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BAETIDAE FROM SRI LANKA WITH SOME GENERAL
REMARKS ON THE BAETIDAE OF THE ORIENTAL REGION
(INSECTA: EPHEMEROPTERA)

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ABSTRACT

The nymphs of nine species of baetid mayflies from Sri Lanka are described in detail. These include *Baetis frequentus* sp.n., *B. acceptus* sp.n., *B. conservatus* sp.n., *B. collinus* sp.n., *B. geminatus* sp.n., *B. pulchellus* sp.n., *B. ordinatus* sp.n., and *Procloeon regularum* sp.n. A single nymph of *Cloeon* appears closely related to *Cloeon bimaculatum* Eaton. The first four species mentioned do not fit in any known species-group. *Baetis geminatus* sp.n. and *B. pulchellus* sp.n. are associated with the Oriental *molawinensis* species-group (which corresponds to the European *atrebatinus* species-group and to the North American *propinquus* species-group). The *sumigarensis* sub-group is proposed within the *molawinensis* species-group. The nymphs described herein are the first nymphs to be described in the family Baetidae from Sri Lanka. The genus *Procloeon* is recorded from the Oriental Region for the first time. A key to the baetid nymphs of Sri Lanka is included.

RESUMEN

Se describen en detalle las ninfas de nueve especies de efemerópteros de Sri Lanka. Se incluyen *Baetis frequentus* sp.n., *B. acceptus* sp.n., *B. conservatus* sp.n., *B. collinus* sp.n., *B. geminatus* sp.n., *B. pulchellus* sp.n., *B. ordinatus* sp.n., y *Procloeon regularum* sp.n. Una ninfa de *Cloeon* parece estar cercamente relacionada a *Cloeon*

bimaculatum Eaton. Las primeras cuatro especies mencionadas no pertenecen a ningún grupo de especies conocidas. *Baetis geminatus* sp.n. y *B. pulchellus* sp.n. pertenecen al grupo de especies oriental *molawinensis* (que corresponde al grupo de especies europeo *atrebatinus* y al grupo de especies norteamericano *propinquus*). Se propone el subgrupo de especies *sumigarensis* en el grupo de especies *molawinensis*. Las ninfas que se describen en este trabajo son las primeras ninfas de la familia Baetidae descritas de Sri Lanka. Se registra por primera vez para la Región Oriental el género *Procloeon*. Se incluye una clave para las ninfas de Baetidae de Sri Lanka.

The baetid fauna of Sri Lanka is poorly known. Fernando (1964) referred to five species in three genera: *Baetis consuetus* (Hagen 1858), *B. feminalis* Eaton, 1885, *B. solidus* (Hagen, 1858), *Cloeon marginale* (Hagen 1858), and *Procloeon bimaculatum* (Eaton, 1885). Both males and females are known of the three *Baetis* species (*consuetus*, *terminalis*, and *solidus*); no nymph of any *Baetis* species from Sri Lanka has been described previously. None of the three *Baetis* species has been rediscovered since its original description and none has ever been associated with nymphs (Hubbard and Peters 1978). Recently ten additional species of Baetidae (in *Indobaetis*, *Indocloeon*, *Pseudocloeon*, and *Centroptella*) have been described from Sri Lanka (Müller-Liebenau 1982a, 1982c, 1983; Müller-Liebenau and Morihara 1982).

The genus *Procloeon* was known previously only from the Palaearctic Region. Three species of "*Procloeon*" were mentioned by Hubbard and Peters (1978) from the Indian Subregion: 1) *Procloeon bimaculatum* was described from Sri Lanka by Eaton (1855) as *Cloeon bimaculatum*. 2) *Procloeon harveyi* was described from Calcutta by Kimmins (1947) from males and females. Kimmins distinguished *P. harveyi* from *P. bimaculatum* by the color pattern of the abdomen and pterostigma of the female. Gillies (1949) stated that the nymph attributed by Ulmer (1940: 650-653) to *P. bimaculatum* under the name *Cloeon bimaculatum* might possibly belong to *P. harveyi* and that both species might be placed in *Cloeon*. 3) *Procloeon debilis* (Walker 1860) was described originally from "Hindustan" as *Cloeon debilis* and later transferred by Kimmins (1960) to *Procloeon*. All three species are indistinguishable from *Cloeon* and must be regarded as *Cloeon* species.

Cloeon marginale (Hagen 1958), originally described from Sri Lanka, is known from males and females. The nymph is unknown. The single *Cloeon* nymph contained in the material studied appears closely related (if not identical) to the nymph described by Ulmer (1940) under the name *Cloeon bimaculatum* Eaton.

The status of the genus *Procloeon* is somewhat in doubt: Burks (1953) synonymized *Procloeon* with *Cloeon* although he gave no reason, and Gillies (1980) tentatively suggested that *Procloeon* should be regarded as at most of subgeneric status. Nevertheless, in the absence of further study of the genus *Procloeon*, the single species of the genus contained in the collection studied is preliminarily treated as *Procloeon* in this paper. Thus *Procloeon regularum* sp.n. is the first record of the genus from the Oriental Region.

We have carefully examined the type-specimens of *Baetis consuetus*, *Baetis solidus*, *Baetis feminalis*, and *Cloeon marginale* from the collections of the Museum of Comparative Zoology, Harvard University, in an unsuccessful attempt to associate these specimens with nymphs from Sri Lanka. Unfortunately, the nymphal color patterns and markings are not particularly well defined and, as is common in the Baetidae, are very difficult to correlate with adult patterns. It appears that definite association of the described adults with nymphs will require at the least more specimens, or, more probably, reared specimens.

Present-day systematics in the family Baetidae is based largely upon nymphs. Adults are often unknown, or if known, have so far generally proven to be of little help in determining relationships among species and higher taxa. This is particularly true in the Oriental Region. We have decided that the best course of action at this time is to describe the taxa below as new species based on nymphs even though we probably will be creating synonyms with some of the species which had been described previously as adults.

Most of the material studied herein was collected by Prof. Dr. F. Starmühlner, Vienna, and supplemented by Dr. G. Weninger, Vienna, and Dr. H. H. Costa, Kelaniya, during the Austrian-Ceylonese Hydrobiological Mission 1970 of the 1st Zoological Institute, University of Vienna (Austria), and the Department of Zoology of the Vidyalandara University of Ceylon, Kelaniya. The following genera and species of Baetidae already have been described from the same material: *Indobaetis costai* and *I. starmuehlneri* (Müller-Liebenau and Morihara 1982), *Indocloeon primum* (Müller-Liebenau 1982a), *Pseudocloeon difficile*, *P. orientale*, *P. ambiguum*, and *P. klapaleki* (Müller-Liebenau 1982c), *Centroptella ceylonensis*, *C. similis*, and *C. soldani* (Müller-Liebenau 1983).

A detailed description of all collecting sites of the material studied is given by Costa and Starmühlner (1972).

The holotypes and some paratypes are deposited in the Florida State Collection of Arthropods, Department of Entomology, Florida A&M University, Tallahassee, Florida. Additional paratypes are deposited in the Naturhistorisches Museum, Wien.

DESCRIPTIONS

1. *Baetis frequentus* sp.n.

Fig. 1, 10, 18

MATERIAL: 170 nymphs.

Body length: male 3.5 mm, cerci 2.0 mm; female 5.8 mm, cerci 2.6 mm.—*Color pattern,* surface and posterior margin of *terga* as in Figs. 10, 18.—*Labial palpus:* inner apical lobe of second segment slightly developed.—*Mandibles:* right mandible with outermost tooth set back (as in Fig. 1e).—*Gills:* on abdominal segments 1-7.—*Hind wing pads* of normal size.—*Legs:* outer margin of femur with a number of distinct bristles; smaller, apically rounded bristles also on dorsal surface of femur and tibia, on tibia only on the half basal to tibial seam (Fig. 1g); outer margin of tibia and tarsus with a number of shorter bristles that appear apically split under the microscope but which actually are rounded apically (Fig. 1g); all leg segments covered with scales and scale bases.

The canine area of the mandibles and the bristles on the outer margins of the tibia and tarsus distinguish *B. frequentus* sp.n. from all other *Baetis* species treated in the paper.

About 160 non-type nymphal specimens are referred to this species. Some of these have the spines of the posterior margin of the *terga* less pointed than in Fig. 18, but all of them have bristles on the outer margin of the tibia which appear apically split (Fig. 19). These bristles are hyaline and only the margins and the midline are easily visible under the microscope giving the appearance of bristles which are apically split.

Baetis frequentus sp.n. does not belong to any known species group. *Baetis frequentus* sp.n. is the most frequent species in the collections studied. This species was collected at 20 different sites from 30 m to 1500 m above sea level (Fig. 27) where they live mostly under stones in the current and near the banks.

Holotype: dissected nymph on slide preparation: Ceylon, Veli-Oya, Belihuloya, (FC 26a), 8.12.1970, leg. Starmühlner.—*Paratypes:* 8 slide preparations. *Non-type material:*

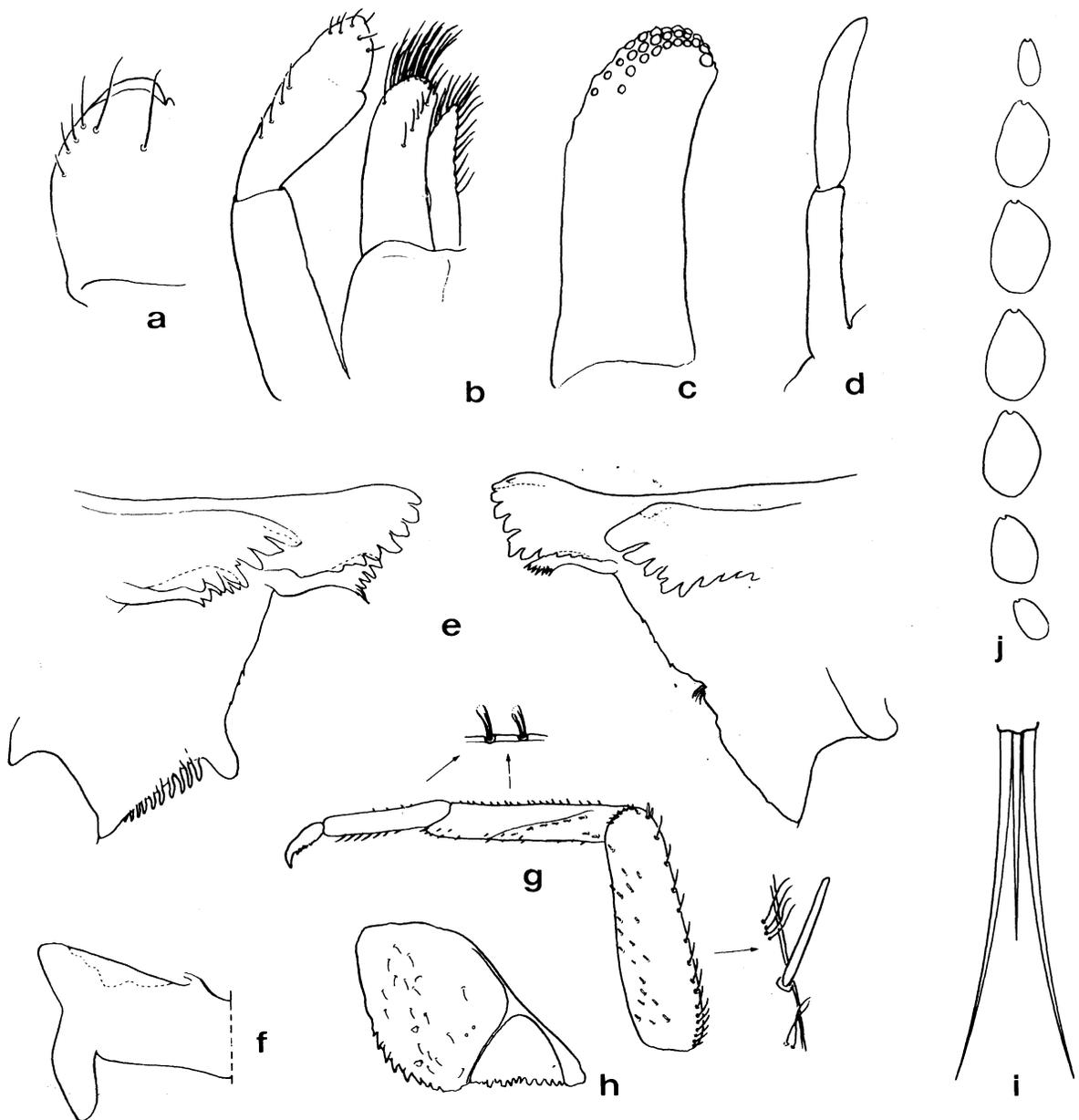


Fig. 1. Nymph of *Baetis frequentus* sp.n.; a) left half of labrum; b) left half of labium; c) paraglossa (enlarged; ventral); d) maxillary palpus; e) canine and molar area of left and right mandibles; f) left half of metanotum with hind wing pad; g) leg; h) paraproct; i) caudal filaments; j) gills 1-7.

