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SHORT COMMUNICATION

Estimating the body size of orchid bees (Hymenoptera: Apidae: Euglossini) using the distance between their tegulae

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Abstract. Body mass is an important morphological trait, which is associated with the physiology and ecology of insects. In the past, estimates of body mass were often based on general mathematical equations in which body mass was related to linear measurements of anatomical structures. For example, in female bees, estimates of dry body mass are expected to follow a non-linear relationship (power function) with the distance between the tegulae on their thorax, also known as the intertegular distance (ITD). Nonetheless, a major group of bees not included in previous studies are the Neotropical orchid bees of which mostly males are collected. We investigated whether a similar non-linear relationship is also the case for male orchid bees and we found positive evidence as the relationship can be represented by a power function providing reliable estimate of dry body mass. This is particularly important for estimating dry body mass of individuals stored in collections.

INTRODUCTION

Body size in orchid bees (Apidae: Euglossini) has been used as a predictor in studies addressing ecological, physiological and anatomical aspects such as population dynamics (Lawton, 1990; Roubik & Hanson, 2004), immunocompetence (Arriaga-Osnaya et al., 2017), vertical flight (Dillon & Dudley, 2004) or energy used in flight (Darveau, 2004; Darveau et al., 2005). In these types of study, body size is estimated as the wet body mass of the specimens.

For studies that do not require wet body mass, body size measured as the distance between the two insertion points (tegulae) of the wings on the thorax (intertegular distance) is used as a response variable to environmental changes (Suni & Dela Cruz, 2021) and anthropogenic effects (Garlin et al., 2022). Cane (1987) introduced the use of the ITD as an estimator of body size in bees, which strongly correlates with their dry body mass. For Euglossini, Peruquetti (2003) was the first to use ITD as a response variable to evaluate variation in morphology as a result of fluctuations in resource availability and seasonality. Currently, ITD is even used as a standardization variable; for example, Brand et al. (2018) used ITDs to standardize the use of neuroanatomical volumes in the euglossine *Euglossa dilemma*. However, there is no study on whether the ITD of orchid bees is a good estimator of body size, within and between species.

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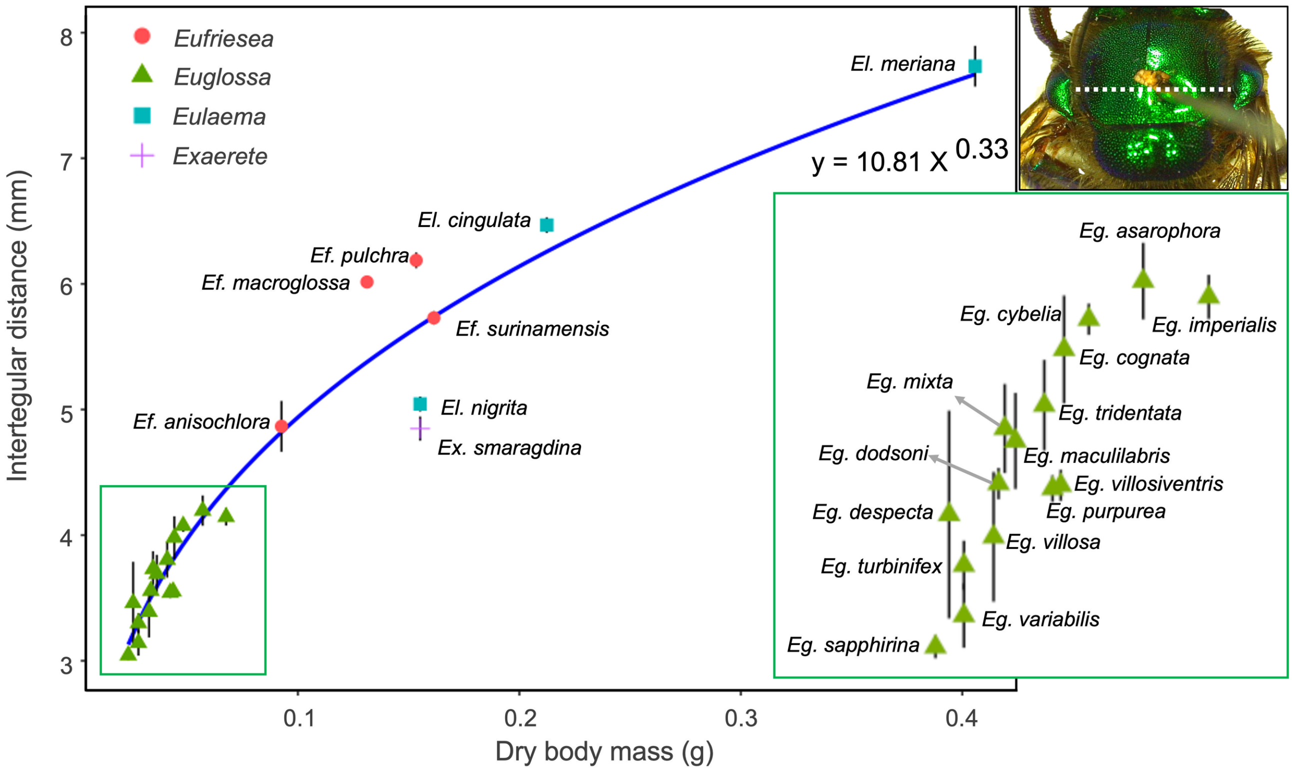

