OBSERVATIONS OF A POPULATION, INCLUDING JUVENILES, OF *GEOPHILUS CARPOPHAGUS* LEACH, 1815, SENSU STRICTO FROM OXFORDSHIRE

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ABSTRACT

Geophilus carpophagus sensu lato has been split into two species; *G. carpophagus* sensu stricto and *G. easoni* (Arthur *et al*, 2001). Previously published descriptions of *G. carpophagus* s.l. in Britain primarily refer to the more widespread *G. easoni* and little is known of *G. carpophagus* s.s. in Britain. This paper presents observation of 20 specimens of *G. carpophagus* s.s., representing all stadia, collected from Oxfordshire, southern England. Differences between British examples of *G. carpophagus* s.s. and *G. easoni*, including pigmentation, structure of labrum, distribution of coxal pores, proportions of the articles of walking legs and of the apical claws, are highlighted. First and second stadia juveniles of *G. carpophagus* s.s. are described. Outline habitat preferences and distribution in Britain and Ireland are presented. It is suggested that *G. carpophagus* s.s. has a more central European distribution, while *G. easoni* has a strict Atlantic distribution. Problems of identification of material outside north-west Europe are discussed.

INTRODUCTION

Eason (1979) noted that *Geophilus carpophagus* sensu lato (s.l.) from urban habitats had more podous segments and reached a greater length than those found in rural habitats. Although Lewis (1985) suggested that the two forms might be sibling species, records were not differentiated by the Provisional Centipede Atlas (Barber & Keay, 1988). On the basis of morphological characters and molecular evidence, Arthur, Foddai, Kettle, Lewis, Luczynski and Minelli (2001) concluded that the two forms were indeed distinct species. Since Eason's long 'urban' form conformed to Leach's type specimen of *G. carpophagus*, the short 'rural' form was described as a new species, *G. easoni* Arthur *et al*.

In Britain the two species are readily distinguished by the number of trunk segments (leg pairs), the number and visibility of the coxal pores, the form of the labrum and the body pigmentation (Arthur *et al*, 2001; Barber, 2009). The ecology and behaviour of the two species is different (Arthur, Johnstone & Kettle, 2002). *G. carpophagus* s.s. is a climbing species that inhabits a variety above ground microsites. *G. easoni* seems to be the more widespread species (Barber, 2009), typically occurring at ground level.

Although Eason (1964) acknowledged the existence of a long form, reaching 60 mm in length and with up to 55 trunk segments, the text and figures describe typical *G. easoni* (Arthur *et al*, 2001). This, and probably other descriptions of *G. carpophagus* s.l. previously published in Britain, refer to *G. easoni*. This study stems from the need of one author (TB) for specimens of *G. carpophagus* s.s. for illustrations. Arthur *et al* (2001) highlight the distinctions between the two species and Arthur *et al* (2002) report rearing *G. carpophagus* s.s. in laboratory culture. However, little is known of the various age classes of this species and this paper presents observations of a population, consisting of juveniles and adults, from Oxfordshire.

METHODOLOGY

Twenty specimens of *G. carpophagus* s.s. were collected from a garden wall at Hill Farm, Little Wittenham, Oxfordshire (OS grid reference SU563927; vc22, Berks; 90m asl). Specimens were collected from beneath stones capping a mortared wall about 1.5 m high on 11th November 2008. The mortar was old and weathered and, although tight fitting, the capping stones were easily lifted. A selection of individuals representing the

full range of size classes present was readily collected. The Bristly Millipede *Polyxenus lagurus* (Linné) was common in the same microsite and the occasional specimen of *Lithobius melanops* Newport was observed.

For each specimen, preserved in 70% alcohol, the following data were recorded:

- Body colour and pigmentation patterns; noted in live and preserved specimens.
- Body length (excluding antennae and rear legs); measured using a millimetre ruler.
- Sex of the specimen; male, female or juvenile.
- Number of trunk segments; i.e. the number of leg pairs.
- Maximum body width, head length, head width and length of antennae; measured using a microscope graticule.
- Number of antennal articles.
- Sternites bearing carpophagus fossae.
- Maximum width of carpophagus fossae (i.e. on sternite 8 or 9) and the width of its associated sternite; measured using a microscope graticule.
- Shape and position of the sternal pore groups.
- Number of pores present on the coxae of the last pair of legs; specimens cleared in clove oil.
- The labrum was dissected from a specimen and illustrated; cleared in clove oil.
- Apical claws of walking legs: length, width of base, width of claw tip (i.e. diameter of circle required to cover tip of claw); measured using a microscope graticule.
- Walking legs: length and width (mid-point) of metatarsus/tarsus, tibia, femur and prefemur of legs from trunk segment 10, 25 and c. 40 were examined in 2 male and 2 female specimens (and 2 male and 2 female of *G. easoni*); measured using a microscope graticule.

RESULTS

The data for the twenty specimens is presented in Tables 1 and 2.

Field observations

Unlike most centipedes, *G. carpophagus* s.s. appears to be gregarious and in this study small groups of individuals were readily found beneath most capping stones lifted. Specimens typically cling to the substrate and are difficult to dislodge. Arthur *et al* (2002) also noted this clinging behaviour and suggest that this may be an adaptation for climbing.

Colour

Head, forcipular segment and posterior end are a uniform reddish-brown, which contrasts against the greenish-grey to brownish-grey trunk segments. Fresh specimens were typically mottled with concentrations of purple pigment, visible through the cuticle, which forms a regular pattern either side of the gut and around the leg insertions (Figure 1). Although this was quite apparent in live specimens, this pattern became increasingly diffuse and the pigment was ultimately lost in preserved specimens (leaving the uniform greenish-grey to brownish-grey background). Arthur *et al* (2001) noted that DNA samples from *G. carpophagus* s.s. extract this purple pigment (while those of *G. easoni* remain clear).

Live and fresh specimens of *G. easoni* are a uniform reddish-brown colour throughout, which fades following preservation (Barber, 2009).

Body length

Adult males in this study varied in body length from 27 to 39mm (Table 1), the largest female reached 55mm. In our collection females reach a much larger size than males and the majority of females were larger, both in terms of body length and head width, than all males examined. *G. carpophagus* s.s. is reported to reach 60mm (Eason, 1979). In Britain, *G. easoni* rarely exceeds 40mm.

