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A new record of *Chironomus* (*Chironomus*) *acidophilus* Keyl (Diptera, Chironomidae) from the Uzon volcanic caldera (Kronotsky Reserve, Kamchatka Peninsula, Russia), its karyotype, ecology and biology

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Abstract

Morphology, cytology, ecology and biology of Holarctic *Chironomus* (*Chironomus*) *acidophilus* Keyl, 1960 (Diptera, Chironomidae) was examined from material collected in the geothermal Vosmerka Lake (pH=2.0–2.5). An illustrated re-description of *C. acidophilus* is given on the basis of adult males reared from field-collected pupae, and of simultaneously collected larvae. Additional larvae belonging to the pseudothummi-complex were identified as *C. acidophilus* on the basis of their karyotype. The karyotype of *C. acidophilus* (2n=8) and detailed mapping of the 4 chromosome arms A, E, D and F are provided. The population of *C. acidophilus* from Kamchatka was found to be karyologically monomorphic. Information on distribution and ecology of *C. acidophilus* from Vosmerka Lake (total mineralization 1583.5 mg/l) is also given. *Chironomus acidophilus* is the only species of aquatic insects recorded in this lake. Lack of competition and a richness of food resources contribute to the high abundance (35161 ind./m^2) and biomass (11.342 g/m^2) of the larvae of *C. acidophilus* in Vosmerka Lake.

Key words: *Chironomus acidophilus*, non-biting midge, taxonomy, karyotype, acidic water

Introduction

The Uzon volcanic caldera is located in the Uzon-Geysernaya tectonic depression within the central area of the Eastern tectonic belt of Kamchatka, where about 40 thousand years ago Uzon-Geyser hydrothermal system formed. On the south, west, and north the caldera is outlined with terraces 200–800 m high; its flat bottom measuring 8×12 km lies at 650 m above sea level. Temperature anomaly zones in the caldera occupy a total area of 61000 m^2 and produce a total heat efflux of 268 MW (Leonov *et al.* 1991). The most typical geothermal phenomena in the Uzon volcanic caldera are various hot and boiling pots and funnels which unite in some places to form thermal lakes. Larvae of midges of the genus *Chironomus* were discovered in the peripheral zones of the acidic lakes Fumarolnoe, Sernoe, Vosmerka, and Khloridnoe (pH=1.5–2.5) containing intermittent bottom springs and giving out strong hydrogen-sulfide odor (Lobkova & Chebanova 2010; Lobkova 2014). Our study of the polytene chromosomes of these chironomids from the Vosmerka Lake has shown them to be identical to those of *C. acidophilus* Keyl, 1960.

Chironomus (*Chironomus*) *acidophilus* was described by Keyl (1960) from Germany based almost exclusively on the giant chromosomes in the salivary glands of the larvae. The description of the male imago by Keyl (1960) is very brief (“Merkmale der Färbung und des Hypopygbaues stimmen mit denen von *Ch. pseudothummi* Str. überein.”) and insufficient to identify this species. Earlier, Thienemann & Strenzke (1951) had treated the male of this species under the name *C. meigeni* Kieffer, but this was a misidentification (see the following paragraph). The pupa of *C. acidophilus* was described for the first time by Langton & Visser (2003). The description of larval morphology by Keyl (1960) was very brief: ”Thummityp, appendices laterales fehlen”. The detailed morphology

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of larvae from Switzerland was described by Webb & Scholl (1990) and Martin (2015b). By the combination of chromosome arms (AE, CD, BF, G) the species was placed in the *pseudothummi* cytocomplex, within which it was recognized as distinct based on the polytene chromosome banding pattern (Keyl 1960, 1962). Here, *Chironomus acidophilus* is recorded from the Russian Far East for the first time.

Thienemann & Strenzke (1951) treated under the name *C. meigeni* Kieffer, 1921 adult males reared from larvae that had been collected along with those subsequently described as *C. acidophilus*. Keyl (1960: 191) proposed the latter name, explaining that Strenzke had changed his mind and considered *C. meigeni* as an unusable nomen dubium. According to recent personal communication from Martin Spies (Zoologische Staatssammlung Muenchen = ZSM, Germany), the name *C. meigeni* has remained unused and dubious until today, because Kieffer's corresponding description is insufficient to recognize the species, and his adult type specimens have not been found in any collection. At ZSM there are pupal exuviae from the original samples of *C. meigeni* Kieffer that would allow this name to be revalidated. However, these exuviae do not fit any morphotype known from the western Palaearctic region (e.g., Langton & Visser 2003). Specifically, the ZSM exuviae *sub C. meigeni* and those of *C. acidophilus* Keyl are so different that synonymy is ruled out and *C. acidophilus* remains a valid name (M. Spies, pers. comm.).

In this paper we present an illustrated redescription of *C. acidophilus* on the basis of adult males reared from field-collected pupae, and of simultaneously collected larvae. Also new data on the living conditions, some elements of biology, and specific karyological traits of *C. acidophilus* are provided.

Material and methods

Studied area. The material was collected in July-September 2009–2013 years in the peripheral zone of the Vosmerka Lake (Kamchatka, Kronotsky Reserve, the Uzon volcanic caldera; 54°30'12.3"n.l., 160°00'22.6"e.l., 650 m above level of sea; Fig. 1) at depths 7–30 cm, using a mesh 15 bolting sieve with an area of 0.018 m^2. The water is cloudy from suspended particles of fine clay, sulfur, and iron sulfides; along the perimeter of the foam floats a pyrite slick. Along the coastline of the northern lake is a wide littoral strip (up to 8 m) to a depth of 10–20 cm. At the southern lake littoral rather abruptly goes to a depth of 40 cm. The coastal zone and the bottom soil of the lake consist of fine gray clay with the inclusion of hydrothermal microalgae. There are also the black interlayers of mud. Under the soft ground is distributed black scoria. The lake from mid-November to mid-April freeze, only the pulsating hydrothermal craters are ice-free.

FIGURE 1. Vosmerka Lake.

Reared material and its analysis; male, pupa and larva. Males were reared in cages from pupae collected together with the larvae. For morphological studies, the chitinized parts of larvae, pupae, and males were transferred to For-Berlese fluid. The morphological terminology and abbreviations follow those of Strenzke (1959), Sæther (1980), Webb & Scholl (1985), Webb *et al.* (1985), and Shobanov (1989, 2003, 2005). Male: TL/WL—total body length to wing length; AR—length of apical flagellomere 13 to length of flageromeres 1–12; CP—head width to length of palpal segments 1–4; Al/Pl—length of antenna to length of palpal segments 1–4; Ac—acrostichals, Dc—dorsocentrals, Pa—prealars, Scts—scutellars, Sq—squama, VR—length of Cu to length of M; P_{1-3}—legs; fe—femura; ti—tibia; ta_{1-5}—tarsomere 1–5; LR—length of tarsomere 1 to length of tibia; SV—length of femur plus tibia to length of tarsomere 1; BV—length of femur, tibia and tarsomere 2–5; BR—length of longest seta of tarsomere 1 to minimum width of tarsomere 1; tiR—length of ti to length ta_4 of fore legs; GsR—length of gonostylus to its width; HR—length of gonocoxite to length of gonostylus. Pupa: ALR—length of anal lobe to its width. Larva: AR—length of basal antennal segment to combined length of remaining segments; L1—length of basal segment of antenna; L2—length of second segment of antenna; MS—distance between tops of first lateral teeth of mentum; R—distance from ring organ to base of basal segment of antenna; ROR—length of basal segment of antenna to distance between base of basal segment and ring organ; VmPR—width of ventromental plate to its length; VmPSR—mean width of two ventromental plates to distance between them; W1—width of basal segment of antenna.

