Research Article

Atypical Wing Venation in Dialictus and Hemihalictus and Its Implications for Subgeneric Classification of Lasioglossum

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The subgeneric classification of hundreds of species in Lasioglossum Curtis sensu lato is currently unstable due to differing opinions on the suitability of wing venation characters for differentiating subgenera. The subgenera Dialictus Robertson and Hemihalictus were both originally defined primarily by the forewing having two submarginal cells. I present examples of variation in submarginal cell number in the type species of these two subgenera: L. (Dialictus) anomalum (Robertson) and L. (Hemihalictus) iustrans (Cockerell). These results suggest that submarginal cell number is insufficient for recognizing subgenera in Lasioglossum. The variability of this character is used to refute the classification proposed by some authors that Chloralictus Robertson, but not Dialictus, be synonymised with Evylaeus Robertson.

1. Introduction

Lasioglossum Curtis sensu lato (Apoidea: Halictidae) is the largest genus of bees with over 1700 described species [1]. This cosmopolitan genus includes many commonly collected bees which can, in both temperate and tropical areas, dominate the bee fauna in terms of number of individuals (see [2] for Ontario, [3] for Louisiana, [4] for North Carolina, and [5] for Maryland, Chihuahuan desert, and Columbia plateau, Ngo et al. in prep. for Costa Rica). In addition, the behaviourally diverse Lasioglossum s.l. has been the focus of numerous sociobiological studies (reviewed in [6–9]) and is an ideal group for studying the evolution of social behaviour [10].

There are competing classifications currently in use within Lasioglossum s.l. [11–15] that result in unstable nomenclature for many species and confusion among researchers [16]. These classifications depend on whether wing venation characters are sufficient to recognise genus-group names in Lasioglossum s.l. The utility of these characters is examined in an attempt to provide support for a more stable classificatory system. Stable classification and nomenclature for these important bees are highly desirable to facilitate continued study and communication of results.

Lasioglossum s.l. has been subdivided into two “series” based on the strength of the distal veins of the forewing [11, 17]. The Lasioglossum series has the outermost veins, 2rs-m, 2m-cu, and the second abscissa of M weak; the Hemihalictus series has an additional weakened vein, 1rs-m. In some cases 1rs-m is absent resulting in two rather than three submarginal cells (Figure 1). The Hemihalictus series, at least, seems to be a monophyletic group [17, 18] and likely resulted as a transition from an ancestral strong vein state with the state seen in the Lasioglossum series as a possible intermediate. The Hemihalictus series consists of more than half (>900) of the species in the genus Lasioglossum, including those under consideration in this paper.

The presence or absence of vein 1rs-m has been used to recognise genus-group names for taxa included in the Hemihalictus series (see [11, 13, 14, 19–25], and [16] for a complete list of genus-group names). In competing classifications, several hundred species in the Hemihalictus series are classified as either Dialictus Robertson or Evylaeus Robertson depending on the status of the genus-group name Chloralictus Robertson [11, 13]. Chloralictus was formerly in common use for many species [23] but now is conventionally treated as a junior synonym of either Dialictus [11, 15, 24, 26]
or *Evylaeus* [12–14]. *Hemihalictus* Cockerell is the oldest name in the *Hemihalictus* series but has only ever been applied to a single species, *L. lustrans* (Cockerell).

