

Larvae of Bembidiini: subgenera *Synechostictus* and *Pseudolimnaeum* of the genus *Bembidion* and their taxonomic position (Coleoptera: Carabidae)

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The larvae of five species of the subgenera *Synechostictus* (*B. ruficorne* Sturm, *B. nordmanni* Chaud., *B. millerianum* Heyd., *B. atroviolaceum* Dufour, all instars) and *Pseudolimnaeum* (*B. lederi* Rtt., first and second instars) are described. The distinguishing features of immature stages of *Synechostictus* and *Pseudolimnaeum* are given. Based on the remarkable larval morphology, these taxa should be separated within the tribe Bembidiini.

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Introduction

In spite of numerous larval descriptions of the tribe Bembidiini listed in Kryzhanovskij & al. (1995), very little is known about larval micromorphology and chaetotaxy. Since the publication of the most important methodological article by Bousquet & Goulet (1984), only the excellent review of larvae of the subgenus *Bracteon* (genus *Bembidion*) by Maddison (1993) has been published.

The subgenera *Synechostictus* Motsch. and *Pseudolimnaeum* Kraatz are distributed in mountain systems in humid areas of the Palaearctic and Oriental regions from the West Mediterranean to South-East Asia and are missing from dry mountains of Central Asia. They comprise over 20 species (Kryzhanovskij, 1983). Adults and larvae inhabit the banks of small rivers and streams in the middle- and low-altitude mountain zone and demonstrate a more or less pronounced tendency to cryptic (microcavernicolous) mode of life. Immature stages of these species have been poorly studied. Only the third instar of *B. (S.) elongatus* Dej. has been described (Raynaud, 1975, as *S. elongatus*) from one exuvium.

The subgenera *Synechostictus* and *Pseudolimnaeum* are closely related and represent a monophyletic group, as was assumed by nu-

merous authors (Netolitzky, 1942; Perrault, 1981; Müller-Motzfeld, 1995). The differences between these two subgenera are not always evident, especially when the Oriental fauna is concerned. Some authors considered this group a separate genus (Perrault, 1981) belonging (together with *Amerizus*) to the *Synechostictus* complex of genera and opposed to *Lymneops*, *Ocys*, *Cillenus*, *Asaphidion*, and *Bembidion*. Others regarded this group as two closely related subgenera isolated within the genus *Bembidion* (sensu lato) and placed them near *Ocydromus* (Müller-Motzfeld, 1995).

This study is based on the results of comparison of 229 larvae of the subgenera *Synechostictus* and *Pseudolimnaeum* with the larvae of some Palaearctic Trechitae. Some of them (89 specimens) were reared ex ovo from females collected in the vicinity of the Mezmay village (Kurdzhips River, the West Caucasus) and in the vicinity of Polyanytsya village (Prut River, the Ukrainian Carpathians) in spring 1995. In addition, larvae of *Synechostictus* collected by the author in the West Caucasus and larvae from the collection of Moscow Pedagogical State University were studied.

B. (S.) ruficorne Sturm, 1825: 1 L1, 1 L2 (ex ovo), West Caucasus, Kurdzhips River, near Mezmay, 500 m (on slide), 11.IV.1995;

Table. Measurements of *Synechostictus* and *Pseudolimnaeum* larvae, mm

Species	Stage	Number	Head length	Head width at the level of eyes	Head length/width	Head/epicranial suture length
<i>B. (P.) lederi</i>	II	1	0.58	0.55	1.04	6.53
<i>B. (S.) atroviolaceum</i>	I	3	0.42 ± 0.04	0.40 ± 0.01	1.05 ± 0.07	5.99 ± 0.50
	II	4	0.63 ± 0.01	0.63 ± 0.01	1.00 ± 0.02	4.98 ± 0.26
	III	3	0.99 ± 0.05	0.99 ± 0.06	1.00 ± 0.01	4.08 ± 0.22
<i>B. (S.) millerianum</i>	I	1	0.45	0.44	1.03	6.91
	II	2	0.65 ± 0.04	0.62 ± 0.02	1.04 ± 0.02	5.12 ± 0.08
	III	2	0.99 ± 0.03	0.96 ± 0.02	1.03 ± 0.01	4.45 ± 0.13
<i>B. (S.) nordmanni</i>	I	5	0.36 ± 0.01	0.36 ± 0.01	0.99 ± 0.03	6.06 ± 0.15
	II	4	0.54 ± 0.04	0.53 ± 0.02	1.02 ± 0.07	5.48 ± 1.04
	III	9	0.82 ± 0.03	0.81 ± 0.06	1.01 ± 0.05	4.11 ± 0.74
<i>B. (S.) ruficornis</i>	I	2	0.49 ± 0.01	0.47	1.03 ± 0.02	5.04 ± 0.21
	II	10	0.74 ± 0.10	0.69 ± 0.07	1.08 ± 0.04	4.82 ± 1.01
	III	9	1.16 ± 0.09	1.05 ± 0.09	1.10 ± 0.05	4.02 ± 0.28

2 L1, 12 L2, 33 L3, Caucasus Nature Reserve, Laura locality, 600 m (2 L1, 3 L2, 4 L3 on slide), 10.V.1993; 13 L2, 44 L3, West Caucasus, River Belaya, Syug creek, 550 m (2 L2, 2 L3 on slide), May-August 1994; West Caucasus, environs of Tuapse: 2 L2, 8 L3, Dede River, 50 m (2 L2, 1 L3 on slide), 28.VI.1993; 1 L2, Nauzha River, 500 m (on slide), 4.V.1993; 1 L2, 4 L3, Chumakovka River, K. Arnoldi leg. (1 L2, 2 L3 on slide), 12.V.1954; 1 L3, Caucasus Nature Reserve, environs of Guzeripl, 900 m (on slide), 1.V.1994.

