Neotropical Biology and Conservation
6(3):178-186, september-december 2011

Analysis of morphometry and dimorphism in *Enhydrus sulcatus* (Wiedeman, 1821) (Coleoptera: Gyrinidae)

Análise do dimorfismo e morfometria em *Enhydrus sulcatus*

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Abstract

Enhydrus sulcatus (Wiedeman, 1821) (Coleoptera: Gyrinidae) were found swimming in circles on the surface of streams shaded by forests in preserved sites. The sexual dimorphism was evaluated in that species through the quantification of differences occurring among the length of the first pair of legs, width of the mesonotum, total length and body mass of 112 individuals, 71 being females and 41 males. There was significant difference among the width of the mesonotum (KW-H(1.112) = 32.80; p < 0.05), total length (KW-H (1.112) = 38.00; p < 0.05), length of the first leg (KW-H(1.112) = 47.58; p < 0.05) and body weight (KW-H (1.82) = 23.86; p < 0.05) of male and female E. *sulcatus*. The length of the first leg relates positively and significantly with the width of the mesonotum (r2 = 0.40; p < 0.05), with the total weight (r2 = 0.36; p < 0.05) and with the total body length of individuals E. *sulcatus* (r2 = 0.33; p < 0.05). The total length of individuals of E. *sulcatus* relates positively and significantly with width of the mesonotum (r2 = 0.65; p < 0.05). In this study a clear sexual dimorphism was shown in *Enhydrus sulcatus* and was present in various other body structures besides the tarsal dilations.

Key words: sexual dimorphism, Gyrinidae, *Enhydrus sulcatus*, measured morphometrics.

Resumo

Enhydrus sulcatus (Wiedeman, 1821) (Coleoptera: Gyrinidae) foram encontrados nadando em círculos na superfície de riachos sombreados por matas em locais preservados. O dimorfismo sexual foi avaliado nessa espécie através da quantificação de diferenças ocorrentes entre o comprimento do primeiro par de pernas, largura do mesonoto, comprimento total e massa corporal de 112 indivíduos sendo estes 71 fêmeas e 41 machos. Houve diferença significativa entre a largura do mesonoto (KW-H(1, 112) = 32,80; p < 0,05), comprimento total (KW-H (1, 112) = 38,00; p < 0,05), comprimento da primeira perna (KW-H(1, 112) = 47,58; p < 0, 05) e peso corporal (KW-H (1,82) = 23,86; p < 0,05) de machos e fêmeas de *E. sulcatus*. O comprimento da primeira pata relaciona-se positiva e significativamente com a largura do mesonoto (r2 = 0,40; p < 0,05), com o peso total (r2 = 0,36; p < 0,05) e com o comprimento total do corpo dos indivíduos de *E. sulcatus* (r2 = 0,33; p < 0,05). O comprimento total dos indivíduos de E. *sulcatus* relaciona-se positiva e significativamente com largura do mesonoto (r2 = 0,65; p < 0,05). Neste estudo, é mostrado um claro dimorfismo sexual em *Enhydrus sulcatus* e presente em várias outras estruturas corporais além das dilatações tarsais.

Palavras-chave: Dimorfismo sexual, Gyrinidae, *Enhydrus sulcatus*, medidas morphometric.

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Introduction

Possessing about 35,000 known species, the order Coleoptera is one of the largest insect orders (Triplehorn and Johnson, 2005). In Brazil the suborder Adephaga, is found in 6 families and about 245 genera and 1,480 species; it includes several families that occur in aquatic or semi-aquatic environments, or associated to the litter or semi-decomposed wood in forested areas, most of the species being predatory on other insects, in the larval and adult stage (Costa, 1997). Hydradephaga, Coleoptera from aquatic habits, for the most part, have been represented in Brazil, up to now, by 497 species distributed in 48 genera in the families Dytiscidae, Gyrinidae, Haliplidae and Noteridae (Benetti *et al.*, 2003).

In the world there are 900 species of Gyrinidae allocated to 13 genera, the highest diversity being in the tropical and subtropical areas, that is, the highest diversity in hot countries (Mascaró, 1967). All of the species are aquatic and present an elliptical form with short antennae and divided eyes (Booth *et al*. 1990), which enable them to see out of, as well as in the water, favoring their defense from natural enemies. On being alarmed, they move quickly and show a circular movement, that gives them the name of "whirligig beetles." The representatives of Gyrinidae are excellent divers and at the same time capable of flight, a property that they use to disperse themselves. Their complete life cycle is dependent on water, since larvae, as well as adults, they are aquatic. The larvae usually inhabit the bottom of ponds and slow streams (Skaife, 1979), but the adults are neustonic, commonly found in dense and conspicuous aggregations, inhabiting still waters of small streams, lakes or temporary pools (Eisner and Aneshansley, 2000). When harassed, they liberate substances from pygidium glands that act as an alarm and defense against predators (Barth, 1960; Eisner and Aneshansley, 2000).