Fig. 1. Power function relationship between dry body mass (g) and ITD (mm). The vertical lines are the standard deviations for the ITD, and each symbol is the mean for a particular species. The regression equation and a diagram of the ITD are in the upper right corner of this figure.

Here, the relationship between ITD and dry mass in male orchid bees was evaluated. Initially the concern was the lack of information for relationship between these two measurements for orchid bees since the seminal study of Cane (1987) did not include any species of the tribe Euglossini. Moreover, he used only female bees, whereas studies on Euglossini mostly collect only males (Añino et al., 2019), with one sample only including one female per species for 20 species. Finally, the mathematical precision is a bit misleading since it indicates exponential growth, although its representation and the equations indicate a power function.

MATERIAL AND METHODS

A total of 105 male individuals stored in the collection of the Invertebrate Museum of the University of Panama (relative humidity: 65%), belonging to 23 species collected between 1967 and 2019 were studied, including four of the five genera of orchid bees (*Eufriesea* Cockerell, *Euglossa* Latreille, *Eulaema* Lepeletier and *Exaerete* Hoffmannsegg; Supplement S1). The South American genus *Aglae* Lepeletier & Audinet-Serville containing one species was not included. All the individuals were identified using the taxonomic key of Roubik & Hanson (2004). Five individuals per species were measured except in the case of species for which there were few individuals in the museum. We used specimens mounted and stored in entomological boxes and we attempted to maximize the variation in body size. Each bee was weighed on a digital balance (0.001 g) and photographed using a CMOS digital camera attached to a Leica stereomicroscope (S9i LED2500), supported by the Leica Software Application Suite X. Adobe Photoshop (CS6) was used for image stacking of eight photographs in order to produce the final image of the dorsal part of the thorax of each bee. This generated high resolution images, which increased the precision with which the ITD could be measured using the program ImageJ (Abràmoff et al., 2004).

The relationship between dry mass (g) and ITD (mm) using a power function (misidentified by Cane, 1987 as exponential growth) is

$$Y = aX^b$$

where Y is the dry mass, X is the ITD and a and b are regression parameters. The values used in the model are the averages for each species, since it is possible that the mass varied due to the activity of collection pests such as dermestid beetles. In addition, the model was also run with the individual measurements (Supplement S2). Finally, this analysis was done using only *Euglossa* species, which is the richest genus in the tribe. The lm function in R (R Core Team, 2023) was used to build the model.

RESULTS

For Euglossini males there is a strong relationship between mean ITD and mean dry body mass, the best fit for which is a power function ($p < 0.0001$, $R^2 = 0.93$, Fig. 1). The power function based on the individual measurements is similar ($p < 0.0001$, $R^2 = 0.91$, Supplement S2). An analysis of individual measurements for *Euglossa* species also follows a power function ($p < 0.0001$, $R^2 = 0.68$, Supplement S2)

DISCUSSION

The results of this study corroborate those of Cane (1987) based on females of other tribes of bees. ITD is an indirect measurement of body size and dry mass and should not be used in studies that require wet body mass, unless a relationship with wet mass is established. Power function relationships between dry mass and measurements of body size are reported for other insects (Smock, 1980; Lobo, 1993). Further studies are needed to evaluate whether the power function calculated for recently dried individuals is the same as that for those stored for a long time in a collection.

Specimens in collections may be eaten by other insects (e.g., Dermestidae and Ptinidae beetles: Duarte et al., 2018; Vivar et al., 2005), which would reduce their dry mass. Large sample sizes may compensate for that. More work is required to determine whether within-species variation in ITD is closely correlated with dry body mass in euglossines. As suggested by Cane (1987), this relationship should be validated for species of interest.

Finally, this study revealed that a power function for males of the Euglossini tribe can be used for estimating dry body mass and this relationship holds for all *Euglossa*. A problem of working with orchid bees is that females are mostly unknown and that in some Hymenoptera forewing width is a better predictor of body size in females (Ohl & Thiele, 2007). Although reports of power functions between body dry mass and body parts are relatively common in insects (Smock, 1980; Cane, 1987; Lobo, 1993), they are not universal since in some insects and other arthropods, simple linear relationships provide much better fits (García-Barros, 2015; Penell & Raub, 2018). Therefore, other studies should evaluate this relationship for other groups of bees and whether ecological variables can account for any variation. This relationship is an important tool for studying traits related to body mass such as flight-related morphology, metabolic rates, allometry or foraging behaviour, as well as in the study of stressors influencing body size (parasites, pesticides, abiotic factors, resource availability).