TABLE 1: Data for twenty specimens of *Geophilus carpophagus* s.s. collected from Little Wittenham
J1 = First stadium, J2 = Second stadium, M = male, F = female
Measurements in millimetres * Cephalic shield removed, no data

Sex or stage	No. leg pairs	Body length	Number coxal pores	Body width	Head length	Head width	Number antennal articles	Max length antennae	Sternites with fossae	Max. fossae width	Sternite width
J1	55	12	0 + 0	0.64	0.39	0.39	14 + 14	1.21	4 - 13	0.10	0.30
J1	53	12	0 + 0	0.64	0.46	0.43	14 + 14	1.18	4 - 13	0.10	0.28
J1	53	15	0 + 0	0.75	0.43	0.43	14 + 14	1.21	4 - 13	0.10	0.28
J2 M	51	17	2 + 3	0.79	0.68	0.64	14 + 14	1.68	5 - 12	0.18	0.40
J2 M	53	20	2 + 2	0.89	0.68	0.64	14 + 14	1.61	3 - 13	0.18	0.40
J2 F	55	21	2 + 2	0.86	0.64	0.61	14 + 14	1.86	4 - 13	0.15	0.38
M	53	27	3 + 3	1.21	0.79	0.75	14 + 14	2.21	3 - 14	0.23	0.53
M	53	30	3 + 4	1.18	0.82	0.79	14 + 14	2.04	4 - 13	0.28	0.60
M	53	31	3 + 3	1.32	0.82	0.79	14 + 14	2.25	4 - 13	0.28	0.60
M	53	32	3 + 3	1.43	0.96	0.89	14 + 12	2.79	4 - 14	0.30	0.73
M	53	33	3 + 3	1.29	0.89	0.89	14 + 14	2.32	4 - 13	0.33	0.63
M	53	39	4 + 4	1.50	0.89	0.89	14 + 13	2.86	3 - 14	0.35	0.65
F	57	28	3 + 4	1.07	0.79	0.75	14 + 14	1.96	4 - 14	0.25	0.53
F	53	37	5 + 6	1.61	*	*	*	*	3 - 13	0.25	0.55
F	55	40	7 + 7	1.68	1.04	1.00	14 + 14	3.21	4 - 14	0.35	0.78
F	55	43	6 + 6	1.57	1.00	0.93	14 + 4	2.96	4 - 14	0.35	0.75
F	55	46	7 + 7	1.71	0.96	0.96	14 + 12	2.64	4 - 14	0.33	0.73
F	55	49	5 + 5	1.86	1.14	1.14	14 + 14	3.54	4 - 14	0.40	0.78
F	55	50	6 + 6	1.89	1.21	1.14	11 + 10	3.61	4 - 13	0.43	0.88
F	55	55	8 + 8	2.21	1.18	1.14	14 + 14	3.46	4 - 15	0.40	0.90

TABLE 2: Body proportions (ratios) for data presented in Table 1

Sex or stage	Body length mm	Body length to width	Antennae length to body length	Antennae length to head width	Head length to body length	Head length to head width	Fossae to sternite width
J1	12	18.7	0.11	3.4	30.5	1.00	0.33
J1	12	18.7	0.10	2.8	25.8	1.08	0.36
J1	15	20.0	0.08	2.8	35.0	1.00	0.36
J2 M	17	21.6	0.10	2.6	25.1	1.06	0.44
J2 M	20	22.4	0.08	2.5	29.5	1.06	0.44
J2 F	21	24.5	0.09	3.1	32.7	1.06	0.40
M	27	22.2	0.08	3.0	34.4	1.05	0.43
M	30	25.5	0.07	2.6	36.5	1.05	0.46
M	31	23.5	0.07	2.9	37.7	1.05	0.46
M	32	22.4	0.09	3.1	33.2	1.08	0.41
M	33	25.7	0.07	2.6	37.0	1.00	0.52
M	39	26.0	0.07	3.2	43.7	1.00	0.54
F	28	26.1	0.07	2.6	35.6	1.05	0.48
F	37	23.0	*	*	*	*	0.45
F	40	23.8	0.08	3.2	38.6	1.04	0.45
F	43	27.4	0.07	3.2	43.0	1.08	0.47
F	46	26.8	0.06	2.7	47.7	1.00	0.45
F	49	26.4	0.07	3.1	42.9	1.00	0.52
F	50	26.4	0.07	3.2	41.2	1.06	0.49
F	55	24.8	0.06	3.0	46.7	1.03	0.44

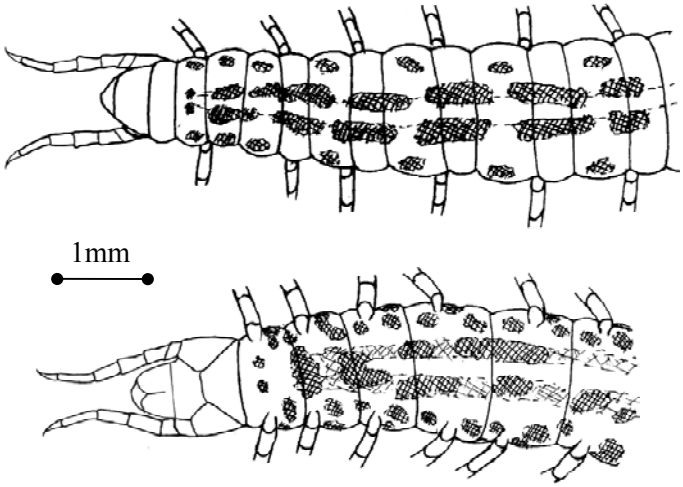


FIGURE 1: *Geophilus carpophagus* s.s., Little Wittenham
Posterior region showing typical pattern of internal pigmentation seen in live specimens.
Female, 46mm length. Above dorsal view, below ventral view

Body proportions

Figure 2 indicates that in adults the body length remains more or less proportional to body width irrespective of sex or size of specimen. Males vary between 22-26 times longer than width, whilst females are possibly slightly more slender at 23-27 times (Table 2). Juveniles are relatively stout, being approximately 19-24 times longer than width.