B. (S.) nordmanni Chaud., 1844: 25 L1, 8 L2, 14 L3 (ex ovo), West Caucasus, Kurdzhips River, near Mezmay, 500 m (8 L1, 3 L2, 4 L3 on slide), 11.IV.1995; 2 L2, 4 L3, Caucasus Nature Reserve, locality Laura, 600 m (2 L2, 2 L3 on slide), 10.V.1993; 1 L3, West Caucasus, Belaya River, Syug creek, 550 m (on slide), May-August 1994; 1 L3, West Caucasus, environs of Tuapse, Dede River, 50 m (on slide), 28.VI.1993.

B. (S.) millerianum Heyd., 1883: 11 L1, 4 L2, 13 L3 (ex ovo), Ukrainian Carpathians, Prut River, near Polyanytsya, 800 m (4 L1, 3 L2, 6 L3 on slide), 3.V.1995.

B. (S.) atroviolaceum Dufour, 1820: 4 L1, 3 L2, 3 L3 (ex ovo), Ukrainian Carpathians, Prut River, near Polyanytsya, 800 m (2 L1, 2 L2, 2 L3 on slide), 3.V.1995.

B. (Pseudolimnaeum) lederi Rtt., 1888: 1 L1, 1 L2 (ex ovo), West Caucasus, Kurdzhips River, near Mezmay, 500 m (1 L1, 1 L2 on slide), 9.V.1995.

For comparison, larvae belonging to the following taxa have been studied: 41 species

of the tribe Bembidiini (genera *Bembidion*, *Ocys*, and *Asaphidion*), 7 species of Tachyini (genera *Tachys*, *Elaphropus*, *Porotachys*, and *Tactyta*), 10 species of Pogonini (genera *Cardioderus*, *Pogonus*, and *Pogonistes*), and larvae of 12 species of Trechini (genera *Perileptus*, *Thalassaphilus*, *Aepus*, *Trechus*, and *Epaphius*).

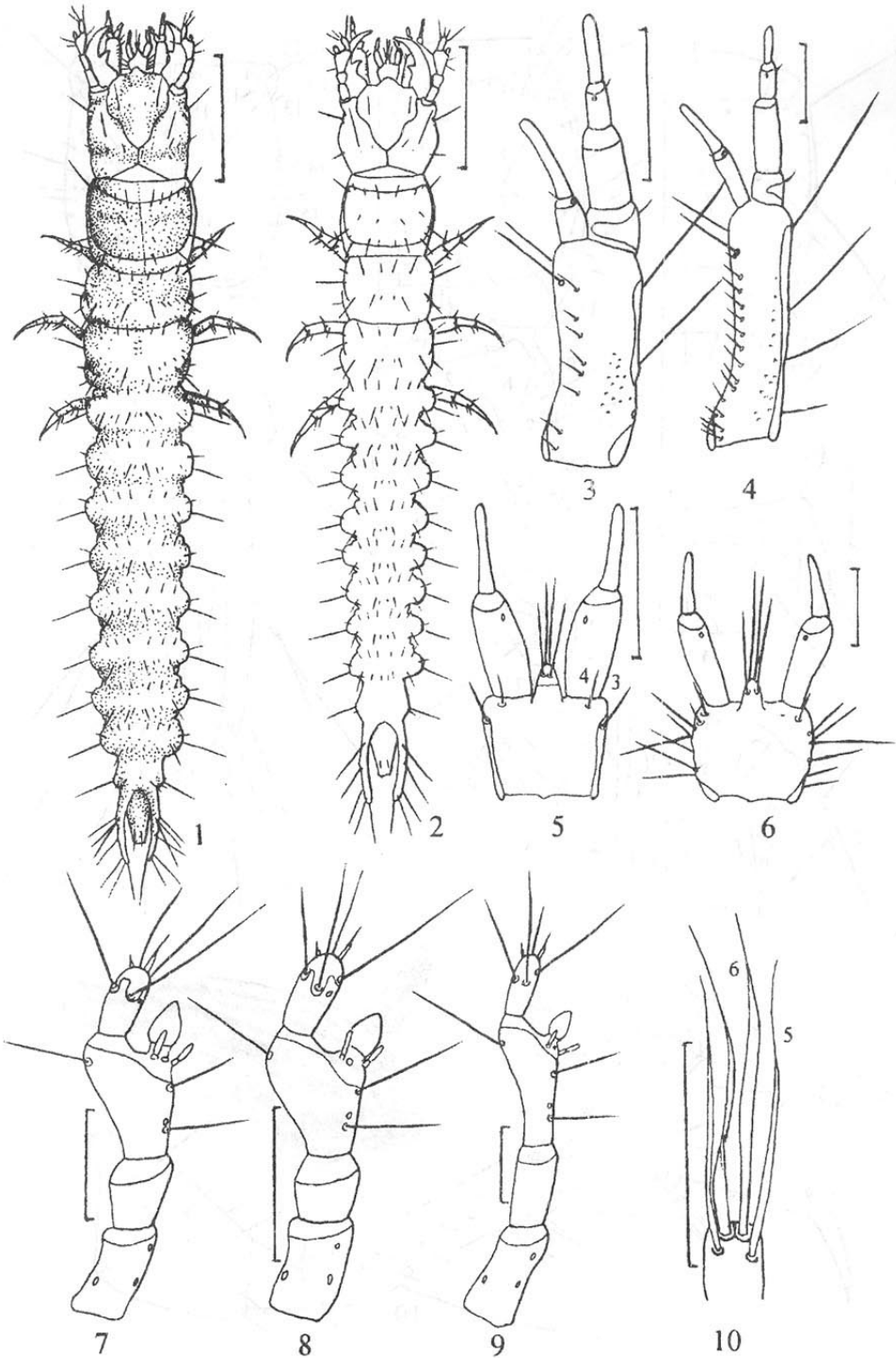
Larvae have been deposited in the collection of the author and in the Department of Zoology and Ecology, Moscow State Pedagogical University.