Cytogenetic studies. Samples for karyological analysis were taken in August–September 2013. Larvae of *C. acidophilus* were fixed immediately after collection in a mixture of 3 parts of 96% ethanol and 1 part of glacial acetic acid; the fixative was changed 1 h later. Squash preparations of polytene chromosomes were made by the standard method (Chubareva & Petrova 1982), stained with acetic orcein, and treated with lactic acid. Visual analysis of the chromosome banding patterns showed them to be totally consistent with the original description (Keyl 1960). Mapping of arms A, E, F of chromosomes I and III was performed by the standard of *C. acidophilus* (Keyl 1960, 1962); arm D has been mapped after Devai et al. (1989) and Martin (2015a); while arms C, B, and G has not been mapped by us. Our karyological analysis included material from 43 larvae.

Ecological studies. During the field collecting of larvae we measured the temperature and pH of the water using the appliances Checktemp and Checker pH-meter from Hanna Instruments. The larvae were counted by age class and weighed on an analytical balance.

The larvae, pupae and male imagoes studied are kept in the Institute of Biology and Soil Science, Russian Academy of Science, Far East Branch, Vladivostok; karyological slides are kept in the Zoological Institute, Russian Academy of Sciences, St. Petersburg.

Results

Systematics

Chironomus (*Chironomus*) *acidophilus* Keyl, 1960

(Figs 2–36)

Chironomus meigeni Kieffer sensu Thienemann & Strenzke (1951: 8, fig. 1)—misidentification.

Chironomus acidophilus Keyl, 1960: 191; Webb & Scholl (1990: 1, fig. 1 A, B, E, F, fig. 2 A, B, fig. 4 A, fig. 5 A, C, E, fig. 6 A, C, E, fig. 7 A), Wülker (1999: 431); Martin 2015b.

Material. Male, pupa, larva, Russia, Kamchatka Peninsula, Kronotsky Reserve, the Uzon volcanic caldera, Vosmerka Lake, 13.VIII.2010, leg. L. Lobkova (rearing); female, pupa, larva, the same location, 17–24.VII.2009, leg. L. Lobkova (rearing); female, pupa, larva, the same location, 03–13.VIII.2010, leg. L. Lobkova (rearing); male, pupa, larva, the same location, 07.VIII.2011, leg. L. Lobkova (rearing); male, pupa, larva, the same location, 08.VIII.2012, leg. L. Lobkova (rearing); male, pupa, larva, the same location, 16.VI.2013, leg. L. Lobkova (rearing); larvae, the same location, 05–09.VIII.2013, leg. L. Lobkova (for karyological research).

Diagnostic characters. The imago males of *C. acidophilus* Keyl 4.5–6.0 mm long, wing length 2.7–3.0 mm; flagellum dark brown, AR 2.81–3.06; ground color of thorax and scutellum yellowish, mesonotal stripes and postnotum dark brown, Aps 1 (rarely 0), Ac 15–21, Dc 18–29, Pa 4–6, Scts 27–42, Sq 12–26; abdomen and legs brown or dark brown, sternite II with 12–14 median and 0–4 lateral setae, LRP$_1$ 1.33–1.51, BRP$_1$ 2.78–3.89; tergite IX with 9–14 median setae, anal point expanded in the apical 1/3, sometimes widest at about middle, superior volsella S–type, gonostylus widest at proximal 1/3. The pupa length 5.8–7.5 mm; tergite VI with X-shaped shagreen, tergite VII with two patches of shagreen in proximal part, tergite VIII with two bands of shagreen laterally; pleura of segment III with several posterolateral spines, pleura of segment IV with longitudinal rows of spinules; paratergites V–VI with a band of spinules; hook row with 53–77 hooks; conjunctives IV/V, V/VI and VI–VII with small spinules, sometimes on conjunctives IV–V spinules absent; sternites II–IV covered with median shagreen, sternite V in distal part with median path of shagreen; anal comb with 2–4 teeth; anal lobe with 70–87 lamelliform setae. The larva has a yellowish brown head, AR 1.63–1.95, L1 107–144 µm, L2 27–37 µm, L1/W1 4.2–4.5, L1/L2 3.5–4.7, blade 61–65 µm long, reached to the segment 5; 3rd mandibular tooth usually brown, rarely pale, type mandible IIB/IIC, anterior margin of the base maxilla slightly convex, type of mentum by the characters of the median trifid tooth—III/IV; type of mentum by the degree of development of the 4th lateral teeth—I/II, ventromental plate 173–184 µm wide, distance between ventromental plates 58–61 µm, ventromental plates with 40–45 striae, VmPR 0.47–0.56, VmPSR 1.47–1.61, lateral tubules on segment VII absent; ventral tubules present.

Male (n=4). Total length 4.5–6.0 mm; wing length 2.7–3.0 mm. Total length / wing length 1.5–2.2.

Coloration. Antenna dark brown; ground color of thorax and scutellum yellowish; mesonotal stripes and postnotum dark brown; abdomen and legs brown or dark brown.

Head. Head width 624–640 µm. Height of eyes 376–408 µm. Frontal tubercles finger-shaped, length 24–34 µm, and width 10–17 µm (Fig. 2). Antenna 1281–1449 µm long. Ultimate flagellomere 945–1092 µm long. AR 2.81–3.06. Verticals 25–28. Clypeus with 35–38 setae. Cibarial pump 136–143 µm long, 95–99 µm wide. Maxillary palp 736–800 µm long, lengths of last 4 palpomeres (in µm): 56–72; 216–240; 192–208; 264–296. CP 0.80–0.84; Al/Pl 1.81–1.91.

Thorax. Antepronotals 1 (rarely 0); acrostichals 15–21; dorsocentrals 18–29; prealars 4–6; supraalars 1. Scutellum with 27–42 setae.

Wing. Length 2.7–3.0 mm, width 0.60–0.68 mm. Veins R, R$_1$ with 64–83 setae, R$_{4+5}$ with 24–42 setae. Squama with 12–26 setae; brachiolum with 2–3 setae. VR 1.05.

Legs. Spurs of middle tibia 27 µm, of hind tibia 34 µm long. TiR 2.04–2.33. Lengths and proportions of legs as in Table 1.

