Biological cycle and larval morphology of *Cychrus cordicollis* Chaudoir 1835 (Coleoptera: Carabidae)

Enrico Busato
DIVAPRA - Entomologia e Zoologia applicate all’Ambiente “C. Vidano”, Università di Torino, Via Leonardo Da Vinci 44, I-10095 Grugliasco (Torino), Italia

**Abstract.** Little information is available on the pre-imaginal stages of Cychrini and nothing is known on the life history of high-altitude *Cychrus* species. In this work the author describes some unpublished observations on the biology of *Cychrus cordicollis*, a species endemic to the Pennine Alps, in the Mount Rose massif, and to part of the Lepontine and Rhaetian Alps. In particular, for the first time for a high-altitude *Cychrus* species, some data are given about oviposition and female prolificity, obtained from laboratory rearings.

The larval morphology of the first, second, and third instar is described in detail. Some differential characters in the larval chaetotaxy of this species are highlighted comparing it with the already known larval descriptions of other six *Cychrus* species and with the models proposed by Bousquet & Goulet (1984) and Makarov (1993).

**Keywords:** Coleoptera, Carabidae, *Cychrus cordicollis*, larval morphology, biological notes.

The monophyletic tribe Cychrini is, within the subfamily Carabinae (Coleoptera: Carabidae), a very homogeneous group widely spread in Eurasia and North America. In the past it was considered predominantly Nearctic, because in the American continent there are 60 species about, attributed the three genera: *Scaphinotus* Dejean 1826, *Sphaeroderus* Dejean 1826, and *Cychrus* Fabricius 1794 (the latter with only 2 species) (Erwin 2007). Over the last two decades, following the description of several new taxa of the genera *Cychrus* and *Cychropsis* Boileau 1901 (thanks in particular to the several articles by Cavazzuti, Deuve and Imura), the total number of the Asiatic species has risen to over 100 and currently it is evident that the most important area of speciation of Cychrini is the Palaearctic Asia (Deuve 1997).

In Europe, the tribe is represented only by the genus *Cychrus*, spread from Spain to Caucasus. This genus in Italy includes 9 species, some of them endemic to the country. It is a quite high number, considering that all the European species are only 14 (Vigna Taglianti 2004).

The subject of this research is the species *Cychrus cordicollis* Chaudoir 1835 (fig. 1). With the other two species *C. angulicollis* Sella 1874, and *C. grajus* K. Daniel & J. Daniel 1898, *C. cordicollis* represents a homogeneous group (“*cordicollis* group” in the sense of Casale et al. 1982) of high-altitude species typical of the Western Alps, with a very homogeneous structure of the male genitalia. The greater affinities emerge comparing *C. cordicollis* with its immediate southern vicariant, *C. grajus*. These affinities are so evident that *C. grajus*, described as a separate species by K. & J. Daniel, was later considered as one of the three subspecies, with the typical subspecies and *lauzonensis* Schatzmayr 1939, ascribed to *C. cordicollis* (Schatzmayr 1939; Magistretti 1965). However *C. grajus* was also approached to *C. angulicollis* (Amiet 1962). These are opinions that were not shared by Casale et al. (1982). They considered all the three species of the “*cordicollis* group” monotypical.
and the taxon *lauzonensis* as a population with extreme characteristics within the chorology of *C. grajus* (these considerations were later accepted by the most of the authors).

In the current work the larval morphology of *C. cordicollis* is described. These notes partially close the gaps in the knowledge on the young stages of high-altitude *Cychrus* species. Among these, up to now only the larval morphology of *C. cylindricollis* Pini 1871 was known (Casale & Vigna Taglianti 1991), a taxon which belongs to another, very distinct species group. In particular, some characters typical of this species are highlighted, comparing them with the few ones known for the all genus *Cychrus* in the world (6 species), and the larval chaetotaxy of *C. cordicollis* is fully defined in comparison with the models proposed by Bousquet & Goulet (1984) and Makarov (1993). Moreover, some original notes on the biology of *C. cordicollis*, that should be reflected in the biology of other high-altitude *Cychrus* species, are provided.