about 160 nymphs in alcohol are also referred to this species. (See Fig. 27 for localities from which *B. frequentus* sp.n. has been collected.)

Etymology: adj., from *frequens*, L., meaning numerous.

2. *Baetis acceptus* sp.n.

Fig. 2, 11, 19

MATERIAL: 14 nymphs.

Body length: male 5.3 mm, cerci 5.2 mm, terminal filament 2.9 mm; female 6.2 mm, cerci 5.9 mm, terminal filament 3.1 mm.—*Color pattern*: surface and posterior margin of terga as in Fig. 11, 19.—*Labial palpus*: inner margin of third segment rather rounded.—*Hind wing pads*: narrow.—*Gills*: on abdominal segments 2-7. Dorsal surface of abdominal gills pigmented above a longitudinal median line, and covered on pig-

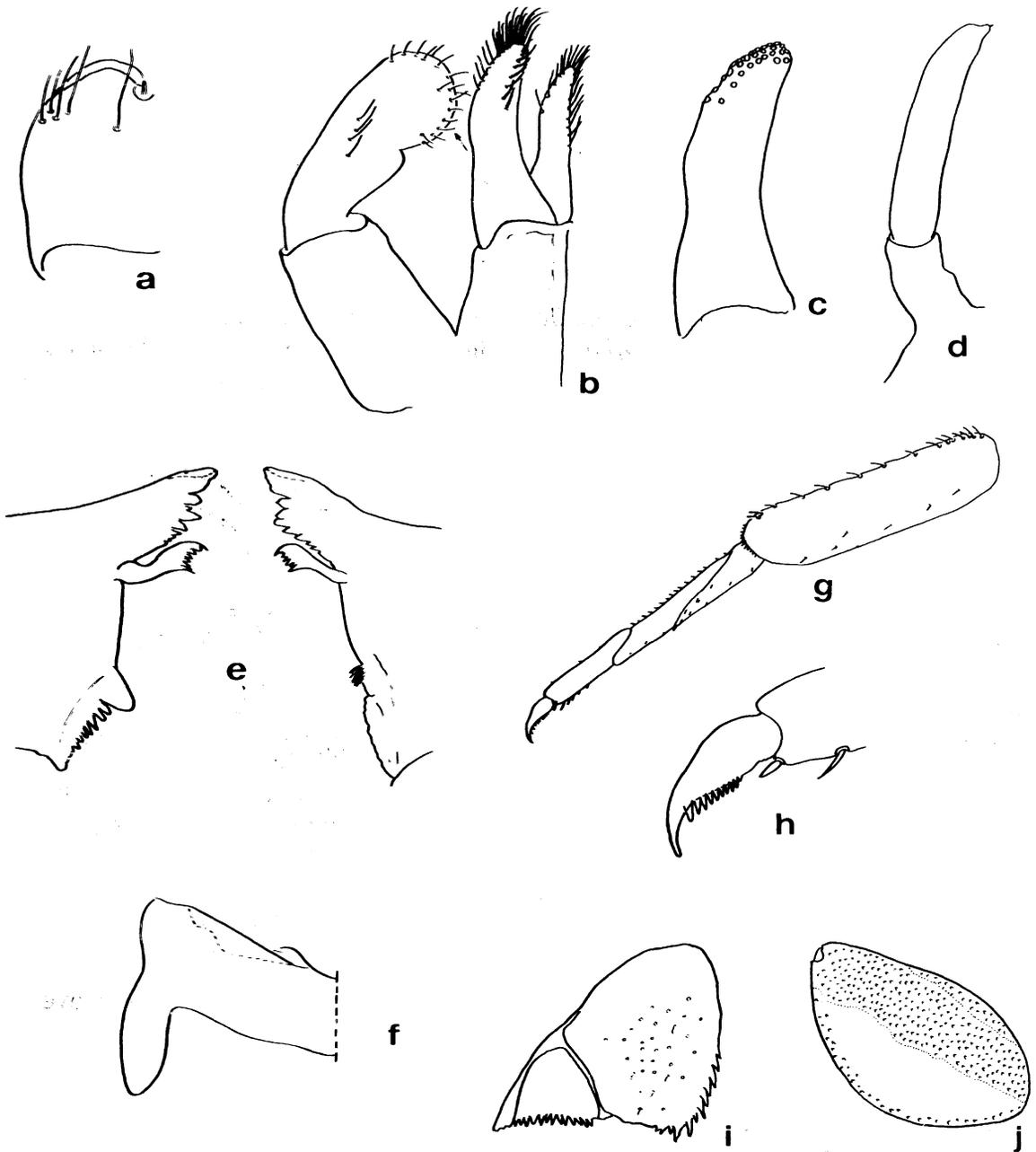


Fig. 2. Nymph of *Baetis acceptus* sp.n.: a) left half of labrum; b) left half of labium; c) paraglossa (enlarged; ventral); d) maxillary palpus; e) canine and molar area of left and right mandibles; f) left half of metanotum with hind wing pad; g) leg; h) claw; i) paraproct; j) gill.

mented half and along hind margin with scales and scale bases smaller than on terga (Fig. 2j).—*Legs*: bristles on outer margin of femur and tibia pointed (in two specimens these bristles are rather blunt at apex); all three segments of legs covered with scales and scale bases as on terga.

In addition to the morphological characters mentioned above, *Baetis acceptus* sp.n. differs from the other *Baetis* species treated in this paper by the spines on the posterior margins of the terga which are comparatively narrow and pointed (Fig. 19). It differs from the closely related *B. conservatus* sp.n. (see below) mainly by the shape of the labial palpus, the gills, and the spines on the posterior margins of the terga. These differences are discussed in the following description of *B. conservatus* sp.n. *Baetis acceptus* sp.n. does not belong to any known species group.

Baetis acceptus sp.n. was collected at four localities between 700 m and 1200 m above sea level (Fig. 27); the nymphs live on sandy substrate.

Holotype: dissected female nymph on slide preparation: Ceylon, Veli-Oya, Belihuloya, (FC 26a), 8.12.1970, leg. Sarmühlner.—*Paratypes*: 5 slide preparations, 8 nymphs in alcohol (localities in Fig. 27).

Etymology: adj., from *acceptus*, L., meaning welcome or agreeable.

3. *Baetis conservatus* sp.n.

Fig. 3, 12, 20

MATERIAL: 3 male nymphs.

Body length: male 5.2 mm, cerci 5.2 mm, terminal filament 2.9 mm.—*Color pattern*, surface and posterior margin of *terga* as in Figs. 12, 20. *Labial palpus*: inner margin of 3rd segment rather straight.—*Gills*: on abdominal segments 2-7. Gills not pigmented as in the preceding *B. acceptus* sp.n. and entire gill surface covered with scales and scale bases smaller than on *terga*.—*Legs*: bristles on outer margin of femur and tibia pointed; all leg segments covered with scales and scale bases.—Subimaginal *Hind wing*, visible inside exuvial hind wing pad, with clearly developed costal projection.

Baetis conservatus sp.n. is closely related to the preceding *B. acceptus* sp.n. The main differences are as follows:

B. acceptus sp.n.

1. 3rd segment of labial palpus rounded at inner margin
2. gills pigmented above a median longitudinal line, scales and scale bases only on the pigmented half and along hind margin
3. spines on posterior margin of *terga* pointed and elongate
4. collecting sites 700 m to 1200 m above sea level

B. conservatus sp.n.

- 3rd segment of labial palpus rather straight at inner margin
- no pigmented area on gills, scales and scale bases over entire gill surface
- spines on posterior margin of *terga* pointed, short, rather triangular
- collecting site 1500 m above sea level

Baetis conservatus sp.n. cannot be not placed in any known species group.

The three specimens of *B. conservatus* sp.n. were collected at one site at 1500 m above sea level (Fig. 27) at the bank on sandy substrate.

Holotype: dissected male nymph on slide preparation: Ceylon, Gartmore-Estate-Dola, Maskeliya, (FC 18a), 30.11.1970, leg. Starmühlner.—*Paratypes*: two slide preparations: 1 mature nymph, 1 juvenile nymph. Same locality as holotype.

Etymology: adj., from *conservo*, L., meaning to maintain.

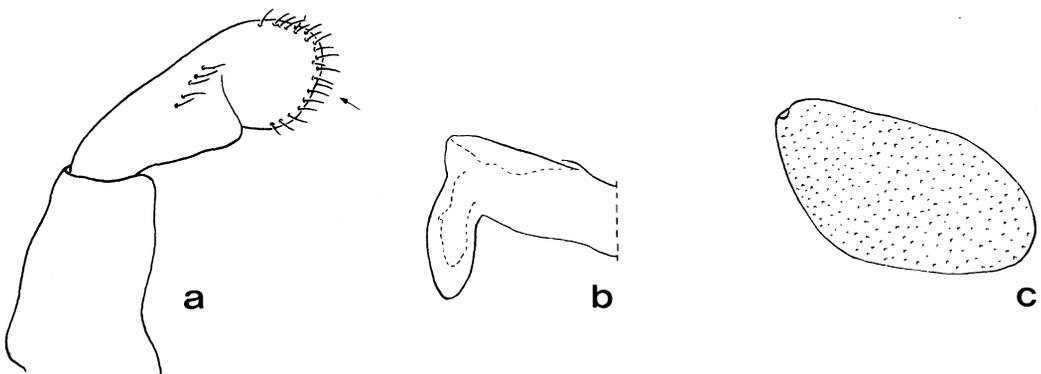


Fig. 3. Nymph of *Baetis conservatus* sp.n.: a) left labial palpus; b) left half of metanotum with hind wing pad; c) gill.

4. *Baetis collinus* sp.n.

Fig. 4, 13, 21

MATERIAL: 7 nymphs.