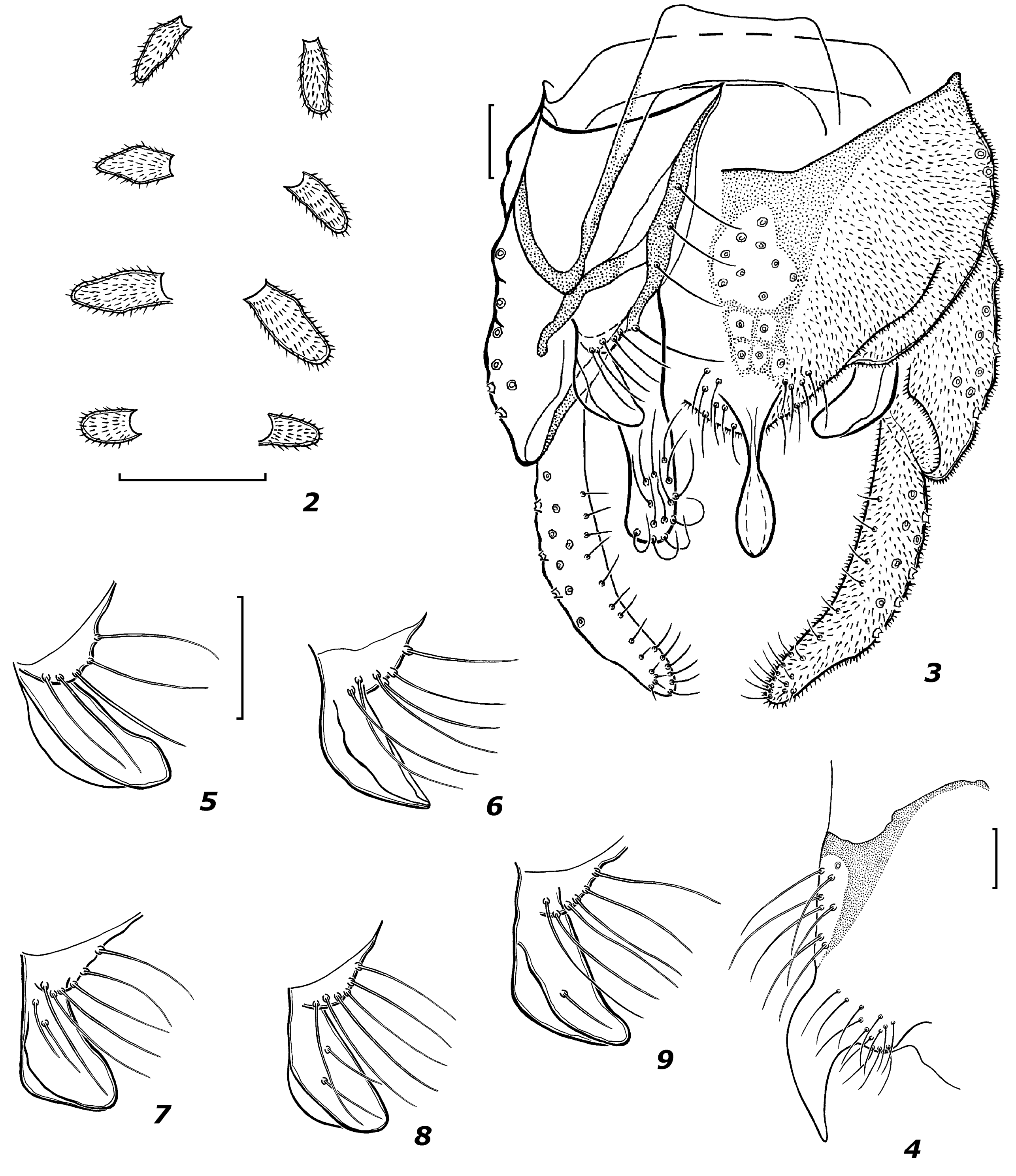
TABLE 1. Lengths (in µm) and proportion of legs *C. acidophilus* Keyl.

P	fe	ti	ta$_1$	ta$_2$	ta$_3$	ta$_4$	ta$_5$
P$_1$	1176–1302	1029–1218	1512–1743	777–945	630–714	441–567	252–315
P$_2$	1260–1386	1155–1302	693–756	420–441	315–336	210–231	147–168
P$_3$	1428–1575	1428–1617	1008–1134	588–693	441–525	294–315	189–210

P	LR	SV	BV	BR
P$_1$	1.33–1.51	1.41–1.52	1.65–1.83	2.78–3.89
P$_2$	0.58–0.61	3.42–3.55	2.78–2.93	3.08–4.00
P$_3$	0.70–1.03	2.75–2.83	2.45–2.56	4.29–5.80

Abdomen. Sternite II with 12–14 median and 0–4 lateral setae.

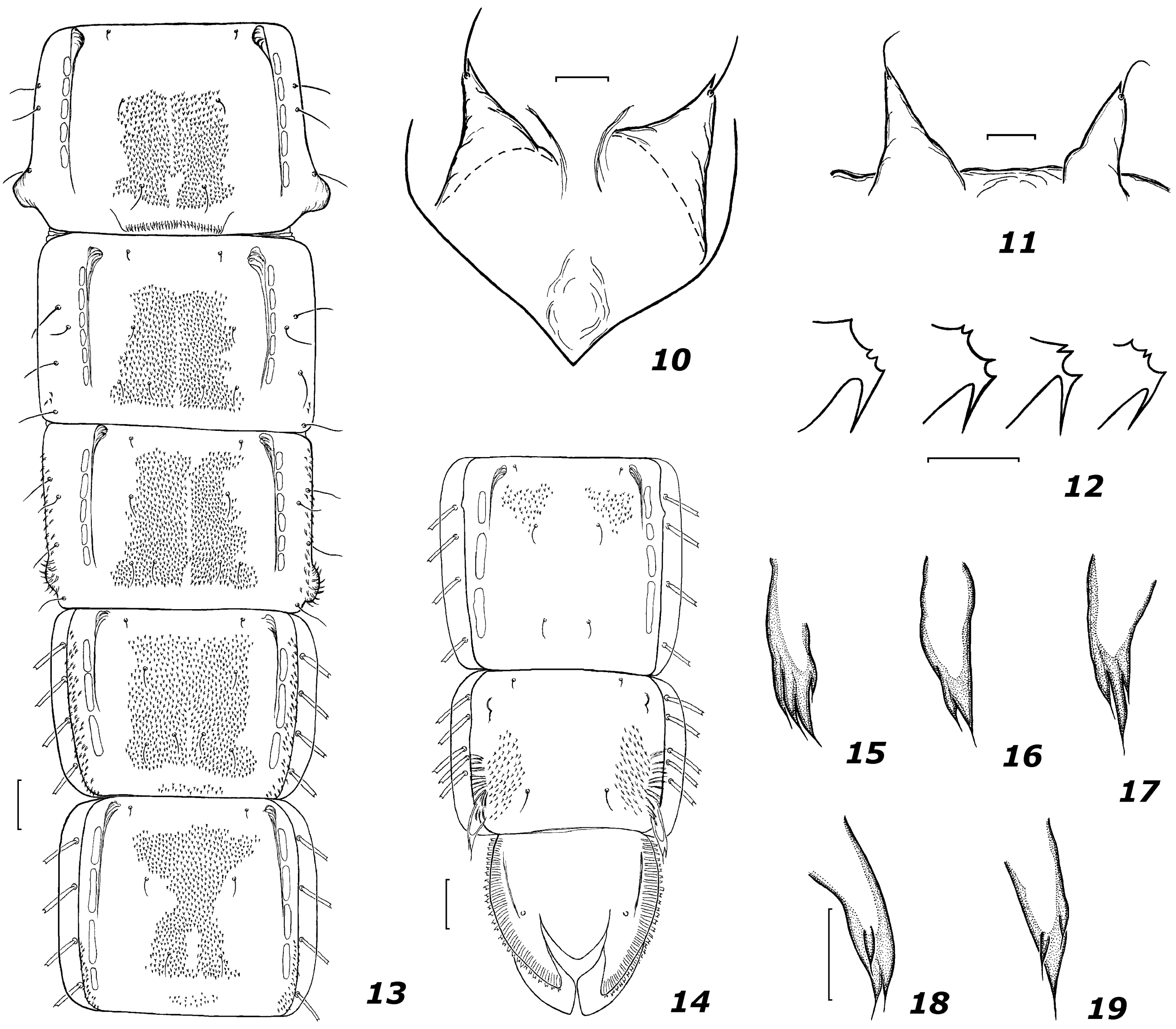
Hypopygium (Figs 3–9). Tergite IX with 9–14 median setae. Laterosternite IX with 4–5 setae. Anal point 92–102 µm long, 24–27 µm wide, expanded in the apical 1/3, sometimes widest at about middle (depends on the position of hypopygium). Transverse sternapodeme 102–136 µm long, without oral projections. Phallapodeme 170–204 µm long. Gonocoxite 197–204 µm long, with 4 inner setae. Total length of superior volsella (S–type) 85 µm; height of apical finger-shaped part 58–68 µm, width—27–44 µm, sometimes with 1–2 setae; base 17–27 µm high, 58–68 µm wide, with 5–8 basal setae and with cover microtrichia (Figs 5–9). Inferior volsella 160–170 µm long, with 12 strong dorsal and 14–16 weak ventral setae. Gonostylus 187–204 µm long, 37–48 µm wide, widest at proximal 1/3, with 1 apical seta and 4–6 subapical inner setae. GsR 3.0–5.0. HR 1.00–1.09.