Adult individuals of *Enhydrus sulcatus* (Wiedeman, 1821), present a metallic dark blue color, striated elytra and a length between 18 and 22 mm, (Costa-Lima, 1952; Hatch, 1926; Regimbart, 1877). The occurrence of *Enhydrus sulcatus* in Brazil has been verified from the states of Espírito Santo to Santa Catarina (Hatch, 1926). According to Mankõ (1997) they are found in lotic waters that run through hills of preserved forest where they inhabit small pools of approximately 6m in diameter.

The sexual dimorphism in *Enhydrus sulcatus* was described by Regimbart, (1924) based on the presence of a conspicuous enlargement in the tarsal of the first leg of the males (Costa-Lima, 1952). However, the magnitude of this dimorphism has not been quantified, up to now, in other corporal structures of this species. In the insects, sexual dimorphism related to size, presents considerable intra-specific variations (Adams and Funk, 1997; Teder and Tammaru, 2005; Fairn *et al.,* 2007a, 2007b; Cook *et al.,* 2006; Andersson, 1994; Nylin and Wedell, 1994).

The present study evaluated morphometric differences occurring in the total length, width of the mesonotum, length of the first leg and corporal mass of *Enhydrus sulcatus* with the intention of elucidating the magnitude and relationships of these measurements in the determination of the dimorphism.

Material and Methods

Study area

The study was conducted from January, 2008 to January, 2009, in high altitude streams of the Reserva Biológica Unilavras-Boqueirão (21^{0}20'47"S/44^{0}59'27"W), in the municipal district of Ingaí, and streams in Delfinópolis, Minas Gerais, Brazil. The distance between the two collection sites is approximately 170 km (Figure 1). The predominant vegetation in the two places is Brazilian Savannah and includes fields, riparian forest and gallery forests (Rizzini, 1997). The streams are bordered by preserved gallery forests (Callisto *et al*., 2002; Diniz *et al*., 2010).

Collection methodology and observation

Individuals of *Enhydrus sulcatus* that collectively swam on the surface of headwater streams were captured with an entomological net with 1x1mm mesh, sexed according to the dimorphism in the tarsal of the first leg, measured with a digital caliper rule, weighed and released at the same capture site. The morphological characteristics measured were total length (TL), width of the mesonotum (WM) and length of the first leg (LFL).

Data analysis

To evaluate the relationships among width of the mesonotum, total length, length of the first leg and weight for all *E. sulcatus* individuals, linear regression was used. The normality of the data was tested to 5% of probability using the Shapiro-Wilk test (Hammer *et al.,* 2001). To evaluate differences in the width of the mesonotum, total length, length of the first leg and weight between males and females of *E. sulcatus,* the Kruskal-Wallis test was used (Hammer *et al.,* 2001). For ordination of the morphometric characteristics in relation to the sex, the non metric multidimensional stagger model was used (*n*MDS). The PAST program was used for the analyses (Hammer *et al.,* 2001).

Results

A total of 112 individuals were measured, 67 females and 39 males, in the Reserva Biológica Unilavras-Boqueirão and 4 females and 2 males in Delfinópolis.

The *E. sulcatus* females presented a length of 1.67cm (sd=0.07), 0.84cm width (sd=0.05), length of the first leg 1.20cm (sd=0.11) and a weight

Figure 1. Map of Brazil with prominence for Minas Gerais (MG) and two municipal districts where morphometric measurements were taken in individuals of *Enhydrus sulcatus* (Wiedman, 1821).

of 0.26g (sd=0.05) on average. The males of *E. sulcatus* presented a length of 1.85 cm (sd=0.13), width 0.91 cm (sd=0.16), length of the first leg of 1.51cm (sd=0.21) and a weight of 0.34g (sd=0.08) on average (Table 1).

The multidimensional stagger (nMDS) (Figure 2) showed a clear separation of female and male individuals of *Enhydrus sulcatus* (Coleoptera: Gyrinidae) in relation to the length of the first leg and total length and width of the mesonotum. However, four male individuals presented morphometric measurements similar to those of females.

