

## Systematics of the Caenidae (Ephemeroptera) in Korea

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**ABSTRACT** Four caenid mayflies, *Caenis moe* n. sp., *Caenis tuba* n. sp., *Caenis nishinoae* Malzacher, and *Brachycercus tubulatus* Tshernova are described from Korea. Larval habitus, line drawings, SEM photographs, and a larval key are provided.

**Key words :** *Caenis*, *Brachycercus*, Caenidae, Ephemeroptera, Systematics, Korea

The pannote mayfly family Caenidae is widely distributed throughout the world, being absent only from New Zealand and most oceanic islands. At present, the family includes 15 genera (Malzacher, 1997) and about 50 species. They are common mayflies in a variety of lentic and lotic habitats, but have not been well known in East Asia because of small body size (3~5 mm in most) (Bae, 1997).

The larvae of Caenidae are similar to those of Neophemeridae (see Bae and McCafferty, 1998), but hindwingpads are absent. The gills present on the abdominal segment II-VI, where gills I are filiform, gills II are subquadrate, operculate, dorsally with Y-shaped ridge, overlapping at midline, and covering the gills III-VI, which are lamellate and marginally fringed. Caudal filaments are three. The adults are generally pale yellow and have a relatively robust thorax and small abdomen. The vein MA<sub>2</sub> of forewings is attached to MA<sub>1</sub> at more or less right angles by a crossvein, and the vein MP<sub>2</sub> is almost as long as MP<sub>1</sub>. Hindwings are absent. The male genitalia is atrophied and the forceps are one-segmented. Caudal filaments are three. Female adults are almost identical to male adults.

In East Asia, 12 species of *Caenis* and five species of *Brachycercus* were known from Russian Far East (Kluge, 1987, 1991, 1997); eight species of *Caenis* were recorded from Taiwan (Kang and Yang, 1994, 1996); *Brachycercus japonicus* Gose, *Caenis nishinoae* Malzacher, and two undetermined species of *Caenis* were known from Japan (Gose, 1985; Malzacher, 1996); and only two undetermined species, *Caenis* KUa and *Brachycercus* KUa,

were known from Korea (Yoon and Bae, 1988). Larvae and Adults of *Caenis* were reported from North Korea (Bae and Soldan, 1997; Bae and Andrikovics, 1997), but has not been identified to species.

The purpose of this study is to review and describe the species of Caenidae based on larval and adult materials collected from Korea and deposited at Seoul Women's University (SWU). Reference materials from Japan and Russian Far East were also examined.

### SYSTEMATICS

#### Genus *Caenis* Stephens 등딱지하루살이속

**Diagnosis: Larva.** Body size is small (2.8~7.0 mm). Head is lacking tubercles. The shape of thorax is robust. Legs are relatively short and stout. Claws are small, slender, and have 2~5 minute ventral denticles. Abdominal tergum II possesses variously produced posteromedian projection. Dorsal surface of operculate gills possess minute tubercles. Three caudal filaments are relatively short. **Adult.** Male and female adults are very similar in shape and coloration. The second segments of antenna are not more than twice the length of the basal segment. The posterior margin of head is almost straight. Pronotum is excavated posteriorly in the median area. Prosternum is relatively narrow. The foretibiae of male are about twice the length of forefemora. Abdomen is pale yellowish.

