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The internal female reproductive tract of *Sicus ferrugineus* (Linnaeus, 1761)

(Diptera, Conopidae)

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The internal female reproductive tract of *Sicus ferrugineus*, a typical representative of Conopidae, is described and the homology of some of its elements discussed.

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Introduction

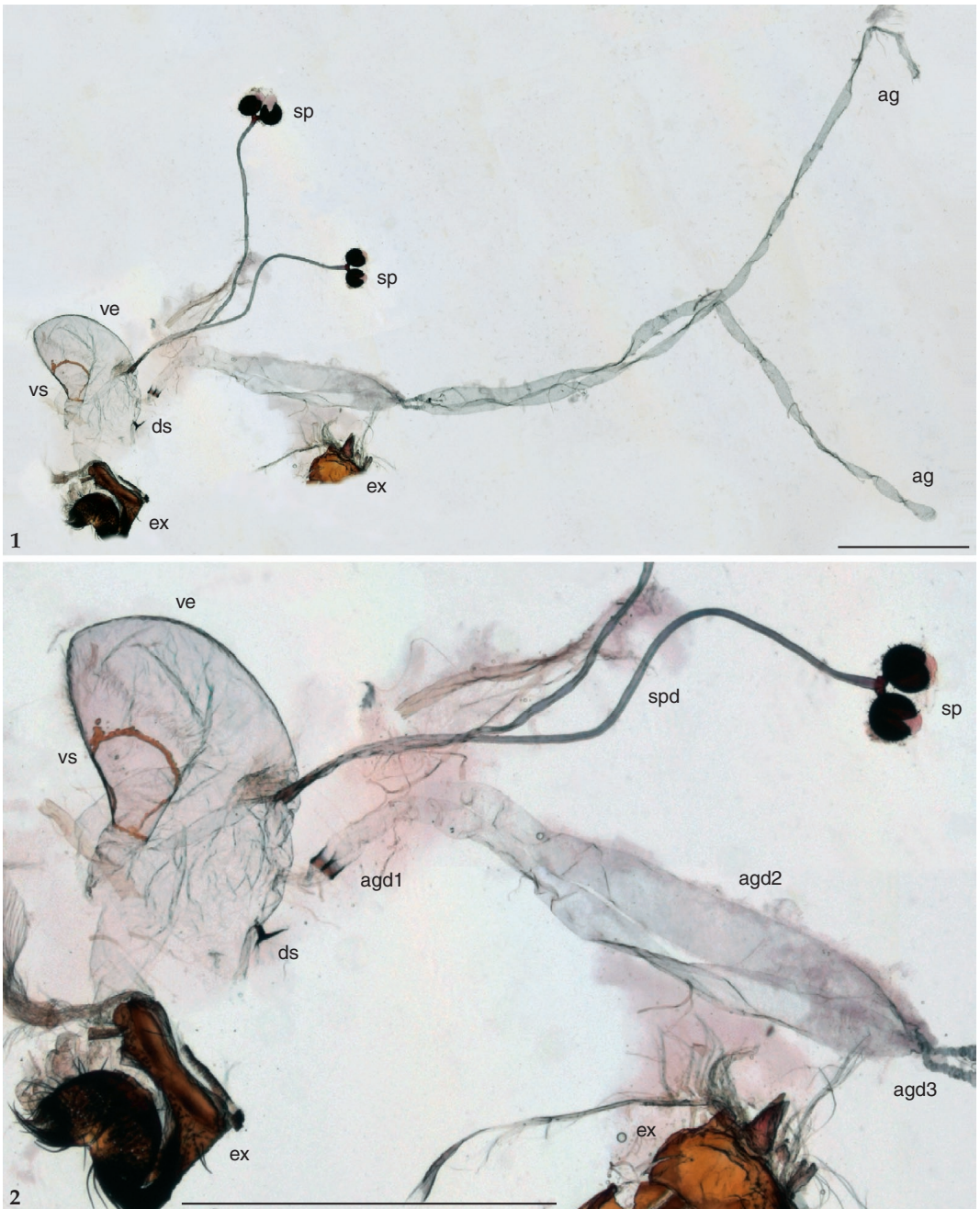
One of the most difficult chapters of dipteran systematics is undoubtedly the acalyprate Schizophora, and, among these, especially the thick-headed flies Conopidae (Hennig 1952, 1971, McAlpine 1989). Their systematic position is still highly controversial (Han & Ro 2005, Gibson et al. 2010).