**Material and methods**

The larvae of *C. cordicollis* described in this work originated from rearing adults collected in: – Aosta Valley, Gressoney Saint-Jean (AO), Pra Bianco 2000 m - 24.VII.2004. 1♂ and 1♀ - Legit E. Busato; – Aosta Valley, Gressoney La Trinité (AO), Lago Gabiet 2300 m - 25.VII.2004. 1♂ and 1♀ - Legit E. Busato. The rearings were carried out following Malausa (1977) and allowed to obtain several eggs, larvae and some unpublished data on the biology of this species. For a more comprehensive larval morphology, the development of some specimens was followed until the second and third instar. Adults and larvae were reared in the laboratory, trying to reproduce in the best way the environmental conditions (particularly referring to the seasonal average temperatures) of the places of origin. The temperature was maintained at 10 ± 2 °C. The breeding of the couples began on 25.VII.2004 and lasted until the natural death of individuals. Adults and larvae of *C. cordicollis* were fed exclusively with live snails, of varying size, belonging to the species *Xerolenta obvia obvia* (Menke 1828) (Gastropoda: Hygromiidae) collected in two different localities: – Aosta Valley, Verrayes (AO), 580 m Champagnet locality - VII-IX.2004 - Legit R. Tedeschi; – Aosta Valley, Saint-Jean (AO), 850 m Mt Torrette - VII-IX.2004 - Legit E. Busato. Some larvae of the first, second and third instar of *C. cordicollis* were individually mounted on a small plastozote support through micropins and then dipped in alcohol 70% and drawn. The dipping into alcohol 70% is particularly useful to allow easy identification and drawing of pores and setae, contrary to what happens in cases where, for the morphological study, we adopt the dry preparation that often causes the fall of many setae and a slight deformation of the specimens analyzed.

The terminology adopted in the text is in agreement with Böving (1911), Jeannel (1920), Casale *et al.* (1982), Bousquet & Goulet (1984).

**Results**

**Biological notes**

Rearrings. The rearings started on the 25.VII.2004 with two pairs of *C. cordicollis* placed in two separate

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**Figures 1–3**

*Cychrus cordicollis*. 1, female in its natural habitat at the moment of the capture: Aosta Valley, Gressoney La Trinité, Gabiet Lake m 2300 - 25.VII.2004 - Legit E. Busato; 2, mature egg, obtained in the laboratory; 3, third instar larva, obtained in the laboratory. Pictures with different magnifications.
Figures 4–5
Third instar larva of Cychrus cordicollis: habitus in 4, dorsal and 5, ventral view (Scale: 1mm).
containers. Numerous snails, varying in size and belonging to the species *X. obvia obvia* (Menke 1828) were provided alive as food. This snail was chosen because it was easy to find in quantity and for the low production of mucus for defensive purpose and for its size. *X. obvia*, introduced from Eastern Europe, was already reported in Italy in the early '70s, but only for the middle-eastern Alps (Alzona 1971). Its appearance in the Western Alps is even more recent (Gavetti et

Table 1. Length/width ratio (l/w) of the frontale calculated for each instar of *Cychrus cordicollis*.

<table>
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<tr>
<th>Instar</th>
<th>1st Instar</th>
<th>2nd Instar</th>
<th>3rd Instar</th>
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<tbody>
<tr>
<td>n</td>
<td>l/w (m±sd)</td>
<td>n</td>
<td>l/w (m±sd)</td>
</tr>
<tr>
<td>11</td>
<td>1.30±0.03</td>
<td>4</td>
<td>1.36±0.03</td>
</tr>
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**Figures 6–7**
6, First instar larva of *Cychrus cordicollis*: habitus (Scale: mm 1); 7, detail of the head: ruptor ovi (Scale: 0.5 mm).
Biological cycle and larval morphology of *Cychrus cordicollis*

Figures 8–15
Second instar larva of *Cychrus cordicollis*. 8, head in dorsal view; 9, left antenna in dorsal and 10, lateral view; 11, left mandible in dorsal view; 12, right maxilla in dorsal and 13, ventral view; 14, labium in dorsal and 15, ventral view (Scale: 1 mm).

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181
al. 2008). The areas outlined in this paper are the first for the Aosta Valley. The species lives in herbaceous vegetation of natural and semi-natural grasslands, xeric grasslands from 550 m to 2000 m above the sea level.