Body length: 5.4 mm, length of cerci not known because they are broken in all specimens available (all three of them are of about same width at base).—*Color pattern*, surface and posterior margin of *terga* as in Fig. 13, 21.—*Labial palpus*: 3rd segment considerably longer than wide, inner apical lobe of 2nd segment very slightly developed.—*Hind wing pads* of normal size.—*Gills*: on abdominal segments 2-7.—*Legs*: all segments covered with scales and scale bases.

In the collections studied, *B. collinus* sp.n. is the only species without spines on the posterior margins of the *terga*. This character distinguishes it easily from all other *Baetis* species described herein.—*Baetis luzonensis* from the Philippines (Müller-Liebenau 1982b) also lacks spines on the posterior margins of the *terga*, but it differs from *B. collinus* sp.n. in several other morphological characters (i.e., hind wing pads are lacking and abdominal gills occur on segments 1-7). *Baetis collinus* sp.n. cannot be placed in any known species group.

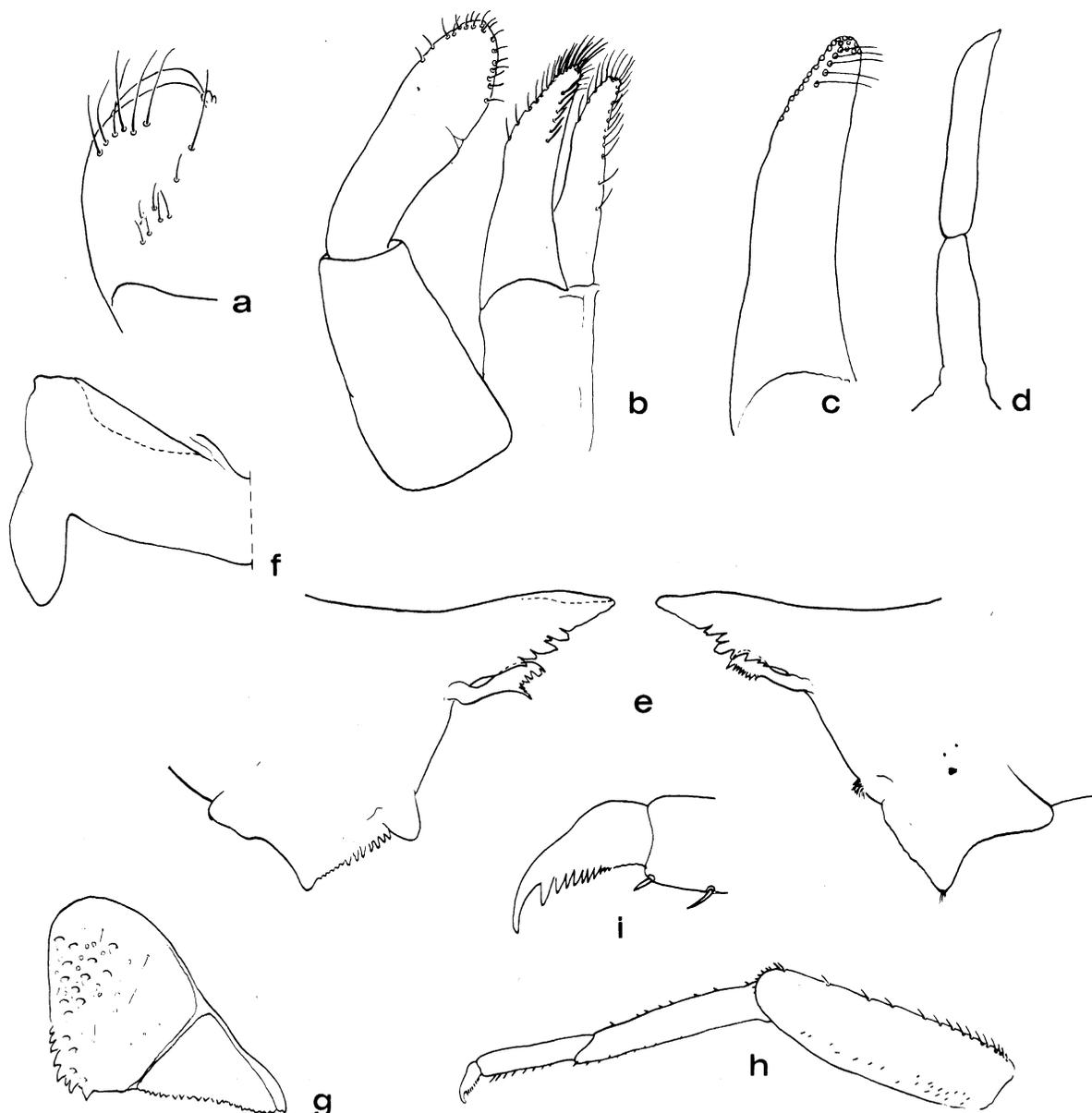


Fig. 4. Nymph of *Baetis collinus* sp.n.: a) left half of labrum; b) left half of labium; c) paraglossa (enlarged; ventral); d) maxillary palpus; e) canine and molar area of left and right mandibles; f) left half of metanotum with hind wing pad; g) paraproct; h) leg; i) claw.

Baetis collinus sp.n. appears to prefer higher altitudes: the seven specimens were collected at three different places at altitudes of 1300 m, 1500 m, and 1850 m above sea level (Fig. 28), near the banks on sandy substrate and also under stones in cascades.

Holotype: dissected nymph on slide preparation: Ceylon, Gartmore-Estate-Dola, Maskeliya, (FC 18/a), 30.11.1970, leg. Starmühlner.—*Paratypes*: 6 nymphs in alcohol (for locations see Fig. 27).

Etymology: adj., from *collis*, L., meaning hill.

5. *Baetis geminatus* sp.n.

Fig. 5, 14, 22

MATERIAL: 12 nymphs.

Body length: male 4.5 mm, cerci 4.0 mm; female 4.5 mm, cerci 4.0 mm.—*Color pattern*, surface and posterior margin of *terga* as in Figs. 14, 22.—*Labrum*: submarginal bristles clavate and arranged in a dense row.—*Labial palpus*: median lobe of 2nd segment greatly enlarged with frontal margin concave. *Antenna*: outer apical lobe of pedicel clearly developed.—*Maxillary palpus*: second segment with slight indentation near apex.—*Hind wing pads* lacking.—*Gills*: on abdominal segments 2-7.—*Legs*: all segments covered with scales and scale bases.

The morphological characters of the nymph described above show striking correspondence in most details with the nymph of *B. diffundus* (Müller-Liebenau 1984) from Malaysia. Differences are seen in: 1) the maxillary palpus has a distinct indentation at the inner margin near the apex in *B. diffundus* but the indentation is only slightly developed in *B. geminatus* sp.n.; 2) the 3rd segment of the labial palpus in *B. geminatus* sp.n. is wider than the inner apical lobe of the 2nd segment but is of about the same width as the inner apical lobe in *B. diffundus*; and 3) the paraprot of *B. diffundus* is rather short compared to the paraprot of the nymph of *B. geminatus* sp.n.—The color pattern on the dorsum of the abdomen is pale and undefined in both species. *Baetis geminatus* sp.n. from Sri Lanka and *B. diffundus* from Malaysia should probably be considered sibling species and both are members of the *sumigarensis* subgroup within the Oriental *molawinensis* species-group (Müller-Liebenau 1984). This newly proposed subgroup will be discussed later in this paper.

The 12 specimens of *B. geminatus* sp.n. were collected at altitudes ranging from 150 m to 1200 m above sea level (Fig. 27). They are found on sandy substrate and under stones near the bank.

Holotype: dissected female nymph on slide preparation: Ceylon, Mocha-Dola, Maskeliya, (FC 16/a), 28.11.1970, leg. Starmühlner.—*Paratypes*: 2 slide preparations, 8 nymphs in alcohol (for locations see Fig. 27).

Etymology: adj., from *gemino*, L., meaning to double or pair.

6. *Baetis pulchellus* sp.n.

Fig. 6, 15, 23

MATERIAL: 14 nymphs.

Body length: 4.2 mm, cerci 2.5 mm. *Color pattern*, surface and posterior margin of *terga* as in Fig. 15, 23. Caudal filaments with a dark band posterior to midpoint.—*Labrum*: submarginal fine bristles single (not in a dense row).—*Maxillary palpus*: distinct subapical indentation at inner margin of 2nd segment.—*Hind wing pads* present, comparatively narrow.—*Gills*: on abdominal segments 1-7, with scales and scale bases on dorsal surface.—*Legs*: all segments covered with scales and scale bases.

Baetis pulchellus sp.n. differs from the preceding *B. geminatus* sp.n. in the pattern of submarginal bristling on the labrum (Fig. 6a), the inner apical lobe of the second segment of the labial palpus (Fig. 6b), and in the presence of well developed hind wing

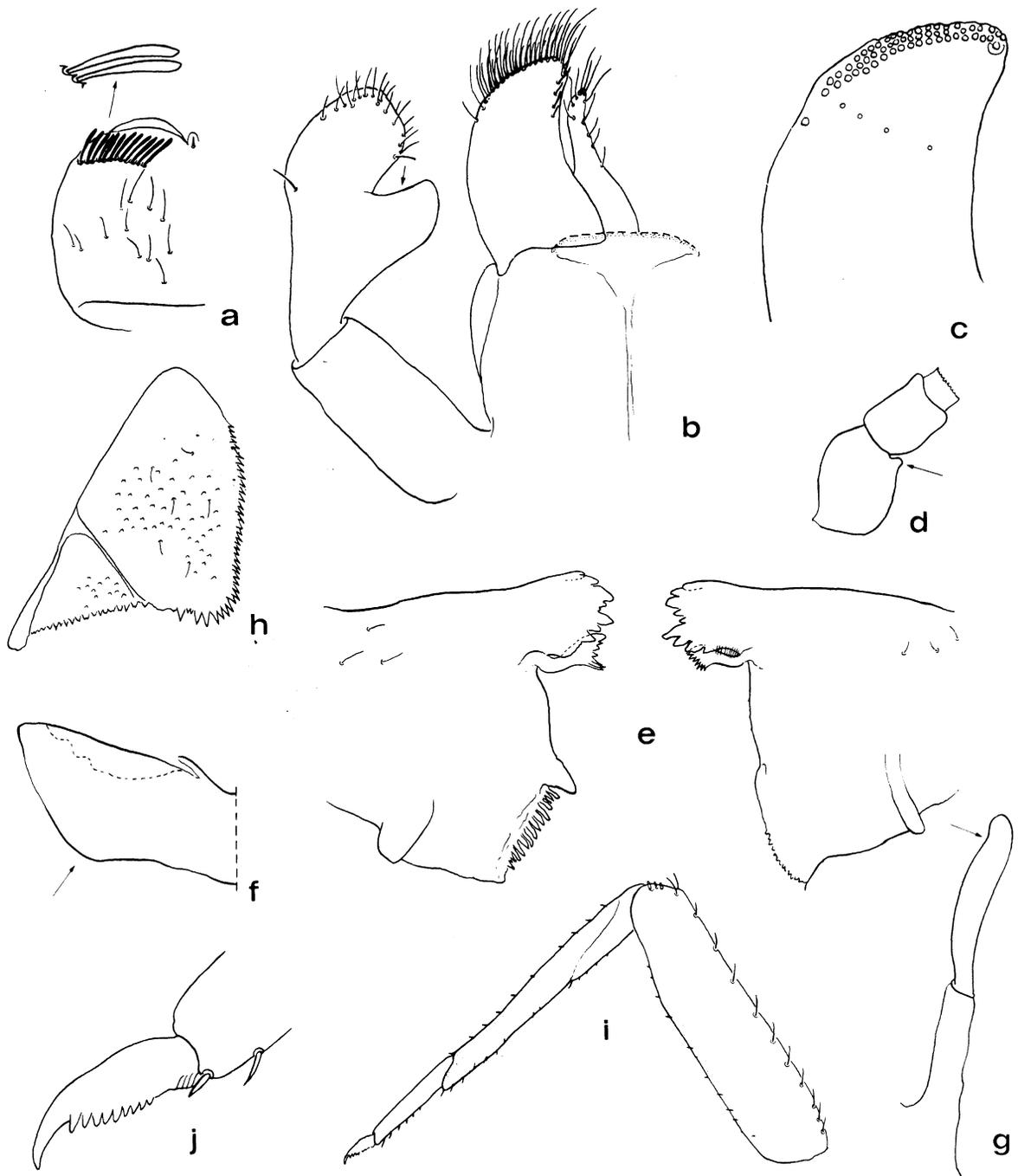


Fig. 5. Nymph of *Baetis geminatus* sp.n.: a) left half of labrum (with submarginal clavate bristles enlarged); b) left half of labium; c) apex of paraglossa (enlarged; ventral); d) basal segments of antenna; e) canine and molar area of left and right mandibles; f) left half of metanotum (no hind wing pads developed); g) maxillary palpus; h) paraproct; i) leg; j) claw.

pads (Fig. 6f). It differs from both *B. geminatus* sp.n. and the following *B. ordinatus* sp.n. in having 7 pairs of abdominal gills.