Eason (1964) gives dimensions of 28-30 times longer than broad, which probably refers to *G. easoni*.

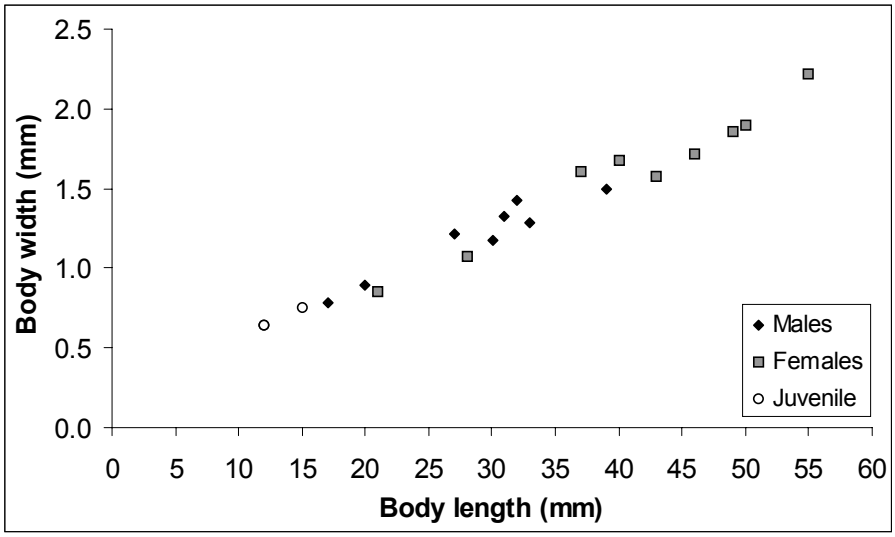


FIGURE 2: *Geophilus carpophagus* s.s., Plot of body length against body width.
Males and female are plotted separately, except for first stadia juveniles.

Number of trunk segments

The frequency distribution of the number of leg pairs within the sample is shown in Figure 3. There was very little variation within this one population. Males predominantly have 53 leg pairs (one specimen with

51), whereas females mainly have 55 (one each with 53 and 57). This is similar to the frequency distribution found in British material examined by Haswell, Enghoff and Arthur (2006). The sex of three first stadium juveniles could not be determined.

The number of leg pairs in *G. easoni* in Britain is quoted as being 47-49 (males) and 49-51 (females) (Barber, 2009).

Ratio of males to females

Although the sample size is small, the eight males and nine females collected suggest that the population studied comprised approximately equal numbers of both sexes. Since the specimens were specifically chosen to provide a representative selection of size classes, and were not a random sample, it is not possible to comment on the age structure of the population.

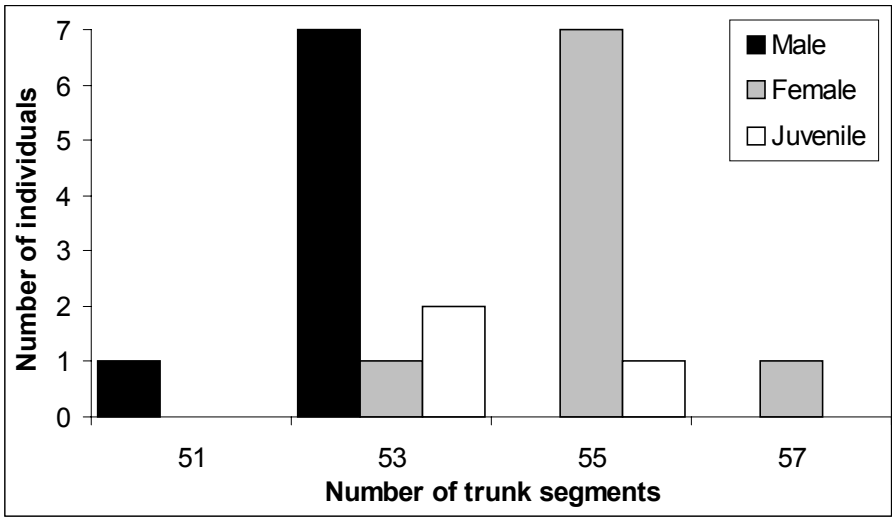


FIGURE 3: *Geophilus carpophagus* s.s., Frequency distribution of trunk segments (leg pairs) within the sample. Males and female are plotted separately, except for first stadia juveniles.

Antennae

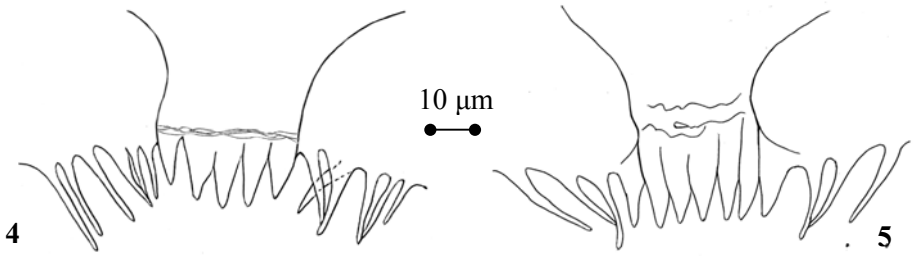
The length of the antennae was about 2.5 to 3.2 times the width of the head irrespective of body length or sex (Table 2). In adults the antennae were between 6% to 9% of the total body length. This is similar to that seen in *G. easoni.* The antennae were relatively longer in juveniles (stadia 1 and 2), around 8% to 11% of body length, and appear relatively broad when compared those of adults.

The antennae of geophilids are invariably composed of 14 articles (Eason, 1964). It is apparent that 25% of all specimens collected had either damaged or apparently regenerated antennae (Table 1). One specimen had 14+13 articles, two 14+12 (Figure 6) and one 11+10. Another large female had recently had one of its antennae severed just above the forth segment, which had healed with black scarring.

Labrum

Two specimens were examined. The teeth of mid-piece of the labrum, which numbered three or five, were relatively elongate and tapered to a rounded point (Figure 4). This agrees with Haswell *et al* (2006) (Figure 5). The mid-piece was more or less similar in colour to the adjacent side-pieces of the labrum. Our two examples had 24 and 27 fimbriae projecting from the side-pieces, respectively. Haswell *et al* (2006) report 12-19 fimbriae in the British material they examined.