Some larvae were cleared in hot 10% potassium hydroxide, prepared in Fore-Berlese liquid, and studied under a stereomicroscope at magnifications of 150-900. Some larvae were studied using a Hitachi S-405 scanning electron microscope.

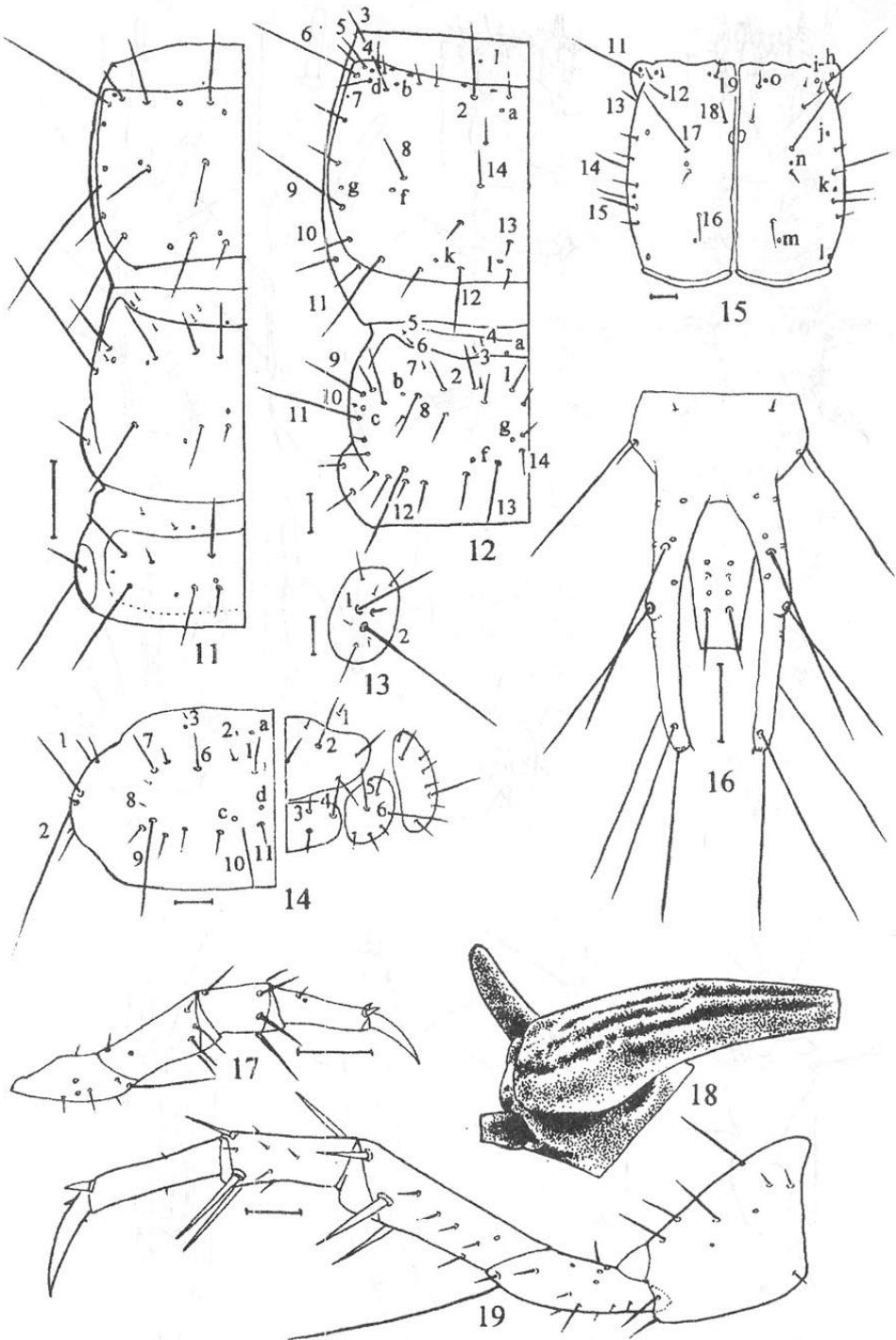
Terminology of larval morphology and chaetotaxy follows Bousquet & Goulet (1984) and Bousquet (1985) with modifications by Makarov (1992, 1994). All main morphometrical characteristics are given in the Table.