*Caenis moe* n. sp. 뽕등딱지하루살이 (Figs. 1, 5, 6 and 11)

**Larva: Dimensions** (mm). Body length 3.6~4.2;

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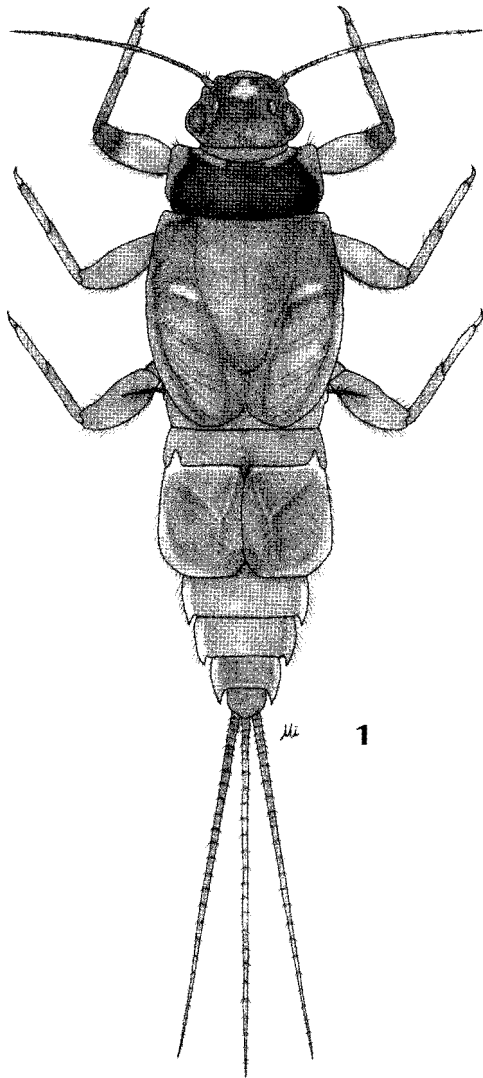


Fig. 1. *Caenis moe*, larval habitus.

antennae 0.7~1.2; forefemora, foretibiae, and foretarsi 0.45, 0.35, and 0.27; midfemora, midtibiae, and midtarsi 0.50, 0.30, and 0.30; hindfemora, hindtibiae, and hindtarsi 0.65, 0.40, and 0.35; cerci 1.8~2.6. **Coloration.** General body color dark brown. **Head.** Vertex with dark reticulations. Antennae pale. Maxillary palp 3-segmented; segment III setaceous, apically pointed, and ca. 1.33 × length of segment II. Labial palp setaceous and 3-segmented. **Thorax.** Notae and wingpads with dense porous microtrichia as in Fig. 11. Pronotum lateral margins round and pale; anterolateral margins poorly developed (Fig. 1). Legs ground color pale with dark band on apical femora and basal tibiae. Femora outer margin with a row of sparse hairlike setae. Forefemora with transverse row of stout setae dorsoapically (Fig. 1). Tarsi inner mar-

gin with a row of sparse stout setae. Claws light brown, ca. 0.5 × length of tarsi, with 2~3 minute denticles basally. **Abdomen.** Terga I, II, VII, and VIII brown; tergum IX and X dark brown. Posterior margin of tergum VII and VIII with long setae; posterior margin of tergum IX with denticles. Posteromedian projection of abdominal tergum II strongly developed (Fig. 1). Operculate gills brown, with distinct Y-shaped ridge and marginal hairlike setae; dorsal surface with dense tubercles and dense porous microtrichia (Figs. 5 and 11), with long hairlike setae along inner and posterior arms of Y-shaped ridge; ventral surface with two rows of microtrichia (Fig. 6). Caudal filaments pale, with whorls of short stout setae, with few lateral setae.

**Adult:** Unknown.

**Diagnosis.** Larva of *Caenis moe* can be distinguished from other species of the genus by the combination of the following characters: dark body color, small body size, poorly developed anterolateral projection of pronotum (Fig. 1), strongly developed posteromedian projection of abdominal tergum II (Fig. 1), dense porous microtrichia on operculate gills (>400 ×) (Fig. 11), and poorly developed lateral setae on caudal filaments.

**Type material: Holotype.** Mature larva (BAE-345, in alcohol, right operculate gills on SEM stage with gold coat): Korea, Cheju-do, Soguiipo, Kangjongchon (Cr.) at 1st Kangjonggyo (Br.), 1996-V-26, Y.J. Bae, deposited at SWU. **Paratypes.** 2L (BAE-346, in alcohol): same locality and data as holotype.