Previous studies in various acalyprate taxa have shown that the internal female reproductive tract provides a number of morphological characters which can be taxonomically and phylogenetically informative (e. g. Sturtevant 1925, 1926, Kotrba 1995, 2007, Kotrba & Baptista 2002, Meier et al. 1997, Roháček 1996, 1999a,b). However, descriptions of these characters in Conopidae have been scarce and usually restricted to the spermathecae. Besides the description of the internal female reproductive tract of *Stylogaster stylosa* Townsend 1897 (Kotrba 1997), a species whose inclusion in Conopidae is not entirely certain, the only description of the conopid female reproductive system so far is a relatively superficial one of *Zodion obliquefasciatum* (Macquart, 1946) by Howell (1967). The present study describes the internal female reproductive tract of *Sicus ferrugineus*, another typical and widespread representative of the Conopidae, in detail with microscopic images of the most important structures.

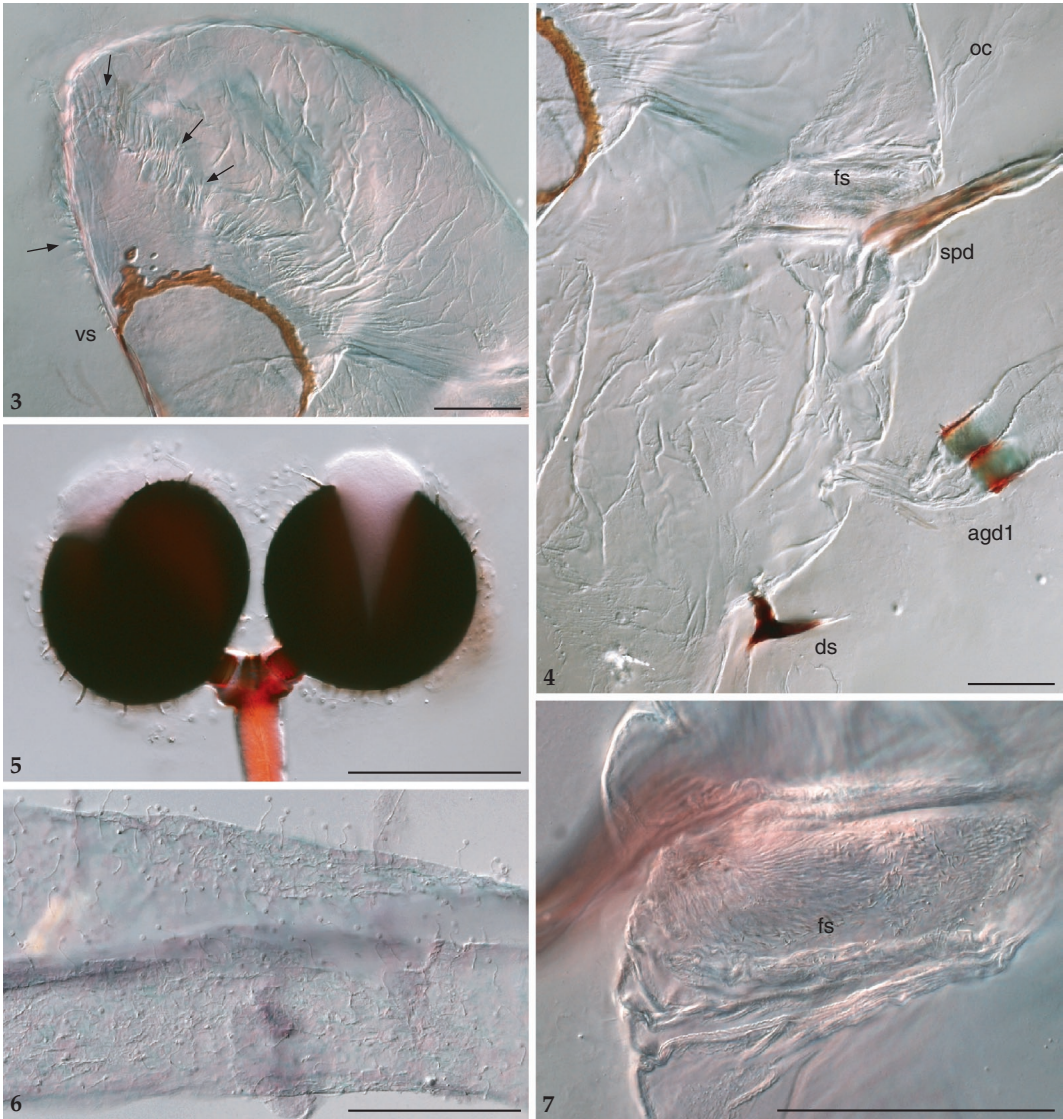
Methods

The internal female reproductive organs of *S. ferrugineus* were studied in three pinned specimens. One was recently collected; the other two were older specimens from the collection of the Smithsonian National Museum of Natural History, Washington (USNM). The abdomina were severed and macerated in cold KOH before the reproductive organs were removed and dissected. Subsequently the organs were rinsed in distilled water with an addition of acetic acid and embedded in polyvinylactophenol with an admixture of chlorazol black E. Some mature eggs present in the oviduct were embedded as well.

The preparations were observed and documented in bright field and DIC contrast using a Zeiss Axioskop 2 compound microscope equipped with a Zeiss Axio-Cam digital camera. Ovaries and oviducts were not studied because these organs are not lined by cuticle and thus lost during maceration. For terminology and a general introduction to the internal female reproductive tract of Diptera see Kotrba (2000). Following common practice, the term sclerotized refers to darkened cuticular structures that are not stained blue by chlorazol black E and appear brown under the bright field.



