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Rearing of *Eumerus nudus*, *E. olivaceus* and *E. pulchellus* (Diptera, Syrphidae) from asphodel, with notes on separation of *E. nudus* and *E. olivaceus*

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Summary

For the first time, larval host plants are reported for the syrphids *Eumerus nudus* Loew, 1848 and *Eumerus olivaceus* Loew, 1848. Observations are provided on the rearing of *E. nudus* from tubers of *Asphodelus ramosus* and *E. olivaceus* from tubers of *A. albus* and *A. ramosus*. Rearing of *Eumerus pulchellus* Loew, 1848 is also reported from tubers of *A. ramosus*. Notes are provided on recognition of the adults of these three *Eumerus* species. The potential significance of synchronous occupancy of tubers, bulbs, etc., by the phytophagous/ saprophagous larvae of more than one syrphid species is discussed.

Introduction

Eumerus is arguably the most poorly known of all the large European syrphid genera. Upwards of 60 species have been reported from the continent, but the only key purporting to deal with them all is that of Stackelberg (1961), which was produced before 17 of the species now known from Europe had been described. Further, Stackelberg's key omits some of the European species then known and involves some very dubious interpretations of others. Given the difficulties inherent in identification of the adults, it is perhaps unsurprising that almost nothing is known about the life histories of the great majority of European *Eumerus* species. The known larvae (Speight 2012) inhabit the tissues of water and nutrient storage organs of herbaceous plants – rhizomes, bulbs, tubers, corms etc. – usually beneath the soil surface, but sometimes in the litter layer (for instance fallen platyclades and fruit of *Opuntia:* Pérez-Bañón and Marcos-García 1998) and are partly phytophagous, partly saprophagous. A few have been the subject of investigation, because their larvae can be pests of horticulture, e.g. in onion or narcissus crops (see for instance, Creager and Spruijt 1935).

Malaise trapping of syrphids, carried out (January 2011 – December 2012) in the Jardin Mediterranéen, at Banyuls-sur-Mer (Pyrenées-Orientales), almost at sea-level on the Mediterranean coast of France, yielded eleven species of *Eumerus*, and *Platynochaetus setosus* (Fabricius, 1794), most of them in some numbers. This prompted the idea of searching for larvae of these species there, since the life histories of most of them were unknown. A preliminary search, carried out one afternoon in late September, resulted in discovery of large final instar larvae, apparently belonging to the genus *Eumerus*, in tubers of *Asphodelus ramosus*. Two other localities above Banyuls, in the vicinity of the Tour de Madeloc, were then searched the next day, attention being confined to plants of *A. ramosus*. At both localities more *Eumerus* larvae were found in the tubers of this plant. A second collection of larvae was made in January 2013, from tubers of *Asphodelus albus* collected at 1700m, from Angoustrine in the Pyrenees.

Here we provide the first information on the life histories of two of the three *Eumerus* species reared from these asphodel tubers and also seek to increase the reliability with which the adults of all three of them can be identified.

Methods

A) Collection of larvae

When in bloom, *Asphodelus ramosus* displays a metre-high spike of white flowers on a sturdy, rod-like stem, encircled by tough, grey-green, lanceolate leaves, similar to those of *Iris* plants. It is a strictly Mediterranean species, in the vicinity of Banyuls occurring only within 5km of the coast. It flowers in May, the plant thereafter progressively dying back, to present by the end of summer a dead and blackened flowering stem with the curled and withered remnants of its leaves around the base. Underground, it has by then formed a huge mass (up to the size of a football) of tubers on its roots, numbering anywhere from 20 to the best part of 100. Each tuber is more or less cylindrical, 8-10cm long and nearly 2cm in diameter, tapering to a point at both ends (Fig. 1). The root mass is at 15-20cm depth in the ground. In late summer / early autumn dead asphodel plants are extremely easy to locate and recognise from their general appearance, and the individual species can be identified from the size and character of the seed pods. A pick-axe or a mattock makes a suitable tool for excavating the root masses beneath the dead stems.

Fig. 1. Root mass of *Asphodelus ramosus* (late September).