FIGURES 2–9. Imago male of *C. acidophilus* Keyl. 2—variability of frontal tubercles; 3—hypopygium, dorsal view; 3—tergite IX, lateral view; 5–9—variability of superior volsella. Scale bar 50 µm.

Pupa (*n*=7, males). Total length 5.8–7.5 mm.

Cephalothorax. Cephalic tubercles conical 92–119 µm long, 65–119 µm wide; frontal setae 41–51 µm long (Figs 10–11). Base of thoracic horn 102–133 long µm, 41–54 µm wide. Thorax granulose. Prealar tubercle absent. Pc_1 and Pc_2 50 µm long; MAps 102–136 µm long; LAps absent; Dc_1 34–92 µm long, Dc_2 85–119 µm long, Dc_3 51–102 µm long, Dc_4 34–58 µm long; distance between setae Dc_1–Dc_2 51–92 µm, Dc_3–Dc_4 41–61 µm, Dc_2–Dc_3 68–119 µm. Wing sheath length 313–340 µm, width 78–85 µm.

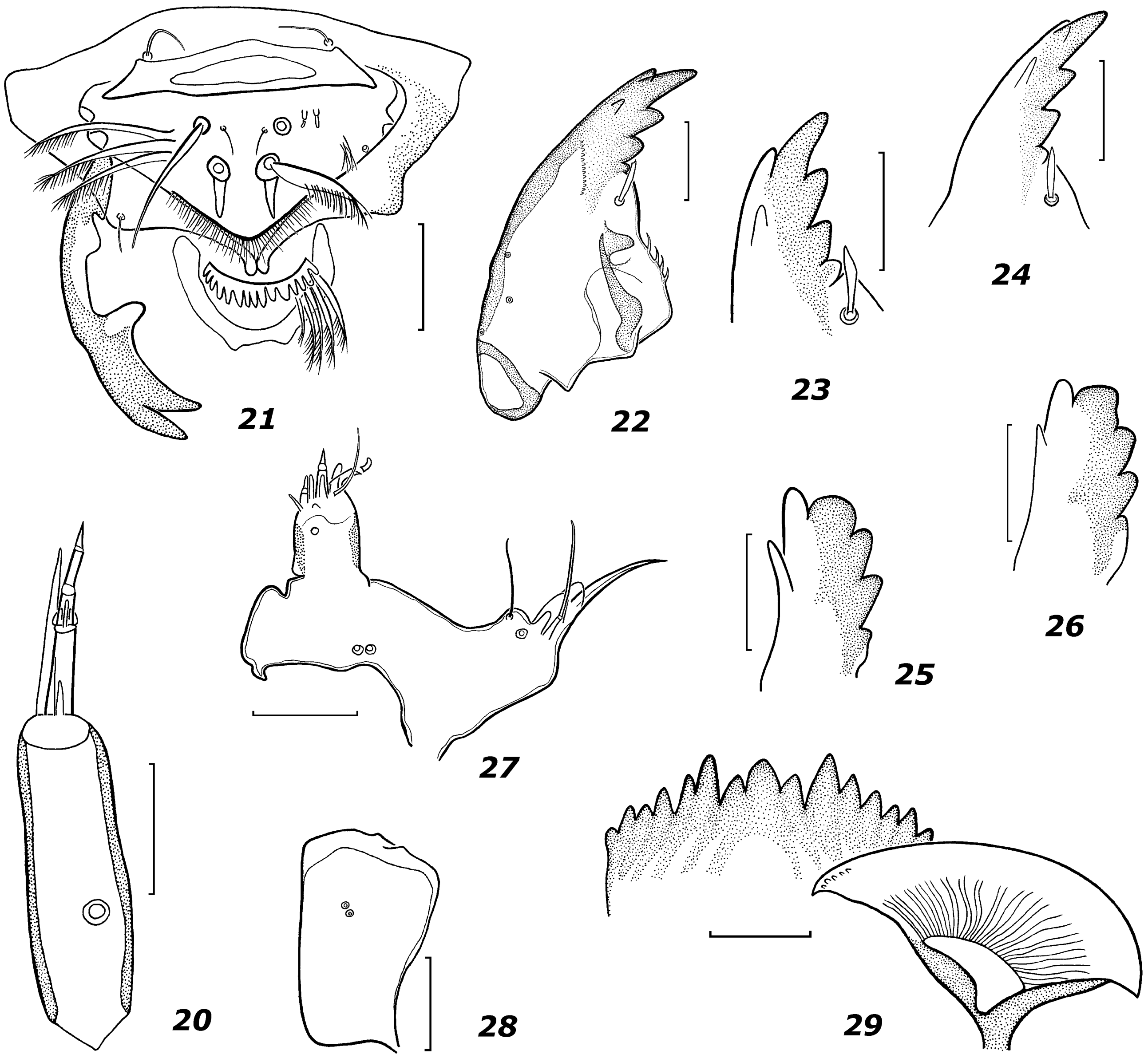


FIGURES 10–19. Pupa of *C. acidophilus* Keyl. 10–11—frontal tubules, dorsal view; 12—median hooks on the posterior margin of tergite II, lateral view; 13—tergites II–VI; 14—tergites VII–IX; 15–19—variability of anal combs. Scale bar 50 µm.

Abdomen (Figs 12–19) length 5.0–6.5 mm. Tergites II–V covered by square shagreen; tergite VI with X-shaped shagreen; tergite VII with two patches of shagreen in proximal part; tergite VIII with two bands of shagreen laterally. Pleura of segment III with several posterolateral spines, pleura of segment IV with longitudinal rows of spinules. Paratergites V–VI with a band of spinules (Figs 13–14). Anal segment without shagreen, but in posterior part granulose. Hook row with 53–77 hooks; tips of median hooks with 3–5 small teeth (Fig. 12). Conjunctives IV/V, V/VI and VI–VII with small spinules, sometimes on conjunctives IV–V spinules absent. Sternites II–IV covered with median shagreen, sternite V in distal part with median path of shagreen. Segment I with anterior pedes spurii B. Dark brown anal comb of segment VIII with 2–4 elongated teeth, dorsal spines absent (Figs 15–19). Segment II with 3 L setae, III–IV each with 4 L setae (1 seta always situated intersegmentally), and V–VII each with 4 LS setae, VIII with 4–5 LS setae. Anal lobe with 70–87 lamelliform setae; length of anal lobe 464–496 µm, width 432–560 µm. ALR 0.87–1.07.