Baetis pulchellus sp.n. is placed in the Oriental *molawinensis* species-group. It shows a certain relationship to *B. multus* from Malaysia (Müller-Liebenau 1984, Fig. 9, 24, 42); especially remarkable are the correspondence of the comparatively narrow hind wing pads, and the color pattern of the pronotum and dorsum of the abdomen in both species. Although the scales and scale bases on the surface of the terga are similar in both species, the spines on the posterior margin of the terga are comparatively larger in *B. pulchellus* sp.n. than in the Malaysian *B. multus* and there are about half as many in *Baetis pulchellus* sp.n. as in *B. multus*.

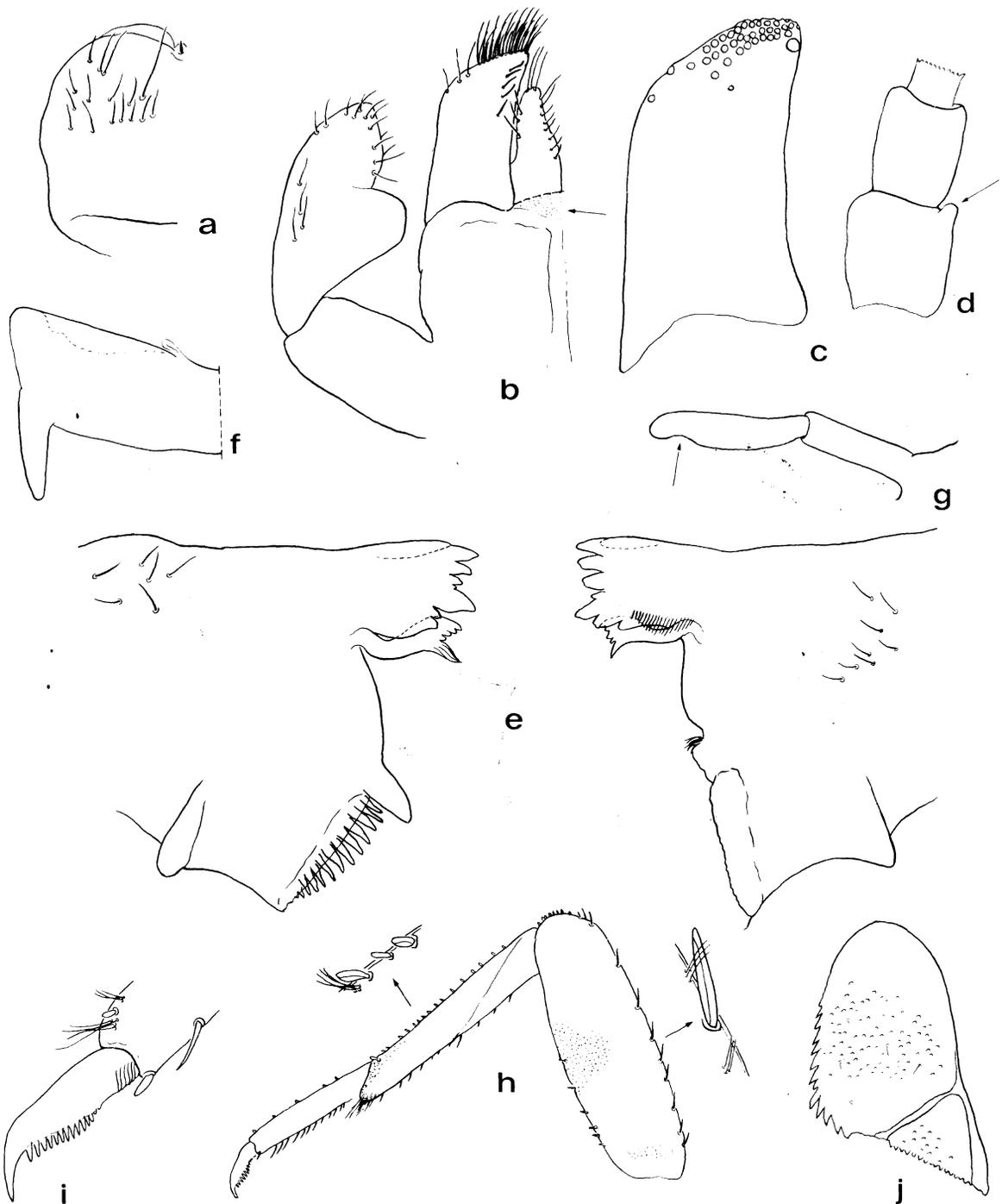


Fig. 6. Nymph of *Baetis pulchellus* sp.n.: a) left half of labrum; b) left half of labium; c) paraglossa (enlarged; ventral); d) basal segments of antenna; e) canine and molar area of left and right mandibles; f) left half of metanotum with hind wing pads; g) maxillary palpus; h) leg; i) claw; j) paraproct.

Baetis pulchellus sp.n. appears to range widely in altitude: 13 nymphs were collected between 60 m and 600 m above sea level (Fig. 27) mostly on sandy substrate; a single specimen was collected at 1200 m above sea level. Further collections of these nymphs are needed to confirm the altitudinal distribution of *B. pulchellus* sp.n.

Holotype: dissected male nymph on slide preparation: Ceylon, Dick-Oya, Maskeliya, (FC 23a), 3.12.1970, leg. Starmühlner.—*Paratypes*: 4 slide preparations, 6 nymphs in alcohol (for localities see Fig. 27).

Etymology: adj., from *pulchellus*, L., meaning very pretty.

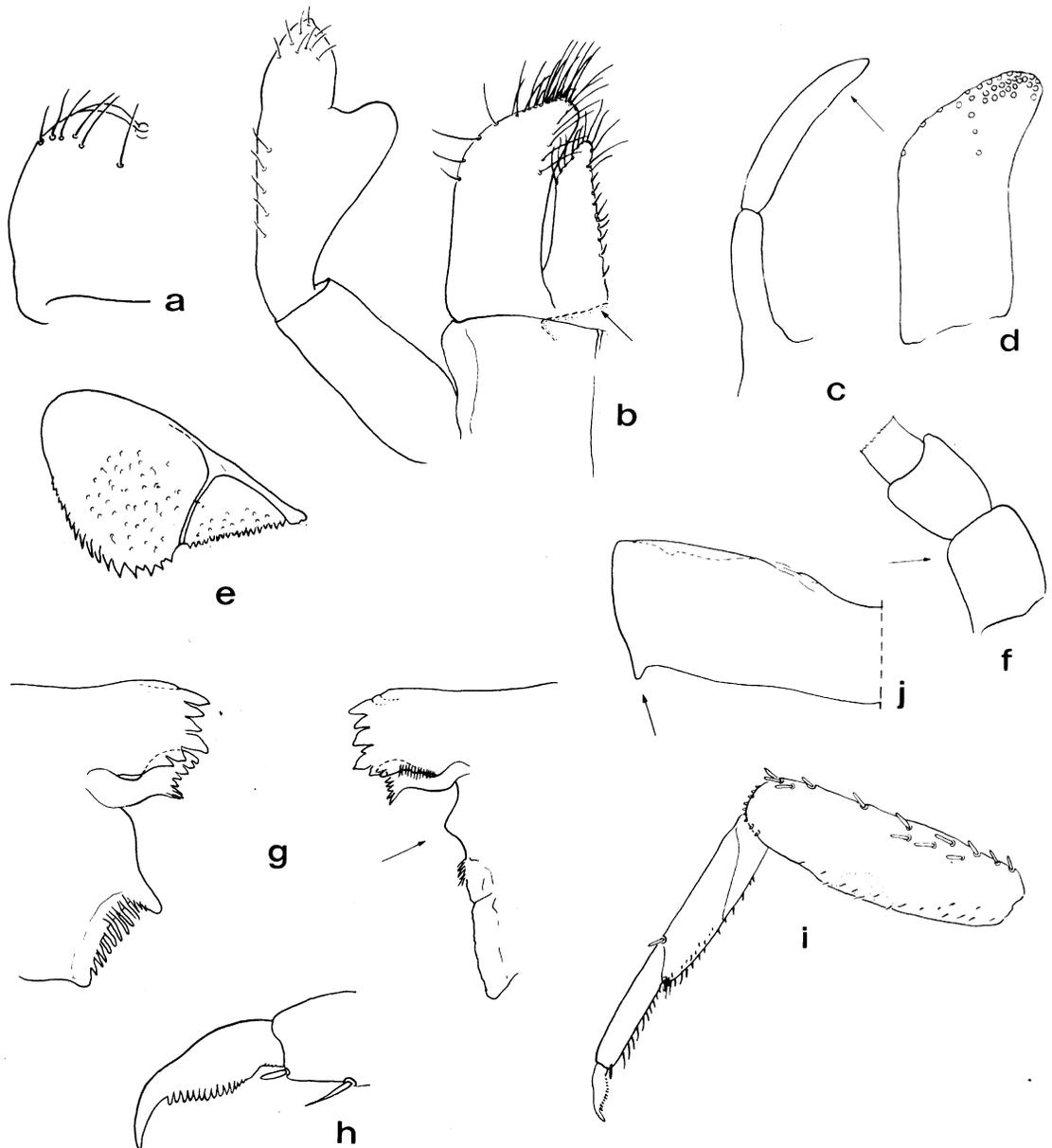


Fig. 7. Nymph of *Baetis ordinatus* sp.n.: a) left half of labrum; b) left half of labium; c) maxillary palpus; d) paraglossa (enlarged; ventral); e) paraproct; f) basal segments of antenna; g) canine and molar area of left and right mandibles; h) claw; i) leg; j) left half of metanotum.

7. *Baetis ordinatus* sp.n.

Fig. 7, 16, 24

MATERIAL: 7 nymphs.