With an asphodel root mass dug up and put on a white, plastic sheet it was possible to systematically check each tuber for presence of larvae. Uninvaded tubers are very solid and without holes in them. Invaded tubers can often be identified by the presence of a visible hole, 1-2mm diameter, into the interior of the tuber. But squeezing the tubers proved a more reliable guide, since entry holes were not necessarily evident. An invaded tuber was invariably soft, due to the cavity within. Only 1 or 2 tubers per root mass were found to contain larvae, but up to 7 larvae could be found together in an occupied tuber (Fig. 2). The larvae in a tuber were not necessarily of the same size, suggesting the possibility of multiple origins (and identities) of its occupants. Entirely empty tubers were also found within the root masses, with just the dry, papery skin of the tuber remaining. The flesh of healthy tubers of *Asphodelus ramosus* is a bright yellow-green, but the flesh of tubers containing larvae was in various stages of liquefaction, usually reduced to a black, viscous liquid, in which the larvae wallowed. The tubers from Angoustrine were found frozen when excavated from the ground in January, as were the larvae within them. Once thawed out, and provided with *A. albus* tubers, these larvae continued to feed and wallow in the decaying tuber contents, like the Banyuls larvae.

Fig. 2. Consumed asphodel tuber with larvae (arrows indicate larvae).

B) Rearing of larvae

Collected larvae were transferred, in the tubers they inhabited, to a transparent plastic container, approximately 15x10x10cm, with small holes drilled through its lid, to provide aeration. The bottom of the container was first lined with white paper kitchen towelling. The container was itself placed within a cardboard shoe box and the lid of the shoe box put back on, so that the larvae could be kept in the dark. The shoe box was then kept in a centrally-heated room. The room temperature in the immediate vicinity of the shoe box was checked by a thermometer kept on top of it, which demonstrated that temperature varied from 16-22°C. Periodically, a tuber of *A. ramosus* was added to those in the larval container, from a bundle of tubers kept in a plastic bag in a refrigerator. Every few days the contents of the larval container were searched through for puparia. Some of the larvae were definitely feeding, the added tubers being progressively hollowed out, their flesh after a few weeks reduced to the same thick black "syrup". Other larvae remained almost immobile in the liquefied tuber tissue, which was retained within the tuber by its tough, impermeable skin. This outer skin was untouched by the larvae, apart from the initial entry hole made through it. By February all larval feeding seemed to have ceased, but the larvae remained immersed in the liquefied tuber tissue (Fig. 3) until shortly before pupation. All larvae left the tubers prior to puparium formation.

Fig. 3. Larva of *Eumerus olivaceus or E. nudus* covered in decomposed asphodel tuber "syrup".

Once found, a puparium was removed and placed in a small plastic tub lined with a pad of kitchen towelling. A slip of paper carrying a unique number was also added to the tub, so that the progress of each puparium could be followed individually. The tub was itself then placed in another plastic container like the larval container (Fig. 4), again with small holes drilled in its lid, to provide aeration. The floor of the puparial container was lined with paper kitchen towelling and half a carrot (sliced lengthwise, so that it would lie flat and not roll around in the container) was then added to provide a low level of humidity. Finally, some dry, dead, branching stems of a small herbaceous plant (marjoram) were added to the puparial container, so that any hatching fly would have something to hang from, whilst its wings were expanding and drying. The puparial container was then placed alongside the larval container, in the same shoe box, so that it was in the dark and subject to the same temperature regime as the larvae.

C) Identification of adults

Reference collections (MNHN, Paris; NNMN, Leiden; IRSNB, Brussels), together with Stackelberg's (1961) key and named reference material received from other syrphidologists (C. Claussen, M.J. Ebejer, K. Kassebeer) were used in confirming the identity of the reared species. Features that may be used to recognise these species are presented in the Results section of this text. Intra-specific variability was adduced from the material available to us from the Malaise trapping in the Jardin Mediterranéen (*E. nudus*, n = 20; *E. pulchellus*, n = 350), the reared specimens listed here and supplementary material of *E. olivaceus* in the reference collections of MS (n = 35).

