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A morphometric examination of *Anthrenus flavipes flavipes* LeConte 1854 (Coleoptera: Dermestidae: Anthrenini)

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Abstract

A morphometric examination of *Anthrenus flavipes flavipes* LeConte 1854 from Central Macedonia, Greece is carried out and compared with data from previous publications. Size ranges for both sexes are generated. Males are significantly smaller than females. The body width/body length ratio is calculated. Images of body size range, antennal club and aedeagus are provided. Elements of the elytral colour pattern are considered in the light of LeConte's original description.

Key words: *Anthrenus isabellinus*, *Anthrenus pimpinellae*, aedeagus, antenna, colour pattern.

Introduction

The hide, larder and carpet beetles, Dermestidae Latreille 1804, is a relatively speciose family containing over 1800 species (Háva, 2023). It is an understudied group and new species are being discovered at a high rate. Háva (2023) indicates the number of valid taxa has more than doubled since the publication of Mroczkowski's (1968) world catalogue. Beyond species with pest status, for example *Anthrenus verbasci* F. 1776 and *Anthrenus flavipes flavipes* LeConte 1854, little is known about the distribution and ecology of many species, and for some parts of the family the taxonomy is poorly understood. The genus *Anthrenus* Geoffroy 1762 is large, numbering over 280 species (Háva, 2023), and provides a good example of a genus within Dermestidae where the taxonomy is in a state of flux. Most workers split the genus into 10 subgenera based on adult characteristics (Háva, 2023). However, Kadej (2018) focused on larval characteristics and established that only *Anthrenus* (sensu stricto) is monophyletic with the remaining nine subgenera forming a single polyphyletic group.

Contemporary study of Dermestidae taxonomy often involves examination of genital and antennal structure (see Beal, 1998; Kadej *et al.*, 2007 by way of example). In addition, morphometric analysis has sometimes been useful in differentiating among species (Holloway and Bakaloudis, 2020; Holloway *et al.*, 2020). The importance of considering morphology, especially the structure of the male genitalia, has been demonstrated several times for the *Anthrenus pimpinellae* complex of species in the Palaearctic. For a period of time, this group of species was considered to be one or a small number of species along with several subspecies and varieties (Háva, 2023). The group has been split into 24 valid species so far, largely based on genital structure (Kadej *et al.*, 2007; Kadej and Háva, 2011; Holloway, 2019; 2020; 2021). However, many old descriptions of species never considered morphology and metrics, focusing as they did almost entirely on colour pattern. A good example of this is LeConte's (1854) brief description of *A. flavipes flavipes*. This species is a very common and widely distributed, especially across warmer climates (Beal, 1998). Perhaps because of

its abundance and being considered a familiar species, no analysis of the morphology of the species has been carried out. Lessons from the splitting of the *A. pimpinellae* complex into many species indicates that as much information as possible is desirable, even for very common species.

The purpose of the current study was to carry out a thorough examination of the morphology of *A. flavipes flavipes*, focusing on male genitalia, with a consideration of elytral colour pattern.

Materials and methods

The study insects were derived from an infestation in the natural history collection in the School of Forestry and Natural Environment, Aristotle University, Thessaloniki, Greece (Holloway and Bakaloudis, 2021). Study insects were stored in 2% acetic acid prior to use and identification was confirmed using Peacock (1993), Háva (2011), and Herrmann (2023). Insects were dissected following the procedure described by Holloway and Bakaloudis (2020). Dissection was carried out under a Brunel BMSL zoom stereo LED microscope. Images of the male and female habitus, dorsal and ventral sides, were captured at $\times 20$ using a Canon EOS 1300D camera mounted on the BMSL microscope. Dissection of males involved detaching the abdomen from the rest of the insect using two entomological pins. The soft tergites were then peeled off the harder sternites to expose the genitalia. The aedeagus was detached from the ring sclerite. In addition to the aedeagus, sternite IX was also detached from the ring sclerite and the aedeagus. Images of aedeagi and sternite IX were captured at $\times 100$ magnification for measurement using the EOS camera mounted on a Brunel monocular SP28 microscope. After dissection, all body parts were mounted on card. The antennae were teased out and images of the antennae taken at $\times 200$ SP28 microscope. All images were fed through Helicon Focus Pro version 6.8.0 focus-stacking software. Morphometric measurements were made using DsCap.Ink Software version 3.90.

Measurements taken: Body length (BL) - distance from anterior margin of pronotum to the apex of the elytra; Body width (BW) - distance across each elytron from the

mid-point of the outer margin to the centre (values for each elytron summed); Antennal club length (AL) - length of the last three antennomeres; Antennal club width (AW) - maximum width across the terminal antennomere; Aedeagus length (AE) - distance from the anterior end of the aedeagal cap to the apex of the parameres; Sternite IX length (SL) - distance from the tip of one anterior horn to the tip of the posterior margin.