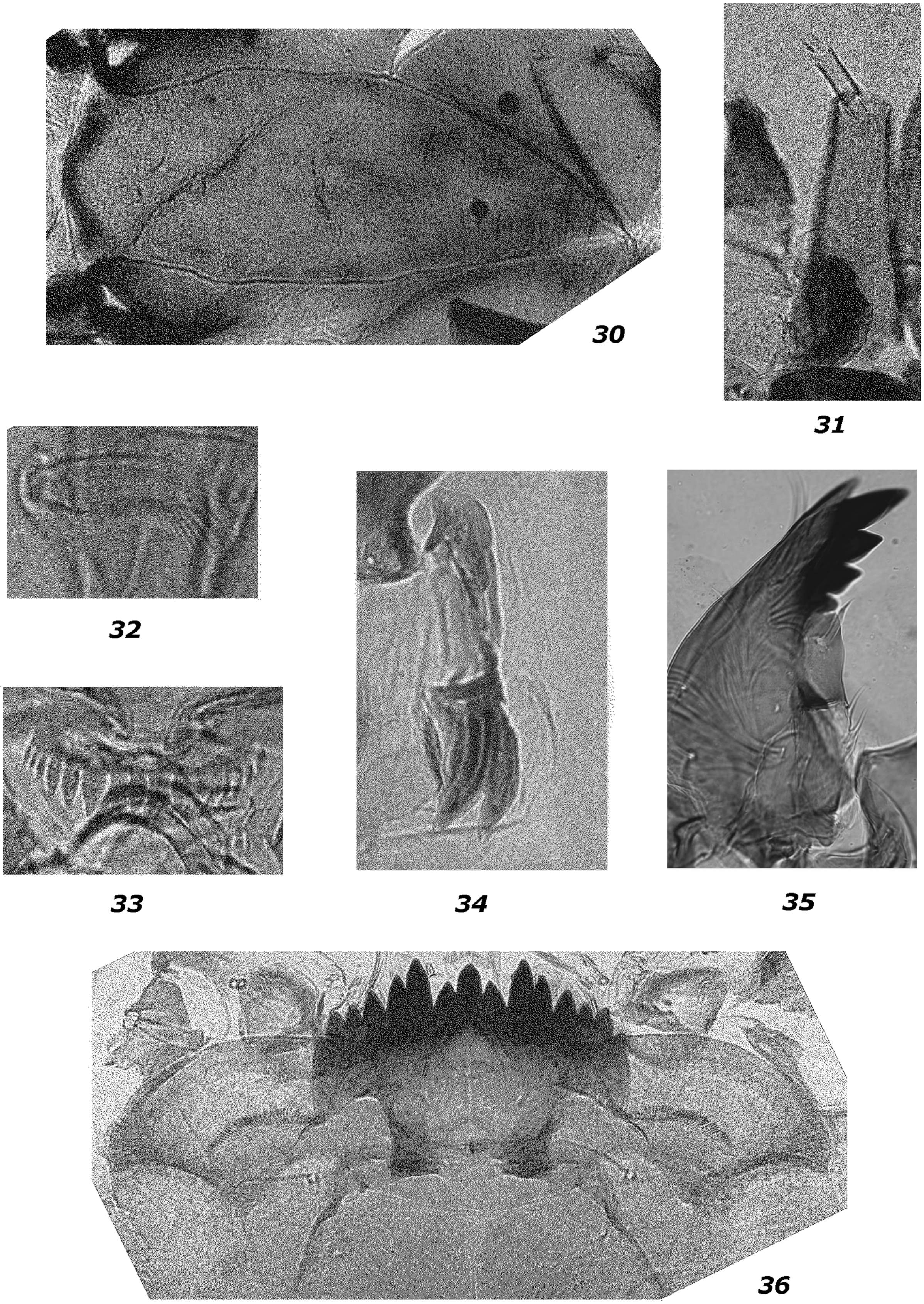
Fourth instar larva (n=5).

Coloration. Body blood red. Head capsule uniformly yellowish brown; gular region and frontoclypeus unpigmented .



FIGURES 20–29. Larva of *C. acidophilus* Keyl. 20—antenna; 21—labro-epipharyngeal region; 22—mandible; 23–26—apex of mandible; 27—maxilla; 28—anterior margin of base maxilla; 29—mentum and ventromental plate. Scale bar 50 µm.

Head (Figs 20–29, 30–36) yellowish brown, length 0.65 mm, width 0.50 mm, cephalic index (W/L) 0.77. Frontoclypeal apotome 536 µm long, 168–184 µm wide (Fig. 30). Distance between setae S_1–S_1 75–85 µm, S_2–S_2 119–129 µm, S_3–S_3 133–143 µm, S_4–S_4 126–143 µm, S_5–S_5 156–167 µm. Antenna 192–207 µm (Fig. 20, 31), length of each segment (in µm): 119–133; 31–37; 8.5–10.2; 10.9–13.6; 8.5. AR 1.63–1.95. Maximal width of basal segment 34–40.8 µm. Ring organ distribute in the proximal 2/3 basal segment; distance from ring organ to base of antenna 44–61 µm; ROR 2.1–2.9. Blade 61–65 µm long, reached to the segment 5; accessory blade 13.6 µm. S I 31–44 µm long (Fig. 32), S II 68 µm long, S III 14–17 µm long, S IV 11.9–13.6 µm long. Labral chaetae consist of 3 pairs of well-developed pectinated chaetae and 2 pairs of shorter chaetae. Pecten epipharyngis 51–61 µm long, with 14–18 teeth (Fig. 33). Premandible 136–154 µm long, with 2 teeth about equally long, inner tooth about 1.2–1.5 times wider than the outer; premandibular seta simple 24–27 µm long (Fig. 21, 34). Mandible (length 221–145 µm, width 112–136 µm) with 2 yellowish dorsal teeth length (14–17 µm and 10–20 µm respectively), dark brown apical (length 31–34 µm) and 3 inner teeth; 3rd tooth usually brown, rarely pale (Figs 22–26, 35). Type mandible IIB (tooth partly free on lower margin and some degree of pigmentation present on 3rd tooth) or IIC (3td tooth as dark as other teeth). Seta subdentalis 27 µm long. Pecten mandiblaris with 10–14 setae. Mola with 3–4 spines. Maxillary palp 27–34 µm long, 24–27 µm wide (Fig. 27). Anterior margin of the base maxilla slightly convex



FIGURES 30–36. Larva of *C. acidophilus* Keyl. 30—frontal apotome; 31—antenna; 32—seta of labrum S I; 33—pecten epipharyngis; 34—premandible; 35—mandible; 36—mentum and ventromental plates.

(Fig. 28). Mentum 177–180 µm wide, central tooth conical 17–18.7 µm wide, median trifid tooth 42.5–47.6 µm wide, distance between first lateral teeth 71.4–78.2 µm, distance between second lateral teeth 92–102 µm; distance between the top of first lateral teeth 61.2–64.6 µm. Type of mentum by the characters of the median trifid tooth—III/IV; type of mentum by the degree of development of the 4th lateral teeth—I/II. Ventromental plate 173.4–183.6 µm wide and 85–98.6 µm height (Fig. 29, 36). Distance between ventromental plates 57.8–61.2 µm. Ventromental plates with 40–45 striae. VmPR 0.47–0.56. VmPSR 1.47–1.61.

Body. Lateral tubules absent on abdominal segment VII; ventral tubules present on segment VIII (*thummi* type). Procercus 32–64 µm height and 40–48 µm wide.

Karyotype. The karyotype is 2n=8, 2n=8+B (Fig. 37). The chromosome arm combination is AE, CD, BF, G (pseudothummi-cytocomplex). Chromosomes CD and BF are metacentric, AE is submetacentric, G is acrocentric. The centromeric bands are thin and do not differ visually from other bands in the chromosome; these bands were identified in *C. acidophilus* by comparison with *C. pseudothummi.* The karyotype is usually characterized by one permanent nucleolus (N) and two Balbiani rings (BR) in chromosome IV. In addition, some larvae revealed a puffed region in the near-telomere part of arm E; the end of the chromosome was fan-shaped. This puffed region, and also the segment of chromosome IV between the N and the dark heterochromatin band are almost always asynaptic. B-chromosomes are present sometimes. In the banding pattern, *C. acidophilus* most closely resembles *Chironomus* sp. Ya4 and *C. pseudothummi*.

Since arms B, C, D were mapped by Devai *et al.* (1989) much later than the original description of the karyotype was made (Keyl 1962), and arm G were not mapped, we estimated only the degree of their polymorphism.

Chromosome AE.

