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Notes on morphology and behaviour of the reproductive stage of *Ceratophysella denticulata* (BAGNALL, 1941) (*Collembola*: *Hypogastruridae*)

DARIUSZ SKARŻYŃSKI
Zoological Institute, Wrocław University, Sienkiewicza 21, 50-335 Wrocław, Poland,
e-mail: hypogast@biol.uni.wroc.pl

ABSTRACT. Morphology and behaviour of reproductive individuals of *Ceratophysella denticulata* (BAGNALL, 1941) were studied. Morphological modifications associated with the reproductive period are described and illustrated. Reproductive behaviour is described. An explanation of the biological meaning of these phenomena is given.

Key words: entomology, morphology, behaviour, reproductive stage, *Collembola*, *Hypogastruridae*, *Ceratophysella*

Studies on morphological changes associated with the reproductive period in some species of the genus *Ceratophysella* BÖRNER, 1932 were carried out by CASSAGNAU (1964), BOURGEOIS (1973, 1974, 1981), BOURGEOIS & CASSAGNAU (1970, 1973) and ZETTEL & ZETTEL (1994). The reproductive behaviour of *Ceratophysella sigillata* (UZEL, 1891) was studied by ZETTEL & ZETTEL (1994). As a result of these studies morphology and behaviour of a ceratophysellan reproductive stage were preliminarily described.

During taxonomical studies on the Polish population of *Ceratophysella denticulata* (BAGNALL, 1941), some new data on the morphology and behaviour of its reproductive stage were obtained; they are given below.

MATERIAL AND METHODS

Two populations of *C. denticulata* were studied:

- Deciduous forest with *Quercus ruber* L. and *Carpinus betulus* L. in the Odra river valley, Wrocław, 110 m a.s.l., (Nizina Śląska Lowland, SW Poland), leg. D. SKARŻYŃSKI. The litter samples were taken at monthly intervals from March 1999 to March 2000.

- Spruce forest (*Picea excelsa* Lam. Lk.) at the top of Szczeliniec Mountain, 900 m a.s.l. (Góry Stołowe Mountains, Sudetes, SW Poland), leg. A. SMOLIS. The litter samples were taken at monthly intervals from April 1996 to December 1998.

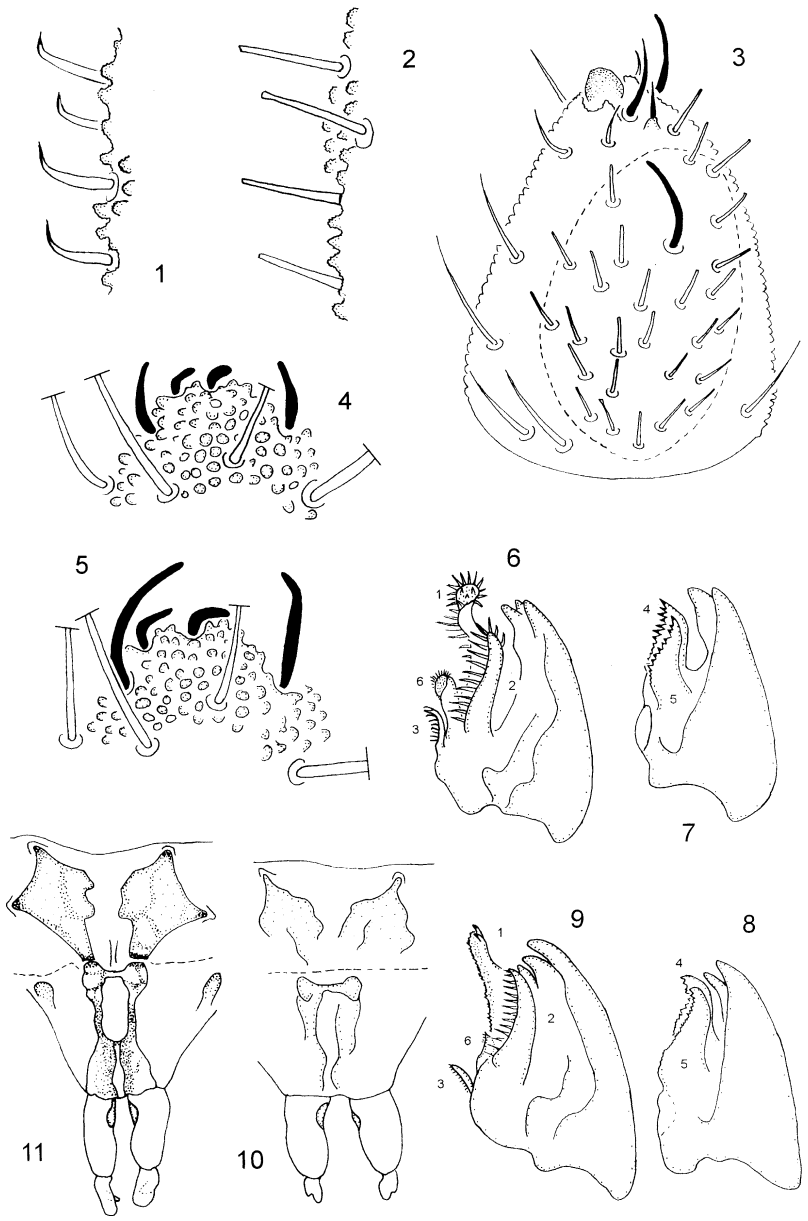
Comparative, morphological data were based on c. 150 adult specimens for each population. These data were confirmed by observation on individuals in ecdysis from the prereproductive to the reproductive stage. In order to study the reproductive behaviour, the individuals collected in the field (Wrocław) in April and October 1999 were observed under laboratory conditions. The collected specimens were kept in glass jars with moistened plaster of Paris mixed with charcoal. Yeast were used as food. The culture jars were kept in the dark freezer at 12-15°C.

