

ORIGINAL ARTICLE

# First record of *Baetis taiwanensis* Müller-Liebenau from Japan, with description of the imago and subimago (Ephemeroptera: Baetidae)

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## Abstract

*Baetis taiwanensis* is recorded from Japan, and its imagoes and subimagoes are described for the first time. We provide diagnostic characters which are useful to distinguish *B. taiwanensis* from an allied species, *Baetis sahoensis*, in imago, subimago and nymph. We reveal that the line drawings of *B. taiwanensis* and *Nigrobaetis tatuensis* were inadvertently interchanged in the original description.

**Key words:** *Baetis sahoensis*, diagnosis, new record, *Nigrobaetis tatuensis*.

## INTRODUCTION

To date, more than 200 species have been described in the genus *Baetis* throughout the world, excluding the polar regions, oceanic islands and New Zealand. In Japan, 33 species are currently known in the genus. Keys for imagoes of Japanese species were provided by Gose (1980a) and those for nymphs by Gose (1980b, 1985). Kobayashi (1987) provided keys for nymphs of 18 Japanese species, of which five were nominal and the remaining 13 were treated under alphabetical provisional names. Tanida (1991) showed photographs of 14 Japanese species, of which four were nominal and 10 had alphabetical provisional names.

*Baetis taiwanensis* was described as a nymph from Taiwan by Müller-Liebenau (1985). We collected its nymphs and reared them to imagoes and subimagoes in Japan. Nymphs of *B. taiwanensis* are quite similar to those of *Baetis sahoensis* Gose, 1980, and probably the two were confused due to their morphological similar-

ity. We found morphological characters which are useful to distinguish this species from *B. sahoensis* in imago, subimago and nymph.

Here we record *B. taiwanensis* from Japan and describe its imagoes and subimagoes for the first time. We also note that figures of *B. taiwanensis* were inadvertently interchanged with those of *Nigrobaetis tatuensis* (Müller-Liebenau, 1985) in the original description (Müller-Liebenau, 1985), and that these species were subsequently misidentified in Kang *et al.* (1994).