Subgenus *Synechostictus* Motschulsky, 1864

Description of 1st instar larvae (Fig. 2). Head (Figs 30-33) uniformly red-brown, usually without black spots near eyes; ocellar area slightly darker. Eyes with 6 ocelli. Postocellar groove well developed, its dorsal branch extending to pore PAd. Epicranial groove absent. Head sides near PA5 straight. Egg-bursters absent, 2-8 irregular small teeth situated on frontale along grooves.



Figs 1-10. Larvae of *Bembidion (Synechostictus) nordmanni* Chd. (1-6, 8, 9) and *B. (S.) ruficorne* Sturm (7, 10): 1, L3, general view; 2, L1, general view; 3, L1, right maxilla; 4, L3, right maxilla; 5, L1, labium; 6, L3, labium; 7, 8, L1, right antenna; 9, L3, right antenna; 10, L3, ligula. Scale: 1 - 1 mm; 2 - 0.5 mm; 3-10 - 0.1 mm.



Figs 11-19. Larvae of *Bembidion (Synechostictus) nordmanni* Chd. (11-17) and *B. (S.) ruficorne* Sturm (18, 19): 11, L1, pronotum, metanotum and 4th abdominal segment; 12, L3, pronotum and metanotum; 13, L3, right epipleurite (lateral view); 14, 4th abdominal segment (dorsal and ventral views); 15, L3, head (ventral view); 16, L1, 9th abdominal segment, urogomphi and pygidium; 17, L1, leg (without coxa); 18, L3, claw (from scanning electron microphotograph); 19, L3, leg. Scale: 0.1 mm.

Microsculpture of parietal sclerites transverse, more strongly developed on temples; near epicranial groove 9-20 teeth-like spines. Microsculpture on under side of head less developed. Dorsal tentorium fossae, postmentum, disc and basal part of frontal sclerite with less developed isodiametric microsculpture. Clypeus, paraclypeus, antennal segments and temples distal of PA4 without microsculpture.

Nasale (Figs 34-38) strongly projecting, with numerous small teeth. Spines of cibarium very small, arranged in parallel rows. Anterior angles of cibarium with 12 round sensilla, 2-3 of them aggregated together.

Head without additional sensilla, all ancestral setae and pores present. Setae PA1-PA3 drawn together, distance between them less than distance PA3-PA6; PA5 short (as PA1) or long (as PA4); FR1 situated below the level of PA10; FR4 and FR5 not drawn together, distance FR4-FR5 not less than distance FR4-FR4. Setae FR4 and FR6 short, their length 0.2 times that of FR5.

Mandibles curved (Figs 41-44). Base of mandibles with sharp pointed microsculpture on dorsal side. Seta MN1 situated below retinaculum level. Penicillum long, reaching top of retinaculum.

Stipes (Fig. 3): length : width ratio 3.38. In gMX 11-12 setae. Setae MX5 short, their length 0.6-0.8 times width of MX6; distance between them short, not more than 4 diameters of MX6.

Labium (Fig. 5) transverse (length : width ratio 1.17). Ligula strongly projecting, with sclerotized processes. Dorsal side of labium without large teeth. Setae LA5 and LA6 subequal and flat (Fig. 10), their tops extending to base of 2nd palpomere. Length of LA6 twice that of LA3 and 1.5 times that of LA4.

Antennae (Figs 7-8) typical of *Bembidion* larvae. Length of sensorial appendages of 3rd joint 0.75 times length of 4th one. Length of dorsal campaniform sensilla of 3rd joint subequal to width of 4th segment at base.

Pronotum (Fig. 11) red-brown, paler than head. Set of thoracic sensilla typical of *Bembidion* larvae: all primary setae and pores present, except pores PRc, PRe, PRh, PRi, PRj, MEd, MEe on all tergites and seta ES1 on metanotum. Pronotum without microsculpture. Transverse microsculpture developed on pretergites of meta- and mesonotum.

Legs (Fig. 17) without additional sensilla. Claw with one small seta at base. Dorsal side of claw with 2 furrows convergent apically.

Abdominal sclerites (Fig. 11) without additional sensilla, pore TEb absent. Seta TE6 on 7th and 8th segments small, not longer than UR9. Sclerites colourless. Pointed microsculpture developed only on tergites.