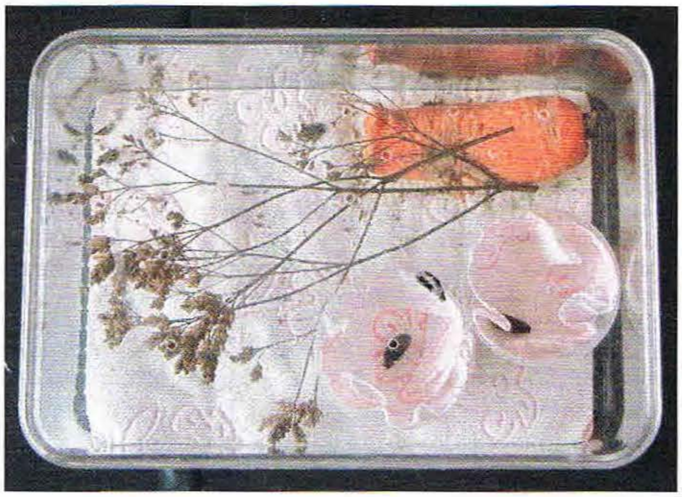

Fig. 4. Plastic container used for hatching *Eumerus* puparia (see text).

Figs 5-6. Puparia: 5, *Eumerus olivaceus*; 6, *Eumerus nudus*.

Results

A) Pupariation and eclosion

The first puparium was found on 25 December and hatched on 5 January, producing a fine male of *Eumerus olivaceus*. The fly was left in the puparial container for 12 hours, to fully mature, and then removed, killed and identified. The same procedure was followed with the specimens that hatched subsequently. Altogether, three *Eumerus* species were reared from the asphodel tubers, *E. olivaceus*, *E. nudus* and *E. pulchellus*. The puparia of *E. olivaceus* and *E. nudus* (Figs 5 and 6) are 10-11.5mm long (including the posterior respiratory process) and 4.5-4.75mm wide, of the same shape and with no obvious, distinguishing features. Those of *E. pulchellus* are noticeably smaller (8mm long, including the posterior respiratory process; 3mm wide), with a longer posterior respiratory process and with a less rugose surface (Fig. 7). The puparia of *E. nudus* and *E. olivaceus* were formed either loose, hidden within the layers of paper tissue on the floor of the container, or strongly attached to that tissue, in concealed positions. Puparia of *E. pulchellus* were formed loose, anywhere on the container floor, within tissue or entirely exposed.

Fig. 7. Puparia of *Eumerus olivaceus* (left) and *E. pulchellus* (right).

Table 1 shows dates of pupariation and eclosion for each of the reared specimens. In total 25 adults were reared. One larva died and one of the adults was unable to expand its wings on emergence. All puparia formed hatched. There was no visible evidence of parasitism or fungal infections. The dates of hatching of the *E. nudus* and *E. pulchellus* puparia (Table 1) are within the known flight period of these species in the wild, in the Mediterranean zone of Europe (Speight 2012). The dates of emergence of the *E. olivaceus* puparia from larvae collected around Banyuls-sur-Mer are not within the known flight period of that species. By contrast, the dates of hatching of the puparia from Angoustrine, shown in Table 2, more or less are, though a little early.

Puparial formation	**Adult eclosion**	**Species**	**Sex**
16.iii.2013	27.iv.2013	n	m
16.iii.2013	25.iv.2013	n	f
30.iii.2013	28.iv.2013	n	m
15.iv.2013	23.v.2013	n	f
18.iv.2013	23.v.2013	n	f
18.iv.2013	24.v.2013	n	f
23.iv.2013	26.v.2013	n	m
23.iv.2013	30.v.2013	n	m
27.iv.2013	6.vi.2013	n	f
1.v.2013	7.vi.2013	n	f
2.v.2013	9.vi.2013	n	f
7.v.2013	11.vi.2013	n	f
26.v.2013	1.vii.2013	n	m
1.vi.2013	5.vii.2013	n	m
3.vi.2013	6.vii.2013	n	f
25.xii.2012	5.i.2013	o	m
10.i.2013	12.ii.2013	o	f
13.i.2013	16.ii.2013	o	f
16.ii.2013	22.iii.2013	o	f
13.iv.2013	25.iv.2013	p	f
20.iv.2013	8.v.2013	p	f
25.iv.2013	15 v.2013	p	m

Table 1. Dates of puparium formation and eclosion of adults, for the larvae of *Eumerus nudus* and *E. olivaceus* collected in the vicinity of Banyuls-sur-Mer. Abbreviations used: f = female; m = male; o = *Eumerus olivaceus*; n = *Eumerus nudus*; p = *Eumerus pulchellus*.