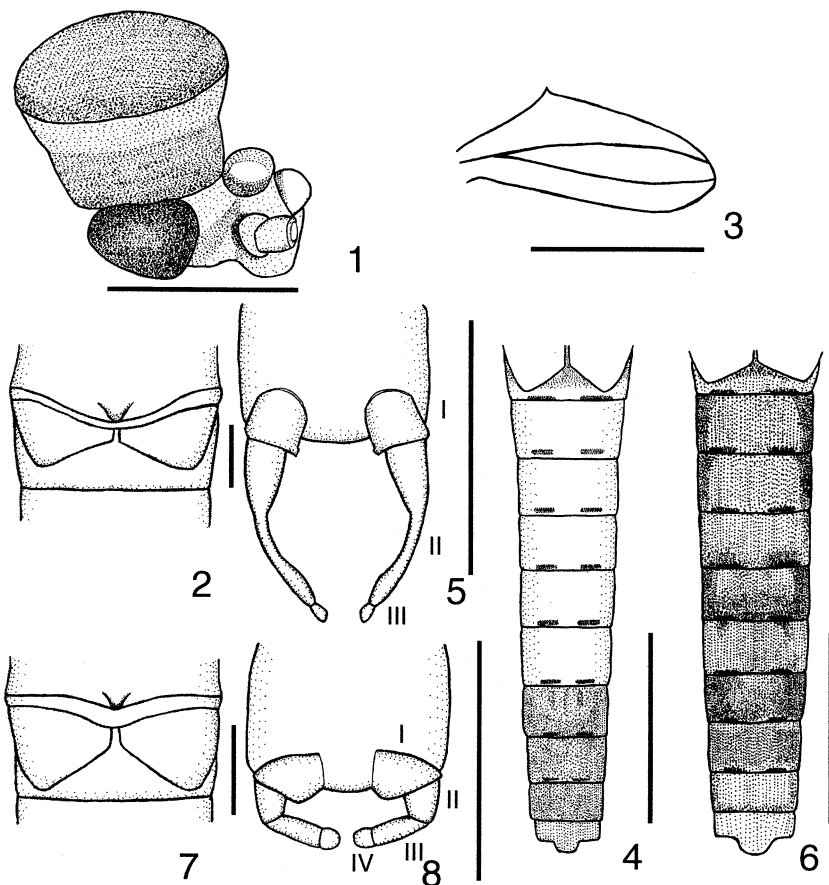
## MATERIALS AND METHODS

We reared imagoes and subimagoes from nymphs in the field following the method used by Müller-Liebenau (1969). Mature nymphs were put in plastic cups with pores. We set the cups in a float and covered the cup mouths with pieces of nylon stocking to obtain the imagoes and subimagoes. We also conducted light trapping to collect imagoes and subimagoes.

We followed Kluge (1994) for terminology of the imaginal thorax. We also adopted setal terminology of Morihara and McCafferty (1980) in regard to fine setae and robust setae. However, some setae are even finer than the former, and we termed them hairy setae. The length of head referred to the distance from the anterior

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Figures 1–8 Characters of the imago and subimago of *Baetis taiwanensis*. 1 Head, lateral view. 2,7 Metathorax, dorsal view. 3 Hind wing. 4,6 Abdomen, dorsal view. 5,8 Forceps, ventral view. 1–5 Male imago. 6 Female imago. 7,8 Male subimago. Scale lines: (1–3,5,7,8) 0.5 mm; (4,6) 1 mm.

end of the frons to the posterior end of the occipit, and the length of the turbinate eye to its maximum length in lateral view. The following abbreviations are applied to collecting methods: lt, light trapping; rm, rearing method.

Materials examined are deposited in the Entomological Laboratory, Graduate School of Agriculture and Biological Sciences and the Ecological Laboratory, College of Integrated Arts and Sciences, Osaka Prefecture University, Japan. We borrowed the specimens of *Baetis* species collected in Taiwan from the Department of Entomology, National Chung Hsing University, Taiwan.

## DESCRIPTION

### *Baetis taiwanensis* Müller-Liebenau

(Japanese name: Futamon-kokagerou.)

*Baetis taiwanensis* Müller-Liebenau 1985: 94 (fig. 2 as *B. tatuensis*).

*Baetis* (*Tatubaetis*) *tatuensis*: Kang *et al.* 1994: 23 (misidentification).

*Baetis tatuensis*: Waltz and McCafferty 1997: 137.

*Male imago*. Length: body 3.3–5.5 mm, forewing 3.4–6.3 mm, hindwing 0.4–1.1 mm, foreleg 2.4–5.1 mm, middle leg 1.4–2.2 mm, hindleg 1.3–2.2 mm, cercus up to 13.4 mm.

Head brown; antenna pale brown; turbinate eye orange; lower eye dark gray; ocellus white, base dark brown. Anterior margin of head straight in lateral view (Fig. 1). Length of turbinate eye 1.0- to 1.2-fold that of head.

Thorax brown, posterior scutal protuberance dark brown; fore wing hyaline, Sc and R brown at base; hindwing hyaline; leg pale brown except for brown coxa. Metathorax with weak projection (Fig. 2). Hindwing with two simple longitudinal veins (Fig. 3).

Abdominal terga I, VII and VIII brown, II–VI semi-hyaline, white, IX and X pale brown, I–VII or I–VIII with a pair of brown spots near posterior margins (Fig. 4); abdominal sterna semi-hyaline, white; cercus white. Forceps three-segmented; total length 1.3- to 1.8-fold width of abdominal segment IX; segment I with a

weak projection at posterior end of inner margin; segment II tapering in anterior part, elongate and weakly swollen near distal end in posterior part; segment III oval, inner margin expanded (Fig. 5).

*Female imago.* Length: body 2.9–5.4 mm, forewing 3.4–6.6 mm, hindwing 0.4–0.8 mm, foreleg 1.5–3.0 mm, middle leg 1.7–2.8 mm, hindleg 1.6–2.8 mm, cercus up to 10.1 mm.