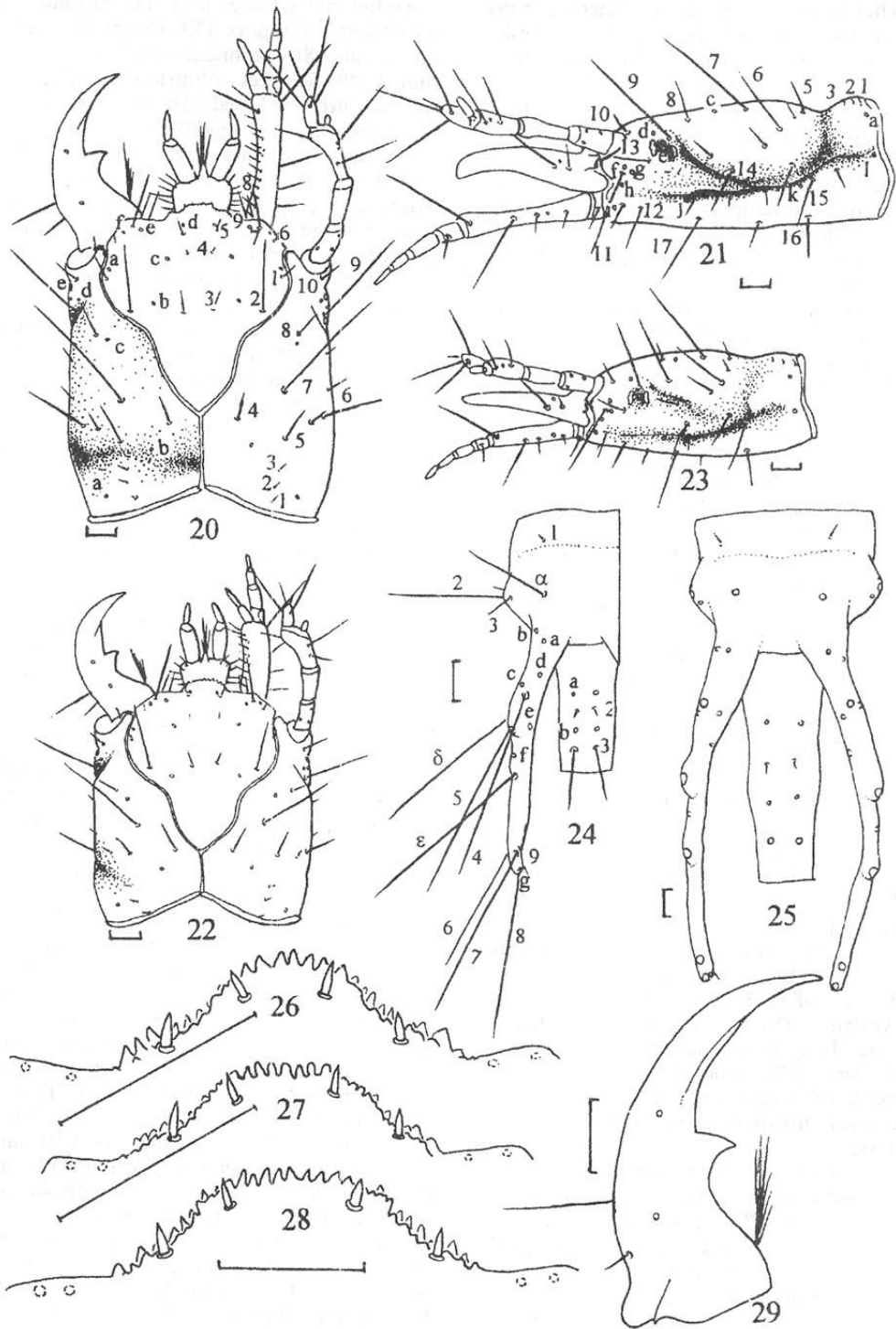
Urogomphi and pygidium (Fig. 16) not pigmented. All primary sensilla present. Setae EPI, UR9, PY2, PY5 and PY6 small. Microsculpture of 9th tergite multipointed. Base of urogomphi at level of UR4 and dorsal surface of pygidium with pointed microsculpture. Apical areas of urogomphi without microsculpture.

Description of 2nd and 3rd instar larvae (Fig. 1). Epicranial groove present, its dorsal branch extending to level of additional seta between PA5 and PA6. Head with lateroventral keel. Transverse microsculpture less developed on parietal sclerites. Ocelli partly reduced and aggregated in anterior and posterior rows, borders between ocelli within rows absent.

