Descriptions of the puparia of three *Graptomyza* species (Diptera Syrphidae), with comments on probable larval biology

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Descriptions of puparia and third instar cephalopharyngeal skeletons of *Graptomyza mitis* Curran & Bryan 1926, *G. signata* (Walker 1860), and *G. triangulifera* (Bigot 1883) are given. The rearing data and the feeding habits of these species are discussed. Feeding habits and mouthpart morphology reveal that members of the genus are saprophagous and that *G. mitis* may use filter feeding as a means of mycetophagy.

KEY WORDS: Diptera, Syrphidae, *Graptomyza*, puparia, larval biology.

INTRODUCTION

Descriptions of immature stages and rearing data can contribute greatly to the taxonomically useful information available for the development of sound classifications and for evolutionary evaluation of characters for systematic analyses. For many syrphid taxa there is still insufficient data covering a wide enough range of species, for such characters to be useful in a systematic sense, although ROTHERAY & GILBERT (1989) have provided new data for European predacious Syrphidae. A large amount of data has been accumulated from the descriptions and study of syrphid larvae by, among others, HEISS (1938), BHATIA (1939), DIXON (1960), HENNIG (1968), ROTHERAY (1986, 1987a, 1987b, 1988a, 1988b, 1988c, 1990) and ROTHERAY & DOBSON

(1987). Nevertheless, larvae of numerous syrphid taxa remain poorly known (ROTH-ERAY 1987a, 1988c and VOCKEROTH 1969), especially in the southern hemisphere.

Prior to this paper no immature stages of *Graptomyza* Wiedemann 1820 had been described. Described species are based entirely on adult material covering 80-85 species, from the Afrotropical, Oriental and Australasian regions. Species from the latter two regions require revision, thus the total number of species given is artificially low. The Afrotropical species were revised by WHITTINGTON (1992). Unfortunately no larvae are known for the genus, but certain useful larval characters are available from puparia (specifically from the third instar cephalopharyngeal skeleton retained in the anterior portion of the puparium).

In addition to the useful taxonomic characters provided by the cephalopharyngeal skeleton, useful data concerning feeding habits of immature stages can be obtained. Correlation of cephalopharyngeal skeletal morphology and feeding habits in other syrphid species (HARTLEY 1963, ROBERTS 1970) and in other Diptera (HAGEN 1966; DOWDING 1967; ROBERTS 1969, 1971) can be used to better understand the larval feeding habits in *Graptomyza*.

There has been some contention in the past with regard to feeding habits in *Graptomyza*. THOMPSON (1972) proposed two phylogenies, based on whether larvae of *Graptomyza* had saprophytic feeding habits or scavenged in colonial hymenopteran nests. THOMPSON (1991) accepted the saprophytic nature of the feeding habits, indicating that the diphyletic nature (THOMPSON 1972: fig. 3b) of the Old World volucellines (*Graptomyza* and *Volucella* Geoffroy 1762) should be accepted. The data evaluated here, to some extent, support THOMPSON's (1991) conclusions.

No key for *Graptomyza* puparia has been provided, since only three species are described below and these are easily identified from the descriptions and figures.

MATERIALS AND METHODS

During the analysis of adult morphology for a recent revision of the Afrotropical members of this genus (WHITTINGTON 1992) I found several pinned adult flies which bear puparia or rearing data on the same pin. These specimens were loaned from the following institutions (listed with codens and curators responsible): BMNH = The Natural History Museum, London, England (Dr B.R. Pitkin, Mr N.P. Wyatt); BPBM = Bernice Pauahi Bishop Museum, Honolulu, U.S.A. (Dr N.L. Evenhuis); CNCI = Canadian National Collection of Insects, Ottawa, Canada (Dr J.R. Vockeroth); NMSA = Natal Museum, Pietermaritzburg, South Africa; SANC = National Collection of Insects, Pretoria, South Africa (Dr M.W. Mansell). This paper is a result of the study of the puparia associated with these specimens.

TECHNIQUES

Puparia were examined with no attempt to clear surface detritus. Measurements and illustrations were made with a Wild M5 stereomicroscope and a Wild 1.25 × drawing tube. Dimensions, given as ranges for the material examined, are based on the maximum measurement across the puparium, e.g. the width includes extruding lobes or protrusions and length includes the posterior spiracular process. Bilaterally symmetrical features are described in the singular. The third instar cephalopharyngeal skeletons were removed from the leading ventral edge of the interior of the puparia, lightly macerated in hot KOH and then viewed and stored in glycerine.