Coloration of head, antenna and ocellus and shape of anterior margin of head as in male. Compound eye dark gray.

Coloration of thorax, forewing and hindwing and leg, structure of metathorax and venation of forewing and hindwing as in male.

Abdominal terga brown, a pair of brown spots as in male (Fig. 6); abdominal sterna pale brown; cercus pale brown.

*Male subimago.* Length: body 3.1–4.7 mm, forewing 3.0–5.5 mm, hindwing 0.6–0.7 mm, foreleg 2.4–3.5 mm, middle leg 1.6–2.3 mm, hindleg 1.7–2.2 mm, cercus up to 8.0 mm.

Coloration of head, antenna, turbinate eye, lower eye and ocellus, and shape of anterior margin of head as in male imago. Length of turbinate eye 0.9- to 1.1-fold that of head.

Thorax brown, with pale brown medial longitudinal suture and medioparapsidal sutures; forewing and hindwing gray, opaque; leg pale gray but coxa brown. Metathorax with weak acute projection posteromedially (Fig. 7). Forewing and hindwing fringed with cilia laterally and posteriorly, venation as in male imago.

Abdominal terga I–VI and IX–X pale gray, VII–VIII brown, a pair of brown spots as in male imago; abdominal sterna pale gray; cercus pale gray. Forceps four-segmented; total length 0.7- to 1.0-fold width of abdominal segment IX; segment I without projection, segments II and III cylindrical, segment IV oval (Fig. 8).

*Female subimago.* Length: body 3.7–4.0 mm, forewing 4.3–6.6 mm, hindwing 0.6–0.8 mm, foreleg 1.7–2.5 mm, middle leg 1.9–2.3 mm, hindleg 2.0–2.4 mm, cercus up to 7.0 mm.

Coloration of head, ocellus and compound eye and shape of anterior margin of head as in male imago; antenna brown; compound eye gray.

Coloration of thorax, forewing, hindwing and leg, structure of metathorax and venation of forewing and hindwing as in male subimago.