These four genus-group names were first erected based primarily on differences in wing venation and colouration (Table 1) [20, 21]. *Dialictus* and *Chloralictus*, as originally defined, both have metallic colouration but differ in their number of submarginal cells: *Dialictus* has two (vein 1rs-m absent) and *Chloralictus* has three (vein 1rs-m present). *Hemihalictus* and *Evylaeus* have a similar relationship; both are nonmetallic but have two and three submarginal cells, respectively. The presence or absence of metallic colouration is now widely regarded as a poor character for recognising genus-group names in these bees because it can vary within species and among closely related species (see [11, 15, 24, 31, 33, 34]). As a result *Dialictus s.l.* (+*Chloralictus*) and *Evylaeus s.s.* both include species with and without metallic colouration [11, 28]. Mitchell [26] was the first to treat *Chloralictus* as a junior synonym of *Dialictus*. Individuals from many species of *Chloralictus* and *Dialictus s.s.* may have vein 1rs-m present in one wing and absent in the other [29]. At least two metallic species not closely related to the type species of *Dialictus, L. anomalum* (Robertson), are known to be polymorphic for the presence or absence of vein 1rs-m, *L. parvum* (Cockerell) [30] and *L. asteris* (Mitchell) [15]. *Lasio glossum parvum* belongs to the *tegulare* species-group of Gibbs [31] whereas *L. asteris* is a social parasite [32] only distantly related to the aforementioned groups (see [18], Gibbs unpublished data). Mitchell [26] considered the absence of vein 1rs-m to be an unreliable character for these bees. Many subsequent authors have followed his classification (e.g., [11, 15, 24, 31, 33, 34]).

In contrast, Ebmer [13, 25, 27] has argued that the presence or absence of vein 1rs-m is sufficient to classify *Dialictus* and *Chloralictus* as separate subgenera. As such, *Chloralictus* is then considered by him to be a junior synonym of *Evylaeus* because colour is not considered a reliable character [27]. The classification espoused by Ebmer [13, 25] is followed by others [12, 14] and results in a paraphyletic *Evylaeus* (+*Chloralictus*) [18, 35] because *Dialictus sensu* Ebmer [13], Pesenko et al. [12] and Murao and Tadauchi [14] is derived from within it (see [18]; Gibbs unpublished data). Ebmer [13] explicitly rejects a strict cladistic classification for these bees. Thus, the classification set forth by Ebmer [13, 25], and used by many Old World authors, depends solely on the reliability of the presence or absence of vein 1rs-m for separating *Dialictus* from *Chloralictus*.

The genus-group name *Hemihalictus* has only ever been applied to a single species, *L. lustrans*, a solitary oligolege on *Pyr rhophappus* DC [36] and related Asteraceae in the tribe Cichorieae (M. Arduser in litt.). *Hemihalictus* renders *Dialictus s.l.* paraphyletic [18] but has never been treated as a synonym because it has priority over all other names in the *Hemihalictus* series [11, 16] and would require hundreds of name changes if the synonymy was applied. *Hemihalictus* is characterized by the lack of vein 1rs-m, nonmetallic integument, serrate inner hind tibial spurs of females, and short flagellomeres in males. The flagellomere character is also seen in some *Dialictus s.l.* (e.g., *L. pectorale* (Smith)) as well as some *Evylaeus s.s.* (e.g., *L. marginatum* (Brullé)), and the hind tibial spur character is similar to those of some *Evylaeus s.s.* (e.g., *L. laeve* (Kirby) and *L. lineare* (Schenck); see [12] for variation in hind tibial spurs). All of the species in the preceding sentence would be considered *Evylaeus* in some classifications [13, 24, 26, 27].

Variation in the wing venation of *L. anomalum*, the type species of *Dialictus, and L. lustrans*, the type species of *Hemihalictus*, is described herein based on large-scale taxonomic studies of *Dialictus s.l.* [15, 31, 37]. The implications of this variation for the subgeneric classification of *Lasio glossum s.l.* are discussed.

### 2. Methods

My revisionary studies of North American *Dialictus s.l.*, which include the type species of both *Dialictus* and *Chloralictus*, have involved the examination of many tens of thousands of specimens [15]. In addition to morphology, my studies have included a molecular component for aiding taxonomic study [15, 31, 37–39]. A database of over three thousand homologous DNA sequences (DNA barcodes) for *Lasio glossum s.l.* is currently stored on the Barcode of Life Data Systems [40] and GenBank.