The indentation index first used by KNUTSON (1966) as a taxonomic guide to the size of the indentation between the cornua of the cephalopharyngeal skeleton of Sciomyzidae, has been given for the three species described here. The index is the length of the indentation (*ab*, Fig. 2) over the length of the dorsal cornu (*cd*) multiplied by 100. The higher the resultant value, the deeper the indentation.

Details in 'Material examined' have been standardised, so that localities are listed by country, from north to south and west to east. The locality (with latitude and longitude in square brackets if not provided on the data label) is given first, followed by date, collector, any other relevant details and lastly the institutional coden (see Materials and methods). Label data are not quoted verbatim. Dates conform to the format 'day.month.year', with the day and year in Arabic numerals and the month in upper case Roman (e.g. 8.III.1991).

Rearing data obtained from labels pinned with adult specimens were listed in 'Material examined' in WHITTINGTON (1992).

<div align="center">DESCRIPTIONS OF PUPARIA</div>

Graptomyza mitis Curran & Bryan 1926 (Figs 1-3)

Dimensions (in mm). Length 5.2-5.3; width 2.4-2.9; height 2.0-2.3; length of respiratory horn 0.4-0.6; length of posterior spiracular process 0.8-0.9. Colour: dull brown.

Ovate; dorsally gibbose; ventrally flattened; abruptly tapered posteriorly; respiratory horn glabrous, slightly curved dorsolaterally, poorly annulated, pointed terminally; crochets in paired rows on ventral surface of mesothoracic and abdominal segments 1-7, pale buff, black tipped, curved at tip in posterior direction; posterior spiracular process glabrous, spiracles with slightly wavy margin, V-shaped, arranged around central button as in Fig. 3; surface setose, the setae adhered in clumps by detritus, often with small quartz-grain inclusions; transverse grooves distinct.
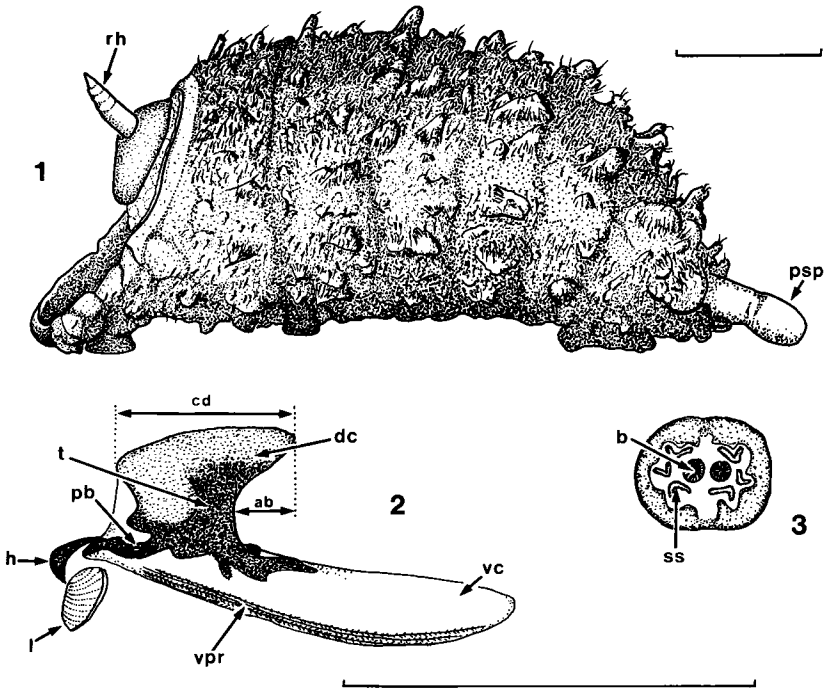
Third instar cephalopharyngeal skeleton (Fig. 2): mouthhook crescent-shaped, dorsally slightly angular, not sharply pointed nor toothed; mandibular lobe small, narrower than mouthhook length; parastomal bar small; pharyngeal sclerite darkly pigmented medially and on tentorium, with dorsal cornu short, ventral cornu long and narrow, indentation index 44.6; ventral pharyngeal ridges present.

Material examined. Australia: 1 specimen Queensland, Stradbroke Island [26°55'S 152°19'E; no date, no collector] (CNCI); 2 paratypes [no data labels] (BPBM, CNCI).