Body length: male 3.9 mm, cerci 2.9; female 4.1 mm, cerci 2.1 mm.—*Color pattern*, surface and posterior margin of *terga* as in Fig. 16, 24.—*Caudal filaments* with a dark band posterior to midpoint and with dark apex.—*Labrum*: submarginal fine bristles single (not in a dense row). *Maxillary palpus*: no subapical indentation at inner margin of second segment.—*Antenna*: outer apical lobe on scape not developed.—*Right mandible*: a tubercle at inner margin between incisor and molar area.—*Hind wing pads* reduced.—*Gills*: on abdominal segments 2-7.—*Legs*: all segments covered with scales and scale bases as on *terga*.

The morphological characters shown in Fig. 7 in combination with scales and scale bases on the surface of the *terga* and with spines on the posterior margins of the *terga* which are broad at the base and apically rounded easily separate *B. ordinatus* sp.n. from both the preceding species *B. geminatus* sp.n. and *B. pulchellus*.

Baetis ordinatus sp.n. appears closely related to *B. numeratus* from Malaysia (Müller-Liebenau 1984, Fig. 11, 26, 44): no inner apical lobe is developed on the pedicel of the antennae, and the hind wing pads are greatly reduced. Within the Oriental *molawinensis* species-group both species have an additional common character: the right mandible with a tubercle between the incisor and the molar area (Fig. 7g) (in the North American *propinquus* group, *B. ephippiatus* has a similar structure). In addition, the spines on the posterior margin of the terga are broad at the base and apically rounded (the same is true in *B. moriharai* from Malaysia), although in *B. ordinatus* sp.n. the rounded spines on the posterior margin of the terga are most typical on segments 1-4, getting narrower and more elongate on segments 5-10, and are apically pointed on the last segments. In *B. numeratus* sp.n. (and in *B. moriharai*) the spines are broad at the base and rounded on all segments.

The seven nymphs of *B. ordinatus* sp.n. were collected at 80 m and 700 m above sea level (Fig. 27).

Holotype: female nymph on slide preparation: Ceylon, Kalu-Ganga at Malwala, Ratnapura, (FC 13/d), 21.11.1970, leg. Starmühler.—*Paratypes*: 4 slide preparations (some only mouthparts and/or legs) (for localities see Fig. 27).

Etymology: adj., from *ordinatus*, L., meaning orderly.

8. *Cloeon bimaculatum*? Eaton, 1885

Fig. 8, 25

MATERIAL: 1 mature female nymph.

Body length: female 5.2 mm, cerci 3.8, terminal filament a little shorter.—*Color pattern*: the exuvia of the only available specimen are nearly completely depigmented and therefore not convenient for a figure. Caudal filaments with about 8 dark rings. Surface and posterior margin of *terga* as in Fig. 25. *Labium*: glossa and paraglossa of about same width, rather stout (Fig. 8b) compared to glossa and paraglossa of *Procloeon* (Fig. 9b).—Spines on lateral margins of abdominal segments are: VI = 1, VII = 1, VIII = 8, IX = 10 (cf. Gillies 1980).—*Gills*: on abdominal segments 1-7, margins smooth. Not all gills of the single specimen are still available, and the rest are detached from the abdomen, so that it is not possible to show them in the right order. All detached gills are doubled; probably the gill lamellae of the seventh segment are single as Ulmer (1940) pointed out for *Cloeon bimaculatum*. The ventral gill lamellae are rounded, the dorsal lamellae are rounded, or elongate and longer than the ventral lamella.—*Legs*: all segments with an irregular row of long fine bristles, on femur near apex, on tibia and tarsus near base.—*Claws* with two rows of denticles (Fig. 9h). In Ulmer's (1940) Fig. 181a only one row of denticles is recognizable; the second row was overlooked by him (a loan of nymphal material from the Ulmer collection, deposited in the Zoologisches Institut und Zoologisches Museum, Hamburg, made a comparison possible).

In Fig. 8 a number of morphological characters additional to those illustrated in Ulmer's Figs. 376-381 (1940) of the nymph in question is shown. *Cloeon bimaculatum* was described by Eaton (1885) based on imagos from Ceylon. Ulmer (1940: 650-653, Fig. 376-381) described the nymph of *Cloeon bimaculatum*, referring to the color pattern on the dorsal surface of the abdomen of the imago (Ulmer 1924). The material studied by Ulmer was collected in Central Sumatra, South Sumatra, East Java, and West Java. Kimmins (1947) studied imagos from Calcutta; based on the proportionate length of the 1st and 2nd segments of the hind tarsus (1:3) he transferred the species to the genus *Procloeon* Bengtsson. As Gillies (1980) pointed out, Kimmins (1947) had overlooked Ulmer's description of the nymph of *C. bimaculatum*. Since the nymphs of most *Cloeon* species are supposed to have the gill lamellae of segments 1-6 doubled (or with recurved dorsal flap) and the seventh gill single, and the nymphs of *Procloeon* are

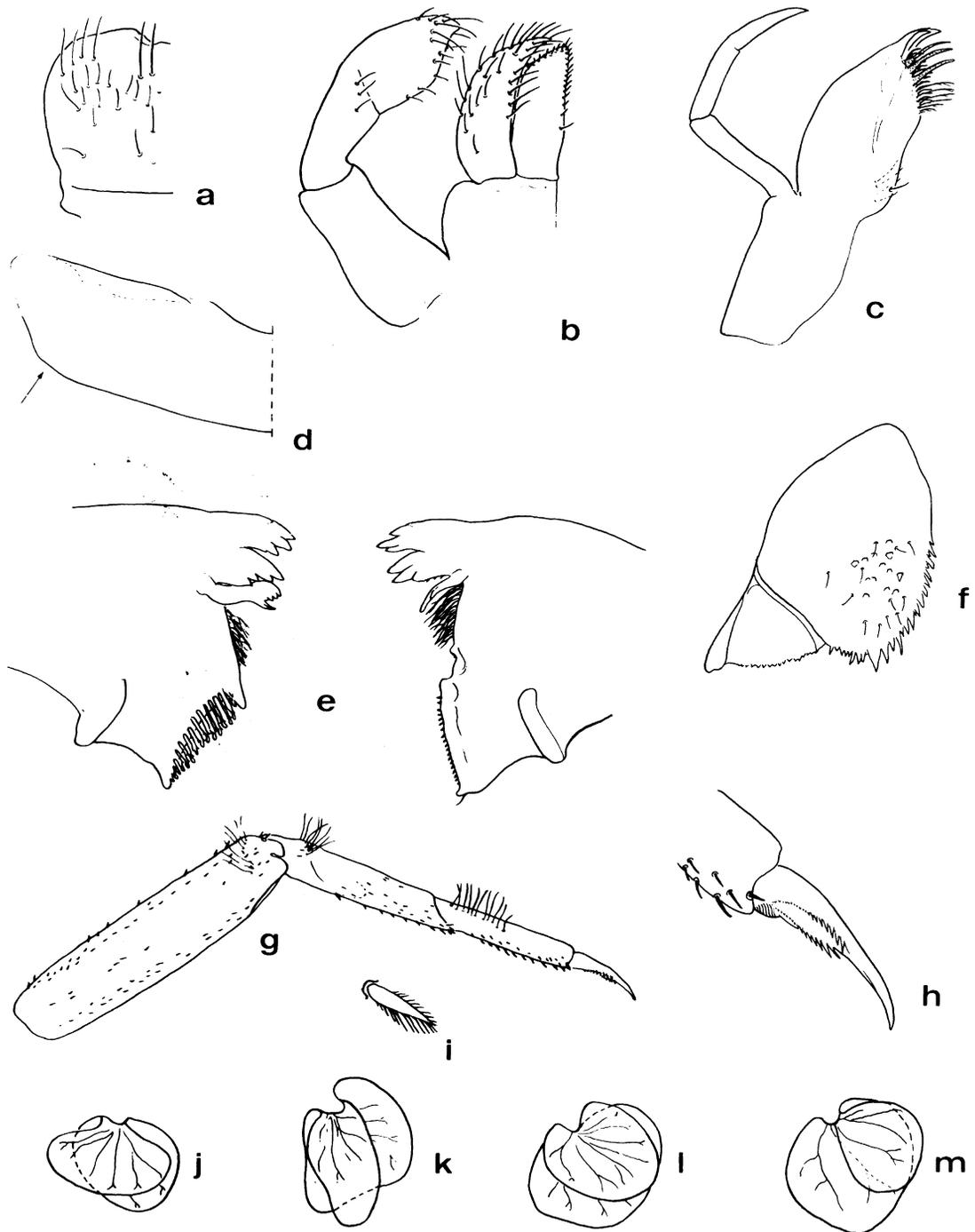


Fig. 8. Nymph of *Cloeon bimaculatum?* Eaton: a) left half of labrum; b) left half of labium; c) left maxilla; d) left half of metanotum; e) canine and molar area of left and right mandibles; f) paraprost; g) leg; h) claw with two rows of denticles; i) feathered bristle from leg; j-m) 4 single gills (detached from abdomen).

known to have all gill lamellae single, we believe that the nymph which was described by Ulmer is *Cloeon* rather than *Procloeon* and that it should remain in *Cloeon*. Since no reared material was ever studied and now only a single nymph from Sri Lanka is available, we hesitate to synonymize this nymph with the *Cloeon bimaculatum* nymph described by Ulmer (1940). A definitive decision needs the study of more material.

The single nymph described herein was collected in the Region of Kitulgala on sandy substrate in the Kelani Ganga near the Kitulgala Resthouse at 60 m above sea level (Fig. 27).

9. *Procloeon regularum* sp.n.

Fig. 9, 17, 26

MATERIAL: 10 nymphs.

Body length: 4.5 mm, cerci 1.8 mm, terminal filament only a little shorter than cerci. Caudal filaments with 7 dark rings and with lateral spines.—*Color pattern*, surface and posterior margin of *terga* as in Fig. 17, 26. All abdominal segments with 1 spine at