DNA barcoding, the use of a standard gene fragment for species-level identification [41], was used to verify the identity of some of the specimens described herein. The standard fragment used for animals is 658 bp on the 5′ end of cytochrome *c* oxidase subunit 1 [42]. Sequencing was performed at the Canadian Centre for DNA Barcoding at the University of Guelph (Guelph, Ontario). DNA was extracted from a single dried leg (or in some cases two legs) using automated extraction protocols for 96-well plates [43]. One of two primer pairs was used to amplify the DNA barcode region (LCO1490 and HCO2198 [44] or the variants LepF1 and LepR1; [45]). Samples that failed to amplify were then reattempted using internal primer pairs (LepF1 and C_AntMr1D-RonIdg_R [46] and LepR1/MLepF1; [47]). PCR and sequencing reactions followed standard Canadian Centre for DNA Barcoding protocols [48]. Sequences were uploaded to the Barcode of Life Data Systems [40].

### 3. Results

Seven individuals of *Lasio glossum* (*Dialictus*) *anomalum* with atypical wing venation were examined (Table 2). Six of these had vein 1rs-m present in one wing but absent in the other. The final specimen, collected in Guelph, Ontario, Canada, approximately 900 km Northeast of the type locality in Carlinville, Illinois, had vein 1rs-m present in both wings (Figure 2) resulting in wing venation typical of *Chloralictus* and *Evylaeus*. The specimens are otherwise morphologically identical to *L. anomalum*. The DNA barcode sequences of the Ontario and Michigan specimens matched DNA barcode sequences of *L. anomalum* individuals with vein 1rs-m absent in both wings sampled throughout its range, including approximately 300 km from the type locality (Figure 3). A
Table 1: Characteristics of Hemihalictus, Dialictus, Evylaeus, and Chloralictus type species.

| Genus-group name | Type species | Date of publication | Vein 1rs-m | Integument colour | Female inner hind tibial spur | Male flagellomere length |
|------------------|--------------|---------------------|------------|------------------|------------------------------|--------------------------|
| Hemihalictus Robertson | Panurgus lustrans Cockerell | 1897, p. 288 | Absent | Nonmetallic | Serrate/denticulate | short |
| Dialictus Robertson | Halictus anomalus Robertson | 1 Feb. 1902, p. 48 | Absent | Metallic | Pectinate | short |
| Evylaeus Robertson | Halictus arcuatus Robertson* | 10 Sep. 1902, p. 247 | Present | Nonmetallic | Serrate/denticulate | long |
| Chloralictus Robertson | Halictus cressonii Robertson | 10 Sep. 1902, p. 248 | Present | Metallic | Pectinate | long |

*Junior subjective synonym of Halictus cinctipes Provancher.

Figure 1: Forewing of Lasioglossum belonging to the Hemihalictus series. Numbers indicate submarginal cells. (a) Vein 1rs-m present. (b) Vein 1rs-m absent. Modified from [31].

Figure 2: Lateral habitus of Lasioglossum (Dialictus) anomalum with three submarginal cells. Bar = 1 mm.

A single male specimen of L. (H.) lustrans with vein 1rs-m present in both forewings has been examined (Figure 4). In other respects, it appears to be a normal specimen of L. lustrans. The identification was also verified using DNA barcodes. The locality data for this specimen is as follows: USA, Wisconsin, Marinette Co., Dunbar Barrens, N45.65149 W088.2415, 13.vii.2005 (C. Destree). A second male specimen with vein 1rs-m absent was also examined from the same locality. Both specimens are stored at the Richter Museum of Natural History, University of Wisconsin, Green Bay, Wisconsin.

4. Discussion
Ebmer [27] argued that metallic colouration was not a reliable character for recognising genus-level differences between Evylaeus and Chloralictus. To support this argument, he used the examples of L. viride (Brullé) and L. morio (Fabricius). In the case of L. viride, both black and metallic forms
Table 2: Lasioglossum anomalum individuals with vein 1rs-m present. PCYU: Laurence Packer’s Collection, York University (Toronto, Canada), AMNH: American Museum of Natural History (New York, USA), ARC: Albert J. Cook Arthropod Research Collection, Michigan State University (East Lansing, USA), and IRCW: University of Wisconsin–Entomology (Madison, USA).