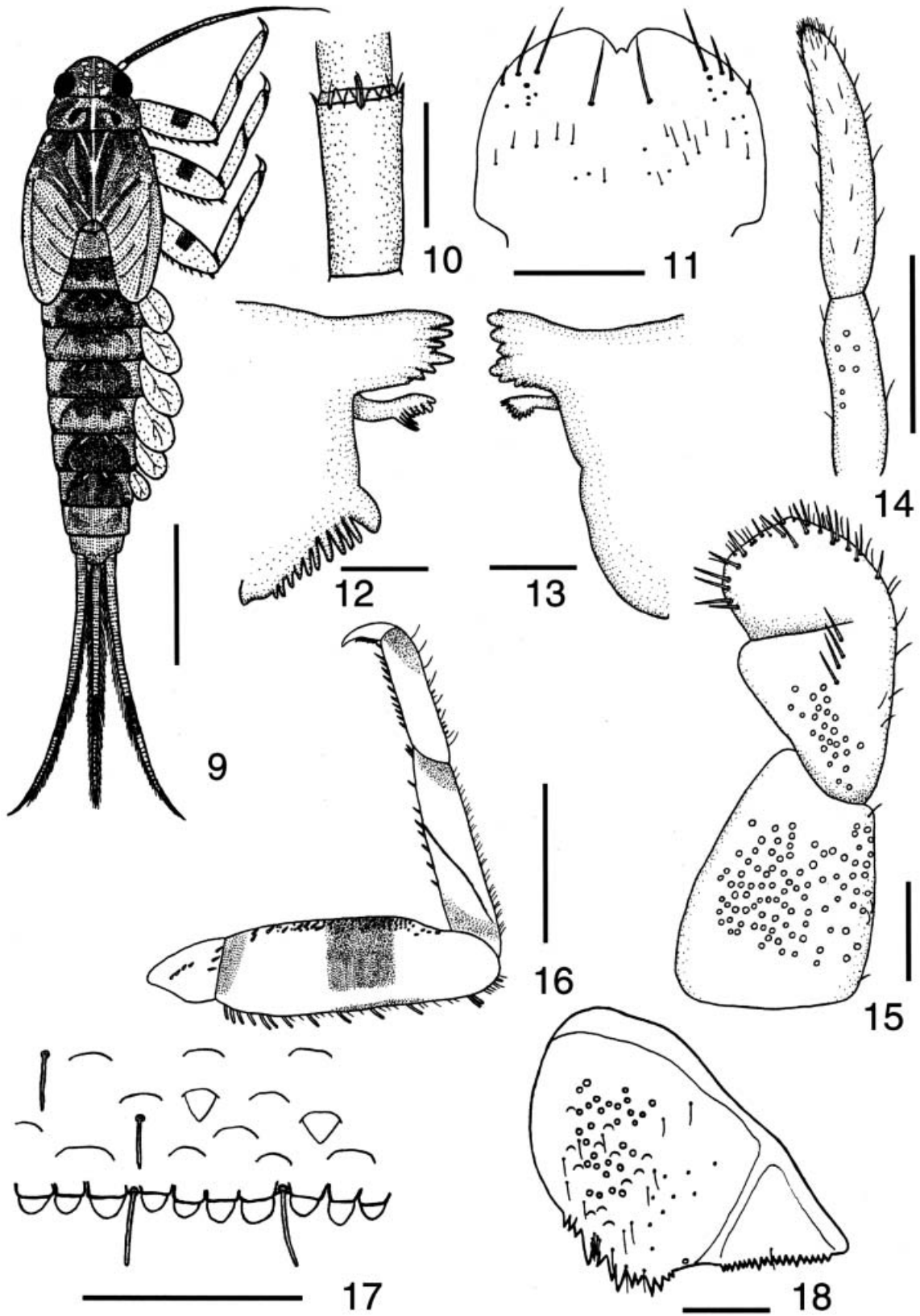
Coloration of abdomen as in female imago; cercus as in male subimago.

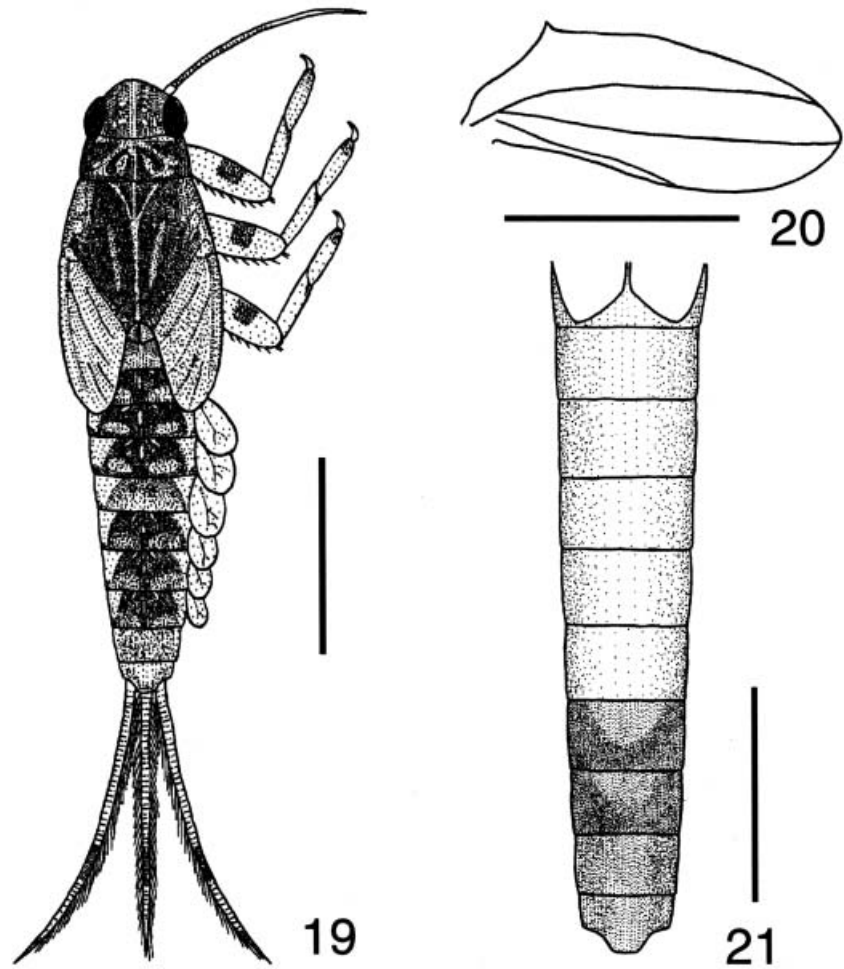
*Final instar nymph.* Length: body 4.1–6.1 mm, foreleg 2.0–2.3 mm, middle leg 1.9–2.1 mm, hindleg 1.8–2.1 mm; cercus up to 2.4–3.1 mm.