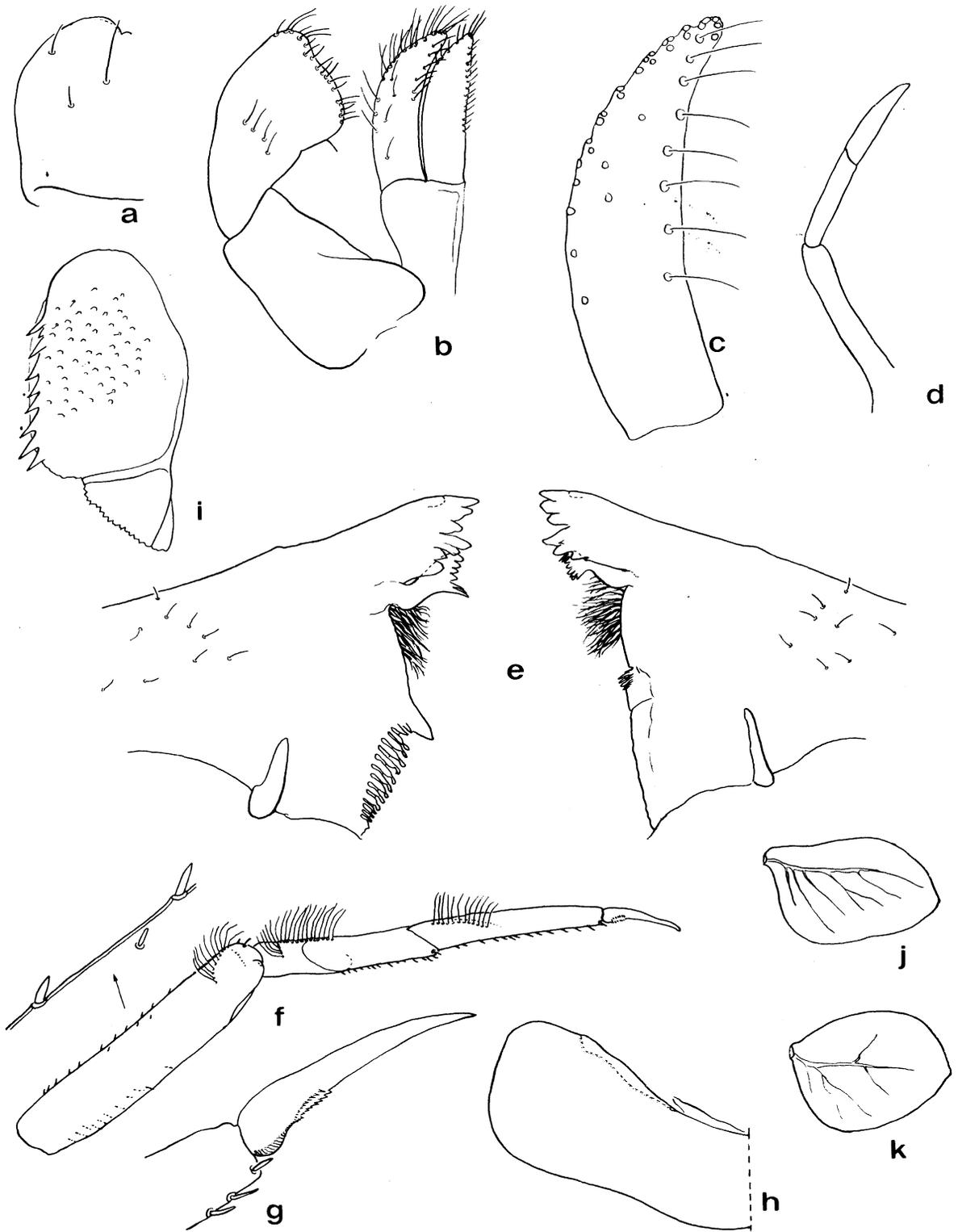


Fig. 9. Nymph of *Procloeon regularum* sp.n.: a) left half of labrum; b) left half of labium; c) paraglossa (enlarged; ventral); d) maxillary palpus; e) canine and molar area of left and right mandibles; f) leg; g) claw with two rows of denticles; h) left half of metanotum; i) paraproct; j) gill of abdominal segment 4; k) gill of abdominal segment 6.

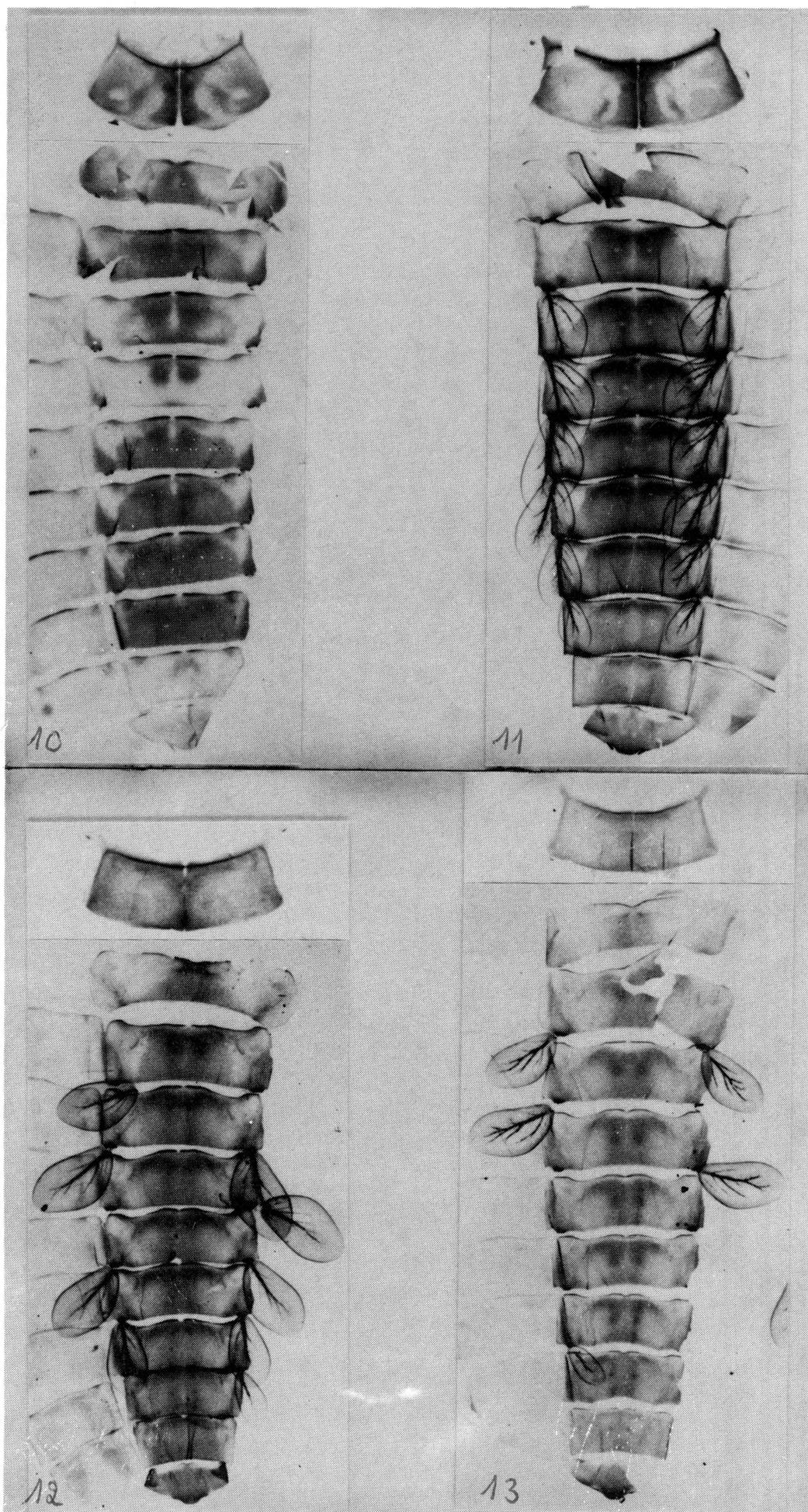


Fig. 10. Nymph of *Baetis frequentus* sp.n.: color pattern of pronotum and abdomen.
Fig. 11. Nymph of *Baetis acceptus* sp.n.: color pattern of pronotum and abdomen.
Fig. 12. Nymph of *Baetis conservatus* sp.n.: color pattern of pronotum and abdomen.
Fig. 13. Nymph of *Baetis collinus* sp.n.: color pattern of pronotum and abdomen.

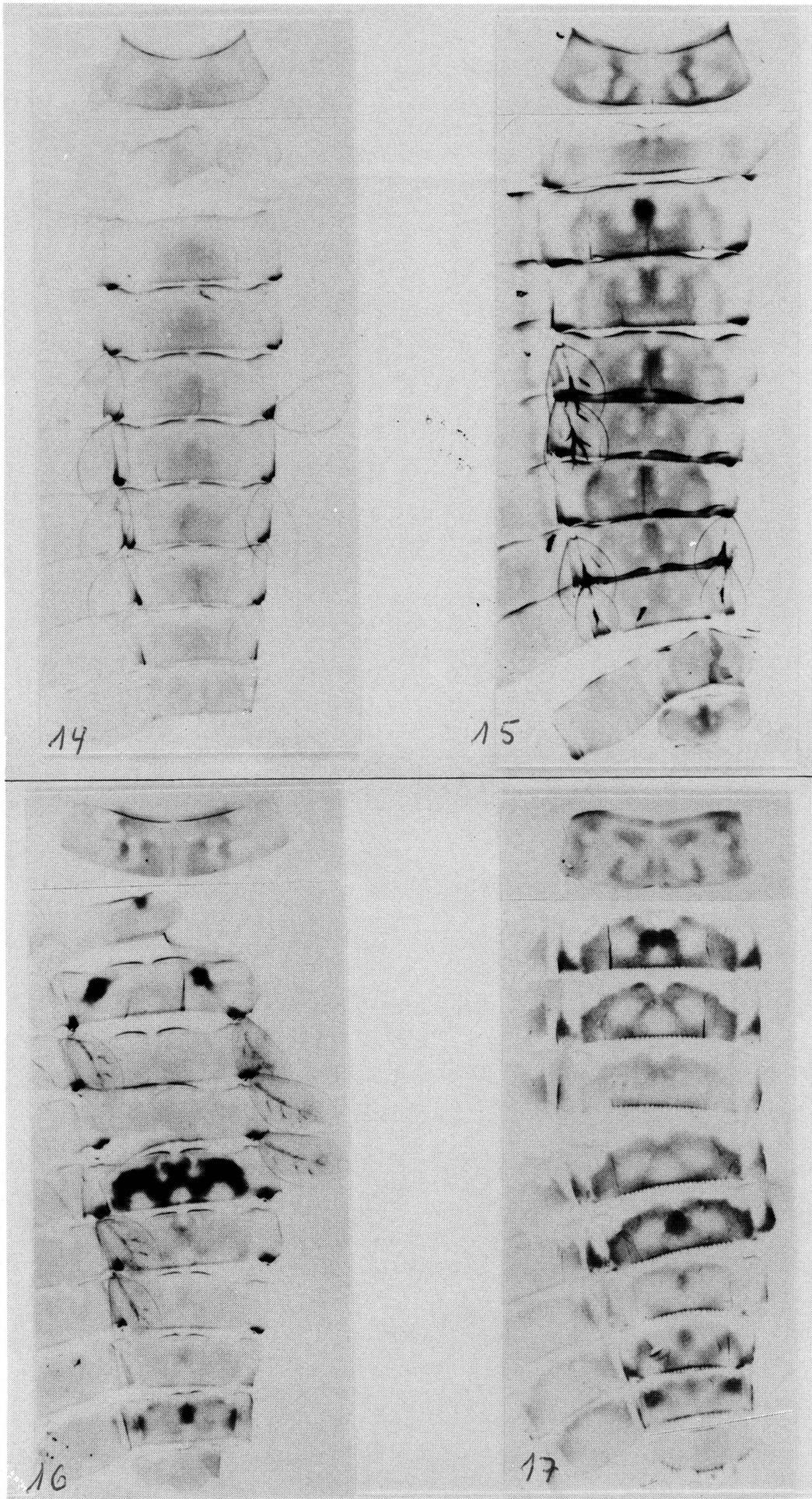


Fig. 14. Nymph of *Baetis geminatus* sp.n.: color pattern of pronotum and abdomen.

Fig. 15. Nymph of *Baetis pulchellus* sp.n.: color pattern of pronotum and abdomen.

Fig. 16. Nymph of *Baetis ordinatus* sp.n.: color pattern of pronotum and abdomen.

Fig. 17. Nymph of *Procloeon regularum* sp.n.: color pattern of pronotum and abdomen.