After Keyl (1962), arm A is subdivided into 19 regions. Afterwards, Kiknadze *et al.* (1996, 2004) and Martin (2015a) described band sequence in this arm as

aciA2 1–2d 15–13 10–12 3–2d 6c–4 9–6d 16–19

It should be noted that many bands in this and other chromosome arms of this species seem to be wider than described by Keyl (1960, 1962); the bands are united into blocks.

It was not accompanied by visible changes in the banding sequences.

After Keyl (1962), arm E is subdivided into 13 regions. Asynapsis of telomeric homologues was observed in arm E of almost all the larvae.

aciE2 1– 3e 10b–3f 10c–13

Chromosome CD.

Arm C is not mapped; it is monomorphic.

Arm D is mapped after Devai *et al*. (1989) and Martin (2015a).

aciD1 1–2g 13–15b 17–15c 7–2h 12–8 18–24

Chromosome BF.

Arm B is not mapped; it is monomorphic.

Arm F is mapped after Keyl (1962), Kiknadze *et al*. (1996, 2004) and Martin (2015a), and is subdivided into 23 regions.

aciF1 1 11–12 19−16 2–10 15–13 20–23

Chromosome G.

The homologues of arm G usually remain asynaptic along the section from the terminal N to the distinct dark band localized in the middle of the chromosome. We have found no rearrangements in the zone of asynapsis in chromosome G. Two BRs lie behind the dark band consecutively. This arm was not mapped; it appears monomorphic by its banding pattern.

One out of 43 specimens (2.3%) had a B-chromosome, which was morphologically similar to the B-chromosome of *C. plumosus* and looked as an amorphous thread or lump of heterochromatin.

Each giant cell of one larva contained only one accessory chromosome.

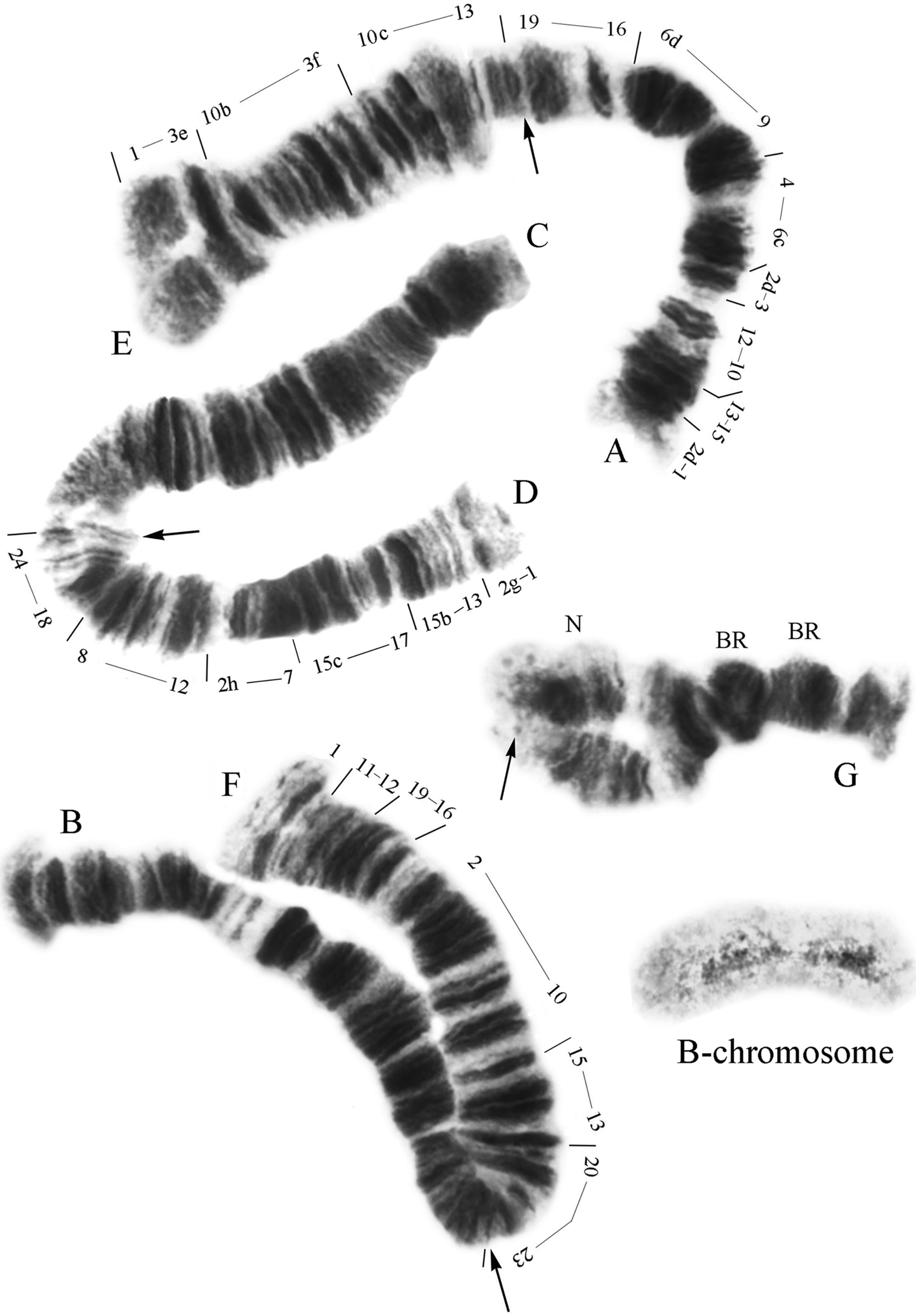


FIGURE 37. Polytene chromosomes of *C. acidophilus* Keyl, 1960. Designations: A, B, C, D, E, F, G—chromosome arms, arabic numerals and letters—chromosome sections, N—nucleolus, BR—Balbiani Ring, arrows indicate the centromeres.

Ecology. The Vosmerka Lake where the larvae were collected is a stagnant reservoir divided with a natural dam into two lakes (Fig. 1) measuring 100×40 and 80×80 m, with the greatest depth of 16 m; pH=2.0–2.5; the water temperature is +21–26°C near the surface and up to 115°C at a depth of 15 m. Above the numerous bottom springs and hydrothermal ejection funnels, the surface water layer gets heated to 40–50°C, between craters the temperature drops to 21°C. The water is turbid due to fine suspended particles of clay, sulfur, and iron sulfide; floating pyrite foam is present on the perimeter. The lake is covered with ice from mid-November to mid-April, except for the areas of intermittent hydrothermal funnels. The water is of the acidic sodium chloride-sulfate type. The chemical composition of water of the northern/southern lake (mg/l): pH=2.0/2.5; Cl^- =277/170, SO_4^{-2} =316/355, Na^++K^+=260/254, total salt content 824.3/800.3. The ionic composition of water of the northern lake:

$$M_{0.8}\frac{SO_4 51 Cl 49}{(Na+K) 90 Fe_4 Mg_3}$$

that of the southern lake:

$$M_{0.8}\frac{SO_4 61 Cl 39}{(Na+K) 90 Fe 6}$$

The shores and bottom consist of fine gray hydrothermal clay with black streaks. The metal content according to spectral analysis of bottom clay (mass %): As=0.03; Ti=0.01; (Mn=0.5; U=2; Cu=0.9; Zr=0.006; Ba=7) × 10^{-3} (Pilipenko 1973). The total salt content in the water of the southern lake measured on 03.VIII.2012 was 1583.5 mg/l at a temperature of 22°C and pH=2.5, ion content in mg/l: H^+ =3.6; NH_4^+ =6.0; Na^+ =183.9; K^+ =6.5; Ca^{2+} =8.8; Mg^{2+} =6.3; Fe^{2+} =25.9; Fe^{3+} =25.9; Al^{3+} =7.6; Cl^- =241.1; SO_4^{2-} =374.6; H_3BO_3=88.3; $H_4SiO_{4\ \text{раств.}}$=146.3; $H_4SiO_{4\ \text{кол.}}$=484.4 (Karpov *et al.* 2014).