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REFERENCES

Abràmoff M.D., Magalhães P.J. & Ram S. 2004: Image Processing with ImageJ. — *Biophotonics* **11**: 36–42.

Añino Y., Parra A. & Gálvez D. 2019: Are orchid bees (Apidae: Euglossini) good indicators of the state of conservation of Neotropical forests? — *Sociobiology* **66**: 194–197.

Arriaga-Osnaya B., Contreras-Garduño J., Espinosa-García F., García-Rodríguez Y.M., Moreno-García M., Lanz-Mendoza H., Godínez-Álvarez H. & del Castillo R.C. 2017: Are body size and volatile blends honest signals in orchid bees? — *Ecol. Evol.* **7**: 3037–3045.

Brand P., Larcher V., Couto A. & Ramírez S.R. 2018: Sexual dimorphism in visual and olfactory brain centers in the perfume-collecting orchid bee *Euglossa dilemma*. — *J. Comp. Neurol.* **526**: 2068–2077.

Cane J. 1987: Estimation of bee size using intertegular span (Apoidea). — *J. Kansas Entomol. Soc.* **60**: 145–147.

Darveau C.-A. 2004: *Evolution of Energy Metabolism in a Lineage of Orchid Bees (Apidae: Euglossini): From Morphology to Molecules*. University of British Columbia, Vancouver, 140 pp.

Darveau C.-A., Hochachka P.W., Welch K.C. Jr, Roubik D.W. & Suarez R.K. 2005: Allometric scaling of flight energetics in Panamanian orchid bees: a comparative phylogenetic approach. — *J. Exp. Biol.* **208**: 3581–3591.

Dillon M.E. & Dudley R. 2004: Allometry of maximum vertical force production during hovering flight of neotropical orchid bees (Apidae: Euglossini). — *J. Exp. Biol*. **207**: 417–425.

Duarte S., Montano-Pérez M. & Aguilar-Veloz L. 2018: Diagnóstico de plagas en las colecciones neontológicas secas. — *Poeyana* **506**: 31–35.

García-Barros E. 2015: Multivariate indices as estimates of dry body weight for comparative study of body size in Lepidoptera. — *Nota Lepidopterol.* **38**: 59–74.

Garlin J., Theodorou P., Kathe E., Quezada-Euán J.J.G., Paxton R.J. & Soro A. 2022: Anthropogenic effects on the body size of two neotropical orchid bees. — *BMC Ecol. Evol.* **22**: 94, 13 pp.

Lawton J. 1990: Species richness and population dynamics of animal assemblages. Patterns in body size: abundance space. — *Phil. Trans. R. Soc. (B)* **330**: 283–291.

Lobo J. 1993: Estimation of dung beetle biomass (Coleoptera: Scarabaeoidea). — *Eur. J. Entomol*. **90**: 235–238.

Ohl M. & Thiele K. 2007: Estimating body size in apoid wasps: the significance of linear variables in a morphologically diverse taxon (Hymenoptera, Apoidea). — *Mitt. Zool. Mus. Berl*. **83**: 110–124.

Penell A. & Raub F. 2018: Estimating biomass from body size of European spiders based on regression models. — *J. Arachnol.* **46**: 413–419.

Peruquetti R.C. 2003: Variação do tamanho corporal de machos de *Eulaema nigrita* Lepeletier (Hymenoptera, Apidae, Euglossini). Resposta mater na à flutuação de recursos? — *Rev. Bras. Zool*. **2**: 207–212

R Core Team 2023: *R: A Language and Environment for Statistical Computing (Version 4.3.1)*. R Foundation for Statistical Computing, Vienna, Austria.

Roubik D. & Hanson P. 2004: *Orchid Bees of Tropical America: Biology and Field Guide.* Instituto Nacional de Biodiversidad (INBio), Heredia, 370 pp.

Smock L. 1980: Relationships between body size and biomass of aquatic insects. — *Freshw. Biol*. **10**: 375–383.

Suni S.S. & Dela Cruz K. 2021: Climate-associated shifts in color and body size for a tropical bee pollinator. — *Apidologie* **52**: 933–945.

Vivar I., Tejuca A. & Fuentes R. 2005: Registros de plagas en los almacenes de fondos de exhibición del museo nacional de historia natural. — *Cocuyo* **15**: 24–26.

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Online supplementary files:

S1 (http://www.eje.cz/2024/006/S01.pdf): Specimen database.

S2 (http://www.eje.cz/2024/006/S02.pdf): Scripts for R and analysis.