Immediately after the rearimg setup it was possible to observe adults preying snails. In conjunction with the feeding, the mating started. After about a week it was possible to observe some ovipositional holes in both breedings. Females laid eggs singly inside an oval cell a little bigger, dug just below the soil surface to a depth of approximately 0.5–1.5 mm, where the ground surface was bare as well as where it was covered by moss or flat stones held slightly raised by the use of small pebbles. The ground was maintained very wet so as to be similar to that present in the wilderness, following the melting of snow. The collection of eggs appears to have been particularly easy on the ground as the female left a very small ovipositional hole with the soil slightly ploughed around it: the cells could be easily identified and gently opened with a spatula. The female ploughed around it: the cells could be

as the female left a very small ovipositional hole with the soil slightly ploughed around it: the cells could be easily identified and gently opened with a spatula. The total number of eggs laid by each female was 21 for the female from Gabiet Lake and 16 for the female from Pra Bianco, respectively, in about 1 month of life. The egg-laying finally ceased in the first days of September, the natural death of reared adults took place between October and December. The newly laid egg of *C. cordicollis* (fig. 2) is round, diaphanous white, and measures approximately 2.0 × 1–1.2 mm; then it gradually assumes a clear yellowish coloration. Its size increases significantly as a result of embryonic development and finally, when the development is completed, it measures approximately 3.0 × 2.0 mm. Embryonic development, at 10 ± 2 °C, is completed in 37–45 days. Of the 37 eggs laid altogether by the two females, 18 had hatched, corresponding to 48.6% of the total. The hatching of the eggs began on 8 September and continued until the end of the month. Immediately after hatching, before feeding, the front of each urotergite remains hidden under the edge of the previous tergite and the larva appears considerably stubby and rounded; after food ingestion, however, the abdomen swells and gets longer. A few days before every moult the larva usually builds a simple pit under a cover, like a simple piece of bark. Then it spends 3–5 days without moving, lying on the back, before the exuviation.

During this time the cuticle is very stretched and sometimes the larva reaches a length greater than that reached immediately after the moult, before the renewal of the trophic activity. After the moult, the larva starts again feeding after a few hours, immediately after the sclerification of the cuticle, but it eats more after 2–3 days.

A high larval mortality was observed, particularly in the first days after hatching and after the first meal. Only 22.2% of the larvae completed their development, from hatching to the first moult, while only the 16.7% of the specimens reached the third instar. The first instar lasted on average 12.0 days, at 10 ± 2 °C, while the second instar lasted on average 15.3 days. The three surviving larvae that reached the third instar (fig. 3) stopped feeding and were then placed at 1–2 °C for overwintering. During the wintering the larvae remained immobile in a small pit under the bark. In the rearing container there were still some live snails. Two larvae pupated on 14.V.2005 and 16.V.2005, respectively, while a third one died. The pupae, however, were malformed and did not reach the emergence.

**Larval morphology**

Silphoid type larva, egg-shaped, broad and depressed, brownish-black to brownish-reddish (figs. 3, 4, 5, 6). Length from mandible tip to end of urogomphi (excluding macrochaetae): first instar mm 5.5–11.0; second instar mm 10.0–14.0; third instar mm 13.0–16.0. These measures are only indicative because the total length of the larva can vary a lot, due to its nutritional condition and to its ability to elongate the neck that is very movable and elastic (fig. 3).

Subrectangular head; chaetotaxy of the cephalic region as in fig. 8; FR, and FR, setae in normal position. Frontal sutures well visible and sinuous. Metopical suture absent, as always in this genus (Thompson 1979). Frontale markedly longer than large: l/w ratio as in Tab. 1. The width measurements were taken from the central part of the frontale, next to the larger part, without considering the lateral lobes to avoid l/w ratio distortion.

Eye area poorly prominent, provided with six stemmata and three setae (PA, PA, PA). Anterior margin of frontale (nasal) trilobate, like in all other known species. Central lobe rounded and just sketched, at the same level of the lateral lobes that have the anterior margin nearly perpendicular to the body axis. Frontale with five couples of dorsal setae in normal position, a long one (FR, FR, FR, FR, FR) and with many setae; third segment subcylindrical with a single seta, second one similar, long about twice the first one and with many setae; third segment subcylindrical, long 2/3 of the second and with the same diameter of the first two ones, provided with several setae and with a domed sensilla (“accessory item” of the authors: cfr. Casale et al. 1982) lateral to the insertion point of the fourth cylindroconical article (fig. 10). The diameter of the latter is a half of the others and has a group of setae, four of which are clearly longer (AN, AN, AN, AN) and located in the apical
part where also three small sensilla were observed. The several setae that cover the second, the third, and the fourth segment, from the base to 2/3 of the length, typical of the *Cychrus* larvae, are not present in the models proposed by Bousquet & Goulet (1984) and by Makarov (1993).