Graptomyza signata (Walker 1860) (Figs 4-6)

Dimensions (in mm). Length 7.3-8.9; width 4.0-4.6; height 3.3-3.8; length of respiratory horn 0.6-1.1; length of posterior spiracular process 1.0-1.1. Colour: dull brown.

Ovate; dorsally gibbose; ventrally flattened; abruptly tapered posteriorly; respiratory horn glabrous, slightly curved dorsolaterally, annulated, rounded terminally; crochets in paired rows on ventral surface of mesothoracic and abdominal segments (mostly obsured by detritus, probably on segements 1-7), pale buff with brown band
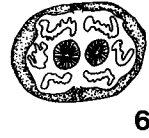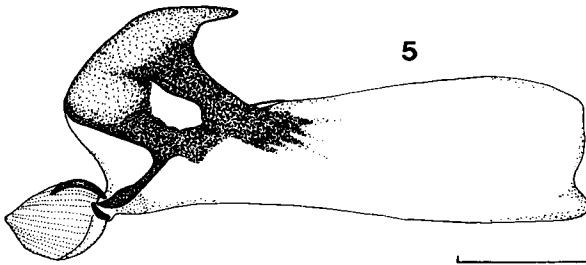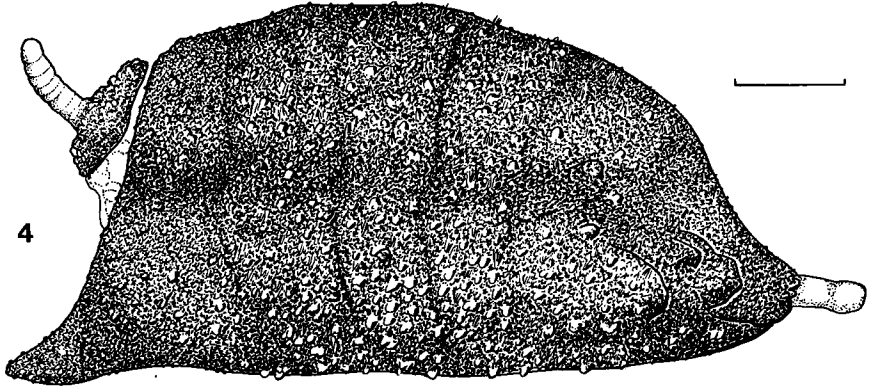
Figs 1-3. — *Graptomyza mitis*. Fig. 1, puparium lateral view (*psp* = posterior spiracular process; *rh* = respiratory horn); surface structure and setae obscured by attached detritus. Fig. 2, third instar cephalopharyngeal skeleton lateral view (*ab* = length of indentation; *cd* = length of dorsal cornu; *dc* = dorsal cornu; *h* = mouthhook; *l* = mandibular lobe; *pb* = parastomal bar; *t* = tentorium; *vc* = ventral cornu; *vpr* = ventral pharyngeal ridges). Fig. 3, posterior spiracle (*b* = button; *ss* = spiracular slits). Scale = 1 mm. (Drawings by the author).
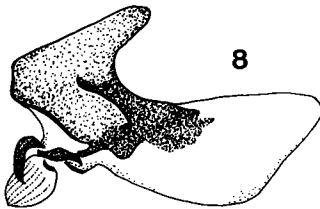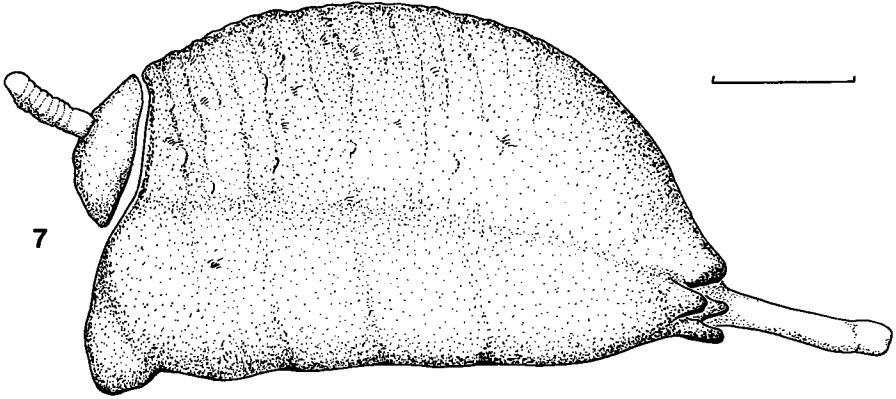
medially, curved in posterior direction from band to tip; posterior spiracular process glabrous, posterior spiracles with scalloped margin, sinusoidal, arranged around central button as in Fig. 6; surface finely lobate with two or three dominant posterior lobes, finely setose and often with white encrustation; transverse grooves indistinct.