This differs from *G. easoni* where the teeth of the mid-piece are close set, stout and bluntly rounded, often appearing truncated (Haswell *et al* (2006), Figure 6). The mid-piece has a dark reddish colouration that contrasts with the adjacent side-pieces (Arthur *et al*, 2001; SG, pers. obsv.). The number of fimbriae on the side-pieces is typically in the range of 30-40 (Haswell *et al*, 2006), but the type specimen (Arthur *et al*, 2001) had c. 12 fimbriae each side (i.e. about 24 total). This suggests considerable variation in this character.



FIGURES 4 - 5: *Geophilus carpophagus* s.s. Labrum, central region
4. Female, 37mm, Little Wittenham
5. British specimen, redrawn from Haswell *et al* (2006)

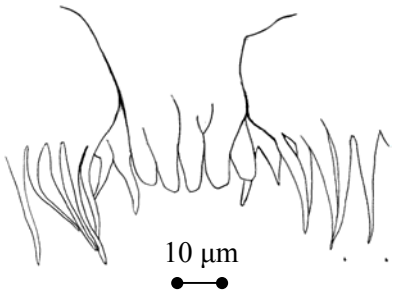


FIGURE 6: *Geophilus easoni,* Labrum, central region
British specimen, redrawn from Haswell *et al* (2006)

Forcipular tergite

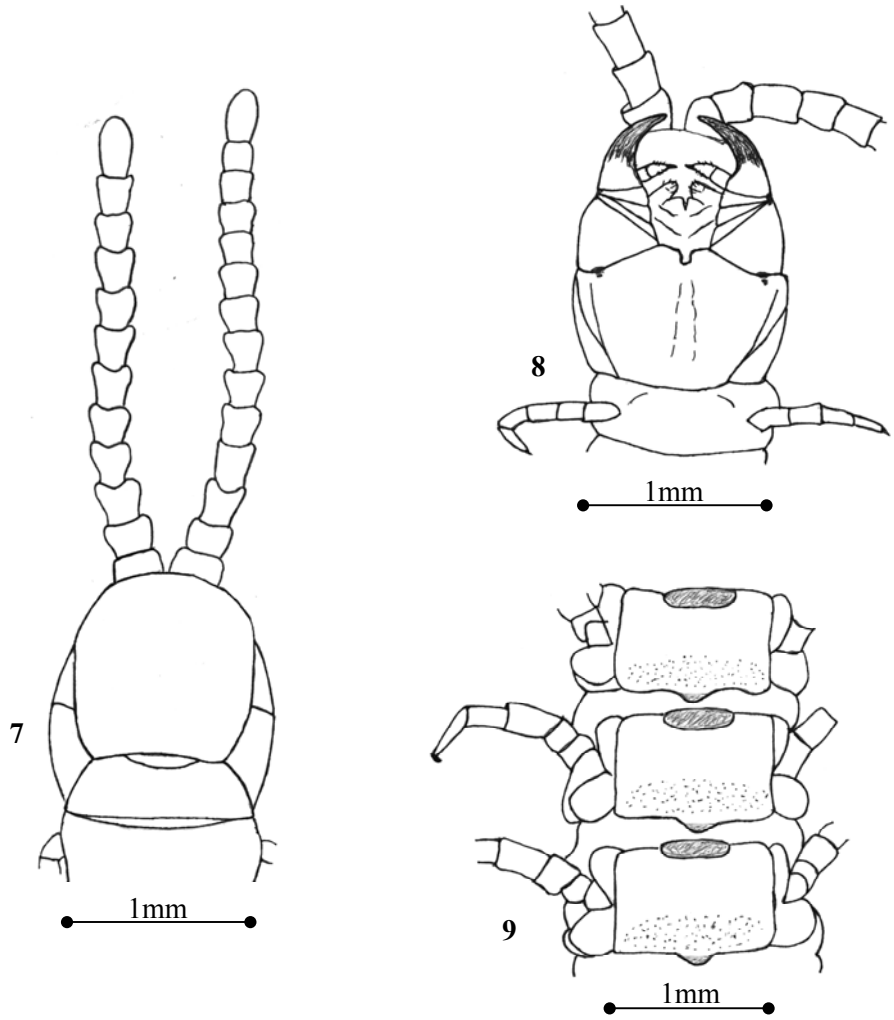
The forcipular tergite was trapezoidal, with the posterior margin distinctly broader than the anterior and distinctly broader than the head. The lateral margins were slightly concave (Figure 7). This is similar to that of *G. easoni.*

Sternites bearing fossae

A series of fossae, apparent as dark brown oval depressions, are present along the anterior margin of the anterior sternites (Figure 9). These begin to appear at sternite 3 or 4 and increase in width to become very distinct by sternites 8 or 9, before becoming less prominent and had completely disappearing by sternite 14 or 15. In adults, the fossae occupy a maximum of 41% to 54% of the width of the sternite. They are less well developed in juveniles, being in the order of 33% to 44% the width of the sternite. In terms of size, shape and colour these fossae are indistinguishable from those of *G. easoni.*

Sternal pores

On the more anterior segments the sternal pores are arranged in a diffuse band along the posterior edge of the sternite and are quite prominent on fossae bearing segments (Figure 9). On subsequent sternites the band splits to form two ovoid groups that became progressively smaller and more restricted towards the posterior corners of the sternites. The pore groups persist until the penultimate segment. This is similar to the pattern seen in *G. easoni*.



FIGURES 7 - 9: *Geophilus carpophagus* s.s., Little Wittenham
7. Anterior region, dorsal view. Note left hand antenna composed of 12 articles, probably as a result of damage and imperfect regeneration. 8. Anterior region, ventral view.
9. Anterior trunk sternites 8-10 showing carpophagus fossae. Note also sternal pores groups.

Coxal pores

In live and freshly preserved specimens the pores present on the ventral surface of the coxae of the last pair of legs were readily observed. The pores were distributed in one or two rows along the edge of the metasternite and were partially obscured beneath the lateral edge of the sternal plate. Following preservation the coxal pores soon became indistinct and in preserved adult specimens it proved virtually impossible to accurately observe the position and number of coxal pores. It was necessary to clear specimens (by immersion in clove oil) before accurate observations could be made.