The dimorphism in the appraised structures is confirmed in Figure 3 and the test of averages that revealed significant difference between the average of the widths of the mesonotum of males and females (KW-H(1.112) = 32.80; $p < 0.05$), between the average of the total lengths of males and females (KW-H (1.112) = 38.00; $p < 0.05$), between the average of the lengths of the first legs of males and females (KW-H(1.112) = 47.58; $p < 0.05$) and between the average corporal weight of males and females of *E. sulcatus* (KW-H (1.82) = 23.86; $p < 0.05$) (Figure 3).

The morphometry also revealed that the length of the first leg relates positively and significantly with the width of the mesonotum in male and female individuals of *E. sulcatus* ($r^2 = 0.40$; $p < 0.05$). The length of the first leg relates positively and significantly with the total weight ($r^2 = 0.36$; $p < 0.05$) and with the total length of the body ($r^2 = 0.33$; $p < 0.05$). The total length of *E. sulcatus* individuals relates positively and significantly with the total width of the body ($r^2 = 0.65$; $p < 0.05$) (Figure 4).

Discussion

Morphometric measurements in insects are important tools to evaluate variations in the form because the exoskeleton can be measured easily and it rarely presents physical distortions occurring in soft parts of other animal groups. Furthermore, a large part of the behavior and way of life of these animals can be a reflection of the dimensions and forms of the exoskeleton (Dally, 1985).

According to Thorpe (1976) variations in the form and size of a same structure in different organisms can be used to test geographical variations and also subspecifics. Besides, they can reflect different forms of niche exploration between males and females and allow the understanding of social and sexual behavioral aspects involved based on the analysis of differences biometrics (Kilhan, 1970; Winkler and Leisler, 1985).

The intraspecific sexual dimorphism is a wide phenomenon distributed among animals (Hedrick and Temeles, 1989; Andersson, 1994; Fairbairn, 1997; Blanckenhorn, 2005). As a general rule, the male assumes larger sizes in groups of birds and mammals (Weatherhead and Teather, 1994; Weckerly, 1998), and smaller sizes in groups of invertebrates and pecilothermic vertebrates (Shine, 1989; Monnet

Table 1. Measurements in centimeters of the total length (TL) and width of the mesonotum (WM), length of the first leg (LFL) and weight in grams of male and female individuals of *Enhydrus sulcatus* (Wiedeman, 1821) in streams in the southeast of Brazil.