Statistical analysis (t-test and linear regression) was carried out using Minitab (version 19.1.1). Means (\pm standard deviation) are presented. Coefficient of variation (CV) values (standard deviation/mean \times 100%) are also included as an indication of a standardised measure of variability of each character.

Results

All data were normally distributed and homoscedastic. A total of 50 individuals were examined: ♂ n = 29, ♀ n = 21. Mean BL: ♂ = 2.988 ± 0.199 mm, ♀ = 3.252

± 0.213 mm. Females were significantly larger than males ($t_{48} = 4.96$, $p < 0.001$). The standard deviations suggest that BL of 95% of male specimens would be 2.5-3.4 mm and 95% of female specimens would be 2.8-3.7 mm. From the study specimens, male BL ranged from 2.6 mm to 3.4 mm and female BL ranged from 2.8 mm to 3.6 mm. Figure 1 illustrates the size range. There was no difference in BW/BL between the sexes ($t_{48} = 0.99$, not significant). Average BW/BL was 0.74 ± 0.02 , CV = 2.6%.

AL: ♂ = ♀ = 238 ± 7.7 μ m, CV = 3.2%. AW: ♂ = ♀ = 142 ± 5.7 μ m, CV = 4%. AL/AW = 1.68. Figure 2 shows the antennal structure. The antennal club is broader vertically than it is along the anterior-posterior axis. The anterior surface is flat, the posterior surface is convex.

Figure 3 shows the aedeagus, Mean AE = 505 ± 13 μ m, CV = 2.6%. Figure 4 shows sternite IX. Mean SL = 468 ± 16 μ m, CV = 3.4%. There is a significant linear relationship between BL and AE ($AE = 403.5 + 0.0341BL$, $p = 0.005$). A 5% change in BL is associated with a 1% change in AE.



Figure 1. Dorsal surface of *A. flavipes flavipes* illustrating size range within the species. Left, a large female, right, a small male. Scale bar = 1 mm.