As in other members of the Geophilidae, the number of coxal pores increases with body length (Figure 10), which approximately equates to age. The earliest juveniles had no coxal pores, with subsequent stadia showing increasing number of such pores. There are clear differences in the numbers of coxal pores observed between the two sexes. The majority of the adult males had 3+3 coxal pores (maximum 4+4) (Figure 11). The number of coxal pores was much more variable in females (Figures 12 & 13), which typically have more than males of the same body length, and reached a maximum of 8+8 in the largest (55mm) female examined. Arthur *et al* (2001) also records a maximum of 8 coxal pores in this species. Females with higher numbers of pores typically had about 4 or 5 large pores, with a few much smaller ones that were less easily seen.

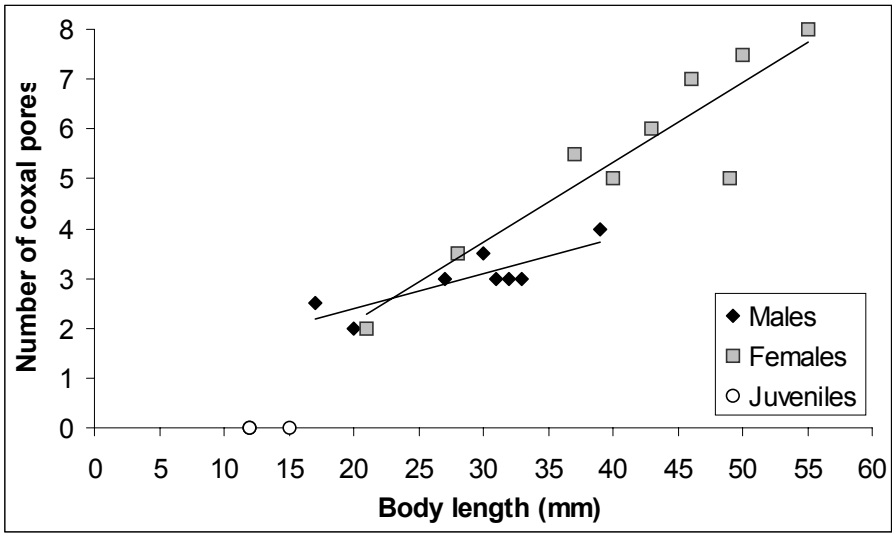
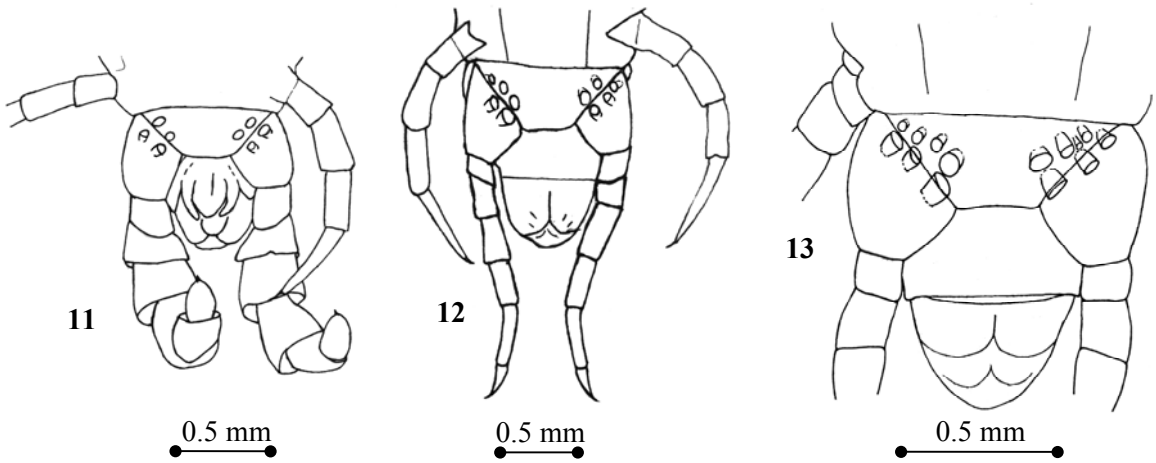


FIGURE 10: *Geophilus carpophagus* s.s., Number of coxal pores (averaged for the two coxae) plotted against body length. Males and females are plotted separately, except first stadia juveniles.

This differs from *G. easoni*, where the larger coxal pores are typically apparent, even in uncleared preserved material, and they tend to be much more numerous with up to 12 on each coxa (Figure 14 & 15). Eason (1964, figs. 163 & 164) also illustrates typical *G. easoni* where the male has 5+6 coxal pores and the female 10+11.



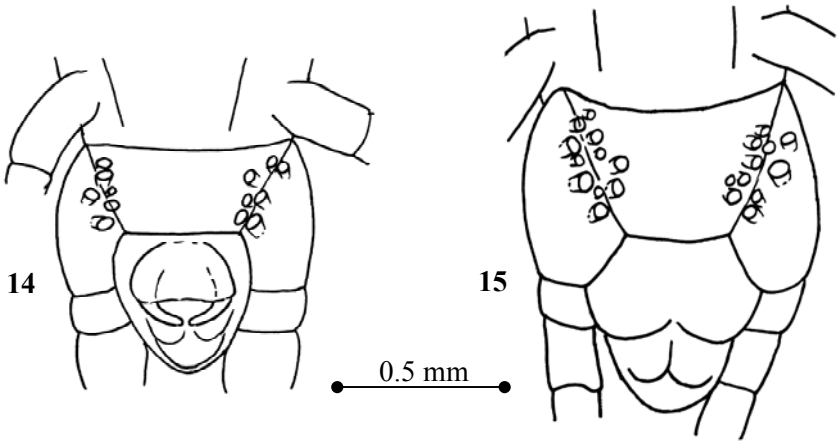
FIGURES 11 - 13: *Geophilus carpophagus* s.s., posterior region, ventral view. Little Wittenham.
11. Male, 40 mm length, 4+4 coxal pores.
12. Female, 49mm length, 5+5 coxal pores. 13. Female, 46mm length, 7+7 coxal pores.