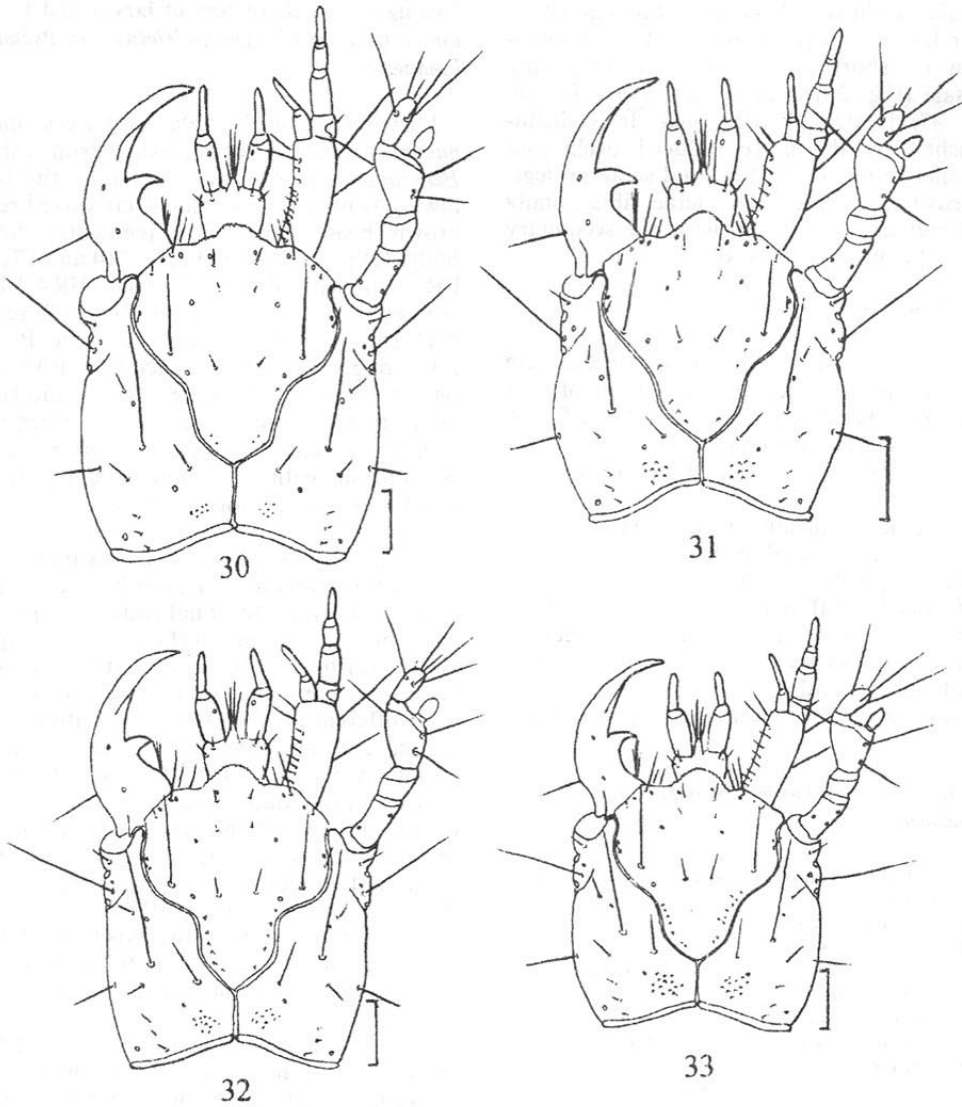
Nasale (Figs 26-28). Set of primary sensilla on head and appendages as in 1st instar (Figs 4, 6, 9, 15, 20-23, 29). Length of seta PA5 2-4 times that of PA1. Parietal sclerites with some additional setae: 3 near PA6, 2 near PA11, 1 distal of PA14 and 2 near PA17. Number and location of secondary setae within group PA15 unusual for *Bembidion* larvae: 2-3 additional setae located distal of PA15 and 1 seta proximal. Length of seta PA6 twice that of PA5. Frontal sclerite without secondary setae. Mandibles without additional setae in 2nd and with one additional seta in 3rd instars. Maxilla narrower, gMX with 12-17 setae. Outer side of maxilla with 1 additional seta in 2nd and 2 additional setae in 3rd instars. Labium at lateral margins with 5-11 secondary setae.

Tergite of pronotum (Fig. 12) with less developed isodiametric microsculpture and some additional setae: 1 seta between PR2 and median suture, 1-2 setae between PR2 and PR3, 1 seta between PR2 and PR14, 1 seta between PR3 and PR8, 1 seta between PR11 and PR12, 2 setae between PR6 and PR9, and 1 or 2 setae between PR13 and PR14. Epipleuron of pronotum with 4-6 setae. Pleurites and sternites without additional setae. Meso- and metanotum with 9-12 secondary setae. Length of seta ME11 twice that of ME9. Setae ME1, ME2, ME8, ME9 and additional seta between ME8 and ME9 subequal. Pleurites with 2 unequal setae.

Legs (Fig. 19) with some secondary setae: 1-2 sometimes on tarsus, 2-6 on tibia, 3-9 on



Figs 20-29. Larvae of *Bembidion* (*Synechostictus*) *ruficorne* Sturm (20, 21, 25) and *B. (S.) nordmanni* Chd. (22-24, 26-29): 20, 22, L3, head (dorsal view); 21, 23, L3, head (lateral view); 24, 25, L3, 9th abdominal segment, urogomphi and pygidium; 26, 27, L2, nasale; 28, L3, nasale; 29, L3, left mandible. Scale: 0.1 mm.



Figs 30-33. Larvae of *Bembidion (Synechostictus)* spp., L1, heads: 30, *B. (S.) ruficorne* Sturm; 31, *B. (S.) nordmanni* Chd.; 32, *B. (S.) millerianum* Heyd.; 33, *B. (S.) atroviolaceum* Dufour. Scale: 0.1 mm.

femur, 2-7 on trochanter and 2-5 on coxa. Claw long, with deep furrow on dorsal side (Fig. 18).

Abdominal tergites (Fig. 14) with 5-6 additional setae. Secondary seta near TE7 small, its length 0.3 times that of TE7. Shape and location of setae on epipleurites (Fig. 13) unusual for *Bembidion* larvae: EP2 very long; near EP1 located little secondary seta and its length 2-3 times diameter of seta EP2. 3-4 additional setae located at margins of epipleurite.

Urogomphi and pygidium (Figs 24-25) with typical of *Bembidion* set of setae and pores. Additional seta near UR3 shorter than UR2 and subequal to UR9. 9th ventral sclerite without secondary seta lateral of SS6. Pygidium ventrally with 1-2 additional setae on each side.

Subgenus **Pseudolimnaeum** Kraatz, 1888

Only two specimens are examined. The details of morphology and chaetotaxy are very

similar to those in *Synechostictus*. The 1st instar larva is distinguished by the combination of short PA5 and more projecting nasale (Fig. 39). 2nd instar larva (Figs 40, 45, 47) is strongly damaged. It is distinguished by the more reduced ocelli and smaller number of additional setae on legs: tarsus without secondary setae, tibia usually without or, sometimes, with 1-2 secondary setae, femur with 2 additional setae.

Keys to species

1st instar larvae of studied species are clearly distinguished by the length of seta PA5 and shape of retinaculum. Only for *B. (S.) ruficornis* Sturm and *B. (S.) atrovioleaceum* Dufour I did not find any distinctions.