Sex	TL	WM	LFL	Weight	Sex	TL	WM	LFL	Weight
F	1.7	0.9	1.1	0.2	M	1.9	0.9	1.6	0.3
F	1.6	0.8	0.9	0.2	M	1.7	0.8	1.4	0.2
F	1.7	0.8	1	0.2	M	2.06	0.98	0.8	0.4
F	1.6	0.8	1	0.2	M	1.8	0.95	1.6	0.4
F	1.8	0.9	1.2	0.3	M	1.58	0.78	1.24	0.3
F	1.7	0.9	1.2	0.2	M	1.94	0.97	1.8	0.4
F	1.6	0.8	1	0.1	M	1.89	0.94	1.72	0.3
F	1.7	0.8	1.2	0.2	M	1.86	0.95	1.68	0.4
F	1.6	0.8	1.4	0.2	M	1.69	0.85	1.46	0.3
F	1.7	0.8	1.2	0.2	M	1.78	0.95	1.62	0.4
F	1.8	0.9	1.4	0.2	M	1.92	0.94	1.6	0.4
F	1.8	1	1.4	0.2	M	1.77	0.93	1.72	0.4
F	1.8	0.9	1.3	0.2	M	1.91	0.89	1.52	0.3
F	1.8	0.9	1.2	0.4	M	1.67	0.81	1.52	0.2
F	1.8	0.9	1.4	0.3	M	1.92	1	1.7	0.4
F	1.9	1	1.4	0.3	M	1.72	0.88	1.4	0.3
F	1.6	0.8	1.2	0.2	M	1.74	0.87	1.28	0.3
F	1.6	0.8	1	0.2	M	1.75	0.78	1.46	0.2
F	1.7	0.9	1.4	0.3	M	1.7	0.9	1.6	0.3
F	1.5	0.76	1.08	0.2	M	1.93	1	1.8	0.4
F	1.86	0.92	1.4	0.4	M	1.7	0.9	1.2	0.2
F	1.55	0.78	1.26	0.2	M	1.85	0.9	1.4	0.3
F	1.57	0.83	1.3	0.4	M	1.92	1	1.62	0.4
F	1.69	0.86	1.22	0.3	M	1.8	0.92	1.46	0.3
F	1.75	0.87	1.38	0.2	M	1.83	0.87	1.52	0.3
F	1.67	0.86	1.36	0.2	M	1.97	1	1.6	0.5
F	1.44	0.75	1.22	0.2	M	2.15	1.04	1.8	0.5
F	1.66	0.84	1.34	0.2	M	2.1	0.9	1.48	0.4
F	1.72	0.91	1.2	0.3	M	1.82	0.9	1.41	0.3
F	1.59	0.79	1.14	0.2	M	2	1	1.6	0.4
F	1.67	0.88	1.28	0.3	M	1.85	1	1.6	-
F	1.7	0.86	1.26	0.3	M	1.9	1	1.4	-
F	1.65	0.85	1.24	0.2	M	1.9	1	1.7	-
F	1.54	0.78	1.24	0.2	M	2.1	1.06	1.86	-
F	1.75	0.89	1.32	0.3	M	1.9	1	1.8	-
F	1.65	0.88	1.2	0.2	M	2	1	1.16	-
F	1.54	0.76	1	0.2	M	1.86	0.97	1.4	-
F	1.6	0.83	1.28	0.2	M	2.01	1.03	1.74	-
F	1.69	0.85	1.2	0.3	M	1.96	0.96	1.68	-
F	1.64	0.83	1.2	0.2	M	1.83	0.88	1.48	-
F	1.7	0.87	1.28	0.3	M	1.88	0.91	1.6	-
F	1.5	0.74	1	0.3	-	-	-	-	-
F	1.7	0.9	1.2	0.3	-	-	-	-	-
F	1.65	0.8	1.2	0.2	-	-	-	-	-
F	1.7	0.82	1.15	0.3	-	-	-	-	-
F	1.73	0.9	1	0.2	-	-	-	-	-
F	1.57	0.8	1.1	0.1	-	-	-	-	-

Table 1. Continuation

Sex	TL	WM	LFL	Weight	Sex	TL	WM	LFL	Weight
F	1.68	0.88	1.4	0.3	-	-	-	-	-
F	1.76	0.82	1.22	0.3	-	-	-	-	-
F	1.79	0.9	1.26	0.3	-	-	-	-	-
F	1.75	0.8	1.1	0.3	-	-	-	-	-
F	1.8	0.9	1.1	0.2	-	-	-	-	-
F	1.65	0.8	1.2	-	-	-	-	-	-
F	1.7	0.9	1	-	-	-	-	-	-
F	1.74	0.86	1.2	-	-	-	-	-	-
F	1.7	0.85	1	-	-	-	-	-	-
F	1.84	0.91	1.4	-	-	-	-	-	-
F	1.78	0.9	1.4	-	-	-	-	-	-
F	1.57	0.81	1.06	-	-	-	-	-	-
F	1.72	0.85	1.24	-	-	-	-	-	-
F	1.7	0.88	1.11	-	-	-	-	-	-
F	1.62	0.85	1.8	-	-	-	-	-	-
F	1.67	0.86	1.6	-	-	-	-	-	-
F	2	0.8	1.2	-	-	-	-	-	-
F	1.82	0.89	1.38	-	-	-	-	-	-
F	1.71	0.84	1.34	-	-	-	-	-	-
F	1.79	0.84	1.16	-	-	-	-	-	-
F	1.8	0.85	1.34	-	-	-	-	-	-
F	1.68	0.79	1.22	-	-	-	-	-	-
F	1.96	0.94	1.62	-	-	-	-	-	-
F	1.82	0.79	1.2	-	-	-	-	-	-
m	1.69	0.85	1.22	0.24	m	1.86	0.93	1.53	0.34
sd	0.09	0.05	0.16	0.06	sd	0.12	0.07	0.20	0.08

and Cherry, 2002; Head, 1995; Teder and Tammaru, 2005).

In this study, it is demonstrated that the males of *Enhydrus sulcatus* have higher average size than the females in a series of corporal characteristics. Similar results, with larger corporal sizes in the structures of males were also related for *Laccophilus maculosus* (Coleoptera: Dytiscidae) (Fairn *et al.,* 2007a). However, in *Dineutus nigrior* (Coleoptera: Gyrinidae), the females presented larger corporal structures than the males (Fairn *et al.,* 2007b).