Figs 1-2. Internal female reproductive tract of *Sicus ferrugineus* (Linnaeus, 1761) (lateral view from the left). **1.** Entire reproductive tract except oviduct and ovaries; **2.** enlargement. **ag**, accessory gland reservoir; **agd1**, sclerotized base of accessory gland ducts; **agd2**, wide membranous portion of accessory gland ducts; **agd3**, narrow part separating accessory gland ducts from gland reservoirs; **ds**, dorsal sclerite; **ex**, fragments of external cuticular elements; **sp**, spermatheca; **spd**, spermathecal duct; **ve**, ventral evagination; **vs**, ventral ring-shaped sclerite. Scale bars 1 mm.



Figs 3–7. Internal female reproductive tract of *Sicus ferrugineus* (Linnaeus, 1761) (details). **3.** Ventral evagination; **4.** dorsal structures; **5.** spermathecae (ruptured); **6.** accessory glands; **7.** anterodorsal field of spicules. **agd1**, sclerotized base of accessory gland ducts; **ds**, dorsal sclerite; **fs**, field of spicules; **oc**, common oviduct; **spd**, sclerotized base of spermathecal ducts; **vs**, ventral ring-shaped sclerite. Arrows, muscle insertions. Scale bars 0.1 mm.

Results

The vagina of *S. ferrugineus* is embedded in a massive layer of muscles inside the bulging cavity of the greatly enlarged seventh abdominal segment. Once removed from that cavity and carefully freed of the surrounding muscle tissue, the general outline of the vagina and associated organs becomes visible (Figs 1–2).

The most prominent element is a large sack-like ventral evagination (ve) of the vagina, which bears a sclerotized ring (vs) in its posteroventral wall (Figs 2–3). The ring consists of a narrow band with irregular outline which enfames a lanceolate area. It is surrounded by a perimeter of fringes – the remnants of muscle attachments (Fig. 3, arrows). An elongate field of tiny spicules (fs) lies anterodorsally near the insertion of the common oviduct (Figs 4, 7).

Into the dorsal wall of the vagina opposite the ventral evagination open the paired spermathecal ducts (spd) and, well posterior to them, the paired accessory gland ducts (agd) (Fig. 4). Both kinds of ducts are sclerotized near their insertion into the vagina, and here the accessory gland ducts are about twice as wide as the spermathecal ducts.

The spermathecal ducts are long and narrow (Fig. 2). Terminally they each bear a short bifurcation bearing two spermathecal capsules (sp). Here the spermathecal duct walls are thickened and slightly sclerotized (Fig. 5). The spermathecal capsules are spherical and strongly sclerotized. Their surface is studded with the end apparatuses of spermathecal gland cells whose insertions at the capsule may be thickened into forming narrow spines.