Anal pores

A pair of anal pores was easily seen in juvenile specimens (Figures 16 & 17), but they were inconspicuous in well-pigmented adults, even in cleared specimens.

Terminal legs

The terminal legs of males were distinctly swollen (Figure 11), as seen in *G. easoni*. This sexual dimorphism became apparent from the second stadium onwards (Figure 18).



FIGURES 14 & 15: *Geophilus easoni*, posterior region, ventral view. Sidlings Copse, Oxfordshire.
14. Male, 30mm length, 6+7 coxal pores.
15. Female, 35mm length, 11+10 coxal pores (Compare to Figs. 11 - 13 above)

Walking legs

Preliminary results (Gregory, in prep.) indicate that each article of the walking legs (metatarsus/tarsus, tibia, femur and prefemur) of *G. carpophagus* s.s. are approximately the same width as those of *G. easoni*, but are relatively greater in length (Gregory, in prep.). Thus, the legs of *G. carpophagus* s.s., which in the sample measured are about 7 to 10.5 times longer than wide, are proportionately longer than those of *G. easoni*, where the length is about 5.5 to 8 times the width (Table 3).

TABLE 3: Relative dimensions of leg length and apical claws in *Geophilus carpophagus* s.s. (Little Wittenham) and *G. easoni* (Sidlings Copse, Oxon)

Species	Leg: ratio length / width	Claw: ratio width of tip / width of base	Claw: ratio width of tip / length
G. carpophagus s.s	7.0 - 10.4	0.09 - 0.13	0.03 - 0.05
G. easoni	5.5 - 7.9	0.14 - 0.19	0.04 - 0.06

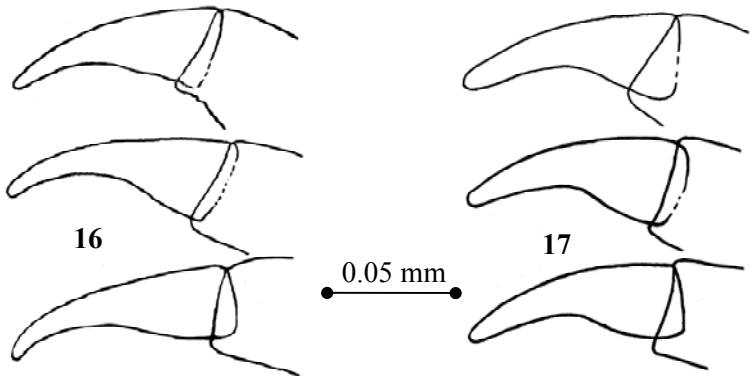


FIGURE 16 & 17: Apical claws of walking legs 10, 25 & c.40
16. *Geophilus carpophagus* s.s., female, 40mm, Little Wittenham, Oxfordshire
17. *Geophilus easoni*, female, 33mm, Sidlings Copse, Oxfordshire

Apical claws

These provisional data (Gregory, in prep.) also indicate that on the walking legs of *G. carpophagus* s.s. the width of the tip of the apical claws is between 9-13% of the width of the base of the claw, compared to the 14-19% observed in *G. easoni* (Table 3). Thus, the apical claws of *G. carpophagus* s.s. (Figure 16) are relatively longer and tapered to a sharper point than those of *G. easoni* (Figure 17).

First stadium juveniles

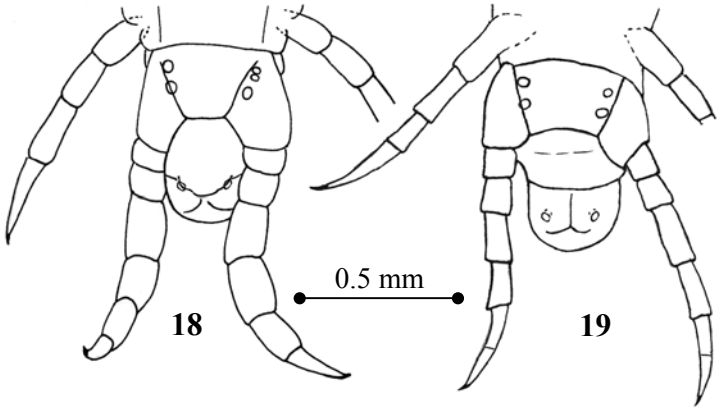
Three specimens were collected. These were 12-15mm in length and were slightly stouter than adults, being approximately 19 - 20 times longer than width. Coxal pores were absent, but a pair of anal pores was apparent. The antennae were relatively long, between 8% - 11% of body length. The carpophagus fossae were poorly developed, appear purplish in colour, and occupy 33% - 36% of the width of the sternite. Head and antennae were pale orange, while the body, including the last trunk segments, was poorly pigmented and appeared pale grey. It was not possible to distinguish the sexes. Arthur *et al* (2001) also records two specimens of *G. carpophagus* of length 12mm and 14mm without coxal pores.

Eason (1964) reports the absence of coxal pores in his description of the first stadium of *G. carpophagus* sensu lato, which probably refers to *G. easoni*. G.B. Corbet (pers. comm.) reports lengths of 8-14 mm for juveniles, but this may include 2nd stadium individuals.

Second stadium juveniles

Three specimens, between 17-21mm in length, were collected. At 21.5 - 24.5 times longer than wide the body proportions lie at the lower end of the range observed in adults. Two had distinct 2+2 coxal pores (Figure 19). The third specimen, upon close examination with a light transmission microscope, had 2+3 coxal pores (Figure 18). In this example, it was apparent that what appeared to be a single normal sized pore was actually two much smaller pores lying adjacent to each other. The anal pores were less distinct than seen in the first stadium. The antennae remain relatively long, between 8% to 10% of length of body. The carpophagus fossae are more conspicuous and occupy 40% to 44% of the width of the sternite. The last pair of legs of the two male specimens are beginning to show a slight swelling at this stage (Figure 18). Pigmentation of head and body was more or less as seen in adult specimens.

Two specimens of *G. easoni* of this stadium collected in Oxfordshire are both 12mm in length and have 2+2 and 2+3 coxal pores (SG pers. obsv.), the latter as in Figure 18.