Head brown; antenna pale brown. Antennal scape and pedicel with fine setae, each flagellomere except some distal ones with fine setae and pointed or blunt projections on its distal margin (Fig. 10). Labrum rounded, with depression in middle of anterior margin; one submedial and two to four submarginal fine setae on each side of dorsal surface (Fig. 11). Left mandible with seven denticles on inner margin of incisor, one denticle rudimentary between anterior and posterior three denticles; prostheca toothbrush-like (Fig. 12). Right mandible with six denticles on inner margin of incisor, with one small denticle on its anterior margin, with small denticles on posterior margin; prostheca manifold (Fig. 13). Maxillary palpus two-segmented, slightly curved inward (Fig. 14). Paraglossa 1.3- to 1.7-fold wider than glossa. Labial palpus three-segmented; length of segment I nearly equal to that of II + III; segment II with a row of three to five fine setae on dorsal surface; segment III with fine setae and hairy setae densely distributed; apex truncated (Fig. 15).

Thoracic terga brown, with pale brown markings and stripes (Fig. 9); thoracic sterna pale brown; leg pale brown, femur with dark brown patches in proximal and medial parts, tibia and tarsus with dark brown patches in distal ends (Fig. 16). Femur with fine setae and one row of clavate setae on outer margin; with pores and robust setae on inner margin. Tibia with dense fine setae and short notched robust setae on outer margin, robust setae on inner margin, distinct seam on dorsal surface. Tarsus with fine setae on outer margin, robust setae on inner margin. Claw with one row of small denticles.

Abdominal terga pale brown, brown markings present on segments I–VIII, markings darker on segments VII–VIII and paler on segments IV and VI in most materials (Fig. 9); abdominal sterna pale brown; cercus pale brown, with dark brown band in middle. Posterior fringes of terga I–IX with rounded or blunt projections and fine setae (Fig. 17), VIII–IX with pointed projections in some materials, X with pointed projections; tergal surface covered with fine setae and triangular scales with rounded bases (Fig. 17). Sternum IX with pointed projections on the posterior margin; surface of sterna as in terga. Gills oval, fringed with fine setae and hook-like projections; six pairs on abdominal segments II–VII or seven pairs on I–VII. Paraproct serrated on posterior part of inner margin and outer part of posterior margin; surface as in abdomen (Fig. 18). Length of terminal filament 0.7- to 0.9-fold that of cerci; terminal filament and inner margin of cercus fringed with cilia (Fig. 9).





Figures 19–21 Characters of *Baetis saboensis*. 19 Habitus of the nymph. 20 Hindwing. 21 Abdomen of the male imago, dorsal view. Scale lines: (20) 0.5 mm; (19,21) 1 mm.

*Distribution.* Japan (Hokkaido, Honshu, Shikoku, Kyushu), Taiwan.