Biology. The larvae of *C. acidophilus* are red in color; the molting larvae appear pinkish gray due to the grayish green fragments of the old cuticle. The young instars live freely in the ground along the lake perimeter, at depths of 5–12 cm. The older instars build cases of ground particles measuring 6–8×2.5 mm, in which they create water current by undulating movements of the abdomen. The prepupae and pupae live on the bottom in open cases made of loose clay. The pupae rise to the surface immediately before the emergence of the adults. Ratio of all larval instars and pupae in the samples, as well as their numbers and biomass are given in Table 2. The young larvae show 2 peaks of abundance: in the middle of June and in last third of August, indicating the development of 2 generations per season. Adults of the first generation start to emerge in May, 2–3 weeks after the clearing of ice along the shore; adults of the second generation emerge from mid-July to mid-August. The larvae of any instar can enter hibernation. Captive larvae continued development without diapause but did not survive to pupation. It should be noted that in Kamchatka, in view of the short growing season, very few insects develop two generations per year, and mostly only those that live in geothermal reservoirs (Lobkova 2014). The number of larvae in the southern (deeper) the lake was higher than in the north: 21645 ind./m^2; 7.68 g/m^2 and 11178 ind./m^2; 6.23 g/m^2 respectively. The maximum observed density of the larvae in the lake periphery was 35161 ind./m^2, and their mass, 11.342 g/m^2. The high number of the larvae of *C. acidophilus* apparently related to the absence of competition and an abundance of food resources. Besides Vosmerka, the larvae of *C. acidophilus* were found, in the Uzon caldera and also in the Fumarolnoe and Khloridnoe lakes, but in much smaller quantities (Lobkova & Chebanova 2010) and in the upper course of the Khloridnyi brook upstream of its confluence with the Veselyi brook. The larvae of *C. acidophilus* are stenotopic with respect to water acidity, being absent at pH<3.0. The larvae occurred at range of temperatures 21–34 °C. *Chironomus acidophilus* serves as food for the grey wagtail *Motacilla cinerea* Tunstall, the black-backed wagtail *M.* (*alba*) *lugens* Gloger, some sandpipers, in particular the grey-tailed tattler *Heteroscelus brevipes* (Vieillot), and possibly also the wood sandpiper *Tringa glareola* L. and the lesser sand plover *Charadrius mongolus* Pallas. From June to mid-August, the narrow clay shore of the lake is densely covered with footprints of these birds. Besides the adult midges, the birds also pick the larvae from the shallow water and humid clay. In addition, the white-winged scoter *Melanitta deglandi* (Bonaparte) may also feed on these chironomids.

TABLE 2. Indicators of biomass, abundance and age ratio of larvae and pupae of *C. acidophilus* in samples.

Data	Instar larva (%)				Pupa (%)	Imago (%)	Abundance (ind./m^2)	Biomass (g/m^2)
	1st	2nd	3rd	4th				
17.VII.2009	0	0	70	27	3	+	1700	–
24.VII.2009	0	0	70	24	6	+	6500	–
03.VIII.2010	30.7	31	32	14	0.3	+	8935	4.08
13.VIII.2010	70.8	12	9.5	7.4	0.3	+	35161	11.34
08.VIII.2012	37	38	55	13	13	+	21564	4.56
16.VI.2013	87	18	3	0	0	?	28916	3.23
05.VIII.2013	80	13	1,7	0,3	5	+	21835	7.68
17.IX.2013	12	38	24	26	0	0	7593	3.89
16.X.2013	1.4	32	37	29.6	0	0	2780	–

Distribution. In present time *C. acidophilus* Keyl is distributed in Austria, England, Czech Republic, Germany, Sweden, Switzerland, and Alaska (Keyl 1960; Webb & Scholl 1990; Michailova *et al*. 2009; Sæther & Spies 2013). In Russia this species was found in Lena, Tatta and Kolyma rivers (Kiknadze *et al*. 1996; Kiknadze *et al*. 2004). *Chironomus acidophilus* is recorded for the Russian Far East for the first time.

Discussion

In the geothermal Vosmerka Lake located in the Uzon caldera (an area with ongoing postvolcanic activity) on Kamchatka peninsula, only one species of aquatic insects was found—*Chironomus acidophilus* Keyl, 1960. Its high levels of abundance and biomass, with two emergence periods per year, are evidence of comfortable living conditions for this species in the lake. The absence of other species of zoobenthos, macrophytes and higher aquatic vegetation reflects the special environmental conditions in the lake, suitable only for *C. acidophilus*. These conditions are characterized by high levels of acidity and salinity, various ionic components in the water and soil, the presence of a sulfur cycle involving thiobacteria, and by stable and elevated temperatures in comparison with other bodies of standing water in the region.

Currently, five species of *Chironomus* in the Holarctic region are known to have larvae which live or survive in highly acidic water. Three of these species have been described from volcanic areas in Japan: *C. acerbiphilus* Tokunaga, 1939 from Lake Katanuma (pH=1.4), a sulphuric stream on the Kirishima volcano, and a highly acidic hot spring at Sukayu; *C. fusciceps* Yamamoto, 1990 from acidic hot springs at Unzen and Tarutama (pH=2.0–3.0); and *C. sulfurosus* Yamamoto, 1990 (Yamamoto 1986; 1990; Sasa & Kikuchi 1995). *Chironomus acerbiphilus* has been recorded also in Poland from a post-mining acidotrophic reservoir (pH=3), in Germany from extremely acidic mining lakes (pH=2–3), and also from elevated temperature sites in North America (Rodrigues *et al*. 2009; Jabłońska-Barna *et al*. 2012; Martin 2015a). Another species, *C. harpi* Sublette, 1991, was described from acidic lakes (pH about 3) in strip-mined areas of the USA and Canada (Wülker *et al*. 1991). The fifth species, *Chironomus acidophilus*, has been recorded from various acidic pools in Germany, Switzerland and Sweden (Keyl 1960; Wülker 1999). The species has been found also in England (Michailova *et al*. 2009), where iron ore mining acts as one of the principal sources of pollution. It inhabits well-heated, shallow stagnant reservoirs with elevated acidity, highly stenobiontic conditions, and various water regimes that include ephemeral and hydrothermal ones. A karyotypically close species, *Chironomus* sp. Ya4, was found in Yakutia (Kiknadze *et al*. 1996). It inhabits waters rich in some heavy metals, including zinc and nickel.

With the exception of *C. harpi*, the adult males of all *Chironomus* species with larvae living in highly acidic waters are very similar in coloration, morphological meristics, and in hypopygial structure (Table 3). However, males of *C. acidophilus* have brown tergites and usually Aps 1, whereas males of other species have a narrow pale band on the posterior margin of tergites and antepronotum without seta. The pupa of *C. acidophilus* is different from *C. fusciceps* by the following features: pleura of segment III with several posterolateral spines, tergite VI with X-shaped shagreen, tergite VII with two separate patches of shagreen in proximal part. While the pupa of *C. fusciceps* has numerous spines on pleura segment III, tergite VI with triangular shagreen extending to its anterior ½

TABLE 3. Comparative table of measurements and color males of *Chironomus* with larvae living in the high acidic waters on literature and original data