The accessory gland ducts are about as long as the spermathecal ducts but much wider and membranous along most of their length (Fig. 2). When freed from their musculature by maceration they are extremely delicate and often get torn or lost in dissections. The tubular accessory gland reservoirs (ag) are not as wide and more than twice as long as the ducts. Their entire surface is studded with the cuticular end apparatuses of accessory gland cells (Fig. 6). The gland reservoirs are separated from the ducts by a short narrow section (agd3) possibly functioning as a valve (Fig. 2).

The common oviduct (oc) inserts anteriorly between the spermathecal ducts and the ventral evagination (Fig. 4). It is not lined by cuticle and therefore hardly detectable in macerated dissections.

A small plough-shaped dorsal sclerite (ds) is attached to the dorsal vagina wall posterior to the insertion of the accessory glands (Fig. 4). Adhering fibres suggest that it serves for the attachment of muscles.

The egg of *S. ferrugineus* is long, cylindrical and whitish (Fig. 8). The micropyle is positioned at the anterior end. It is drawn out into an anchor-like appendage with four barbed prongs (Fig. 9). Other than that the chorion is thin and smooth without any obvious ornamentation.

Discussion

The conditions in *S. ferrugineus* generally concur with Howell's (1967) description of *Z. obliquefasciatum* with the addition of considerable detail and new features such as the ventral ring.

While the homology of most prominent features, such as the spermathecae and the accessory glands, is beyond any doubt, the homology of some other structures cannot be resolved with certainty. The ven-

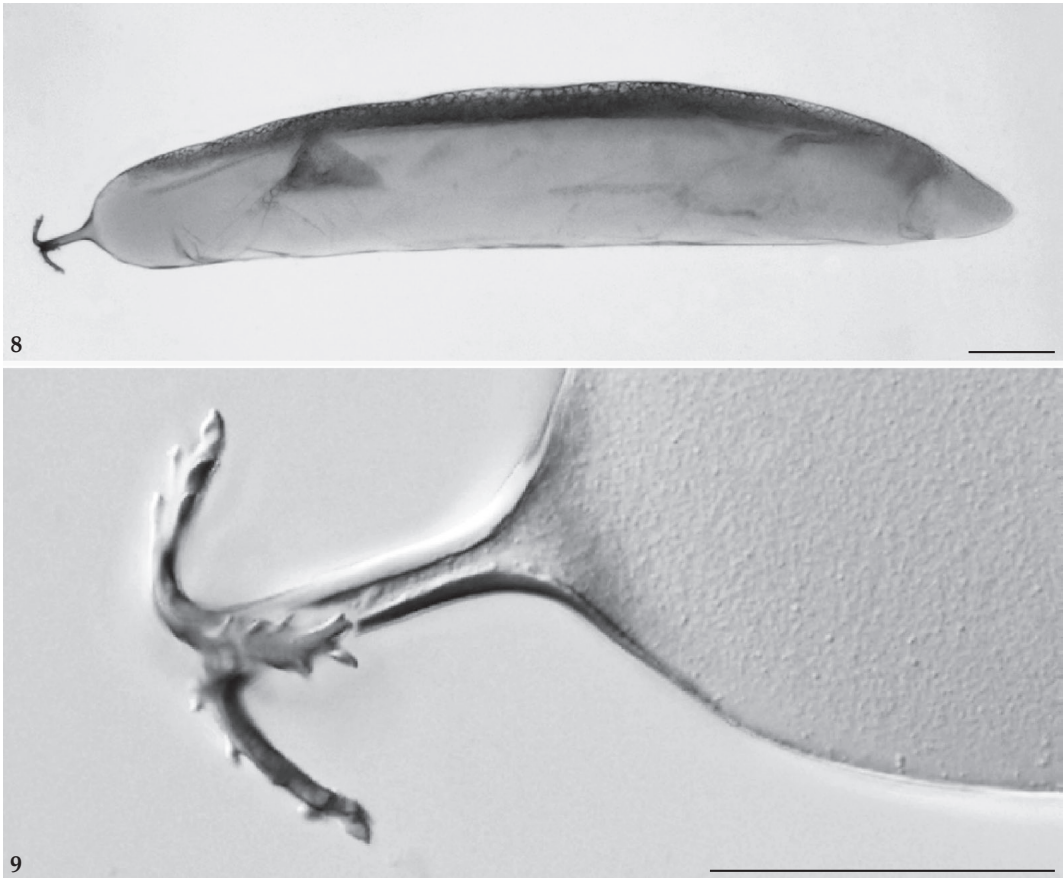
tral evagination of *S. ferrugineus* is unquestionably homologous with the "bursa copulatrix" described in *Z. obliquefasciatum*, and possibly a common feature of Myopinae and Conopinae. In one *Conops quadrifasciatus* De Geer, 1776 female fixed immediately after copulation the ventral evagination was filled by a mass of sperm (Kotrba, unpublished). The structure is therefore appropriately termed "bursa copulatrix" by Howell (1967). On family level, the homology of this structure remains uncertain and should be clarified through future comparative investigations. One candidate for a homologous organ in other Schizophora is the ventral receptacle or fertilization chamber known to occur in most schizophoran flies (Kotrba 2000). This organ, however, generally emanates from the anteriormost part of the ventral vagina wall, while the ventral evagination of *S. ferrugineus* involves a much larger area.