Many studies reveal that males of insects are usually smaller than females mainly when the dimorphism is conspicuous (Teder and Tammaru, 2005). The cause of this pattern seems to be an influence of higher egg production in larger females (Andersson, 1994). However, the cause of males with larger corporal structures than females can be a reflection of the use of these structures aids during mating (Fairn *et al.,* 2007a, 2007c).

Many studies seek to explain the involvement of multiple evolutionary mechanisms, such as sexual selection, fecundity and niche divergence, as determinants of the sexual dimorphism patterns (Hurlbutt, 1987; Hedrick and Temeles, 1989; Stamps, 1993; Fairbairn 1997; Colwell, 2000; Monnet and Cherry, 2002). The sexual selection is frequently suggested as the cause of larger corporal sizes in males by the fact that the acquire advantages in the mating, protection of females and reduction in the niche overlap (Adams and Greenwood, 1983; Slatkin, 1984; Shine, 1989; Andersson, 1994; Weckerly, 1998), however it is difficult to test the action of these mechanisms simultaneously or to define the action of only one in isolation (Hedrick and Temeles, 1989). As an example, in *D. nigrior* the increase in fitness can be modified by the high infestation by mites that occurs in larger females (Fairn *et al.*, 2007a; 2007b).

In our study we can suggest that the larger corporal structures in males of *E. sulcatus* can be used in the capture of females during copulation, to manipulate larger prey or to grip more efficiently in the sediment avoiding niche overlap with females.

However, this dimorphism found between males and females of *E. sulcatus* represents a clear effect of sexual selection, because the length of the first

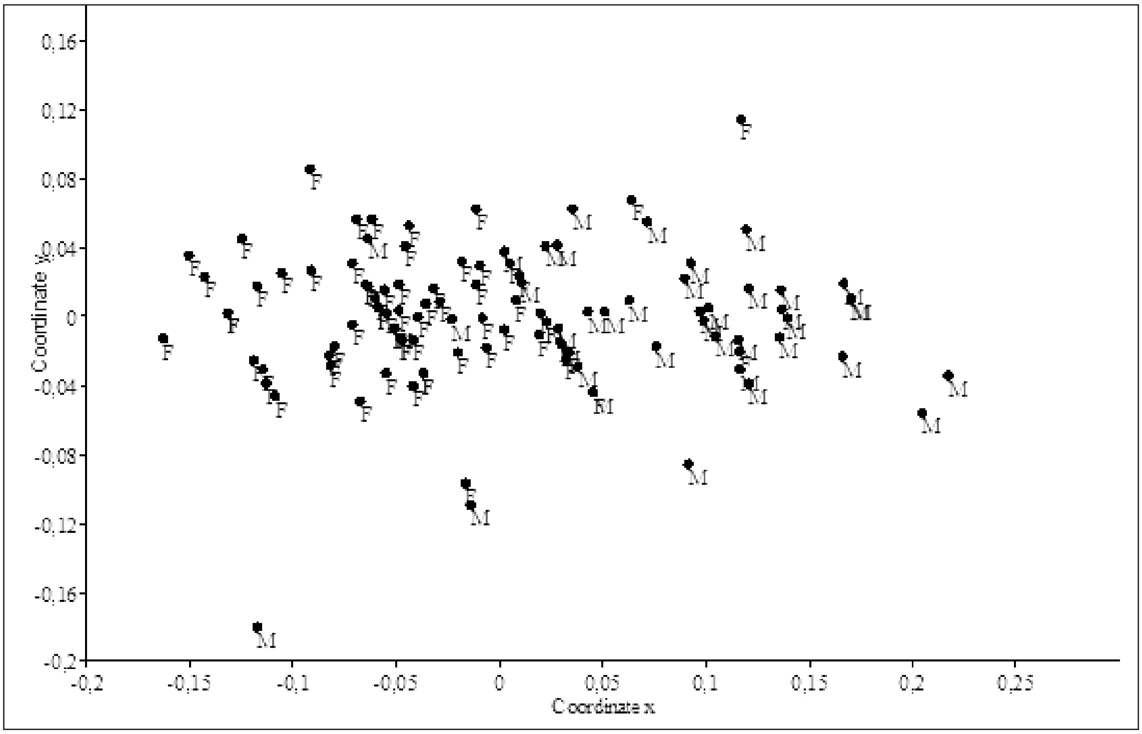

Figure 2. Ordination (MDS) of female (F) and male (M) individuals of *Enhydrus sulcatus* (Wiedeman, 1821) in streams in the southeast of Brazil, using measurements of the length of the first leg (LFL), total length (TL), width of the mesonotum (WM).