Puparial formation	**Adult eclosion**	**Species**	**Sex**
9.iv.2013	22.iv.2013	o	m
9.iv.2013	25.iv.2013	o	f
23.iv.2013	7.v.2013	o	f

Table 2. Dates of puparium formation and eclosion of adults, for the larvae of *Eumerus olivaceus* collected from Angoustrine. Abbreviations used are as in Table 1.

The Malaise trap data, available from the Jardin Mediterranéen at Banyuls, show that adults of *E. nudus* were on the wing there from 1 May to 30 September. Adults of *E. pulchellus* were present in the traps almost throughout the year. *Eumerus olivaceus* was not collected in the Jardin Mediterranéen.

B) Recognition of the reared species

The adults of the *Eumerus* species reared from the Banyuls asphodel tubers are not well served in existing identification literature: *E. nudus* and *E. olivaceus* are extremely similar to each other and cannot reliably be separated using Stackelberg's (1961) key. The third, *E. pulchellus*, is reasonably easy to recognise in the male, but the female is extremely difficult to identify. Vujić and Šimić (1999) provided figures of the male terminalia of *E. olivaceus* and *E. pulchellus*, as recognised here, but no other information on identification of the males of either species, and no information on identification of the females. In Stackelberg's (1961) key, the male of *E. pulchellus* is included, but the female is omitted, without explanation. To clarify the identity of the species reared, and hopefully to render them easier to recognise in future, a diagnosis of each is presented here, together with comments on their separation from other European species. Terminology used for morphological features follows Speight and Sarthou (2012). Reference specimens of *E. nudus* reared during this study, plus their puparia, have been deposited in the following collections: CIBIO, University of Alicante, Spain; Dept of Biology and Ecology, University of Novi Sad, Serbia; the National Museums of Scotland, Edinburgh, UK.

1. *Eumerus nudus* and *Eumerus olivaceus*

In Stackelberg's (1961) key the eyes of *E. nudus* are said to be bare, which they are not, and males of *E. nudus* and *E. olivaceus* are supposedly distinguished by a whitish band along the posterior margin of tergite 4, present in *E. nudus* but absent in *E. olivaceus*. However, this pale band can be just as well developed in males of *E. olivaceus* as it is in males of *E. nudus*. It may also be absent in males of *E. nudus*.

Both *E. nudus* and *E. olivaceus* are among the *Eumerus* species without any trace of orange or red on the antennae or abdomen, except for a dirty yellow mark or band at the posterior margin of the fourth tergite, often present in the males. Tergites 2-4 do, however, each have a pair of well-developed, transverse bars of silver-grey pruinosity. These two species are both also among the small number of European *Eumerus* species in which the anteroventral line of black spikes on the hind femur is carried on a low ridge (very shallow in females of *E. nudus*), as in *Merodon* species, rather than arising directly from the surface of the femur as in most *Eumerus* species. They are both large, with a body length of 11-12mm. Additional useful features are that the facial hair covering is silver-grey, the mesoscutal hairs are upstanding, rather than recumbent and the legs are unornamented apart from the anterior and posterior rows of spines beneath the hind femur. This latter characteristic is more helpful in identifying the males, since males of many *Eumerus* species have additional projections of one sort or another on the hind trochanter, hind femur or hind tibia. The hind femur is greatly thickened in both of these species – more so than in many other *Eumerus* species – being no more than 3x as long as deep in the males (closer to 4x as long as deep in females). In the males of both species, the eye suture is about as long as the median length of the frons and the surface of sternite 4 is not flat, but carries a pair of massive outgrowths. Put together, this combination of morphological attributes segregates *E. nudus* and *E. olivaceus* from other European *Eumerus* species and the greater difficulty lies in separating them from one another. Recognition of the males is easier than recognition of the females, because the massive protuberances on sternite 4 are of diagnostic shape. These protruberances are normally visible without any preparation of the specimen being necessary, in contrast to the male terminalia, which at least have to be pulled out before they can be seen – a procedure first requiring relaxation of the specimen, in dry, pinned material. Examination of sternite 4 is thus a more practical proposition than examination of the terminalia, and provides a similar degree of reliability to the resultant determination. *Eumerus nudus* and *E. olivaceus* may be separated as follows:

Eumerus nudus: eyes almost bare, the hairs sparse, difficult to see and less than half as long as a posterior ocellus; scutellar hairs extremely short, no longer than 0.1 the median length of the scutellum; male with sternite 4 longer than wide and a pair of uniquely-shaped projections and an antero-median brush (Fig. 8) of extremely, long, strong, bristles (which may be either black or white).

Eumerus olivaceus: eye hairs moderately dense, distinct and as long as a posterior ocellus; scutellar hairs longer, one sixth to one quarter as long as the median length of the scutellum; male with sternite 4 wider than long and a pair of uniquely-shaped projections but without an anteromedian brush of bristles, as shown in Fig. 8.

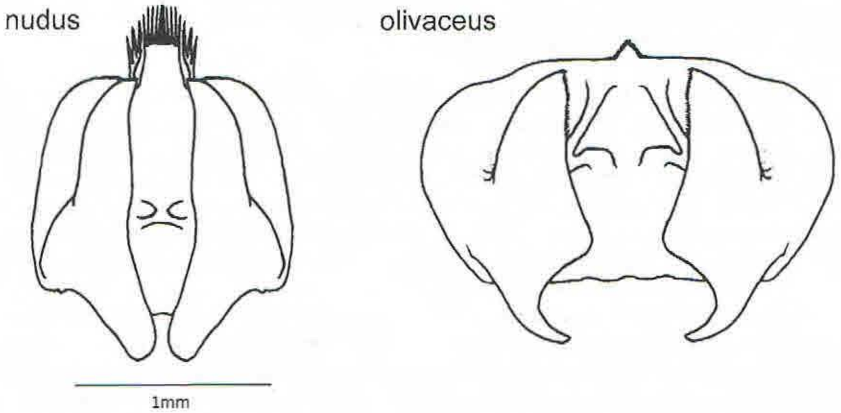

Fig. 8. *Eumerus* species, male sternite 4 of *E. nudus* and *E. olivaceus,* diagrammatic, with general hair covering omitted. Both figures show the anterior margin of the sternite at the top.

2. *Eumerus pulchellus*

Eumerus pulchellus is one of the large group of rather small European *Eumerus* species without any red or orange markings on the abdomen and with a pair of oblique, silver-grey dust bars on each of the tergites 2–4. In terms of some of the features much used by Stackelberg (1961), *E. pulchellus* is an inconvenient insect, since (in both male and female) its third antennal segment varies in colour from a monochrome dark brown to largely orange, the longitudinal dust stripes on the mesoscutum can be well developed or rudimentary and its legs vary from all-black to extensively yellow. The male, luckily, has other features which, taken together, make it readily identifiable: the hind leg lacks protuberances, projections or excavations on any of its segments; on the lateral margins of both tergite 3 and tergite 4 there is a fringe of extremely long, whitish hairs – longer than the depth of the third antennal segment – that curve beneath the abdomen; although there is some variation in its overall proportions, sternite 4 (often largely obscured by the long, marginal hairs of adjacent tergites) is also characteristic, being flat, with a convex basal margin, a deeply concave, but otherwise simple, apical margin and a surface entirely unornamented by protuberances or hair patches, as shown in Fig. 9.

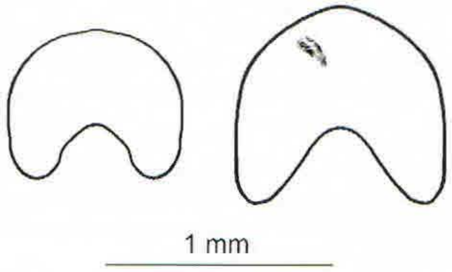

Fig. 9. Sternite 4 of *Eumerus pulchellus* male, diagrammatic, from two different specimens, to show the intra-specific variability of its proportions. Anterior margin of the sternite shown towards the top of the page.