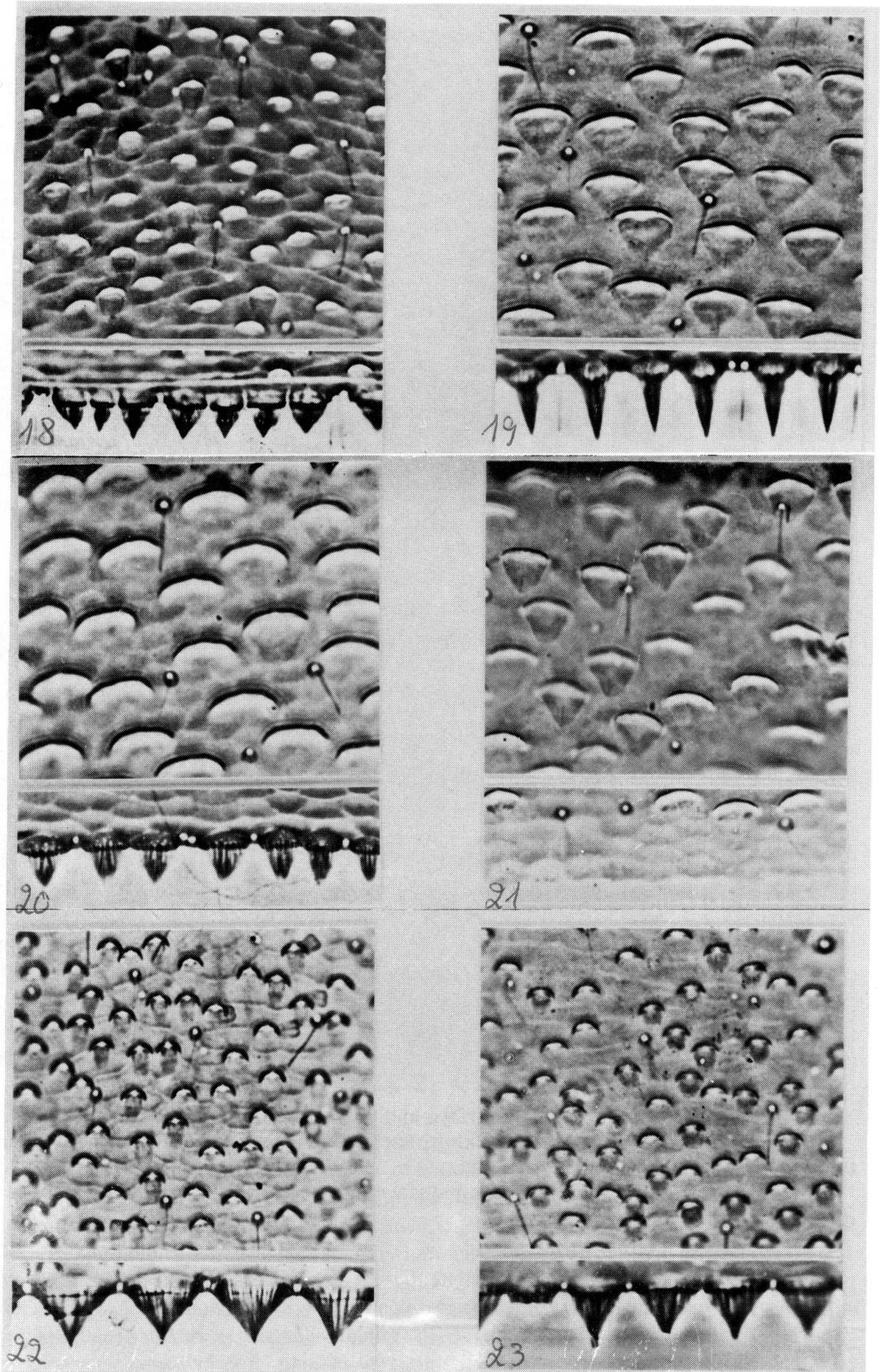


Fig. 18. *Baetis frequentus* sp.n.; surface and posterior margin of nymphal tergum.
 Fig. 19. *Baetis acceptus* sp.n.; surface and posterior margin of nymphal tergum.
 Fig. 20. *Baetis conservatus* sp.n.; surface and posterior margin of nymphal tergum.
 Fig. 21. *Baetis collinus* sp.n.; surface and posterior margin of nymphal tergum.
 Fig. 22. *Baetis geminatus* sp.n.; surface and posterior margin of nymphal tergum.
 Fig. 23. *Baetis pulchellus* sp.n.; surface and posterior margin of nymphal tergum.

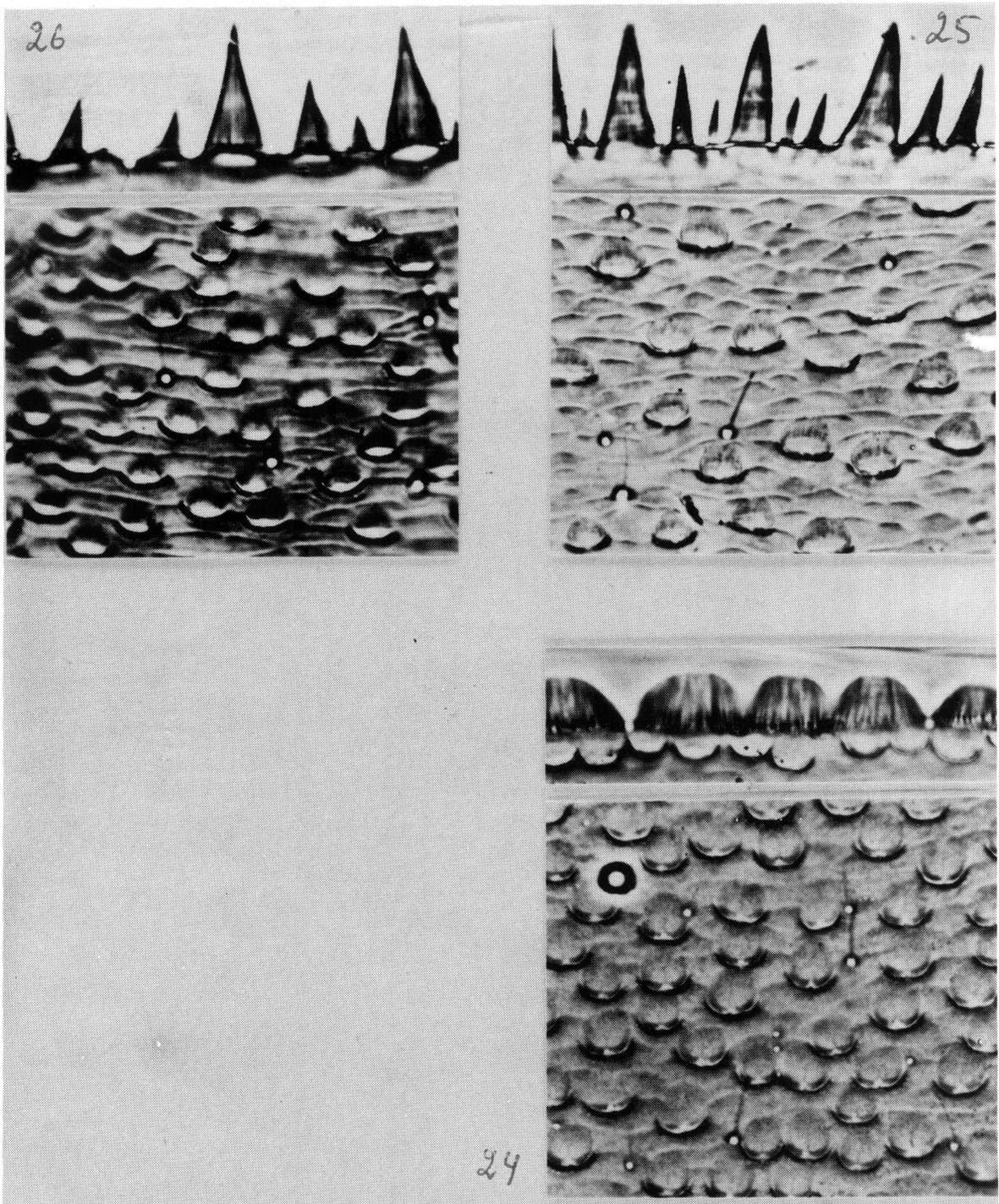


Fig. 24. *Baetis ordinatus* sp.n.; surface and posterior margin of nymphal tergum.

Fig. 25. *Cloeon bimaculatum*? Eaton; surface and posterior margin of nymphal tergum.

Fig. 26. *Procloeon regularum* sp.n.; surface and posterior margin of nymphal tergum.

posterior angle at insertion of gill; segment 10 with 4 or 5 lateral spines.—*Labial palpus* with terminal segment bulging inward; glossa and paraglossa about same width, elongate. *Hind wing pads*: not developed.—*Gills*: gill lamellae single, rather broad, apically pointed.—*Legs*: all segments with a distinct row of long, fine bristles (near apex on femur, near base on tibia and tarsus), and covered with scales and scale bases as on terga.—*Claws* with two rows of denticles. The length/width relation of glossa and paraglossa (compared to *Cloeon*) in combination with single gill lamellae refer this species to the genus *Procloeon* Bengtsson, 1914.

Procloeon regularum sp.n. is the only record of the genus in the Oriental Region (see introduction).

The 12 nymphs of *P. regularum* sp.n. were collected at 10 different sites between 30 m and 1300 m above sea level (Fig. 27). It appears that the altitudinal distribution of this species is of a wide range.

Holotype: female nymph on slide preparation: Ceylon, Campden Hill Dola, Deniyaya, (FC 5a), 11.11.1970, leg. Starmühlner. *Paratypes*: 1 slide preparation of a nymph, 8 nymphs in alcohol (for localities see Fig. 27).

Etymology: adj., from *regularis*, L., meaning according to rule.

Key to the nymphs of Baetidae from Sri Lanka

1. Maxillary palpus three-segmented (Fig. 8c, 9d); femur with a dense row of long fine bristles near base, same kind of fine bristles in an apical transversal row on tarsus, and along outer margin near base of tarsus (Fig. 8g, 9f); claw elongate and narrow, with two rows of denticles (Fig. 8h, 9g); hind wing pads lacking (Fig. 8d, 9h) 2
- Maxillary palpus two-segmented (Fig. 1d, 2d, 4d, 5g, 6g, 7c); femur, tibia, and tarsus without rows of long fine bristles; claws shorter, with only one row of denticles; hind wing pads either lacking (Fig. 5f), heavily reduced (Fig. 7k), or well developed (Fig. 1f, 2f, 3b, 4f, 6f) *Baetis*, 3
2. Abdominal gills single (Fig. 9j-k); outer apical edge of 3rd segment of labial palpus not extremely developed, inner margin bulging inwardly somewhat in the middle; terga as in Fig. 26 *Procloeon regularum*
- Abdominal gills double (Fig. 8j-m); outer apical edge of 3rd segment of labial palpus well developed and inner margin S-shaped (Fig. 8b); terga as in Fig. 25 *Cloeon bimaculatum?* Eaton
3. Median lobe of 2nd segment of labial palpus greatly enlarged (Fig. 5b, 6b, 7b) . 4
- Median lobe of 2nd segment of labial palpus of normal size, not greatly enlarged (Fig. 1b, 2b, 3a, 4b) 6
4. Labrum with a dense submarginal row of clavate bristles (Fig. 5a); frontal margin of 2nd segment of labial palpus concave (Fig. 5b); hind wing pads lacking (Fig. 5f) *B. geminatus*
- Submarginal bristles on labrum pointed, not in a dense row (Fig. 6a, 7a); frontal margin of 2nd segment of labial palpus not concave; (Fig. 6a, 7a); hind wing pads well developed (Fig. 6f) or greatly reduced (Fig. 7k) 5
5. Basal segment of antenna with outer apical lobe (Fig. 6d); maxillary palpus with distinct subapical indentation at inner margin of 2nd segment (Fig. 6g); hind wing pads well developed (Fig. 6f), scale bases on posterior margin of terga triangular, pointed (Fig. 23) *B. pulchellus*
- Basal segment of antenna without outer apical lobe (Fig. 7f); indentation at inner apical margin of 2nd segment of maxillary palpus weak to absent (Fig. 7c); hind wing pads greatly reduced (Fig. 7k); scale bases on posterior margin of terga rounded (Fig. 24) *B. ordinatus*
6. 3rd segment of labial palpus longer than wide, inner apical lobe on 2nd segment absent or very slightly developed (Fig. 4b); outer group of canines fused in one blade (Fig. 4e); posterior margin of terga without spines (Fig. 21) *B. collinus*
- 3rd segment of labial palpus of about same length as width, inner apical lobe of 2nd segment small, but clearly developed (Fig. 1b, 2b, 3b); posterior margin of terga with spines (Fig. 18, 19, 20) 7
7. 3rd segment of labial palpus conically shaped (Fig. 1b); right mandible with outermost tooth set back (Fig. 1e); outer margin of tibia and tarsus with a