According to own dissections of *Zodion intermedium* Banks, 1916 and *Conops quadrifasciatus* (Kotrba unpublished), the ventral ring occurs in these species as well and is therefore possibly a common feature of all Myopinae and Conopinae. Similar ringshaped sclerites in the ventral vagina wall occur in a few other families of acalyptrate flies such as Anthomyzidae (e.g. Roháček 1996, 1999a, b), Diopsidae (e.g. Kotrba 1993, 1995), Canacidae and Tethinidae (Hardy & Delfinado 1980, Wirth 1989), but also in the aschizan Phoridae (Brown 1988). Because the vagina is invaginated from the body wall between sterna 8 and 9, any sclerite in the ventral vagina wall such as the ventral ring of *S. ferrugineus* might possibly be derived from sternum 8.

Because it is associated with the dorsal vagina wall, the dorsal sclerite is possibly derived from sternum 9 similar to the furca or genital fork of many Orthorrhapha. It is possibly homologous to the valve described by Howell between genital chamber and anus in *Z. obliquefasciatum*. The second valve described by Howell between accessory glands and bursa copulatrix in *Z. obliquefasciatum* could not be identified in *S. ferrugineus*.

It is worthwhile noting that the distance between the insertions of the spermathecal and the accessory gland ducts into the vagina is rather large, while in many Schizophora these ducts open very close together in a genital papilla or insemination pouch (Kotrba 2000). This might turn out to be a phylogenetically informative character in future comparative studies.

The micropylar structure with four barbed prongs concurs with illustrations for *S. ferrugineus* (De Meijere 1904) and *Myopa buccata* (Linnaeus, 1758) (McAlpine 1987), but not with illustrations for *Conops flavipes* Linnaeus, 1758, *Physocephala vittata* (Fabricius, 1794) or *Dalmanina punctata* (Fabricius,



Figs 8-9. *Sicus ferrugineus* (Linnaeus, 1761) egg (anterior end to the left). **8.** Total; **9.** detail of micropyle. Scale bars 0.1 mm.

1794) (De Meijere 1904), *Z. obliquefasciatum* (Howell 1967), or various species of *Stylogaster* (reviewed in Kotrba 1997).

The similarities in the female reproductive tract of *S. ferrugineus*, *Z. obliquefasciatum* (Howell 1967), *Z. intermedium* and *C. quadrifasciatus* (Kotrba unpublished) suggest that the general layout of the internal female reproductive tract might be quite uniform in Myopinae and Conopinae. Conversely, there are hardly any similarities with the respective organs of *Stylogaster stylosa* which has only two spermathecae, no ventral sclerite and a differently shaped ventral evagination (Kotrba 1997). The internal female reproductive tract does therefore not provide any new evidence for the inclusion of *Stylogaster* in the Conopidae.

A comparative study involving other Conopid taxa is ongoing. At the same time, other researchers

are strongly encouraged to dedicate more attention to the very diverse and informative structures of the internal female reproductive tract. More detailed comparative studies of these structures with more sophisticated techniques, such as serial microsectioning, will prove informative not only with respect to their phylogenetic significance but also with respect to their functional morphology.

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