Third instar cephalopharyngeal skeleton (Fig. 5): mouthhook weakly crescent-shaped, dorsally evenly curved, not sharply pointed nor toothed; mandibular lobe large, at least twice as wide as mouthhook length; parastomal bar not visible; pharyngeal sclerite darkly pigmented medially and on tentorium, with dorsal cornu short, ventral cornu very long and broad, indentation index 30.6; closed median window present anterior to tentorium occupying 1/3 the width of the medial sclerite; ventral pharyngeal ridges not evident.

Material examined. South Africa: 1 specimen Cape Province, East London, II.1922 [33°02'S 27°55'E; no collector, but probably H.K. Munro] (SANC); 4 specimens 'M22' [= East London; 33°02'S 27°55'E; no collector, but probably H.K. Munro, no date] (NMSA, SANC).

Figs 4-6. — *Graptomyza signata*. Fig. 4, puparium lateral view. Fig. 5, third instar cephalopharyngeal skeleton lateral view. Fig. 6, posterior spiracle. Scale = 1 mm. (Drawings by the author).

Figs 7-9. — *Graptomyza triangulifera*. Fig. 7, puparium lateral view. Fig. 8, third instar cephalopharyngeal skeleton lateral view. Fig. 9, posterior spiracle. Scale = 1 mm. (Drawings by the author).

Graptomyza triangulifera (Bigot 1883) (Figs 7-9)

Dimensions (in mm). Length 5.3-6.7; width 2.5-2.9; height 2.3-2.8; length of respiratory horn 0.6-0.8; length of posterior spiracular process 0.5-1.5. Colour: dull brown.

Ovate; dorsally gibbose; ventrally flattened; abruptly tapered posteriorly; respiratory horn glabrous, slightly curved upwards, annulated, rounded terminally; small crochets in paired rows on ventral surface of mesothoracic and abdominal segments 1-7, glossy, dark brown, black tipped, slightly curved along whole length in posterior direction; posterior spiracular process glabrous, posterior spiracles with smooth margin, sinusoidal, arranged around central button as in Fig. 9; surface wrinkled with two dominant posterior lobes, very finely setose, often with small quartz-grain inclusions; transverse grooves indistinct.

Third instar cephalopharyngeal skeleton (Fig. 8): mouthhook crescent-shaped, dorsally evenly curved, not sharply pointed nor toothed; mandibular lobe small, about as wide as mouthhook length; parastomal bar not visible; pharyngeal sclerite moderately pigmented medially and on tentorium, with dorsal cornu short, ventral cornu short and broad, indentation index 34.5; ventral pharyngeal ridges not evident.

Material examined. Ghana: 1 specimen Tafo [06°13'N 00°22'W], WACRI, pod 15.XI.1964, caged 2.II.1965, adult emerged 3.II.1965 (BMNH). Nigeria: 3 specimens Olokemeji, Ibadan [07°23'N 03°56'E, no collector] (BPBM, NMSA).

DISCUSSION

The puparia and associated structures are distinct for the three species *G. mitis*, *G. signata* and *G. triangulifera*. Little intraspecific variation was observed, except for the length of the posterior spiracular process of *G. triangulifera*. The two African species clearly have closer affinity (apically rounded and clearly annulated respiratory horn, evenly textured puparium surface generally asetose, ventral cornu of cephalopharyngeal skeleton apparently without ventral pharyngeal ridges) than does the Australian species for either of the African species. This is consistent with the findings of WHITTINGTON (1992), in which the two African species were placed in the *G. varia* species-group. The Afrotropical species were, however, not clearly established as a strictly monophyletic clade and the species-groups proposed by WHITTINGTON (1992) remain provisional.

Little can be said about pupation in *Graptomyza*. Puparia of *G. mitis* and *G. triangulifera* have small quartz grains adhered to the surface or partly included in the surface of the puparium, indicating that pupation occurs in loose sandy conditions. Two puparia of *G. signata* are adhered, side-by-side, to a portion of leaf surface of unknown origin and other puparia of this species have a salty encrustation on the outer surface.