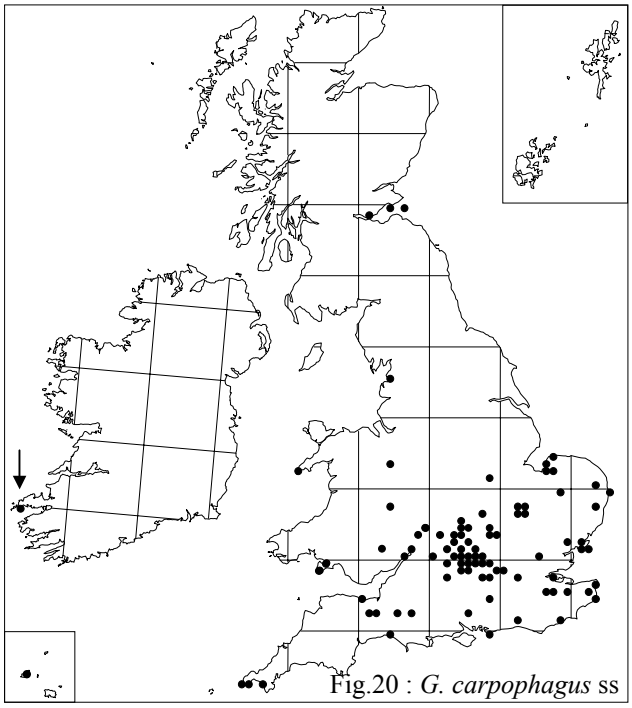
FIGURES 18 & 19: Geophilus carpophagus s.s., second stadia, posterior region, ventral view
18. Male, 20 mm length, 2+3 coxal pores. Note slight swelling of last legs.
19. Female, 21mm length, 2+2 coxal pores. Note pair of anal pores

BRITISH AND EUROPEAN DISTRIBUTION

Geophilus carpophagus s.s.

The provisional distribution map (Figure 20), based on verified records (Barber, in prep.), indicates that *G. carpophagus* s.s. is most frequent, and probably common, across south-eastern England, at least south of the Severn to the Wash. Further north and west it becomes increasingly coastal (i.e. Cornwall, Wales, Lancashire and south-eastern Scotland). In Ireland it is restricted to the south coast (M. Cawley, pers. comm.). Inland it occurs as a synanthrope, typically in above ground micro-sites, such as beneath bark on tree trunks or under stones on walls up to 10m above ground level (e.g. Blower, 1987; Gregory & Campbell, 1996; Whitehead, 2004). It has been frequently reported inside houses. At coastal sites it is often associated with sea cliffs, where it has been found within crevices or within hollow plant stems (G.B. Corbet, pers. comm.).

The few confirmed records outside of Britain indicate that this species has a wide distribution across north-western and central Europe (Figure 22). It is widely distributed across France (Geoffroy & Iorio, 2009), including the Channel Islands (Barber, 2006), and occurs in Switzerland (E. Stöckli, pers. comm.), Belgium (K. Lock, pers. comm.), the Netherlands (Berg *et al*, 2008), and extending northwards into southern Scandinavia; Denmark, southern Norway, Sweden and Finland (Andersson *et al* 2005, G. Andersson, pers. comm.). There are known occurrences in eastern Germany (N. Lindner, pers. comm.) and Poland (Kaczmarek, 1979; M. Leśniewska pers. comm). Matic (1972) reports *Geophilus carpophagus* from Romania, but with leg numbers 47-57 (males) and 49-59 (females) and 3-9 coxal pores but it is possible that his description was, at least in part, derived from elsewhere and its status needs clarification.



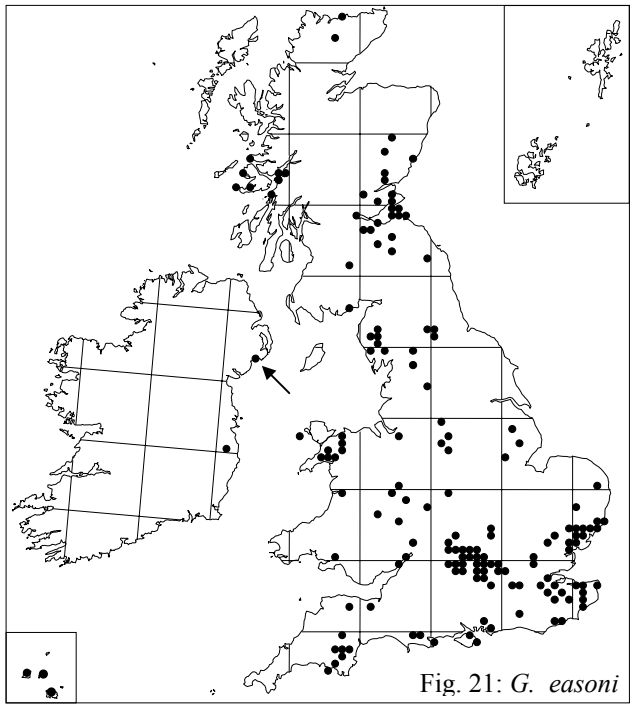


FIGURE 20 & 21: Provisional distribution maps for Britain and Ireland (confirmed records only) for *Geophilus carpophagus* s.s. (left) and *Geophilus easoni* (right) (Barber, in prep.)

Geophilus easoni

Confirmed records of *G. easoni* occur from southern England to northern Scotland (Figure 21). The majority of unconfirmed records (i.e. for *G. carpophagus* s.l., not plotted here) from Ireland and northern England,

north to Orkney, are likely to be of this species (Barber, in prep.). It is usually found in rural sites, such as woodland, heathland or moorland, typically at ground level beneath logs and stones.

On current evidence *G. easoni* has a strict Atlantic distribution (Figure 22). Beyond Britain its range extends southwards from the Channel Islands (Barber, 2006) through western France (Geoffroy & Iorio, 2009; SG, unpublished data), into north-west Spain and penetrating into at least northern Portugal (SG, unpublished data). Specimens collected south of the Pyrenees may have up to 57 leg pairs, making confusion with *G. carpophagus* s.s. possible, but they have up to 18 coxal pores (each side).