RESULTS

The reproduction of the two studied populations takes place in the spring (Wrocław: March-May, Szczeliniec: May-June) and autumn (Wrocław: September-October, Szczeliniec: October-November). During this period the individuals of *C. denticulata* show essential changes in their morphology and behaviour.

Table. The extreme and mean (in parentheses) lenght of the body and values of d/ ratio (parameter after BOURGEOIS 1974) of the studied individuals of *C. denticulata*. Abbreviations: d - distance between setae a_1 and p_1 on th.2, D – length of dens, m – length of mucro, cl – length of claws 3, S – length of macrochaeta p_2 on abd. 4, as – length of anal spines, W – population from Wrocław, S – population from Szczeliniec, A – non-reproductive stage, E – reproductive stage.

	Size (mm)	d/D	d/m	d/cl	d/S	d/as
W A ♀	1.2-1.5 (1.32)	0.72-0.9 (0.81)	1.28-1.56 (1.44)	0.77-1 (0.88)	0.42-0.5 (0.45)	0.83-1.08 (0.92)
W E ♀	1.15-1.65 (1.34)	0.9-1.08 (0.99)	2.5-3.86 (3.06)	1.1-1.4 (1.24)	0.62-1 (0.73)	1.4-2.06 (1.86)
W A ♂	0.88-1.2 (1)	0.72-1 (0.89)	1.33-1.72 (1.56)	0.85-1 (0.94)	0.36-0.52 (0.44)	0.9-1.16 (0.99)
W E ♂	0.8-1.1 (0.98)	0.9-1 (0.96)	2.4-3.6 (2.83)	1.1-1.3 (1.17)	0.5-0.7 (0.6)	1-1.7 (1.32)
S A ♀	1.15-1.4 (1.26)	0.8-0.93 (0.88)	1.6-1.86 (1.73)	0.95-1.04 (1)	0.42-0.52 (0.46)	0.86-1.16 (1)
S E ♀	1.15-1.38 (1.24)	1-1.26 (1.07)	2.8-4 (3.25)	0.96-1.26 (1.12)	0.6-0.84 (0.75)	1.18-2.42 (1.93)
S A ♂	1-1.25 (1.1)	0.85-0.95 (0.9)	1.6-1.86 (1.76)	1-1.13 (1.05)	0.43-0.52 (0.47)	0.77-1.15 (0.95)
S E ♂	0.95-1.25 (1.07)	0.96-1.18 (1)	2.9-3.7 (3.24)	1-1.3 (1.14)	0.5-0.8 (0.61)	1.16-1.6 (1.37)



1-11. *Ceratophysella denticulata*: (1-3) Sensilla in ventral file on ant. 4, 1 - non-reproductive individual, in profile, 2 - reproductive individual, in profile, 3 – reproductive individual, ventral view; (4-5) Ant. 3 organ, 4 - non-reproductive male, 5 - reproductive male of the same size; (6-9) Head of maxilla, 6 - non-reproductive individual, ventral side, 7 – same, dorsal side, 8 - reproductive individual, dorsal side, 9 – same, ventral side; (10-11) Ventral side of abd. 4 and furca (with visible cuticular skeleton of furca), 10 - reproductive individual, 11 - non-reproductive individual