**Other materials examined:** 1L: CLN, Kurye, Hwaomsa at stream near 1st camping site, 1983-V-30, Y.J. Bae.

**Etymology:** The trivial name "moe" is an old Korean word, meaning "mountain," which alludes to its habitat distribution.

**Distribution:** Korea.

**Remarks:** Larvae of *Caenis moe* were found from mid-sized mountain streams (5~20 m) where the water was relatively clean, the current was relatively slow, and the substrate was consist of pebbles, cobble, boulders, and abundant attached algae.

***Caenis tuba* n. sp.** 나팔등딱지하루살이 (Figs. 2, 7, 8 and 12)

**Larva: Dimensions** (mm). Body length 2.8~3.8; antennae 0.9; forefemora, foretibiae, and foretarsi 0.40, 0.25, and 0.20; midfemora, midtibiae, and midtarsi 0.55, 0.30, and 0.25; hindfemora, hindti-

biae, and hindtarsi 0.60, 0.35, and 0.25; cerci 1.2~2.2. **Coloration.** General body color yellowish brown. **Head.** Antennae pale. Maxillary palp 3-segmented; segment III setaceous, apically pointed, and ca.  $2.0 \times$  length of segment II. Labial palp setaceous and 3-segmented. **Thorax.** Notum and wingpads with sparse trumpet-like microtrichia (Fig. 12). Pronotum brown with irregular light markings; lateral margins round and pale; anterolateral margins poorly developed (Fig. 2). Legs light brown. Femora outer margin with a row of sparse hairlike setae. Forefemora with transverse row of stout setae dorsoapically (Fig. 2). Tarsi inner margin with a row of sparse stout setae. Claws with 4~5 minute denticles basally. **Abdomen.** Tergum I-VI light brown; tergum VII-X brown. Posterior margin of tergum VII and VIII with long setae; posterior margin of tergum IX with denticles. Posteromedian projection of abdominal tergum II moderately developed (Fig. 2). Operculate gills light brown, with distinct Y-shaped ridge and marginal hairlike setae; dorsal surface with dense tubercles and sparse trumpet-like microtrichia (Fig. 7), with long hairlike setae along inner and posterior arms of Y-shaped ridge; ventral surface with one rows of microtrichia (Fig. 8). Caudal filaments pale, with whorls of short stout setae and lateral hairlike setae.

**Adult:** Unknown.

**Diagnosis.** Larva of *Caenis tuba* can be distinguished from other species of the genus by the combination of the following characters: light body color, tiny body size, poorly developed anterolateral projection of pronotum (Fig. 2), moderately developed posteromedian projection of abdominal tergum II (Fig. 2), sparse trumpet-like microtrichia on operculate gills ( $>400 \times$ ) (Fig. 12), and well developed lateral setae on caudal filaments.

**Type material: Holotype.** Mature larva (BAE-347, in alcohol): Korea, Kyonggi-do, Namyangju, Kwangnung, 1983-VII-26, Y.J. Bae, deposited at SWU. **Paratypes.** 15L (BAE-348, in alcohol): same locality and data as holotype.

**Other materials examined:** 1L: KG, Kapyong, Kapyongchon at Mokdong, 1994-V-1, Y.J. Bae; 1L: KG, Yaju, Namhangang (R.), 1972-VI-17; 33L: CCB, Tanyang, Osangchon, Ogokchon, 1993-VII-26, Y.J. Bae; 8L: CCN, Taejon, Kapchon at Koigogyo, 1995-V-27, Y.J. Bae; 4L: CLB, Moaksan (Mt.), Kumsansa, 1992-V-23, Y.J. Bae; 1L: CLN, Haenam, Turyunsan, 1993-VI-21, Y.J. Bae.