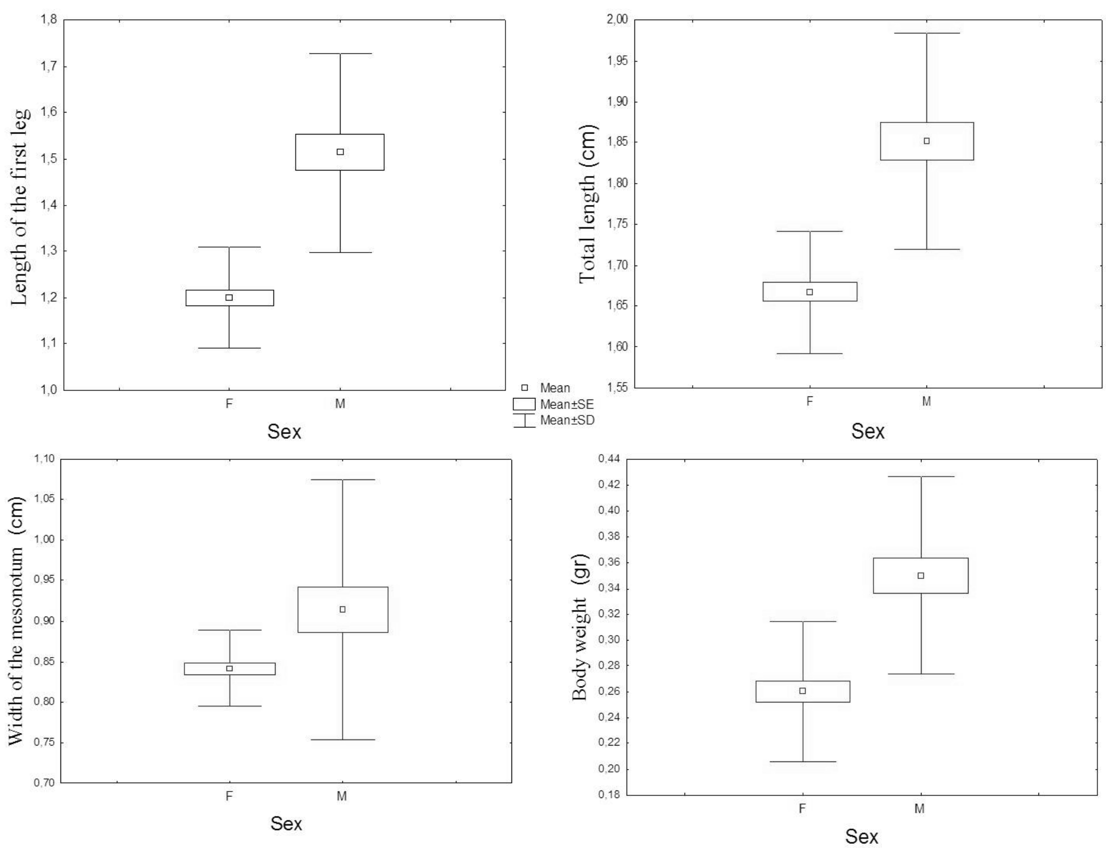

Figure 3. Differences among averages of the measurements of the length of the first leg (LFL), total length (TL), width of the mesonotum (WM), and weight of male and female individuals of *Enhydrus sulcatus* (Wiedeman, 1821) in streams in the southeast of Brazil.