The female is markedly more difficult to identify. Speight *et al.* (2013) provided a key, in which the female of *E. pulchellus* is separated from most of the commoner western European *Eumerus* species, but that key does not include the widespread southern European species *E. amoenus* Loew, 1848. The female of *E. pulchellus* may be distinguished from that of *E. amoenus* by the presence in *E. pulchellus* of obvious hairs on the lateral margin of tergite 3, in the posterior third of its length. In females of *E. amoenus* the lateral margin of tergite 3 is bare. The following combination of features distinguishes the female of *E. pulchellus* from females of other known European *Eumerus* species:

Face thinly pale grey dusted; frons, at level of anterior ocellus, half the width of an eye at the same level; ocellar triangle equilateral or slightly wider than long; upper eye hairs distinctly longer than a posterior ocellus; second antennal segment distinctly shorter than third antennal segment; humeral callus and lateral margin of the mesoscutum undusted, shining; mesoscutum with two, longitudinal stripes of pale grey dusting, these stripes varying from distinct to hardly visible; hairs on scutellar disc no longer than one quarter the median length of the scutellum; costal vein of wing brown for most of its length (may be yellowish at base); hind femur, in dorsal view, >4x as long as its maximum width; ventral surface of the hind femur without a bulge, basally; apical part of ventral surface of hind femur with a posterolateral row of 12–16 stout black spines; white hairs on the posterolateral margin of the ventral surface of the hind femur, including some as long as one third of the maximum depth of the femur; hind tibia without a transverse cleft on the ventral surface; basal third of the length of the posterolateral margin of the ventral surface of the hind tibia with a sharp ridge carrying very short, black, procumbent spinules; second tarsomere of hind tarsus almost 2x as long as wide; tergites entirely without red, orange or yellowish markings; tergite 5 without a longitudinal ridge, enclosing a shallow depression, close to its lateral margins; tergites without any translucent pale markings; tergites 2–4 each with a pair of transverse, silver-grey dust bars; hairs on tergite 5 white; body length 7-8mm.

Discussion

The *Eumerus* larvae collected from tubers of *Asphodelus ramosus* in September 2012 were all subject to the same conditions subsequent to collection. If there was any form of competition between the larvae, within the asphodel tubers, this was not evident. When found in the wild multiple larvae were present in nearly every occupied tuber, and this multiple occupancy continued in captivity. Those that were successfully reared to eclosion demonstrated the presence of three species, *Eumerus nudus*, *E. olivaceus* and *E. pulchellus*, though the uniform appearance of the larvae gave no clue that there was more than one species present, prior to pupariation. At pupariation, it became clear that some larvae were maturing at a smaller size than others, and forming a puparium of different appearance (Fig. 7). On eclosion, these puparia proved to be of *E. pulchellus*. However, the puparia of *E. nudus* and *E. olivaceus* were indistinguishable from one another. Some were paler than others, the nearly black puparia being almost entirely covered in the liquefied tuber contents that adhered to their surface and then dried on (Fig. 6), but this variability was observed in puparia of both species. Puparia of both species could be clean or covered in the black tuber residuum. Neither anterior nor posterior respiratory processes of the puparia showed any obvious species-specific characteristics, including the posterior spiracular plate. Only when they hatched was it apparent that the larger puparia included both *E. nudus* and *E. olivaceus*. If the developmental stages of these two species are to be separated, it would seem that the differences between them will have to be sought in the number and arrangement of the numerous setae occurring over much of the body surface. Comparison between the sclerotised larval mouth-hooks of *E. nudus* and *E. olivaceus*, retained within the puparia, also failed to reveal any obvious difference between these two species. But more detailed examination, based on informed survey of a wider range of *Eumerus* puparia, would probably be required to detect subtle differences, should they exist.