Species	**WL**	**AR**	**LR**	**Aps**	**Ac**	**Dc**	**Scts**	**Am**	$\mathbf{BRP_1}$	**SVo type (Strenzke 1959)**	**Color of tergites**	**Color of fore legs**
C. acerbiphilus Tokunaga, 1939	–	2.68	1.2	0	–	–	–	–	–	S	almost entirely black	black
C. acerbiphilus Tokunaga, 1939 sensu Strenzke 1959	2.4–2.8	3.3–3.8	1.53–1.72	0	3–9	11–22	17–26	6–14	2.4–3.3	D	brown except for pale distal part	dark brown
C. acerbiphilus Tokunaga, 1939 sensu Sasa 1978	3.3–3.6	2.88–3.03	1.25	0	–	–	–	4	–	D	black with a narrow pale band along the posterior margin	black
C. acerbiphilus Tokunaga, 1939 sensu Yamamoto 1986	2.9–3.2	2.50–3.33	1.15–1.25	0	8–10	13–23	22–36	2–5	2.2	S	black with a narrow pale band along the posterior margin	black
C. acerbiphilus Tokunaga, 1939 sensu Jabłońska-Barna *et al*. 2012	2.8–3.5	3.6	1.45	0	–	–	–	8–10	2.75	S	tergites with pale brown bands posteriorly	fe, ti, $ta_{1–2}$ pale brown with brown bands apically
C. acidophilus Keyl, 1960	2.7–3.0	2.81–3.06	1.33–1.51	1 (rarely 0)	15–21	18–29	27–42	9–14	2.78 ± 3.89	S	brown or dark brown	brown or dark brown
C. fusciceps Yamamoto, 1990	1.8–2.6	2.15–2.67	1.43–1.52	0	6–16	15–27	13–30	6?	–	S	black with a narrow pale band along the posterior margin	brown
C. harpi Sublette, 1991	3.58	4.32	1.40	0	17	28	20	5	3.26	E	blackish-brown or tergites III–IV with a dark basal transverse band	yellowish brown or fe and ti pale and $ta_{1–3}$ yellow with black apices, $ta_{4–5}$ dark
C. sulfurosus Yamamoto, 1990	2.3–2.6	2.54–2.92	1.32–1.52	0	–	15–22	26–32	2–3	–	S	black with a narrow pale band along the posterior margin	brown

and with paired patches of small shagreen on the posteromedial area, tergite VII with transverse band of shagreen along anterior margin (Yamamoto 1990). The pupa of *C. acidophilus* most similar to *C. acerbiphilus* on the base of armament of tergites, but differs from the latter on the distribution of shagreen on sternites. As shown by recent studies, the morphology of the pupae *C. acerbiphilus* highly variable and should be considered when comparing species (Rodrigues *et al*. 2009; Jabłońska-Barna *et al*. 2012). The pupa of *C. acidophilus* with median shagreen has on sternites II–IV and with median path of shagreen in distal part of sternite V. Whereas the pupa of *C. acerbiphilus* pupa has the following location on the shagreen sternites: II nearly covered with small isolated points, III with lateral longitudinal bands of small points anteriorly spreading inwards, but not meeting medially, IV without lateral longitudinal point bands, though the anterior inward extensions may be developed (Rodrigues *et al*. 2009). Yamamoto (1990) gives the key to the larvae of three species of *Chironomus* whose larvae live in acidic waters. All studied larvae in our material did not have lateral tubercles, but have well developed ventral tubules (*thummi* type). However, the literature contains data on the presence of well developed lateral tubercles and ventral tubules (*plumosus* type) (Martin 2015b). Perhaps this is due to a variety of environmental living conditions. The larva of *C. acidophilus* closest to *C. fusciceps* based on the lack of lateral tubules on abdominal segment VII, but differs from the latter a yellowish brown coloring of the head capsule, mandible IIB/IIC, labral chaetae consist of 3 pairs of well-developed pectinated chaetae and 2 pairs of shorter pectinated chaetae. The larva of *C. fusciceps* have a uniformly dark brown coloring of the head capsule, mandible IIIC, labral chaetae consist of 6–9 pairs of well-developed pectinated chaetae and 3–5 pairs of shorter simple chaetae (Yamamoto 1990).

TABLE 4. Morphological characteristics of the larvae of *C. acidophilus* Keyl by various authors.

Morphological characters	Literature data (by Webb & Scholl 1990; Martin 2015b)	Our data
L1	107–144 µm	119–133 µm
L2	27–35 µm	31–37 µm
W1	30–35 µm	34–41 µm
R	–	44–61 µm
L1/W1	3.50–4.53	3.17–3.80
L1/L2	3.56–4.69	3.5–4.3
L2/W1	0.76–1.11	0.75–1.0
R/L1	–	0.34–0.47
MS	–	61–65 µm
L1/MS	2.0–2.77	1.94–2.05
L2/MS	0.47–0.68	0.47–0.56
W1/MS	0.54–0.68	0.56–0.63
Type of mentum	I, sometimes II	I/II
Type of median trifid tooth	III, rarely IV	III/IV
Type of mandible	IIA/IIB	IIB/IIC
Number of epipharyngeal teeth	11–25	17–24
Size of ventromental plates	195–244 µm	173–184 µm
Number of ventromental plate striae	41–48	40–45
Number of ventromental plate outer spines	33–50	–
Number of ventromental plate inner spines	262–315	–

In present time sixteen species of *Chironomus* with larvae of the pseudothummi-complex are described in Palaearctic Region (Strenzke 1959; Sasa 1978; Webb & Scholl 1985; Wülker 1999; Martin 2015a, 2015b; Michailova *et al*. 2013). From them the imago male of *C. acidophilus* most similar to *C. holomelas* Keyl, 1961 and *C. saxatilis* Wülker *et al*., 1981 on base the dark brown color of body and SVo S-type, but has a higher value of BRP_1 2.78–3.89. Whereas *C. holomelas* has BRP_1 2.0–2.75 and *C. saxatilis* BRP_1 1.87–2.33 (Wülker *et al*. 1981). The pupa of *C. acidophilus* was described for the first time by Langton & Visser (2003). The pupae found in the

Vosmerka Lake are characterized by a greater length of cephalic tubercles (92–119 µm) and the presence of spinules on the conjunctives IV/V, V/VI and VI–VII. Whereas, according to the original description pupa of *C. acidophilus* has a shorter cephalic tubercles (70–80 µm) and the conjunctives IV/V and V/VI roughened. The pupae are known for most species of the pseudothummi-complex. Unfortunately, mostly these descriptions brief and poorly illustrated, so to make a comparative morphological analysis is not possible.

The far eastern larvae of *C. acidophilus* Keyl on morphological characteristics do not differ from the descriptions made by Webb & Scholl (1990) and Martin 2015b, with the exception of smaller width of the ventromental plates in our specimens (Table 4). The larvae of *C. acidophilus* Keyl are very close to *C. saxatilis* Wülker *et al*., but clearly differ from the latter by the smaller width of the ventromental plates wide (173–184 µm) and a large value of the index of the antenna L1/W1 (4.17–4.53). Whereas, the larvae of *C. saxatilis* Wülker *et al*. has ventromental plates wide of minimum width 287 µm and a lower L1/W1 3.30–3.75 (Wülker *et al*. 1981; Webb & Scholl 1985).

Our study of the karyotype of the chironomid larvae from the Kamchatka Peninsula showed it to be identical to the karyotype of *C. acidophilus* Keyl recorded from Europe (Keyl 1960; Michailova *et al*. 2009). It is remarkable that the population from Kamchatka was found to be karyologically monomorphic, whereas the European populations revealed a considerable number of inherited and somatic chromosomal mutations. These differences may be accounted for by the complex anthropogenic impact in the European region. Since *C. acidophilus* is a stenobiontic species inhabiting acidic waters with elevated mean temperatures and no competition from other chironomids, it may be assumed that the genome of this species is strictly balanced and adapted to its particular environment. The stable living conditions of Kamchatka, not disturbed by any human activity, have led to monomorphism. By contrast, the instability of the European populations may be explained by the human economic activities of varying direction and intensity.

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