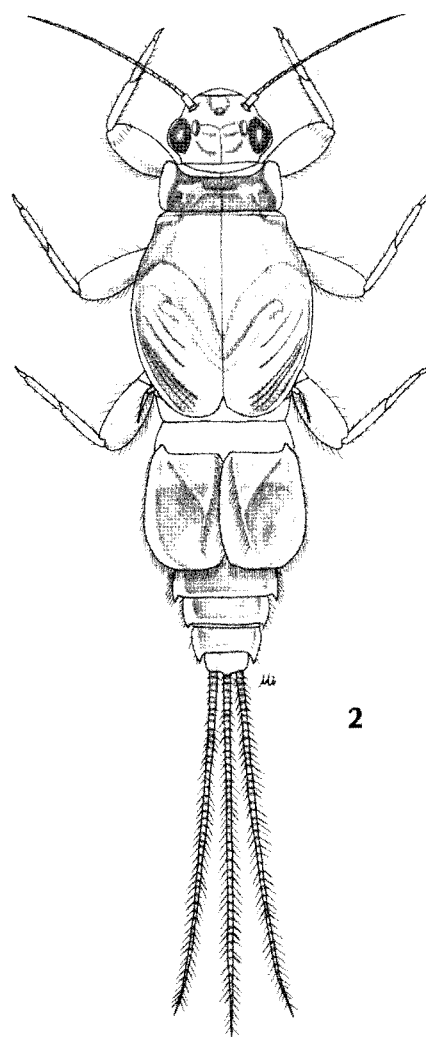


Fig. 2. *Caenis tuba*, larval habitus.

**Etymology:** The trivial name "tuba" is a Latin word alluding to the trumpet-like microtrichia on the dorsal body.

**Distribution:** Korea.

**Remarks:** Larvae of *Caenis tuba* were found from mid to lower reaches of streams or large rivers where the water temperature was relatively high and the water was more less polluted with organic pollutants.

***Caenis nishinoae* Malzacher** 등딱지하루살이 (Figs. 3, 9 and 10)

*Caenis nishinoae* Malzacher, 1996: 1.

*Caenis* nb: Imanishi, 1940: 212. NEW SYNONYM.

*Caenis* KUa: Yoon and Bae, 1988: 183; Bae and Soldán, 1997: 146. NEW SYNONYM.

**Larva: Dimensions** (mm). Body length 3.5~5.0;

cerci 2.0~3.5. **Coloration.** General body color light brown with brown markings. **Head.** Vertex yellowish brown, with dark markings between compound eyes. Antennae pale. **Thorax.** Pronotum mottled with brown markings; lateral margins straight and pale; anterolateral margins well developed (Fig. 3). Notum and wingpads with apically round stout setae. Legs ground color pale. Femora outer margin with a row of sparse hairlike setae. Forefemora with transverse row of stout setae dorsoapically. Tarsi inner margin with two rows of dense setae. Claws light brown, with 2~3 minute denticles basally. **Abdomen.** Terga I-X brown. Posterior margin of tergum VII with long setae; posterior margin of tergum VIII with setae and denticles; posterior margin of tergum IX with denticles. Posteromedian projection of abdominal tergum II weakly developed (Fig. 3). Operculate gills brown, with distinct Y-shaped ridge and marginal hairlike setae; dorsal surface with dense tubercles and dense apically round stout setae (Fig. 9), with long hairlike setae along inner and posterior arms of Y-shaped ridge; ventral surface with one row of microtrichia (Fig. 10). Caudal filaments pale, with whorls of short stout setae and lateral hairlike setae.

**Adult:** See Malzacher (1996).

**Diagnosis.** Larva of *Caenis nishinoae* can be distinguished from other species of the genus by the combination of the following characters: light body color, small body size, well developed anterolateral projection of pronotum (Fig. 3), moderately developed posteromedian projection of abdominal tergum II (Fig. 3), possessing dense apically round stout setae and lacking porous or trumpet-shaped microtrichia on operculate gills ( $>400\times$ ) (Fig. 9), and well developed lateral setae on caudal filaments.