Mandibles (fig. 11) falciform, narrow, lengthened, with the retinacle sharpened and curved, having small pointed teeth in the internal margin, at the base of which there is a tuft of setae (*penicillium*). Internal margin smooth; external margin with a single seta (MN1), at a half of the length.

Maxillae (figs. 12, 13) longer than mandibles, ratio m/M = 1.40–1.51. Stipes twice longer than wide, slightly dilated apically, supplied with several masticatory setae on the internal edge of the dorsal side (gMX). Maxillary palps with the first article subquadrate with rounded edges, second and third one subcylindrical and clearly more elongated, fourth cylindroconic, long about twice the second and a little longer than the third. First article with a medium-long seta on the ventral side (MX10) and with two setae on the dorsal side, one of the same length and another of double length (indicated by Makarov 1993 but not numbered). Second article supplied with a short seta on the dorsal side and another on the ventral side, both supernumerary, not present in the models proposed by Bousquet & Goulet (1984) and by Makarov (1993). Third article with two setae on the dorsal side (MX11, MX12) and one on the ventral side. Galea with two articles, the first one a little longer than the second and with a seta on the ventral side (MX7). Lacinia cylindroconical with an apical seta (MX).

Labium (figs. 14, 15) supplied with two pairs of ventral setae

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Figure 16–17
Third instar larva of *Cychrus cordicollis*: 16, VIII and IX urotergites; 17, left metathoracic leg in ventral view (Scale: 1 mm).
(LA₁, LA₂) and several dorsal setae (LA₃, LA₄, LA₅, gLA₆); ligula with a pair of long setae (LA₇). Labial palps articulated with the sides of the prementum, with two subcylindrical articles: the first one slightly enlarged distally and a little longer than the half of the second, dorsally supplied with 3–4 setae on the distal third (gLA₆); second segment truncated apically, unilobate with the sensorium much lengthened and oblique with respect to the longitudinal axis.

Thorax (figs. 4, 6) totally glabrous, as reported for the Cychrini by Bousquet & Goulet (1984).

Urotergites (figs. 4, 5, 6) widely covering the pleurae, with large and depressed lateral margins; they enlarge progressively from the first to the fourth, then they narrow significantly from the fifth to the last one.

Urite X (fig. 16) with prominent and glabrous latero-posterior lobes with a sharp end.

Urogomphi conical, narrow and weak, not articulated, slightly lobes with a sharp end.

Legs (fig. 17) very long, with trochanter, femur, tibia and tarsus provided with spines in longitudinal rows. Chaetotaxy in agreement with the model proposed by Makarov (1993) for the genus Carabus L. 1758 but with the addition of a series of 4–6 supranumerary spines on the ventral side of the tarsus. On the contrary, on the dorsal side there are normally 3–4 supranumerary spines, thinner, in the prothoracic leg, one or none on the mesothoracic and metathoracic legs. All the three pairs of legs maintain in all the instars the same number of spines, contrary to what happens in other species of the subfamily Carabinae (Bengtsson 1927; Busato 2003). One metathoracic leg taken as a sample, in the different instars, shows the ratios (Tab. 2).

### Discussion

The biological data stated in the present work confirm, for the first time by means of laboratory rearings, the life history of high-altitude Cychrus species, previously supposed by Casale & Vigna Taglianti (1991). They drew this hypothesis by collecting during the year different instars of C. cylindricollis. The particular typology of the life history shows a hibernating larva, as a rule in all Cychrini (Fradois 1945), that hatches in late summer, develops as long as the climatic conditions are favourable and completes its development when the snow starts to melt. It is also possible to hypothesize that in nature the larvae continue to live actively under the snow, in cracks of the rocks where they can find the preys. This can justify the fact that the larvae are impossible to find in the same places where the adults are (Casale et al. 1982). But probably they occupy the same habitat, however they are present in a period of the year when the researchers are not active anymore. The biological cycle corresponds to the “two year development type 6–7” by Paarmann (1979) and it seems to come from the autumn breeder carabids (“autumn breeder” type 3 by Luff 1973) that is an adaptation to the high latitude (and high altitude) conditions. According to what was asserted by Casale & Vigna Taglianti (1991), the classical distinction between the “spring breeder” and “autumn breeder” carabids proposed by Larsson (1939) should be replaced for the European Carabids by a distinction between species with “summer larvae” and species with “winter larvae” (Den Boer & Den Boer-Daanje 1990; Paarmann 1990).