MORPHOLOGY

The reproductive individuals show some progressive modifications: fully developed genital plates (with visible "pre-genital lobes" in females and swollen ejaculatory duct in males), inflated abdomen in females, dark coloured body in males. However, most of the observed modifications is of regressive character: shortened dens, claws, anal spines, body setae, shortened and deformed mucro (Figs 10, 11), simplified subapical dental setae and lack of eversible sac between antennal segments 3-4. Intensity of some of these changes is usually higher in females than in males and varies between the studied populations (Tab.).

Compatibility of the results presented above and those reported by BOURGEOIS (1974) for two French populations of *C. denticulata* suggests a universality of the described phenomena.

Moreover, the reproductive stage in the two Polish populations of *C. denticulata* shows the following morphological changes not reported in the literature:

- Sensilla in ventral file on ant. 4 which in non-reproductive specimens are always thick, curved and flattened at the tip (Fig. 1) become thin, straight and blunt at the tip (Figs 2, 3).
- Sensilla in ant. 3 organ of males become distinctly enlarged (Fig. 5), even twice as long as in non-reproductive specimens (Fig. 4).
- Lamella 1 of the head of maxilla becomes narrow at the tip, slightly shortened and devoid of marginal filaments (Fig. 9). Marginal filaments of lamellae 2-6 become shorter than in non-reproductive individuals (Figs 6-9).
- Cuticular skeleton of furca becomes more delicate and usually seems to be incomplete (Fig. 10). Consequently, it is poorer visible (or completely invisible) than in non-reproductive individuals (Fig. 11).

The intensity of all these modifications varies between the studied individuals and populations.

BEHAVIOUR

C. denticulata has a reproductive behaviour similar to that of *C. sigillata* (ZETTEL & ZETTEL 1994). Feeding is strongly limited (only 2 specimens with gut filled with food were noted) and the activity, especially jumping, is strongly disordered. The surface activity is distinctly less intense. In laboratory culture, the reproductive individuals and laid eggs were usually observed in cavities of the plaster or on the margin of plaster and walls of the culture jar. In the field, reproductive individuals were collected only sporadically on mushrooms or lose bark.

CONCLUSIONS

The reproductive stage of *C. denticulata* shows strong morphological and behavioural modifications. This short-lasting stage during its evolution was submitted to a strong selective pressure which improved reproduction. Undoubt-

edly, a proper reproductive strategy is decisive for an evolutionary success of the species. With respect to *C. denticulata*, natural selection fovoured reproduction in cold, humid, deep layer of soil. The effectiveness of spermatophore transfer and the chance of eggs and the newly hatched individuals to survive were higher than in the superficial layer or on the surface of the soil. In these conditions walking and jumping were difficult or impossible and elongate chaetotactic structures hampered movement in tight soil spaces, especially for females which were larger than males. As a result, the furca, claws, setae and anal spines were reduced. This saved substance and energy which could be invested in reproduction. This was important because reproductive individuals usually do not feed. This period of starvation started evolutionary reduction of unused mouth parts, though a range of these changes was rather small.

It is noteworthy that some of these regressive modifications are convergent to those which took place in numerous groups of springtails during evolutionary transfer from life on the soil surface to life in its deeper layers (STEBAEVA 1970).

Unfortunately, it is difficult to explain biological sense of modifications in some antennal sensilla. The regression of the sensilla in the ventral file on ant. 4 is probably linked with its limited or nonexistent reception of chemical stimuli (smell reception?). The progressive change in ant. 3 organ of males is probably associated with its increased physiological activity (reception of female sexual pheromones?). Also, darker colour of males during reproductive period seems to be an interesting problem; life in the deep, dark layers of soil should have had an opposite effect. All these problems require further studies.

It is necessary to mention taxonomical context of studied phenomena. Number and the shape of the sensilla in ventral file on ant. 4 and the shape of the lamellae in the head of maxilla are commonly used, important diagnostic characters in the genus *Ceratophysella* and the *denticulata*-group (BABENKO et al. 1994, JORDANA et al. 1997, FJELLBERG 1998). Its wrong interpretation could be a reason of erroneous taxonomic decisions.

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