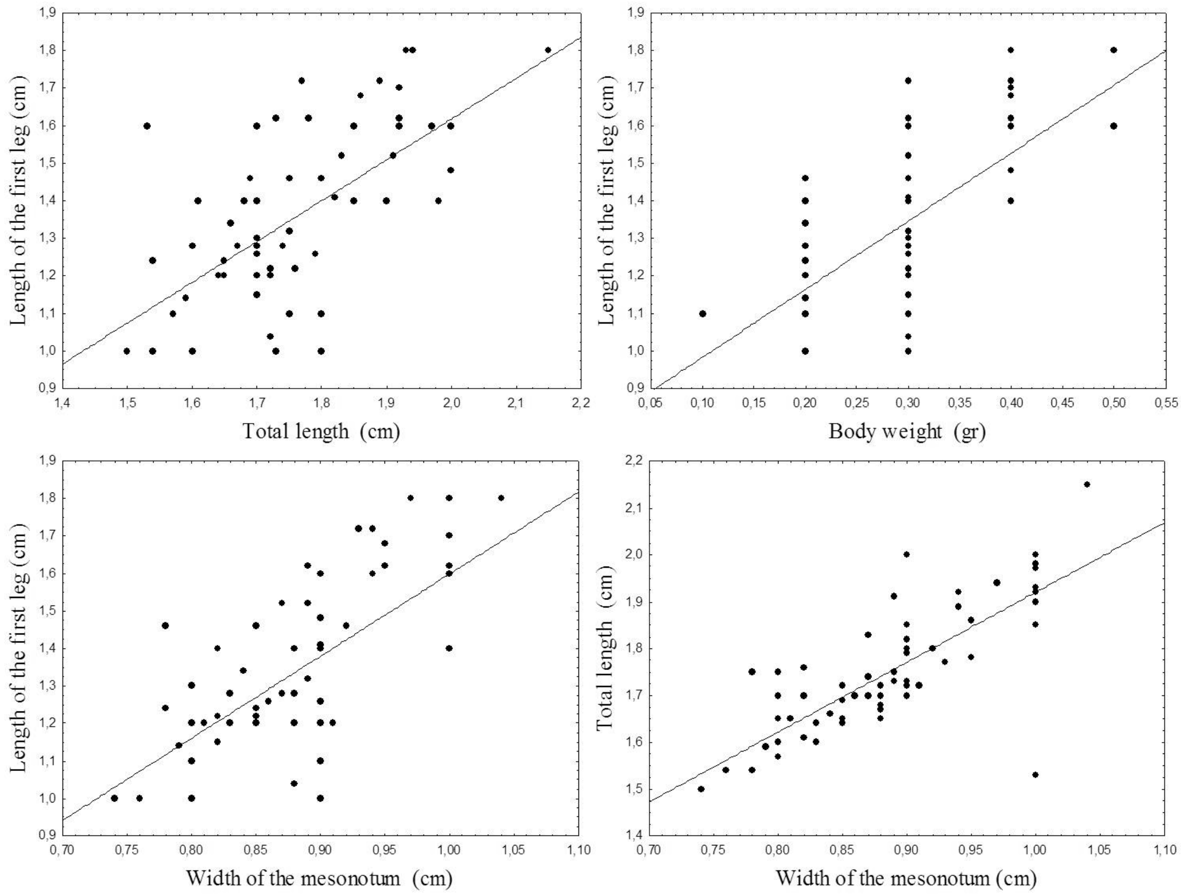

Figure 4. Positive and significant relationships among the measurements of the length of the first leg (LFL), total length (TL), width of the mesonotum (WM), and weight of male and female individuals of *Enhydrus sulcatus* (Wiedeman, 1821) in streams in the southeast of Brazil.

leg in the males can be valuable in the capture of the female for the pre-copulation process. According to Sisodia and Singh (2001), the size of the body in itself, cannot necessarily be the direct objective of the sexual selection, because that association could be the result of the selection in one or many traits correlated with the size.

In *Enhydrus sulcatus* the smaller size and weight of the females can be a product of a trophic limitation that favors lower energy expenditure strategies in the production of eggs, facing the shortage of resources in the environment (Del-Castillo and Nuñez-Farfan, 2008), however a smaller size can work as a risk factor in face of predation (Romey, 1995).

The positive relationship between the total length and the total width maintains a fusiform format in the body of *E. sulcatus* that can probably facilitate the neustonic and nektonic locomotion. Many aquatic animals have their bodies limited to rigid exoskeletons or shells that can potentially restrict flexibility of and capacity for agile maneuvers (Walker, 2000). On the other hand, corporal morphologies also developed in order to be capable to allow varied types of fast maneuvers (Webb, 1984, 1997; Weihs, 1993; Webb *et al*., 1996; Gerstner, 1999; Fish, 2002). Besides, the flexibility allows an animal to move easily in spaces with dimensions smaller than the body length.

Gyrinidae are beetles that present an exoskeleton that makes the body rigid and firm (Nachtigall, 1974), besides possessing a body formed by three low-flexibility tagmata, they also possess the back covered by a hard elytra, however the body presents a longitudinally fusiform and transversely thin design, that can be easily maneuverable, below, as well on the surface of the water. These beetles can propel their bodies with their oar-shaped mid and hind legs and dive quickly (Bendele, 1986). Besides, agile movements can facilitate prey capture, avoid predators and execute territorial behaviors (Humphries and Driver, 1967; Newhouse and Aiken, 1986; Fitzgerald, 1987).