*Specimens examined.* Imagoes: **Japan:** Yamagata: 3♂, 14.x.1999 (lt), Kanayama, Kanayama Stream, Araya Bridge, A. Ohkawa; Kyoto: 6♂6♀ (2♂1♀, 26.iv.1999; 4♂5♀, 27.iv.1999) (rm), Miyama, Tanano Stream, Tanamura Bridge, T. Fujitani (TF); 1♀, 4.viii.1998 (rm), Miyama, Ashu, Yura Stream, TF; 1♀, 26.iv.1999 (rm), Ayabe, Yura Stream, Tamba Bridge, TF; 4♀, 26.iv.1999 (rm), Oe, Kawahigashi, Yura Stream, TF; 2♂ (1♂, 13.xii.1997; 1♂, 26.iv.1999) (rm), Oe, Habi, Yura Stream, TF; 2♂1♀, 8.viii.1999 (lt), Kyoto, Sakyo, Shimogamo, Kamo Stream, TF; 2♂, 14.vi.1999 (rm), Wazuka, Wazuka

Stream, Iwai Bridge, TF. Osaka: 1♂, 27.iii.1999 (rm), Kaizuka, Akiyama Stream, TF; Nara: 1♂, 23.vi.1999 (lt), Higashi-Yoshino, Omata, Omata Stream, Kura-mae Bridge, TF; 1♀, 3.ix.1999 (lt), Higashi-Yoshino, Kozugawa, Takami Stream, TF; 1♂, 31.x.2000 (lt), Ohtou, Ui, TF; Wakayama: 1♂, 4.viii.1999 (rm), Hashimoto, Ki River, Kinokawa Bridge, TF; 1♂, 28.vii.1999 (lt), Miyama, Hidaka Stream, TF; 1♀, 28.vii.1999 (rm), Kanaya, Shuri Stream, TF; Tottori: 1♂1♀ (1♂, 23.xi.1999; 1♀, 24.xi.1999) (rm), Yon-ago, Kamifukubara, Hino Stream, TF; 1♀, 23.xi.1999 (rm), Mizoguchi, Hino Stream, Kimori Bridge, TF; Tokushima: 1♂1♀, 1.xi.1999 (rm), Waki-cho, Waki, Yoshino River, TF.

← Figures 9–18 Characters of the nymph of *Baetis taiwanensis*. 9 Habitus; 10 flagellomere of the antenna; 11 labrum; 12 left mandible; 13 right mandible; 14 maxillary palpus; 15 labial palpus; 16 foreleg; 17 abdominal tergum V, posterior margin; and 18 paraproct. Scale lines: (10–16,18) 0.1 mm; (17) 0.05 mm; (9) 1 mm.

Subimagoes: **Japan:** Kyoto: 1♀, 27.iv.1999 (rm), Miyama, Tanano Stream, Tanamura Bridge, TF; 1♂, 14.v.2001 (rm), Kyoto, Sakyō, Kamitakano, Takano Stream, TF; 1♂, 8.viii.1999 (lt), Kyoto, Sakyō, Shimo-gamo, TF; Osaka: 1♂, 4.xi.2001 (rm), Kaizuka, Sobura, Kogi Stream, TF; Nara: 1♂, 4.iv.2000 (rm), Nara, Kawakami, Saho Stream, TF; 1♀, 1.ix.1999 (rm), Higashi-Yoshino, Kozugawa, Takami Stream, TF; Tottori: 1♂2♀ (2♀, 24.xi.1999; 1♂, 27.xi.1999) (rm), Mizokuchi, Hino Stream, Kimori Bridge, TF.