Rearing data obtained from adult specimens (unfortunately puparia were not pinned with the specimens concerned) indicates a saprophagous-frugivorous feeding habit in the larval stages. *G. signata* has been reared from tomato and unspecified rotting fruit, *G. triangulifera* from unspecified pods and an undetermined Australian (New South Wales, Huonbrook) species (near *G. flavicollis* Ferguson 1926) from

fallen fruit of *Castanospermum australe* A. Cunningham. No rearing data are available for *G. mitis*.

While tomatoes and rotting fruit are soft substrates, *Castanospermum* fruits are large leathery pods (200-230 mm in length and about 50 mm wide). The latter are, however, spongy inside with 3-5 cells enclosing large (20-30 mm), hard ovoid seeds. It is possible that larvae seek out this soft spongy interior of the fruit as food.

HARTLEY (1963) reported that differences in diet between taxa, are mainly reflected in differences in relative proportions and sclerotisation of the sclerites of the cephalopharyngeal skeleton. He added that the sizes of cephalopharyngeal skeletons vary according to species, but not proportionally (i.e. large cephalopharyngeal skeletons do not necessarily imply large third instar larvae). The morphology of the cephalopharyngeal skeletons of the species described here, correlate well with the feeding data given above. The combination of broad apically pointed mouthhooks (which lack secondary teeth) and a well developed mandibular lobe has been shown by HARTLEY (1963) to represent saprophagy and by ROBERTS (1970, 1971) to represent a mycetophagous feeding mode. In addition the ventral pharyngeal ridges (in *G. mitis*) indicate a saprophagous feeding habit (DOWDING 1967).

The mouthhook is used to rake the soft food tissue toward the mouth and the mandibular lobe prevents the entry of large food particles. The ventral pharyngeal ridges further restrict food particle size, allowing partial digestion to occur before swallowing of the particles (ROBERTS 1969) and increasing efficiency of food utilisation by its concentration. Particle size is restricted to between 4 μm and 0.25 μm in *Eristalis* Latreille 1804 (HARTLEY 1963) or greater than 0.6 μm in *Eristalis tenax* (Linnaeus 1758) (DOWDING 1967).

DOWDING (1967) concluded that Cyclorrhaphous larvae possessing pharyngeal ridges were essentially particle feeders, reducing the amount of non-nutritious liquid ingested and concentrating food (consisting of a suspension of bacteria, protozoa, fungal spores and/or yeasts) by sieving. These micro-organisms increase the concentration of proteins and, more importantly, of nitrogenous compounds in decaying fruits and have been shown by BAUMBERGER (1919) to increase developmental rates in *Drosophila melanogaster* Meigen 1830. BAUMBERGER (1919) showed that the latter species is more dependent on the yeast than on decaying fruit, supporting the view that many fly larvae considered to be saprophagous are in fact mycetophagous.

Some species with ventral pharyngeal ridges have a nutritive relationship with symbiotic bacteria. The larvae of the olive-fly, *Dacus oleae* (Gmelin 1790) (Tephritidae), have such ridges and HAGEN (1966) elegantly showed the dependence of this species on the extracellular bacterium *Pseudomonas savastanoi* (Smith) Stevens for utilization of the undecayed olive flesh and for certain essential amino acids lacking in the fruit. Similarly the lesser narcissus-bulb flies, *Eumerus tuberculatus* Rondani 1857 and *E. strigatus* (Fallén 1817), which have ventral pharyngeal ridges (as illustrated for the latter species in HENNIG 1968, ROBERTS 1970 and FERRAR 1987), were shown by CREAGER & SPRUIJT (1935) to have a nutritive dependence on basal-rot *Fusarium*. Accordingly it is evident that some of these symbionts or their products of digestion are ingested by the larvae. Based on the presence of ventral pharyngeal ridges, *G. mitis* larvae may rely on a similar symbiosis for digestion. The diet of *G. mitis* remains speculative, however, and FERRAR (1987) cautions against making unverified statements about diet based on structure alone.

Differences in diet between taxa (as reported by HARTLEY 1963) appears to be

reflected in differences in relative proportions and sclerotisation of the sclerites of the cephalopharyngeal skeleton in *G. signata* and *G. triangulifera*. For instance, the mouthhook of *G. signata* is much less curved than that of *G. triangulifera*, probably being an adaptation to the softer diet of tomatoes or rotting fruit in the former species. There is, nevertheless, little data available and such differences need to be substantiated by further research.

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