2nd and 3rd instar larvae are very similar. Scarcity of material from the Carpathians did not allow to establish limits of inter- and infraspecific differences. The single 2nd instar larva of *B. (P.) lederi* is damaged. Therefore keys are given to 1st instar larvae of all species and 2nd and 3rd instar larvae of species of *Synechostictus* from the Caucasus.

Key to the 1st instar larvae of *Synechostictus* and *Pseudolimnaeum*

- 1(4). Setae PA5 short and thin, subequal to PA1 (Fig. 31).
- 2(3). Retinaculum large (Fig. 41); nasale less projecting (Figs 34, 35) *B. (S.) nordmanni* Chaud.
- 3(2). Retinaculum small (Fig. 46); nasale more projecting (Fig. 39) *B. (P.) lederi* Rtt.
- 4(1). Seta PA5 long and thick, 2-4 times as long as PA1 (Figs 30, 32, 33).
- 5(6). Sides of frontale basal of tentorial fossae parallel (Fig. 32) *B. (S.) millerianum* Heyd.
- 6(5). Sides of frontale basal of tentorial fossae converging (Figs 30, 33) *B. (S.) ruficornis* Sturm, *B. (S.) atrovioleaceum* Dufour.

Key to 2nd and 3rd instar larvae of *Synechostictus* from the Caucasus

- 1(2). Epicranial groove appearing as a wide and flat depression (Fig. 21), its bottom without a furrow; urogomphi and pygidium narrower and longer (Fig. 25); larvae larger: head width in L2 0.74 mm, L3 1.16 mm *B. (S.) ruficornis* Sturm.
- 2(1). Epicranial groove narrower and deeper (Fig. 23), its bottom with a furrow; urogomphi and pygidium wider and shorter (Fig. 24); larvae smaller: head width in L2 0.54 mm, L3 0.82 mm *B. (S.) nordmanni* Chaud.

Distinguishing characters of larvae and taxonomic position of *Synechostictus* and *Pseudolimnaeum*

Larvae of *Synechostictus* and *Pseudolimnaeum* are clearly distinguished from other *Bembidion* larvae known to me by the following features: (1) strongly sclerotized reddish-brown head and poorly pigmented light body; (2) pairs of setae FR4-FR4 and FR5-FR5 somewhat distant, distance FR4-FR5 not less than distance FR4-FR4; (3) setae PA1-PA3 drawn together, distance PA1-PA3 not greater than distance PA1-PA6; (4) setae LA5 and LA6 on ligula long and flat; (5) teeth of cibarium very small, subequal, arranged in parallel rows; (6) anterior angles of cibarium with 2-3 round sensilla aggregated together; (7) dorsal side of claw with 2 furrows.

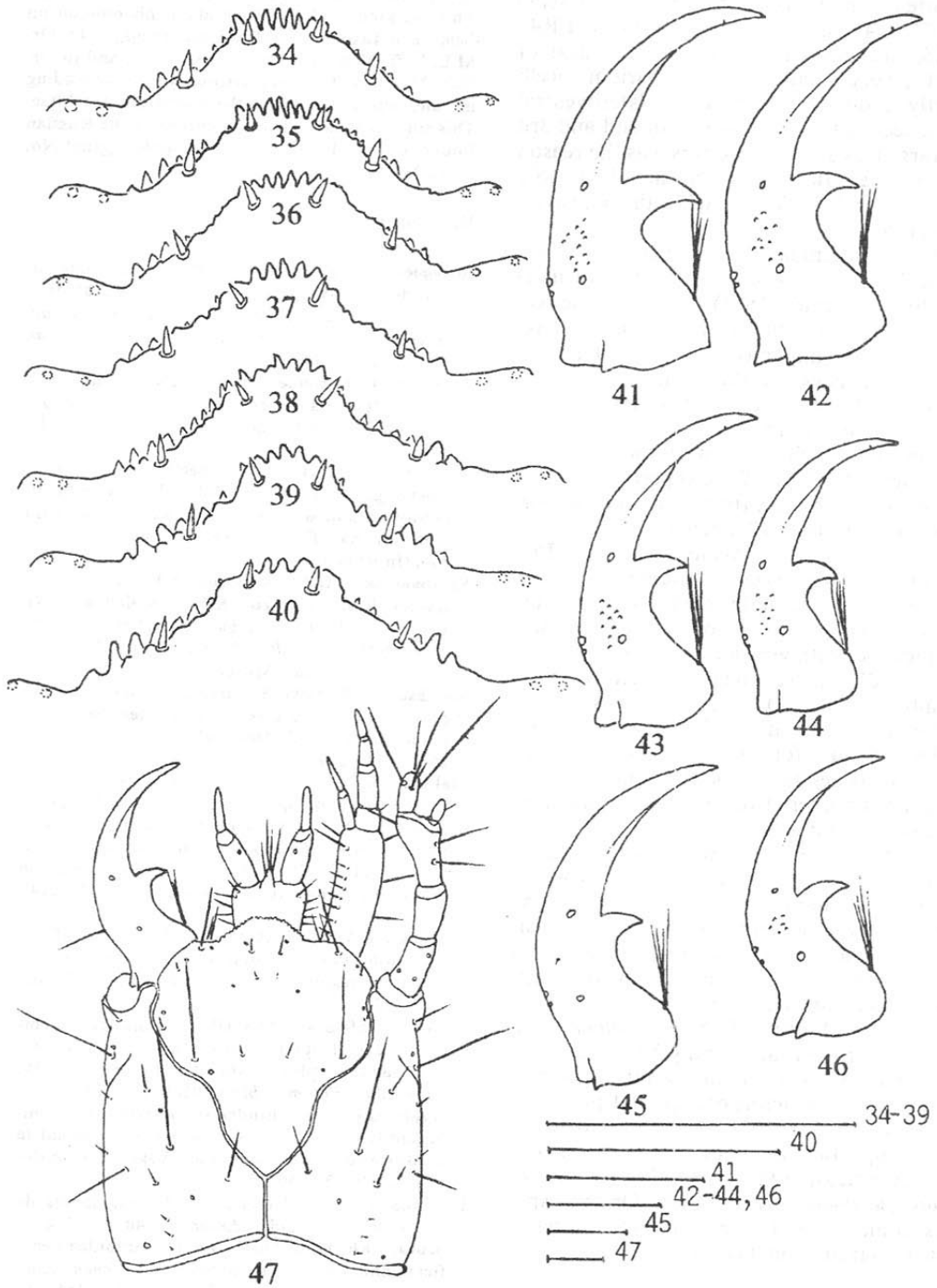
2nd and 3rd instar larvae are distinguished from other *Bembidion* larvae known to me by the following additional features: (1) ocellar tubercles absent, ocelli partly amalgamated; (2) head with lateroventral keel; (3) head sides parallel; (4) outer side of maxilla with different number (1 or 2) additional setae in 2nd and 3rd instars; (5) parietal sclerites with secondary seta basal of PA15; (6) legs with additional setae; (7) epipleurite with very long EP2 and very short additional seta near EP1; (8) secondary setae near UR2 short, not longer than UR3; (9) seta PY2 short, not longer than 0.25 PY3.