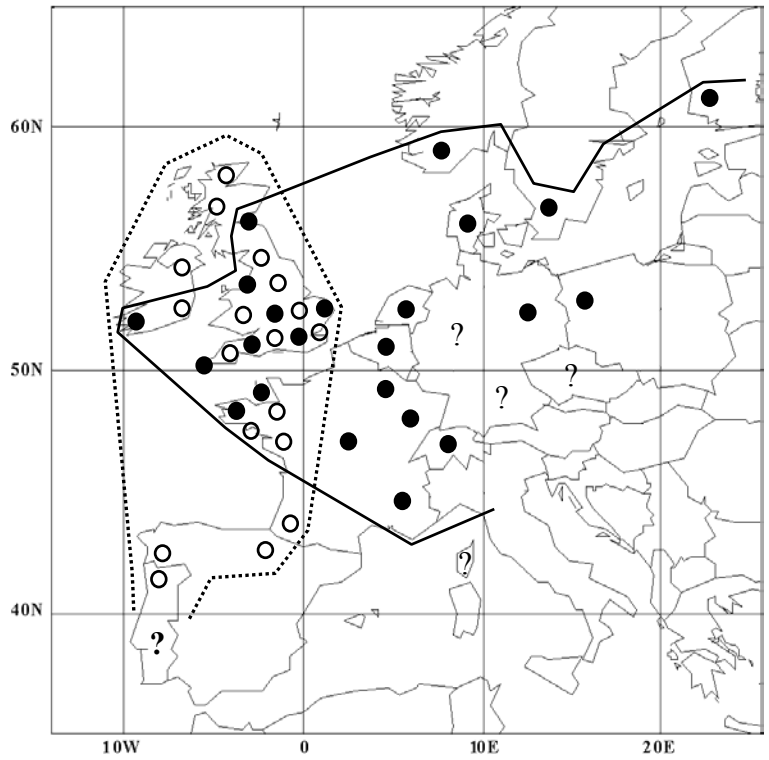


FIGURE 22: Outline distribution in Europe for *Geophilus carpophagus* s.s. (solid dots, solid line) and *G. easoni* (open circles, dotted line)
? indicates non-specific European occurrences of *G. carpophagus* s.l.

DISCUSSION

It is apparent from the data that there are noticeable differences in body length and number of coxal pores between adult male and female specimens of *G. carpophagus* s.s.. The sample is too small to be clear whether this is true sexual dimorphism, with females growing proportionately more rapidly than males or a result of sampling bias, where younger males and older females were collected. Some millipede species (e.g. *Cylindroiulus punctatus*) are iteroparous: the males die in the first season after reaching maturity, whereas females continue to breed, and grow, in subsequent seasons (Blower, 1985). Although this is a possible explanation for the data presented here, this breeding strategy does not appear to occur in other centipedes within the family Geophilidae. Ideally, the species would be bred and reared in laboratory culture so that growth and ecdysis could be followed for known stadia of each sex.

The fact that 25% of all specimens collected had either damaged or apparently regenerated antennae is of note. It is the larger specimens that are affected (Table 1), suggesting that likelihood of damage to the antennae is a function of age. It is not clear whether this damage is primarily aggression between individuals of this 'gregarious' species or due to confrontation with a predator. Other than a few specimens of *Lithobius*

melanops, no other potential predators were observed during sampling, although many species may not be active in November when the specimens were collected.

The characters described herein for *G. carpophagus* s.s. agree with those presented by Haswell *et al* (2006). Although the number of trunk segments (leg pairs) is diagnostic in separating British examples of these two species (and probably also those from north-west Europe), it is clear that *G. carpophagus* s.s. and *G. easoni* are morphologically very similar. *G. carpophagus* appears to be consistently larger than *G. easoni*, from early juvenile stadia through to fully grown specimens. However, this is of no use in distinguishing between animals that undergo continuous growth and ecdysis. More helpful is that mature specimens of *G. carpophagus* have consistently fewer coxal pores than specimens of *G. easoni* of comparable body size. Arthur *et al* (2001) show that for a given body length *G. carpophagus* has approximately half the number of coxal pores relative to *G. easoni*. Arthur *et al* (2002) suggest that the reduced number of coxal pores in *G. carpophagus* may be an adaptation resulting from the preference of this species for much drier microsites than is typically seen in other geophilomorphs. However, it should be borne in mind that the number of coxal pores increases with each ecdysis and that there is considerable variation between individuals of the same stadium. Thus, there is much variation, and much potential overlap between these two species, in both body length and the number of coxal pores.

Preliminary studies suggest that the apical claws of the walking legs of *G. carpophagus* are tapered to a much sharper point than those of *G. easoni*. Possessing sharper claws is clearly beneficial to a climbing species and may explain the observed 'clinginess' of this former species on its substrate (e.g. Haswell *et al*, 2006). There also appear to be differences in the relative lengths and widths of the leg articles, with *G. carpophagus* having proportionately longer legs than *G. easoni*. Whilst, shorter legs are more typical of burrowing species (e.g. millipedes (Blower, 1985)), longer legs are often characteristic of fast moving animals, and the advantage to a climbing species such as *G. carpophagus* is not clear.

FUTURE WORK

There remain problems in determining material from outside north-west Europe. Haswell *et al* (2006) highlight the variability of the number of fimbriae projecting from the side-pieces of the labrum, particularly in non-British material and suggest the possibility of additional cryptic species occurring outside north-west Europe. Specimens of *G. carpophagus* sensu lato collected from northern Portugal and northern Spain (SG, unpublished data) have females with up to 57 leg pairs and 55 mm in length, but on the basis of other characters described in this paper appear to be *G. easoni* (and are plotted in Fig. 22 as that species). An increase in the number of trunk segments is typically observed in more southerly populations of other geophilomorph species (Arthur & Kettle, 2001) so this is perhaps not unexpected. Other characters for separating the two species may be found, such as clypeal setae, antennal sensilla and structure of the poison glands (which are described for *G. easoni* by Arthur *et al* (2001)).

In light of the measurable differences between the walking legs of *G. carpophagus* s.s. and *G. easoni* highlighted above (Table 3) it is intended (by SG) to examine in more detail the relative dimensions of individual articles of the walking legs, apical claws and associated spines of both species. A selection of individuals from populations from across the full breath of Britain will be examined and will be the subject of a subsequent paper.

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