The C. cordicollis larva shows all the typical characters described for the other six Cychrus species, of which the larval morphology is known: C. caraboides (L. 1758) (Schiødte 1867; Fradois 1946; Šharova 1958; Luff 1969, 1993), C. attenuatus (Fabricius 1792) (Verhoeff 1917; Sturani 1962), C. dufouri Chaudoir 1869 (Fradois 1947), C. italicus Bonelli 1810 (Sturani 1962; Casale et al. 1982), C. cylindricollis Pini 1871 (Casale & Vigna Taglianti 1991), and C. spinicollis L. Dufour 1857 (Cardenas et al. 2003).

The aspect and the general shape of the body of C. cordicollis larvae are notably elongate and not stubby (especially in the second and third instar) contrary to what happens in other species, in particular in C. caraboides, C. dufouri and C. spinicollis. Greater resemblances are observed with C. attenuatus and, because of the shape of the head, with the other described high-altitude species, C. cylindricollis. But it should be highlighted that the larva described in this work does not show any exclusive characters compared with those already known for the genus, contrary to what happens with the larva of C. cylindricollis that has a peculiar aspect (very elongate and frail, like the imago). This larva is also the only one that has ovoidal and flat labial palps not truncated at the apex and the frontal

### Table 2. Ratios of the metathoracic leg taken as a sample in the different instars Cychrus cordicollis (C: coxa; T: trochanter; F: femur; t: tibia; ta: tarsus).

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<th>T/C</th>
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<tr>
<td>I&lt;sup&gt;st&lt;/sup&gt; instar</td>
<td>0.64 0.61</td>
<td>0.54 0.54</td>
<td>0.85 0.92</td>
<td>0.58 0.52</td>
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<tr>
<td>II&lt;sup&gt;nd&lt;/sup&gt; instar</td>
<td></td>
<td></td>
<td>0.78</td>
<td>0.54 0.54</td>
</tr>
<tr>
<td>III&lt;sup&gt;rd&lt;/sup&gt; instar</td>
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<td>0.83 0.80</td>
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with edges behind the lateral lobes almost perfectly vertical, and urogomphi with very short setae.

The central lobe of the frontal in *C. cordicollis* is more levelled than in *C. caraboides*, *C. dufouri*, *C. attenuatus* and is close to the one of *C. italicus*, but not so prominent. Among the five couples of dorsal setae, of different length, present on the frontale, the FR2 couple is present only in *C. cordicollis*. However it is possible to believe that it is present in all the species, but that it was not described because very short and thin, hardly identifiable unless flowing a very thin brush across the frontal surface. Personally I could verify its presence in the larvae of *Cyclus* species in my possession (*C. caraboides*, *C. italicus*, *C. attenuatus*) and lent to me (*C. cylindricollis*).

In the genus *Cyclus*, the *raptor ovi* are formed by couples of spinulae, vertically placed one over the other, contrary to what happens in the genus *Carabus* where they are formed by a single spine. The presence of these structures in the first instar larvae of the Cychrini was, in the past, quite disputed and was confirmed by Sturani (1962), Casale et al. (1962), and Cardenas et al. (2002); these authors however illustrated, for *C. spinicollis*, a different orientation of the spinulae.

On the ventral side of the tarsus of the *C. cordicollis* larva, there are 4-6 additional spines that we can call gTA5, normally perfectly longitudinally aligned, placed above and parallel to the gTA spines. On the dorsal side there are normally 3–4 additional spines, thinner, on the prothoracic leg (that we can call gTA5), one or none on the mesothoracic and metathoracic legs. These spines are not reported in the models proposed by Bousquet & Goulet (1984) and by Makarov (1993). According with the observations that I made on the larvae of the species that I could examine and with the drawings of the articles describing the larval morphology of the remaining species, it is possible to state that this character, within the subfamily Carabinae, is peculiar of the *Cyclus* larvae.

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**References**