Taking into account the position of the group in question within the tribe Bembidiini, the morphology of larvae is of a special interest.

The lack of lacinia, pores PRc, PRE, PRI, PRj on pronotum, MEd, MEe on meso- and metanotum, seta ES1 on metanotum and pore TEb on all abdominal tergites of *Synechostictus* and *Pseudolimnaeum* are typical features of all Trechitae larvae known to me.

On one hand, some features of *Synechostictus* and *Pseudolimnaeum* are characteristic of the tribe Bembidiini (absence of pore PRh, presence of ocelli, projecting nasale, one claw with single small seta on its base, absence of additional setae on apex of antennomere 2 and presence of 7 long setae on urogomphi in 2nd and 3rd instar larvae).

On the other hand, larvae of *Synechostictus* and *Pseudolimnaeum* are clearly distinguished by peculiarities of morphology from other Bembidiini larvae. They share some features with members of the tribe Trechini:



Figs 34-47. Larvae of *Bembidion (Synechostictus)* spp. and *B. (Pseudolimnaeum) lederi*: 34, 35, 41, *B. (S.) nordmanni* Chd.; 36, 37, 44, *B. (S.) atroviolaceum* Dufour; 38, 43, *B. (S.) millerianum* Heyd.; 39, 40, 45-47, *B. (P.) lederi* Rtt. 33-39, L1 nasale; 40, L2, nasale; 41-44, 47, L1, left mandibule; 45, L2, left mandibule; 47, L2, head. Scale: 0.1 mm.

strongly sclerotized head and poorly pigmented light body, distance between setae FR3–FR4 almost equal to distance FR4–FR5, presence of additional seta basal of PR15, very small teeth of cibarium, ocelli partly reduced, presence of lateroventral keel, secondary setae on legs in 2nd and 3rd instars. This set of characters was the reason for misidentification of larvae of *B. (S.) ruficorne* as "*Trechus* sp. B" in the Sharova's key (1958).

A certain similarity with members of the tribe Trechini was noted also in adult morphology (Perrault, 1981). Even if some features are shared due to the convergency related to the similar ecological peculiarities, this fact argues for the same evolutionary trends in both groups and ascertains their phylogenetic affinity.

Some morphological features are very rare or absent in larvae of the supertribe Trechitae examined by me; their taxonomic importance is not clear. Flat setae LA5 and LA6 on ligula are known only in the larva of *Thalassophilus longicornis* (unpublished data). Some features actually seem to be unique: claw with a furrow on dorsal surface, epipleurites with very long seta EP2 and very small additional seta near EP1. The different number (1 and 2) of additional setae on outer side of maxilla in 2nd and 3rd instars is known only for the group under discussion. All other larvae of Bembidiini have a constant number (1 or 2) of secondary setae in instars 2 and 3.

To summarize, the position of the subgenera *Synechostictus* and *Pseudolimnaeum* within the tribe Bembidiini is not clear. As for the larval morphology, the both subgenera are much more isolated as compared with other subgenera and even with the genus *Asaphidion*. The high degree of morphological peculiarity of *Synechostictus* and *Pseudolimnaeum* larvae may be a reason to regard them as a separate genus. Unfortunately, the micromorphology and peculiarities of chaetotaxy are yet poorly known for some important Bembidiini taxa (for example: *Amerizus*, *Lymneops*, *Cillenius*, *Zecillenius*, *Bembidarens* and some Oriental species complexes). It seems therefore preferable to refrain from taxonomic changes.

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