**Materials examined:** 1L: SL, Kwangjin-gu, Ttuksom, Hangang at Chamsildaegyo, 1997-X-5; 5L: KG, Namyangju, Wangsukchon at Tonong, 1997-X-30 and 1998-I-14; 2L: KG, Namyangju, Hangang at Paldang, 1997-X-5; 6L: KG, Chongpyong, Chojongchon, 1983-VI-12, 1993-VIII-4, 1994-VIII-21; 2L: KN, Hamyang, Yurim-myon, Suju-ri, 1997-V-13; 1L: CLB, Chinan-gun, Yonggwang-ri, 1997-X-15.

**Distribution:** Japan, Korea, Northeastern China.

**Remarks:** This is widespread caenid species in Korea previously known as *Caenis* KUa. We also

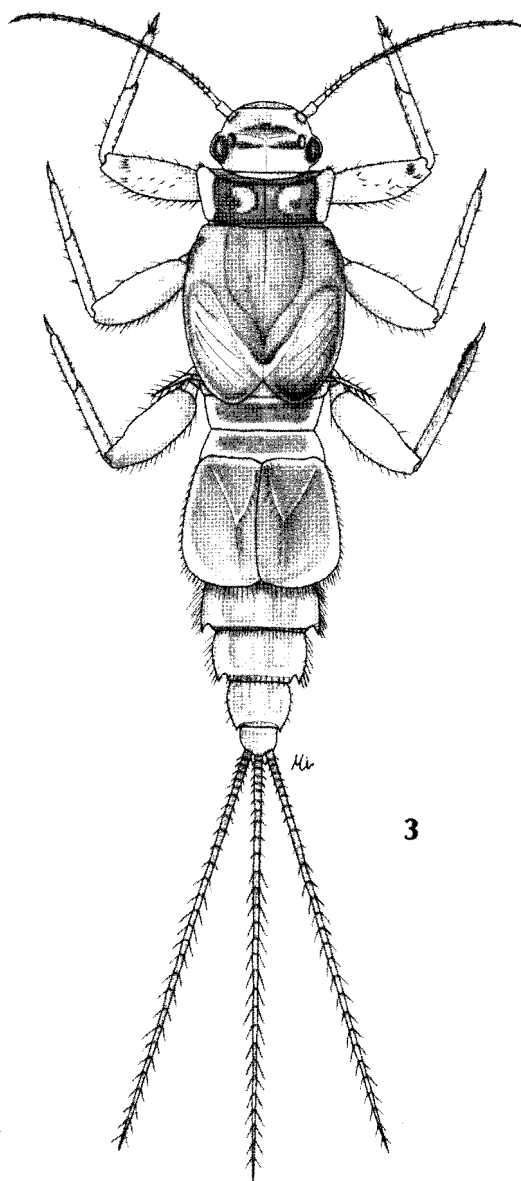


Fig. 3. *Caenis nishinoae*, larval habitus.

synonymized Imanishi's (1940) *Caenis* nb, known from Liaodong peninsula in Northeastern China, with *C. nishinoae* based on close examinations of the description and distribution. We examined larval materials from Senyang, Northeastern China, which were identified as *C. nishinoae*. Larvae of *C. nishinoae* were found from diverse habitats, mid to lower reaches of streams or large rivers, sometimes from the urbanized streams.

**Genus *Brachycercus* Curtis** 세뿔등딱지하루살이속

**Diagnosis: Larva.** Body is somewhat broad and flattened. Head possesses three ocellar tubercles. Legs are relatively long and slender. Claws are

long, slender, and lacking ventral denticles. **Adult.** Thorax is relatively broad. The second segments of antenna are elongated, longer than the basal segment. The veins  $R_4$  and  $R_5$  diverge relatively close to the base; veins  $M_1$  and  $M_2$  and the median intercalary vein all arise at the wing base; forewings possess relatively few crossveins. The base of male genital forceps bear a pair of accessory lateral projections. The caudal filaments of male are much longer than those of female.

