.33	0.06	2.63	1	0.11
Elytra dx width (mm)	2.04	0.03	2.10	0.03	1.69	1	0.19
Elytra sx width (mm)	1.89	0.03	1.95	0.04	0.95	1	0.33
Elytra dx length (mm)	5.46	0.07	5.62	0.06	2.21	1	0.14
Elytra sx length (mm)	5.46	0.07	5.65	0.06	2.81	1	0.09
Antenna length (mm)	3.65	0.13	3.57	0.10	1.48	1	0.22
Head width/body length	0.23	<0.01	0.23	<0.01	3.79	1	0.05
Head length/body length	0.14	<0.01	0.16	<0.01	8.22	1	**0.00**
Thorax width/body length	0.32	<0.01	0.34	<0.01	8.85	1	**0.00**
Thorax length/body length	0.22	<0.01	0.23	<0.01	4.68	1	**0.03**
Elytra dx width/body length	0.20	<0.01	0.21	<0.01	2.55	1	0.11
Elytra dx length/body length	0.54	0.01	0.56	<0.01	4.34	1	**0.04**
Eye distance/body length	1.05	0.03	0.98	0.03	1.90	1	0.17
Eye distance/head width	319.44	0.01	0.68	0.01	7.46	1	**<0.01**
Antenna length/body length	0.36	0.02	0.36	0.01	1.62	1	0.20
Ommatidia numbers	707.15	31.09	704.56	36.04	0.03	1	0.86
Eyes surface (mm^2)	0.39	0.03	0.33	0.02	1.81	1	0.18
Ommatidia density	1937.02	118.66	2237.33	122.10	4.07	1	**0.04**
√ommatidia number/body length	4.20	0.09	4.22	0.12	0.01	1	0.93
Ommatidia number/body length	112.08	4.71	112.65	5.83	<0.01	1	0.95
Ommatidia number/head length	789.99	38.57	718.66	39.79	1.37	1	0.24
Eye surface/head length	0.43	0.03	0.34	0.02	4.43	1	**0.04**
Ommatidia number/head width	482.31	19.77	497.94	25.52	0.06	1	0.82
Eye surface/head width	0.26	0.02	0.24	0.02	0.72	1	0.40

In term of a sexual dimorphism there is a relation between eye area and number of ommatidia in males and females in both studied species. Males usually have an eye area smaller than that of females, but the number of ommatidia is greater than in females. It is confirmed that both studied species are visual hunters (Bauer & Kredler 1993) and the eye parameters are very high as the habits are those of specimens that climb grass stalks to forage on seeds. Indeed, visual hunters generally have about 50% more ommatidia than tactile hunters (Bauer et al. 1998). These species are therefore considered better adapted to open habitats.

The two species present few differences in body and eye traits. Both studied species inhabit abandoned croplands, cultivated fields or other open habitats with herbaceous vegetation, such as pastures and meadows. They possess broad heads, stocky and robust mandibles capable of crushing hard seeds, well-developed eyes and comparatively shortened antennae. These characteristics are typically indicative of the species that feed from seeds (Forbes 1883, Zhavoronkova 1969, Forsythe 1982, Acorn & Ball 1991). Indeed, *H. rufipalpis* and *H. distinguendus* are two zoo-spermophagous species (Talarico et al. 2016). Furthermore, they demonstrate greater eye protrusion and it is known that visual hunters have protruding eyes (Talarico et al. 2018). Laterally protruding compound eyes favor peripheral vision and may be associated with an array of ommatidia improving the resolution of the frontal visual field (Burkhardt & de la Motte 1983). In visual hunters, eyes are not only protruding laterally, but also frontally, over antennal insertions. Differences in the length of an antenna may reflect different sensory abilities/habits since antennae are usually shorter in visual hunters compared to tactile hunters (Bauer & Kredler 1993). A greater number of ommatidia indicates that the two species likely have good dispersal abilities that are typical to species of open landscapes.

CONCLUSIONS

Our results confirm that morphological measurements, especially those of the compound eyes, can be considered sensitive indicators of different habitat demands among closely related species.

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