The *Eumerus* species collected as larvae in September 2013, from *Asphodelus ramosus* tubers, showed different patterns of pupariation and emergence. *Eumerus pulchellus* and *E. nudus* remained as larvae throughout the winter months, to pupariate in April, resulting in eclosion at the beginning of what would be their normal flight period in the vicinity of Banyuls, to judge from Malaise trap data collected in 2011 and 2012. Whatever factors trigger pupariation and eclosion in those two species were not, it would seem, interfered with by the artificial conditions under which the larvae were kept in captivity. By contrast, among the September-collected larvae of *E. olivaceus*, pupariation commenced in December, and eclosion started in January, whereas under natural conditions the flight season for this species begins in May. So it has to be concluded that the captive rearing regime described here resulted in an artificially rapid maturation of the *E. olivaceus* larvae collected from the wild in the autumn. However, the *E. olivaceus* larvae collected in January produced adults at the beginning of the normal *E. olivaceus* flight period. Whether this indicates that conditions in which larvae were kept in the period September/December dictated the premature emergence of resultant adults, or this was precipitated by failure to subject the larvae to a period of cold, is unclear. Since the mature larvae seem easy to keep, the conditions that trigger pupariation could probably be established under laboratory conditions, by subjecting captive larvae to different temperature regimes during the winter months.

There was no noticeable increase in size of the larvae between collection and pupariation, even though they entered undamaged asphodel tubers when presented with them and then remained in those tubers until long after their content was entirely liquefied, moving on only when the liquid content had been consumed or drained away. From the fact that their puparial phase is evidently of short duration (6-7 weeks in *E. nudus*, 2-4 weeks in *E. olivaceus*, 2-3 weeks in *E. pulchellus*), and the other observations made of their development in the shoe box, one can deduce that, under normal circumstances, the larvae of all three of these *Eumerus* species pass the winter within asphodel tubers, moving from one tuber to another as their contents become exhausted, and pupariate in the surrounding soil, in April to early May. Alternatively, if they find themselves in a non-leaky tuber, whose contents have been well liquefied, they may well remain there, more of less comatose through the winter, "bathing" in the mucky brew they have generated. The conclusion that these species overwinter as larvae is supported by the collection of larvae of *E. olivaceus* in January, frozen within asphodel tubers, indicating also that, in this species at least, the larvae are physiologically capable of surviving winter conditions in the soil, since the larvae, once thawed out, subsequently pupariated and hatched into adults of normal appearance. More extensive investigation of the larvae in the wild, involving such activities as digging up asphodel root masses, at regular intervals through the winter and early spring, to determine whether the larvae remain there till spring, would be helpful, to confirm more details of the life history of these insects.

Finding the larvae of *Eumerus nudus* and *E. olivaceus* came about as a result of Malaise trapping, demonstrating the presence of 11 identifiable *Eumerus* species, plus *Platynochaetus setosus*, in the Jardin Méditerranéen, at Banyuls-sur-Mer (Pyrenées-Orientales, France). No prior study of *Eumerus nudus* or *E. olivaceus* led to discovery of their larvae. The local asphodel was investigated simply because it was known to have tubers, is frequent in the Jardin, is easily recognised in the autumn (when the search for larvae was carried out) and is closely related to *Asphodelus aestivus*, already known (Ricarte *et al.* 2008) to host the larvae of *Eumerus pulchellus*. Its tubers were easily dug up and damaged tubers could be distinguished from healthy ones in the field. They were found to contain larvae of three *Eumerus* species. But rhizomes of an *Orobanche* and the rhizomes/tubers of a *Smyrnium* species examined during the same search yielded no larvae and as yet there is no indication of what the larval host plants of the three remaining *Eumerus* species found at the Jardin Méditerranéen with unknown larvae (*Eumerus argyropus* Loew, *E. elaverensis* Séguy, *E. subornatus* Claussen) or *Platynochaetus*, might be. Other possible plant hosts were not examined, due to time constraints, and further larval searches embracing a wider range of plants, particularly at other times of the year, might be expected to yield further *Eumerus* larvae. But is it possible to carry out more targeted searching, using clues provided by the adult flies as to what their larval host plants might be?