***Brachycercus tubulatus* Tshernova (Fig. 4)**

세뿔등딱지하루살이

*Brachycercus tubulatus* Tshernova, 1952: 285  
Kluge, 1991: 19.

*Brachycercus* KUa: Yoon and Bae, 1988: 184.  
NEW SYNONYM.

**Larva: Dimensions** (mm). Body length 5.2; antennae 1.3; forefemora, foretibiae, and foretarsi 0.50, 0.35, and 0.30; midfemora, midtibiae, and midtarsi 1.00, 0.60, and 0.70; hindfemora, hindtibiae, and hindtarsi 1.20, 0.55, and 0.75; cerci broken. **Coloration.** Body color light brown. **Head.** Head with three well developed ocellar tubercles (Fig. 4). Antennae segment I and II enlarged; segment II ca.  $2.5 \times$  length of segment I. Maxillary palp 2-segmented; segments II relatively long and slender. Labial palp 2-segmented; segments II stout. **Thorax.** Thorax relatively broad. Legs relatively long and slender, with sparse hairlike setae marginally (Fig. 4). Forelegs shorter than midlegs and hindlegs. Forefemora ca.  $0.5 \times$  length of midfemora and hindfemora. Foreclaws ca.  $0.7 \times$  length of midclaws and hindclaws. **Abdomen.** Posterolateral margins of abdominal segment III-VI strongly developed; posterolateral margins of abdominal segment VII-IX moderately developed and curved inward. Caudal filaments with whorls of short stout setae and lateral hairlike setae.

**Adult:** Unknown.

**Diagnosis.** Larva of *Brachycercus tubulatus* can be distinguished from other species of the Caenidae of Korea by the combination of the following characters: well developed ocellar tubercles, enlarged antennal segment II, 2-segmented maxillary palp and labial palp, and relatively long and slender legs (Fig. 4).

**Materials examined:** IL: SL, Kwangjin-gu, Hangang (R.) at Ttuksom, 1981-X-3, J.U. Byun; 1L: South Korea (locality and date missing).