Many arthropods have bodies limited by an exoskeleton that theoretically can become a disadvantage during locomotion and movement; however,

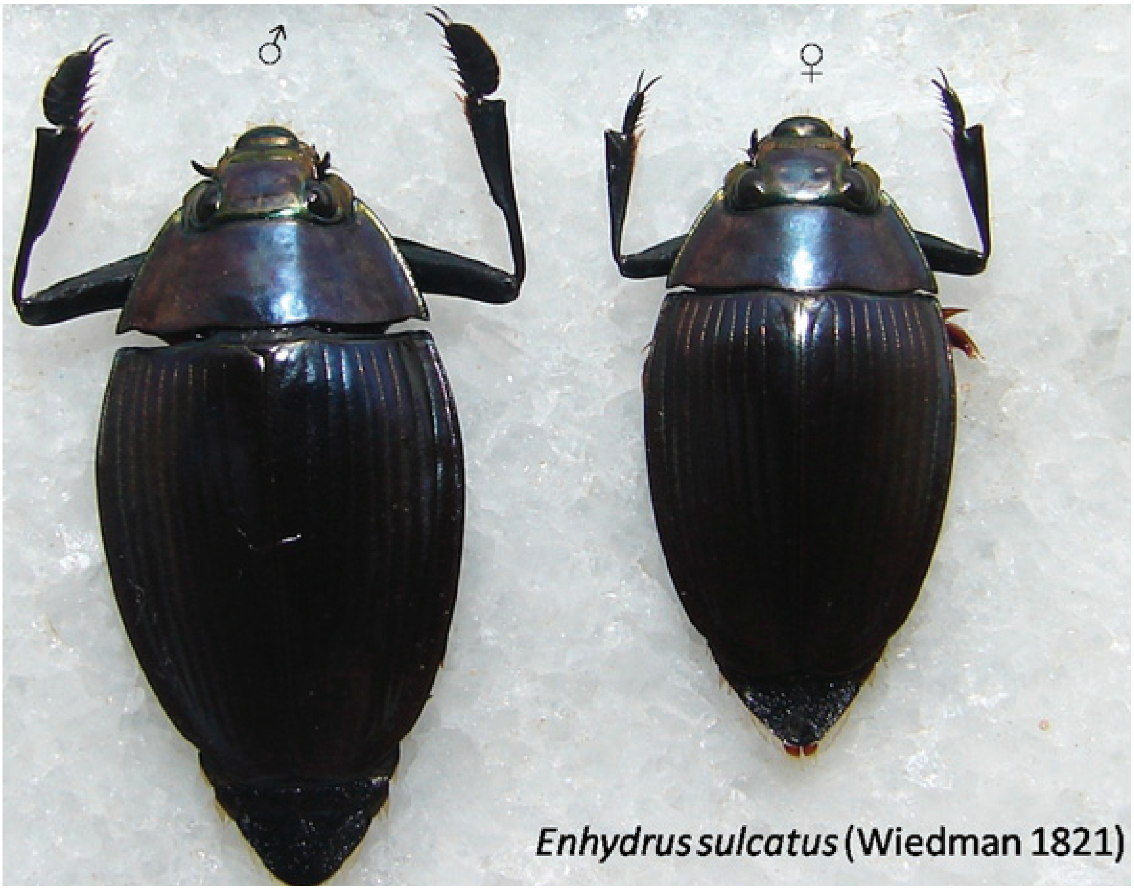

Figure 5. Male and female of *Enhydrus sulcatus* (Wiedeman, 1821) collected in Ingaí, Minas Gerais, Brazil.

many are, indeed, capable of executing fast maneuvers (Webb, 1979).

Conclusion

The present study brings important data of the biology of a species still little known and it evidences some of their intraspecific adaptive responses related to the body size of males and females, that reveals there is a clear sexual dimorphism in *Enhydrus sulcatus* and it is present in several other body structures besides the tarsal dilations, commonly mentioned in the literature. Thus, we can predict that males possess a larger body and first leg size, than females.

Acknowledgments

To the Research Coordination of the University Center of Lavras (UNILAVRAS) and Fapemig for financial support and scientific initiation scholarship.

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Submitted on June 23, 2010
Accepted on January 25, 2011