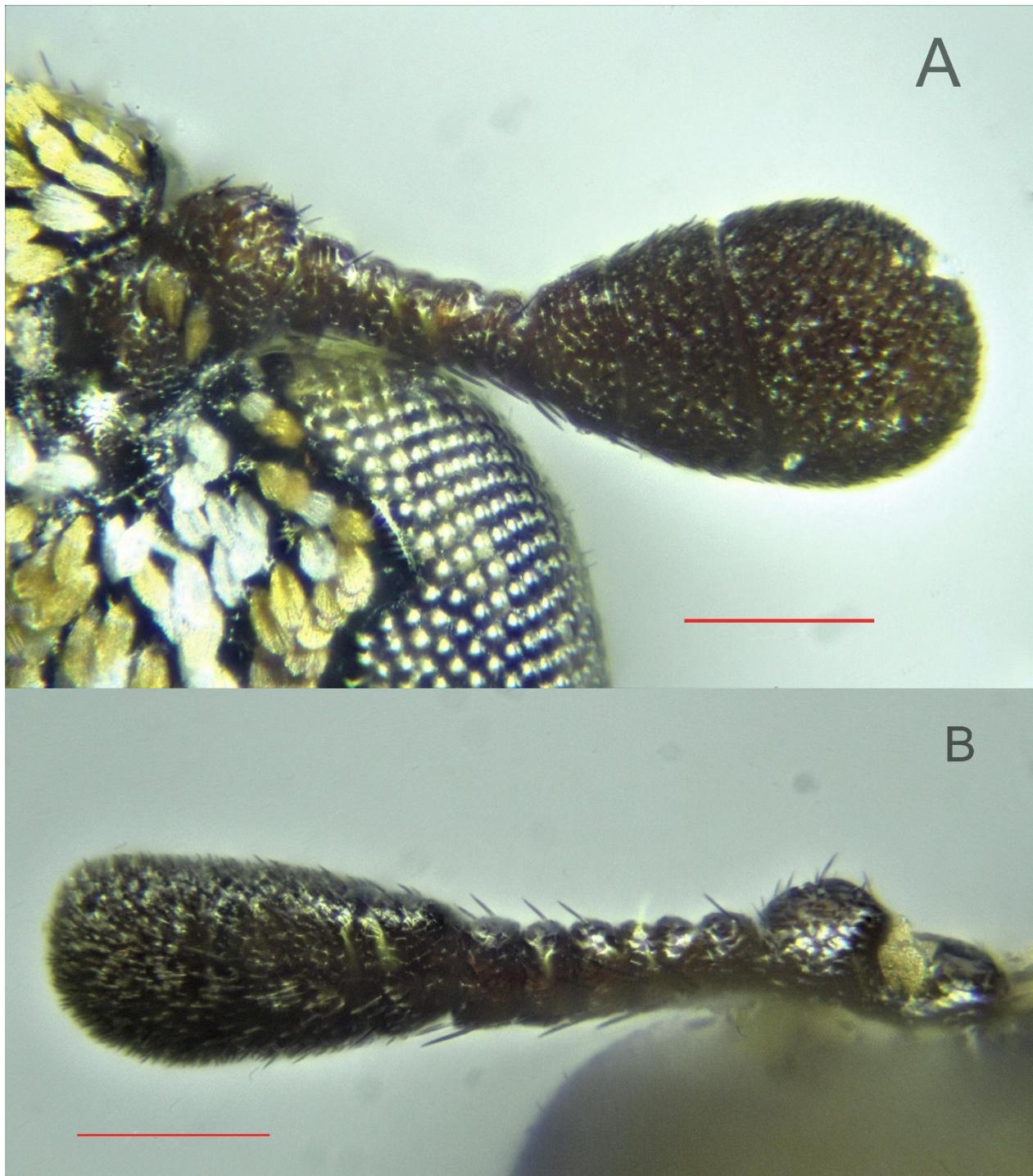


Figure 2. Antennal club of male *A. flavipes flavipes*, **A)** anterior face, **B)** dorso-ventral axis. Scale bar = 100 μm .

Discussion

Very little morphometric data on *A. flavipes flavipes* exists. LeConte (1854) reports BL as 0.12 inch (approximately 3 mm), whilst Hinton (1945) states BL as 2.0-3.5 mm. Herrmann (2023) and Háva (2011) state the same range as Hinton (1945). In the current study we found BL to fall mostly between 2.5 mm for a small male to 3.7 mm for a large female, so the upper limit provided by Hinton (1945) concurs relatively well with the current study, but

Hinton's (1945) value for the smallest *A. flavipes flavipes* is too small (at least for the current study population). Hinton (1945) states that females are externally identical to males. The current study shows that females are significantly larger than males (figure 1). Females are quite often larger than males in *Anthrenus* species, but not always. Female *Anthrenus amandae* Holloway 2019 are significantly larger than male *A. amandae*, but there is no difference in BL between male and female *A. pimpinellae* (Holloway and Bakaloudis, 2020).



Figure 3. Aedeagus of *A. flavipes flavipes*, **A)** dorsal side, **B)** ventral side illustrating distribution of setae in particular at paramere tip. Scale bar = 100 μ m.

Hinton (1945) also provided values for BL, ranging from 2 mm to 3.5 mm, and for BW, ranging from 1.4 mm to 1.7 mm. The value BW = 1.7 mm must be a typographical error and should most likely read 2.7 mm. If that was the case, the BW/BL values would be: 1.4 mm/2 mm = 0.7 and 2.7 mm/3.5 mm = 0.77. Given how coarse Hinton's (1945) measurements are, the values for BW/BL derived from his work are very close to the actual BW/BL value of 0.74. The BW/BL ratio is highly conserved and a useful character to distinguish between some species, so it is important to measure it with precision. LeConte (1854) describes the lateral elytral margins as briefly ovate (translated from Latin), whilst Hinton (1945) states that the lateral elytral margins are 'distinctly rounded'. These types of descriptions are of little value and could relate to any number of *Anthrenus* species. For example, the lateral margins of *A. pimpinellae* are clearly rounded, but less so than *A. flavipes flavipes*. BW/BL for *A. pimpinellae* is 0.68, so it is considerably more parallel sided than *A. flavipes flavipes*. The other factor making BW/BL a

useful aid to species differentiation (in conjunction with other characters) is that it appears to be highly conserved across species studied so far. CV for *A. flavipes flavipes* is 2.6% whilst for *A. pimpinellae* CV is 1.86% (Holloway and Bakaloudis, 2020) with no variation between sexes. Compare this with CV for *A. flavipes flavipes* BL (6.6% for both sexes), *A. amanda* BL (δ = 8.5%, φ = 4.6%) and *A. pimpinellae* BL (δ = 8.3%, φ = 9.8%) (Holloway and Bakaloudis, 2020). The importance of carefully considering the shape of the habitus is illustrated by LeConte (1854) who stated that "the form of the body (of *A. flavipes flavipes*) is that of *A. thoracicus*". This is clearly not accurate. Herrmann (2023) shows an image of *Anthrenus thoracicus* Melsheimer 1844 with a BW/BL of 0.68-0.69. *A. flavipes flavipes* has a BW/BL of 0.74, and it is easy to see that the image of *A. thoracicus* shown by Herrmann (2023) is more parallel sided than *A. flavipes flavipes*. Beal (1998) recorded *A. thoracicus* BL as 2.5 mm for males and 2.8 mm for females, considerably smaller than *A. flavipes flavipes*. Beal (1998) appreciated the value of