**Distribution:** Far East Russia, Korea.

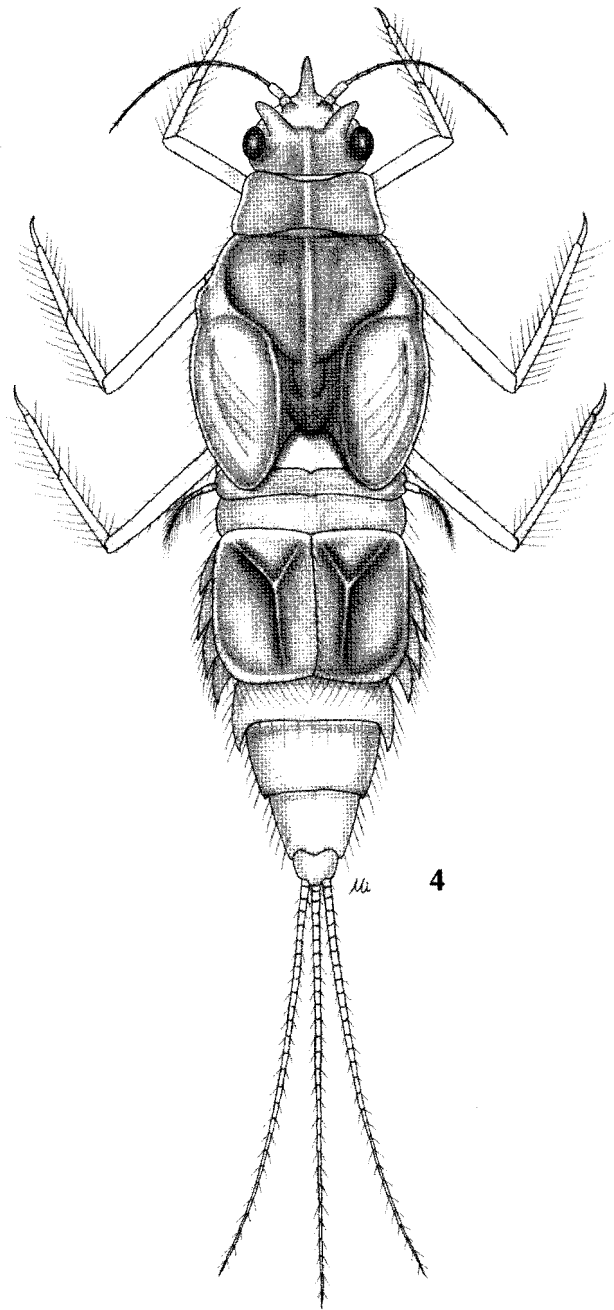


Fig. 4. *Brachycercus tubulatus*, larval habitus.

**Remarks:** Larvae of *B. tubulatus* were found from margins of large rivers where the current was relatively slow and the substrate was consist of sand and embedded stones.

**Larval key to the genera and species of the Caenidae in Korea**

1. Head with three ocellar tubercles (Fig. 4).  
..... Genus *Brachycercus* (세뿔등딱지하루살이속)

- ..... *Brachycercus tubulatus* (세뿔등딱지하루살이)  
 - Head without ocellar tubercles (Figs. 1-3).  
 ..... Genus *Caenis* (등딱지하루살이속) ..... 2  
 2. Body color dark brown. Abdominal tergum II with strongly developed posteromedian projection (Fig. 1). ..... *Caenis moe* (외등딱지하루살이)  
 - Body light brown. Abdominal tergum II with weakly to moderately developed posteromedian projection (Figs. 2 and 3). ..... 3  
 3. Pronotum with well developed anterolateral projections; lateral margins straight (Fig. 3). Dorsal operculate gills covered with apically blunt stout setae (Fig. 9) (This character can be seen under light microscope  $>400\times$ ). Body size small (3.5 ~ 5.0 mm). ..... *Caenis nishinoae* (등딱지하루살이)  
 - Pronotum with poorly developed anterolateral projections (Fig. 2); lateral margins round (Fig. 2). Dorsal operculate gills without apically blunt stout setae, with trumpet-shaped microtrichia (Figs. 7 and 12) (This character can be seen under light microscope  $>400\times$ ). Body size tiny (2.8 ~ 3.8 mm). ..... *Caenis tuba* (나팔등딱지하루살이)