Nymphs: **Japan:** Hokkaido: 3 examples (exs) (2 exs, 8.vii.1985; 1 ex, 9.vii.1985), Teshio, Nio Stream, N. Kobayashi (NK); Ibaraki: 1 ex, 1.vi.1998, Iwai, Nakagawa Elementary School, NK; 1 ex, 19.iii.2001, Ishige, Kinu Stream, TF; Chiba: 1 ex, 19.iii.2001, Nagareyama, Nagareyama, Edo River, TF; Nagano: 1 ex, 22.v.2001, Azusagawa, Azusa, Azusa Stream, TF; Kyoto: 4 exs, 26.iv.1999, Miyama, Ashu, Yura Stream, TF; 7 exs, 1.v.2000, Ayabe, Yura Stream, Tamba Bridge, TF; 1 ex, 11.v.1997, Fukuchiyama, Yura Stream, Otonase Bridge, TF; 2 ex (1 ex, 11.v.1997; 1 ex, 30.v.1997), Oe, Habi, Yura Stream, TF; 15 exs, 8.iii.1998, Oe, Habi, Yura Stream, TF; 1 ex, 26.iv.1999, Oe, Kawahigashi, Yura Stream, TF; Nara: 1 ex, 17.xi.2001, Kawakami, Unokawa, Nakai Stream, TF; Wakayama: 1 ex, 9.iv.2000, Hashimoto, Ki River, Kinokawa Stream, TF; Tottori: 2 exs, 22.xi.1999, Yonago, Kamifukubara, Hino Stream, TF; Tokushima: 2 exs, 30.x.1999, Waki-cho, Waki, Yoshino River, TF; Nagasaki: 2 exs, 7.vi.2001, Sotome, Konoura-Ogiyamago, TF; 1 ex, 6.vi.2001, Matsuura, Tanohira, Sisa Stream, TF. **Taiwan:** 5 exs, 30.x.1994, Taitung Haien, Haituan, Tienlong Chiao, S. C. Kang (SCK); 1 ex, 11.x.1978, Taitung Haien, 4 km north of Tsaotun, Tatu River, G. F. Edmunds and C. H. Edmunds; 1 ex, 7.vi.1991, Taitung Haien, Hsiehshan Chi, K. Tanida (KT); 1 ex, 11.vi.1991, Taipei, Yangming Shan, KT.

### *Baetis sahoensis* Gose

*Baetis sahoensis* Gose 1980b: 79; Gose 1980a: 122; Gose 1985: 21; Kobayashi 1987: 53; Ishiwata 2001: 180.

*Distribution.* Japan (Hokkaido, Honshu, Shikoku, Kyushu).

*Specimens examined.* Imagoes: **Japan:** Shizuoka: 5♂, 3.viii.2000 (lt), Shimizu, Yawata, Kakita Stream, TF; Kyoto: 1♀, 12.x.1998 (rm), Oe, Habi, Yura River, TF; 1♂, 26.iv.1999 (rm), Oe, Kawahigashi, Yura River, TF; 1♂1♀, 26.vi.2001 (lt), Kyotanabe, Fugenji Stream, Kannonji Bridge, TF; Nara: 6♂5♀ (1♂4♀, 23.x.1999;

4♂1♀, 24.x.1999; 1♂, 25.x.1999) (rm), Nara, Kawakami-cho, Saho Stream, TF; Fukuoka: 1♂, 21.ix.2000 (rm), Usui, Onga River, Kodai Bridge, TF.

Subimagoes: **Japan:** Osaka: 1♂, 28.x.2000 (rm), Kaizuka, Sobura, Kogi Stream, TF; Nara: 7♂ (6♂, 23.x.1999; 1♂, 24.x.1999) (rm), Nara, Kawakami-cho, Saho Stream, TF.

Nymphs: **Japan:** Ibaraki: 3 exs, 1.vi.1998, Iwai, Tone River, NK; Kyoto: 1 ex, 30.iv.1998, Miyama, Yura River, Hananoki Bridge, TF; 3 exs (1 ex, 14.vi.1997; 2 exs, 30.vii.2000), Oe, Habi, Yura River, TF; 1 ex, 26.iv.1999, Oe, Kawahigashi, Yura River, TF; 1 ex, 14.viii.2000, Kyoto, Sakyō, Kamo Stream, Izumoji Bridge, TF; 2 exs, 11.viii.2000, Kyoto, Higashiyama, Kamo Stream, Donguri Bridge, TF; Osaka: 7 exs (5 exs, 29.x.2000; 2 exs, 21.x.2001), Kaizuka, Sobura, Kogi Stream, TF; Nara: 45 exs (29 exs, 6.v.1999; 16 exs, 24.x.1999), Nara, Kawakami-cho, Saho Stream, TF; Fukuoka: 20 exs, 20.ix.2000, Usui, Kodai Bridge, Onga River, TF; 14 exs, 21.ix.2000, Tachiarai, Nishibaru, Chikugo River, TF.