the BW/BL ratio and produced ratios for many species, but not for *A. flavipes flavipes*. Holloway *et al.* (2021) used BW/BL when arguing that *Anthrenus isabellinus* Kuster 1848 exists in USA rather than *A. pimpinellae*.

Figure 2 shows the antennal club from different orientations. LeConte (1854) described the antennal club as “broad, round and compressed”. The terms “broad...and compressed” are accurate, but round is misleading. The antennal club has a rounded apex but cannot be described as round. The structure of the antennal club did not vary between sexes and was elongate, 1.6× longer than broad. AL for male *A. isabellinus* from Central Macedonia, Greece is $206 \pm 0.011 \mu\text{m}$ (GJH unpublished data), a species with a similar size range to *A. flavipes flavipes*, so the antennal club of *A. flavipes flavipes* is more elongate than *A. isabellinus*. LeConte (1854) pointed out that the antennal club of *A. flavipes flavipes* is compressed. Hinton (1945) and Beal (1998) both illustrate the anterior face of the antenna of *A. flavipes flavipes* very accurately, but neither mention the lateral compression. The antennal club is compressed along the anterior posterior axis. The anterior face of the antennal club is flat, whereas the posterior side is clearly convex.

Figure 3 shows the aedeagus. Published illustrations or images of the aedeagus of *A. flavipes flavipes* are scarce. Beal (1998) produced a nice illustration of *A. flavipes flavipes* aedeagus, although Beal (1998) does not illustrate the structure of the tip of the aedeagus accurately, nor the substantial tuft of setae at the tip of the parameres which is particularly evident on the ventral side. There is a significant allometric relationship between BL and AE, but this relationship is not 1:1. For a 5% change in BL, AE only changes by 1% indicating developmental constraint on the size of AE. There is a great deal of variation among insect species in genital structure, even among closely related species (Hosken and Stockley, 2004; Mendez and Córdoba-Aguilar, 2004; Grimaldi and Engel, 2005). Theoretical work suggests that the wide among-species variation in genital structure is driven by hidden sexual selection where females select aedeagus structures that promote high levels of fertilisation (Eberhard, 1985; Hosken and Stockley, 2004; Mendez and Córdoba-Aguilar, 2004) and excludes the formation of low-fitness hybrids. The same sexual selection would favour the aedeagal structure that achieves fertilisation most efficiently. This would limit variation in intra-specific aedeagal size and structure. The authors are not aware of any illustration or image of *A. flavipes flavipes* sternite IX (figure 4).

LeConte (1854) passed comment on one specimen from New York, USA and described the white elytral spots as seeming “inclined to form three fasciae”. The specimens studied here did not display any such tendency. The sub-basal elytral white spots do sit within orange scales to form a fascia, but across the middle of the elytra there are two well separated white spots, one adjacent to the elytral suture and the other on the lateral margin (see figure 1). There is a substantial area of black scales separating these two white spots, which show no tendency to form a fascia. The two apical spots sit within orange scales spread throughout the apical region of the



Figure 4. Sternite IX of *A. flavipes flavipes*. Scale bar = 100 μm .

elytra and up the lateral margin to meet the mid-elytral white spots, but again do not really form a fascia.

Apart from the occasional exception (e.g., Kadej *et al.*, 2007), morphometric studies have largely been overlooked in the study of Dermestidae, but they can be a useful tool in the separation of some species from each other, and the resolution of taxonomic issues (Holloway *et al.*, 2020). To date, extensive morphometric analysis has only been carried out on a handful of Dermestidae, namely *A. pimpinellae* and *A. amandae* (Holloway and Bakaloudis, 2020), *A. isabellinus* (Holloway *et al.*, 2020), *Attagenus rufiventris* Pic 1927 (Hermand and Holloway, 2020), *Anthrenus nippensis* Kalik et Ohbayashi 1984 (Holloway and Foster, 2022), *Anthrenus munroi* Hinton 1943 (Holloway and Cañada Luna, 2022), and *Trogoderma angustum* (Solier in Gay 1849) (Holloway and Sparks, 2023). This study contributes to a more thorough understanding of *A. flavipes flavipes*.

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