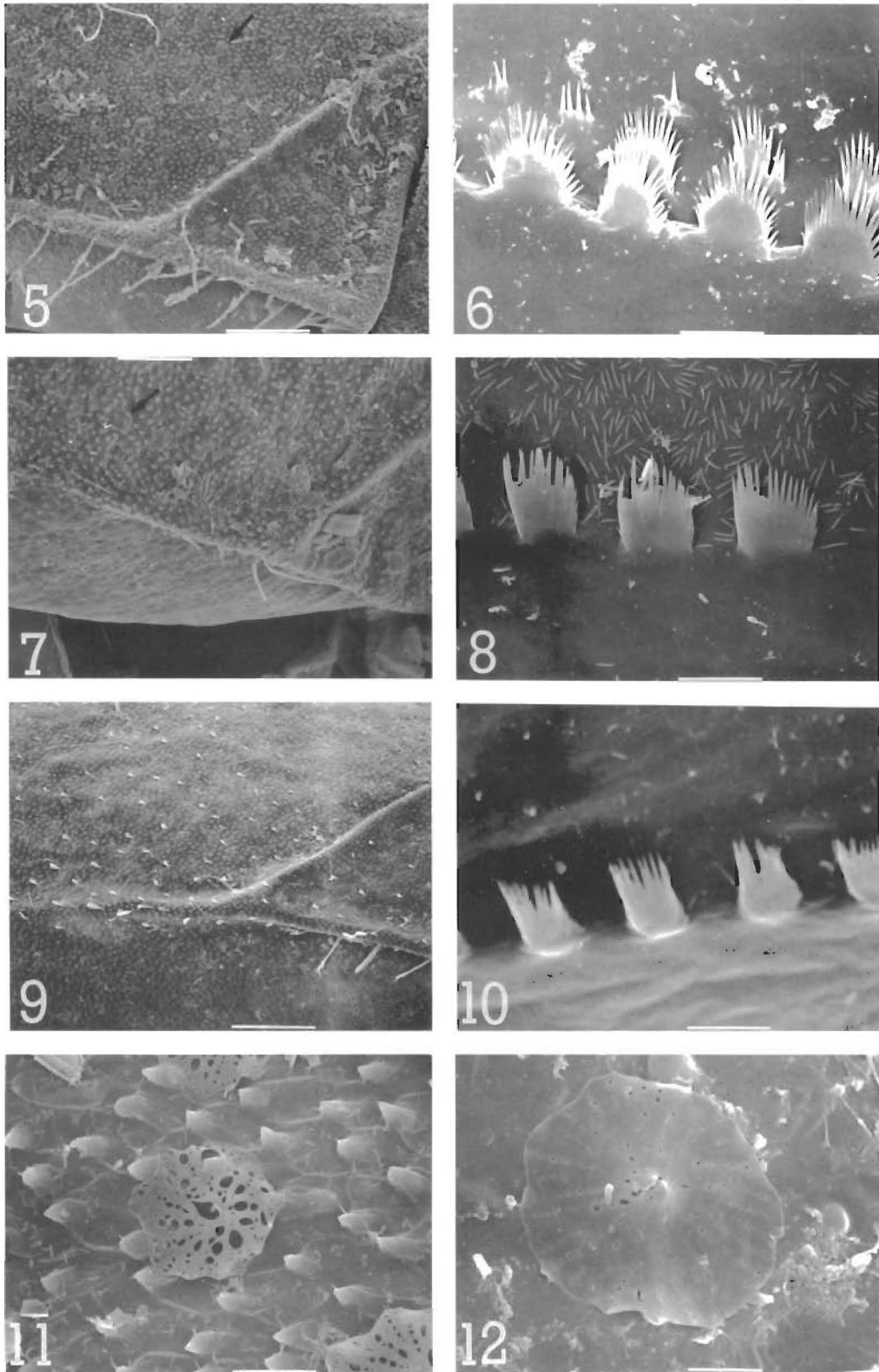
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**Figs. 5-12.** SEMs of larval parts: (5) *Caenis moe*, dorsal operculate gill (bar = 100  $\mu\text{m}$ , arrow indicates porous microtrichia), (6) *C. moe*, microtrichial row on ventral operculate gill (bar = 10  $\mu\text{m}$ ), (7) *C. tuba*, dorsal operculate gill (bar = 50  $\mu\text{m}$ , arrow indicates trumpet-shaped microtrichia), (8) *C. tuba*, microtrichial row on ventral operculate gill (bar = 10  $\mu\text{m}$ ), (9) *C. nishinoae*, dorsal operculate gill (bar = 100  $\mu\text{m}$ ), (10) *C. nishinoae*, microtrichial row on ventral operculate gill (bar = 10  $\mu\text{m}$ ), (11) *C. moe*, microtrichia on dorsal operculate gill (bar = 10  $\mu\text{m}$ ), and (12) *C. tuba*, trumpet-shaped microtrichia on wingpads (bar = 5  $\mu\text{m}$ ).