- number of short bristles that appear apically split (but are actually rounded apically) (Fig. 1g) *B. frequentus*
- 3rd segment of labial palpus not conical, more or less rounded apically (Fig. 2b, 3a); right mandible with outermost tooth not set back (Fig. 2e); bristles on outer margin of tibia and tarsus pointed 8
8. 3rd segment of labial palpus rounded at inner margin (Fig. 2b); abdominal gills pigmented above a median longitudinal line, scales and scale bases present only in the pigmented half and along hind margin (Fig. 2j); spines on posterior margin of terga pointed and elongate (Fig. 19) *B. acceptus*
- 3rd segment of labial palpus rather straight at inner margin (Fig. 3a); no pigmented area on abdominal gills, scales and scale bases over entire gill surface (Fig. 3c); spines on posterior margin of terga pointed, short, rather triangular (Fig. 20) *B. conservatus*

DISCUSSION

The nymphs of nine species of the family Baetidae from Sri Lanka are described. Out of the seven *Baetis* species four species are not included in any known species group, and no close relatives are known from other parts of the Oriental Region previously treated by one of us (Sunda Island, Philippines, West Malaysia, Müller-Liebenau 1981, 1982a, 1984). Otherwise three of the seven *Baetis* species show close relationships to species from the Philippines and from West Malaysia, and based on their morphological characters all three can be included in the Oriental *molawinensis* species-group (which has many morphological characteristics in common with the European *atrebatinus* species-group and the North American *propinquus* species-group; Müller-Liebenau 1984). These three species from Sri Lanka are *B. geminatus* sp.n., *B. pulchellus* sp.n., and *B. ordinatus* sp.n.

Recent comparative studies on baetid nymphal material from the Sunda Islands, the Philippines, and Malaysia (Müller-Liebenau 1981, 1982a 1984) and from Sri Lanka (this paper) have revealed that a considerable number of all *Baetis* species studied are clearly associated with the *molawinensis* species-group. These include: three of seven species from the Sunda Islands (only male and female imago are known); two of four species from the Philippines; six of thirteen species from Malaysia; and three of seven species from Sri Lanka. Further, one of two species from the Bismark Archipelago (Demoulin 1969), and one species from Madagascar (Demoulin 1968) belong to the same species group. Altogether, 15 out of 32 species (47%) known from the Oriental Region (*sensu lato*), when including the Bismark Archipelago and Madagascar, belong to that group. In contrast, of about 35 European *Baetis* species, only 4 belong to the European *atrebatinus* group (11.4%). Only five out of about 42 *Baetis* species (11.9%) are currently known to belong to the North American *propinquus* group (Moriyama and McCafferty 1979). Thus it is conceivable that the Oriental Region could be a kind of "cradle" for *Baetis* species of the *molawinensis*—*atrebatinus*—*propinquus* complex and that the spread of the members of these species groups has taken place by adaptive radiation during the historical evolution of the continents. The comparative situation on the African Continent and in South America is not yet known but future study will certainly reveal interesting additional information on the evolution and dispersion of this species complex.

Within the Oriental *molawinensis* species-group four species have the internal median lobe of the second segment of the labial palpus with the outer margin concave (Fig. 5b). This appears to be a character of substantial taxonomic value, and in combination with additional morphological characters it easily distinguishes the species from the rest of this species group complex. We therefore propose to include these four species in the

sumigarensis subgroup (named after *B. sumigarensis* Müller-Liebenau, 1982, from the Philippines) within the *molawinensis* species-group. These four species are *B. sumigarensis* (Philippines), *B. diffundus* from West Malaysia (Müller-Liebenau 1984), *B. geminatus* sp.n. from Sri Lanka (treated in this paper), and *Baetis* sp. from Madagascar (Demoulin 1968). With increasing knowledge resulting from further study, the establishment of another subgroup is possible, including *B. moriharai* and *B. numeratus* from Malaysia, and *B. ordinatus* sp.n. from Sri Lanka, based on the scales and scale bases on the surface of the terga and the spines on the posterior margins of the terga which are broad at the base and apically rounded (Fig. 24).

In Table 1 we list the *Baetis* species from the Oriental Region, the Bismarck Archipelago, and Madagascar along with the species group with which each is associated.

BIOLOGY AND ECOLOGY

A detailed description of all their collecting sites in Sri Lanka was given by Costa and Starmühlner (1972). Six different Regions were investigated by them for Ephemeroptera. These Regions with their collecting site numbers are:

1. Region of Deniyaya (Sinharaja Forest)	
1.1 Tributaries of the Gin Ganga	Nr. 1-6
1.2 Tributaries of the Nilwala Ganga	7-8
2. Region of Ratnapura	
2.1 Kalu Gana and tributaries	9-15
3. Region of Maskeliya	
3.1 Tributaries of the Maskeliya barrage	16-20 & 23
4. Region of Nuwara Eliya	
4.1 Hakgala Dola and Nuwara Eliya Dola	21-22
5. Region of Belihuloya-Buttala	
5.1 Tributaries of the Wallawe Ganga	24-26
5.2 Tributaries of the Menik Ganga	27
5.3 Tributaries of the Kirindi Ganga	28-29
5.4 We Ganga (tributary of the Kalu Ganga)	30
6. Region of Kitulgala	
6.1 Kelani Ganga and tributaries	34-38

Figure 27 shows the distribution of the baetid mayflies treated in this paper. The numbers in the head line represent the elevation above sea level and the site numbers where the nymphs were collected. See the paper by Costa and Starmühlner (1972) for a comprehensive discussion of the sites.

Not enough material is available for a detailed discussion of the distribution of the described species in relation to the altitude, water temperature and chemistry, and so forth, and Fig. 27 can only give preliminary information based on the first study of baetid nymphs from Sri Lanka. However, a discussion of the general ecology of the Sri Lankan Ephemeroptera can be found in a paper by Hubbard and Peters (1984).

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TABLE 1. *Baetis* SPECIES FROM THE ORIENTAL REGION, BISMARCK ARCHIPELAGO, AND MADAGASCAR, SHOWING ASSOCIATED SPECIES-GROUPS.

SUNDA ISLANDS (Müller-Liebenau 1981)			
<i>novatus</i>	nymph	Java	no species-group
<i>javanicus</i>	nymph, ♂, ♀	Java, Sumatra	no species-group
<i>sumatrana</i>	♂	Sumatra	no species-group
<i>olivascens</i>	♂	Java	no species-group
<i>fulmeki</i>	♂, ♀	Sumatra	Oriental <i>molawinensis</i> gr.
<i>ulmeri</i>	♂	Centr. Sumatra	Oriental <i>molawinensis</i> gr.
<i>necopinatus</i>	♂	Centr. Sumatra	Oriental <i>molawinensis</i> gr.
PHILIPPINES (Müller-Liebenau 1982b)			
<i>luzonensis</i>	nymph		no species-group
<i>realonae</i>	nymph		no species-group
<i>molawinensis</i>	nymph		Oriental <i>molawinensis</i> gr.
<i>sumigarensis</i>	nymph		<i>sumigarensis</i> subgroup within the Oriental <i>molawinensis</i> group
W. MALAYSIA (Müller-Liebenau 1984)			
<i>illiesi</i>	nymph		European <i>rhodani</i> group
<i>minutus</i>	nymph		European <i>niger</i> group
<i>laetificus</i>	nymph		European <i>muticus</i> group
<i>mirabilis</i>	nymph		European <i>gracilis</i> group
<i>gombaki</i>	nymph		European <i>gracilis</i> group
<i>diffundus</i>	nymph		<i>sumigarensis</i> subgroup within the Oriental <i>molawinensis</i> group
<i>difficilis</i>	nymph		Oriental <i>molawinensis</i> group
<i>operosus</i>	nymph		Oriental <i>molawinensis</i> group
<i>maltus</i>	nymph		Oriental <i>molawinensis</i> group
<i>moriharai</i>	nymph		Oriental <i>molawinensis</i> group
<i>numeratus</i>	nymph		Oriental <i>molawinensis</i> group
<i>idei</i>	nymph		no species-group
<i>lepidus</i>	nymph		no species-group
SRI LANKA			
<i>frequentus</i>	nymph		no species-group
<i>acceptus</i>	nymph		no species-group
<i>conservatus</i>	nymph		no species-group
<i>collinus</i>	nymph		no species-group
<i>geminatus</i>	nymph		<i>sumigarensis</i> subgroup within the Oriental <i>molawinensis</i> group
<i>pulchellus</i>	nymph		Oriental <i>molawinensis</i> group
<i>ordinatus</i>	nymph		Oriental <i>molawinensis</i> group
BISMARCK ARCHIPELAGO (Demoulin 1969)			
<i>Baetis</i> sp. 1	nymph		no species group
<i>Baetis</i> sp. 2	nymph		Oriental <i>molawinensis</i> group
MADAGASCAR (Demoulin 1968)			
<i>Baetis</i> sp.	nymph		<i>sumigarensis</i> subgroup within the Oriental <i>molawinensis</i> group

Fig. 27. Collecting sites

<i>m</i> above sea level	1000	700	700	700	700	600	500	500	250	30	80	800	100	1300	1850	1500	1500	1200	1200	700	700	150	200	80	625	60
No. FC	1	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	23	25	26	27	28	34	36	37
1. <i>B. frequentus</i> sp.n.	+		+	+	+	+	+	+	+	+	+		+	+			+	+	+	+	+	+		+	+	
2. <i>B. acceptus</i> sp.n.		+										+						+			+					
3. <i>B. conservatus</i> sp.n.																+										
4. <i>B. collinus</i> sp.n.														+	+											
5. <i>B. geminatus</i> sp.n.		+				+							+	+					+		+	+				
6. <i>B. pulchellus</i> sp.n.						+				+			+						+			+				+
7. <i>B. ordinatus</i> sp.n.				+		+					+															
8. <i>Cloeon</i> <i>? bimaculatum</i> sp.n.																										+
9. <i>Procloeon regularum</i> sp.n.		+	+	+					+	+		+		+						+		+	+			

Fig. 27. Distribution of the baetid mayflies of Sri Lanka treated in this paper. The numbers in the head line denote the elevation above sea level and the collecting sites.

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