### *Nigrobaetis tatuensis* (Müller-Liebenau)

*Baetis tatuensis* Müller-Liebenau 1985: 96 (fig. as *B. taiwanensis*).

*Baetis (Margobaetis) taiwanensis:* Kang *et al.* 1994: 15 (misidentification).

*Nigrobaetis taiwanensis:* Waltz and McCafferty 1997: 138.

*Distribution.* Taiwan.

*Specimens examined.* Nymphs: **Taiwan:** 5 exs, 15.ix.1993, Ilan Hsien, Yuanshan, Fushan, SCK.

## DISCUSSION

### Diagnostic characters of *Baetis taiwanensis*

In nymphs, we found the following characters to be useful to distinguish *B. taiwanensis* from *B. sahoensis*: posterior projections of abdominal terga I–VI and abdominal color patterns (Figs 9,19) (Table 1). In regard to imagoes and subimagoes, we can separate the species by the following characters: number of longitudinal veins in the hindwing (Figs 3,20), shape of metathorax, and presence or absence of paired spots near posterior margins of abdominal terga (Figs 4,6,21; Table 1).

### Notes on the original description and the redescription of *Baetis taiwanensis*

In the original description (Müller-Liebenau 1985), figure 1 provided for *B. taiwanensis* includes a line

**Table 1** Diagnostic characters to distinguish *Baetis taiwanensis* and *Baetis saboensis* in the imago, subimago and nymph

	<i>Baetis taiwanensis</i>	<i>Baetis saboensis</i>
Imago and subimago		
Posterior margin of metathorax	Weakly projected	Distinctly projected
Longitudinal veins of hindwing	Two	Three
Posterior margins of abdominal terga	With a pair of brown spots	Without any spots
Nymph		
Posterior projections of abdominal terga I–VI	Rounded	Pointed
Indistinct abdominal color patterns	In terga IV and VI	In tergum V

drawing of tibia possessing long clavate bristles on the outer margin and lacking a seam. In figure 2 provided for *N. tatuensis*, line drawings of mandible lacking spines on the inner margin, labial palpus straight at the apex and tibia possessing a distinct seam are shown. Comparing these figures with the texts of the original description, we found that figures 1 and 2 had been erroneously interchanged.

We examined materials of nymphs of *B. taiwanensis* and *N. tatuensis* used in Kang *et al.* (1994), and found that the materials of *B. taiwanensis* and *N. tatuensis* were inadvertently identified as *N. tatuensis* and *B. taiwanensis*, respectively. This misidentification was probably caused by the drawings provided for these species in the original description. Kang *et al.* (1994) showed a photograph of the abdomen of *N. tatuensis*. However, the fifth tergum did not have a distinct color pattern, and the color pattern of the nymph was different from that of *B. taiwanensis* and *B. saboensis*. This photograph possibly shows the abdomen of another undescribed baetid species.

Line drawings of seven gills were provided in the original description of *B. taiwanensis*. However, all nymphs we examined, which included a nymph collected from the type locality of *B. taiwanensis*, had six pairs of gills. We compared characters of the materials with those provided in the original description, but did not find any significant differences in the other morphological characters. Thus, we conclude the difference in the number of gills is individual variation.

The holotypes and paratypes of *B. taiwanensis* and *N. tatuensis* are due to be deposited in the University of Utah, USA. (Müller-Liebenau 1985). Dr Edmunds Jr (former Professor of the University of Utah), who collected the type specimens, informed us that now he does not have most of the materials he collected (pers. comm., 2001). We, however, searched for the specimens in the five places where they had possibly been transferred and determined that they had been lost.

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