There is a tendency for the adults of syrphid species with phytophagous larvae to visit (but by no means exclusively) the flowers of the plant species acting as their larval hosts. They also tend to fly in the immediate vicinity of their larval host plant. These tendencies are well developed among *Cheilosia* species and in *Portevinia maculata* (Fallén) (see Speight 2012). The larval host plants of few *Merodon* species are yet known, but the same tendencies seem to be manifested in species of this genus, also (see, for instance, Ricarte *et al.* 2008). *Opuntia*-associated *Eumerus* species can be found in the immediate vicinity of their host plant, to judge from observations on *E. obliquus* (Fabricius) adults in the Jardin Méditerranéen, but adults of other *Eumerus* species do not seem so closely associated. In particular, they seem to show no preference for the flowers of their larval host plants, when flower-visiting. Indeed, they seem to ignore entirely the flowers of their larval host plants. Observations by one of us (MS), of a large population of *Eumerus olivaceus* where

Asphodelus albus was in flower, in large, dense stands, showed no use of the *A. albus* flowers by *E. olivaceus* and no use of the plant's foliage as a resting site, though the flies settled on the foliage of other plants in the vicinity. Similarly, observation (again by MS) of a *Eumerus ruficornis* Meigen population, showed neither use of the flowers of *Scorzonera humilis*, its presumed larval host (Johansson 2011), nor use of that plant's foliage for resting purposes. At present, then, one can conclude that adult *Eumerus* cannot be relied upon to provide many clues, from their behaviour or flower-visiting activities, to their larval host plants. Further, what is known already of the host plants of European *Eumerus* larvae (Speight 2012) indicates that a wide range of plant families are involved, so that it cannot be assumed that unknown plant hosts should be searched for only among the members of genera or families already known to support one or more *Eumerus* species. But there are two additional elements that can be brought into play, when considering how to find *Eumerus* larvae. Firstly, the time of year the adults are in flight can be expected to indicate when the larval host plant is accessible for oviposition purposes and thus, hopefully, also to human observation. Since most potential host plants are present only as sub-surface storage organs for much of the year, among those that are visible at some locality, when adults of a *Eumerus* species are on the wing, should logically be the plant providing for its larvae. Secondly, the flight season of a species can indicate when larvae might most successfully be searched for in the bulb, tap root or tuber of their host plant, namely a few weeks after the flight season commences. This ploy could not be expected to help in all cases – *vide* the two *Eumerus* species whose rearing is described in the present text. But many of the known syrphid larvae that feed in plant tissues feed up rapidly once they hatch from the egg, and then vacate the host plant, to either diapause in the soil or enter a prolonged puparial phase, so that reliance on being able to find the larvae in their host plant at almost any time of the year is not realistic. That approach would seem more likely to result in digging up entirely the correct host plant but finding absolutely nothing, because six months out of seven the larvae aren't there!

Is it coincidental that *Eumerus* larvae have repeatedly been found, and not singly, together with larvae of other syrphids, or of other *Eumerus* species, within bulbs etc. (Brunel and Cadou 1994; Ricarte *et al.* 2008; the present study)? The only thorough study (Creager and Spruijt 1935) of the food requirements of *Eumerus* larvae, carried out on larvae of *Eumerus funeralis* Meigen (as *E. tuberculatus* Rondani), demonstrated clearly that the larvae could not complete their development on the tissues of the plant, but to do so required the accompanying decay organisms, essentially yeasts. It is an intriguing notion that the cohabitation of the larvae of *Eumerus* species with the larvae of other syrphid genera, and with one another, may be less coincidental than characteristic, if *Eumerus* larvae make use of decay facilitated by strictly phytophagous syrphid larvae, or by each other. Experiences with rearing *E. nudus* and *E. olivaceus* indicate that last instar larvae of these species can carry with them the decay organisms they require, when moving from an exhausted asphodel tuber to an undamaged one. But what happens when an egg of *E. nudus* hatches? Does the newly-hatched larva carry with it the micro-organisms needed to decay asphodel tubers in such a way as to produce the decomposition products it requires? Or does it start its development as strictly phytophagous? Then again, perhaps it requires the actions of some other organism to gain access to the tissues of an asphodel tuber and or to initiate appropriate decay processes. The intricacies of the life histories of these small insects clearly require more investigation. As of now, the concept of communities (rather than assemblages) of *Eumerus* and other plant-feeding syrphids, with larvae living in the same bulbs/tubers, cannot be ruled out, with one or more of the *Eumerus* species largely dependent for their survival on the activities of the larvae of other members of the community. Such interdependence might more easily explain the rarity of some *Eumerus* species, than would simple dependence on a rare plant host.

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