| Depository | Forewing (s) with 1rs-m | Country | Province or state | Latitude (north) | Longitude (west) | Collection date |
|------------|-------------------------|---------|------------------|-----------------|-----------------|-----------------|
| PCYU       | 2                       | CANADA  | Ontario          | 43.5            | 80.31           | 16.viii.2007    |
| PCYU       | 1                       | USA     | Iowa             | 43.32472        | 91.13444        | 15.viii.2005    |
| PCYU       | 1                       | USA     | Michigan         | 43.61667        | 83.31739        | 16-20.vi.2008   |
| ARC        | 1                       | USA     | Michigan         | 43.69311        | 83.20706        | 30.vi.2009      |
| ARC        | 1                       | USA     | Michigan         | 43.69311        | 83.20706        | 30.vi.2009      |
| AMNH       | 1                       | USA     | New York         | 40.86806        | 73.42611        | 26.vi.1962      |
| IRCW       | 1                       | USA     | Wisconsin        | 43.28245        | 89.58043        | 5.vi.1995       |

Figure 4: Dorsal habitus of Lasioglossum (Hemihalictus) lustrans with three submarginal cells. Bar = 1 mm.

are known from the same locality. Morphologically they are indistinguishable and the colour variation in these two forms is considered to be a polymorphism. Colour aberrations also occur—Halictus balticus Blüthgen was the name given to a black specimen of the normally metallic L. morio. Other examples of metallic/nonmetallic polymorphism are known from Lasioglossum (J. Gibbs, unpublished data) and in the genus Agapostemon (L. Packer, unpublished observation).

The examples given herein for wing venation are analogous to those provided by Ebmer [27] for colouration. At least two species in the Hemihalictus series, L. parvum and L. asteris, show both the presence and absence of vein 1rs-m with a high frequency. Lasioglossum parvum belongs to the L. parvum/tegulare species group [18, 31] whereas L. asteris is a distantly related parasitic species [18]. Neither of these species is believed to be a close relative of L. anomalum, a view supported by preliminary phylogenetic analyses (J. Gibbs, unpublished data). In the Lasioglossum series, L. (Ctenonomia) bakeri Pauly was described from two individuals, each with a different number of submarginal cells [49]. Less frequent variation, such as that of the L. anomalum and L. lustrans individuals described here, fails to support the utility of this character for species-level identification, let alone genus-level classification.

Even disregarding the benefits of a cladistic classification (for discussion see [50–52]) these examples, strongly suggest that the presence or absence of vein 1rs-m is not sufficiently reliable to recognise Dialictus and Chloralictus as separate genera, subgenera or even to recognise species. Chloralictus should be considered a junior synonym of Dialictus based on the principle of priority (Article 23.3, [53]) following Mitchell [26], Krombein [33], Hurd [54], Moure and Hurd [24], Michener [7, 11], and many others. Chloralictus cannot justifiably be considered a synonym of Evylaeus without the latter name in turn becoming a junior synonym of the older name Dialictus. The type species of Evylaeus belongs to the “carinate-Evylaeus” which is sufficiently different morphologically and phylogenetically [18] from Dialictus + Chloralictus to be recognised as distinct. The evidence presented here and previously [29, 30] does not support the classification used by Ebmer [13, 25] even if a phenetic classification was considered appropriate.

The subgenus Hemihalictus is also recognised primarily on the basis of the absence of vein 1rs-m. This name has priority over all other names in the Hemihalictus series, and its sole species is clearly nested within the Dialictus s.l. clade [17, 18, 35]. The existence of individuals with vein 1rs-m present provides additional support for considering Hemihalictus synonymous with Dialictus s.l. If this synonymy were made, the subgeneric placement of hundreds of species would change. Hemihalictus is an uncommonly collected, monotypic taxon. A petition to set aside the principle of priority in the case where Hemihalictus is considered a synonym of Dialictus or Evylaeus has been submitted to the International Commission of Zoological Nomenclature [16].

Some authors have chosen to elevate subgenera of Lasioglossom to the level of genus [24, 26, 27, 54, 55] which would seem unwise given the difficulty in distinguishing between these higher taxa and the probability that many Lasioglossum subgenera are paraphyletic [17, 18]. A subdivision of Lasioglossom s.l. into smaller genera may be desirable but should await a more complete phylogeny of the group to allow a stable classification [11].

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