Korean J. Limnol. 36 (4): 427~433 (2003)

Two Co-inhabiting Burrowing Mayflies, *Ephemera orientalis* and *E. sachalinensis*, in Korean Streams (Ephemeroptera: Ephemeridae)

Hwang, Jeong Mi, Sung Jin Lee and Yeon Jae Bae*

(*Department of Biology, Seoul Women's University, Seoul 139-774, Korea*)

We provided diagnostic characters of the adult and larval stages of two co-inhabiting species of ephemerid burrowing mayflies, *Ephemera orientalis* and *E. sachalinensis* (new record to South Korea) (Ephemeroptera: Ephemeridae), in Korean streams. *E. sachalinensis* (mean±sd body length male adult 18.44±0.70 mm, female adult 21.46±0.46 mm) is larger in body length than *E. orientalis* (male adult 13.92±0.04 mm, female adult 15.27±0.48 mm), and can be distinguished by male genitalia, forewing markings, and stripes on the abdominal terga VI-IX. The mature larvae of *E. sachalinensis* differ from those of *E. orientalis* in having a deeper and more divergent head frontal process. Their body size distributions and additional ecological findings are discussed.

Key words : body size distribution, burrowing mayflies, *Ephemera*, habitat, morphological diagnosis

INTRODUCTION

The burrowing mayfly family Ephemeridae is widespread in the Holarcitc, Oriental, and Afrotropical regions (McCafferty, 1991). The larvae of Ephemeridae inhabit sand-gravel substrates in streams and rivers. Due to their large body size, common occurrence, and ecological importance in stream ecosystems, members of the family are relatively well known. The family contains six extant genera, and the type genus *Ephemera* Linnaeus is the largest in terms of species diversity and abundance (Hubbard, 1990). *Ephemera* is the only representative in the family in Korea.

The larvae of *Ephemera* can be characterized by a pronounced and bifurcate frontal process, antennae with long whorled setae over most of their lengths, and prothoracic legs whose tibiae are distally rounded and with no process; the long up-curved tusks that are setaceous only at the base are also unique to the larvae (McCafferty, 1975; Bae and McCafferty, 1995). These larval characteristics are adapted for their fossorial habits.

Among the species of the genus, *Ephemera strigata* Eaton, *E. japonica* McLachlan, *E. orientalis* McLachlan, *E. sachalinensis* Matsumura, and *E. separigata* Bae are common in temperate streams in Northeast Asia (Bae, 1997). When the species of *Ephemera* inhabit a stream watercourse, they show a stratified pattern of altitudinal distribution represented by *E. separiagta* or *E. japonica* in the uppermost section, *E. strigata* in the mid-stream section, and *E. orientalis* and/or *E. sachalinensis* in the downstream section of the stream. *E. orientalis* and *E. sachalinensis* are therefore the representatives of lowland streams and rivers showing a high degree of individual abundance particularly in the emergence time (Watanabe 1985; Bae, 1995; Lee *et al*., 1995, 1999).

Although the adults of *E. sachalinensis* were

* Corresponding Author: Tel: 02) 970-5667, Fax: 02) 970-5974, E-mail: yjbae@swu.ac.kr

recorded from North Korea (Bae and Soldán, 1997; Bae and Andrikovics, 1997), only three ephemerid mayflies, i.e. *E. separigata*, *E. strigata*, and *E. orientalis*, are well known in South Korea (Yoon and Bae, 1985; Bae *et al*., 1994; Bae, 1995; Bae and Yoon, 1997). Not only from comprehensive material examinations of Korean *Ephemera* species but also from close field surveys and rearing experiments in Korean streams, however, we have recognized that two species of *Ephemera*, *E. orientalis* and *E. sachalinensis*, are co-inhabited in the downstream reaches in Korean streams. Up to date, these two species have been lumped as *E. orientalis* in numerous faunistic and ecological studies in Korea due to their morphological similarity in the larval stage. We therefore provide their taxonomic accounts and other biological and ecological data in this paper. This is the first formal record of *E. sachalinensis* in South Korea.

MATERIALS AND METHODS

Adult and larval materials of *E. orientalis* and *E. sachalinensis* including some reared materials collected in South Korea since 1990 and deposited in the Aquatic Insect Collection of Seoul Women's University were used for this study. Reference adult and larval materials from Japan, Russian Far East, and China were also examined. Intensive field observation and sampling were conducted in Korean streams, Gapyeong and Wangsuk streams, in Gyeonggi-do since 1998. All the materials are preserved in 80% ethyl alcohol. External morphology of the larval and adult stages of the species were examined and measured under a dissect microscope (10-60×). Line-drawings and macro-photographs of diagnostic characters are provided.

TAXONOMIC ACCOUNTS

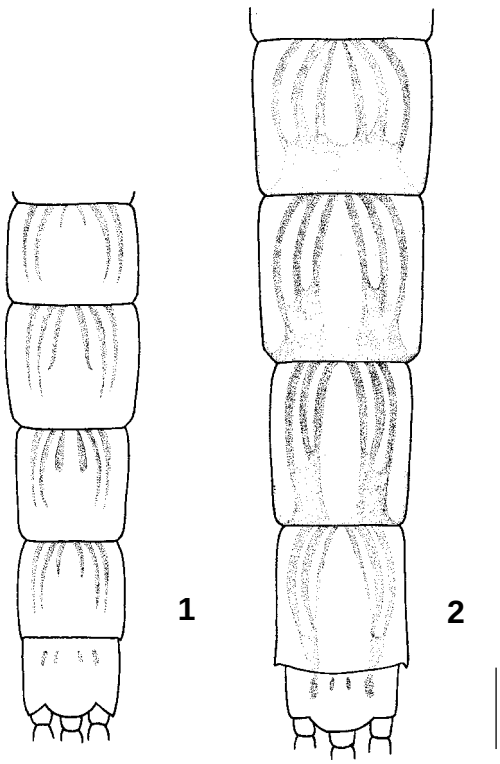
Ephemera orientalis McLachan 동양하루살이

Ephemera orientalis McLachan, 1875: 167; Tshernova, 1973: 225; Gose, 1981: 13; Yoon and Bae, 1985: 99; Yoon and Bae, 1988: 160 (for full synonymy see Bae *et al*., 1994; Bae and Yoon, 1997).

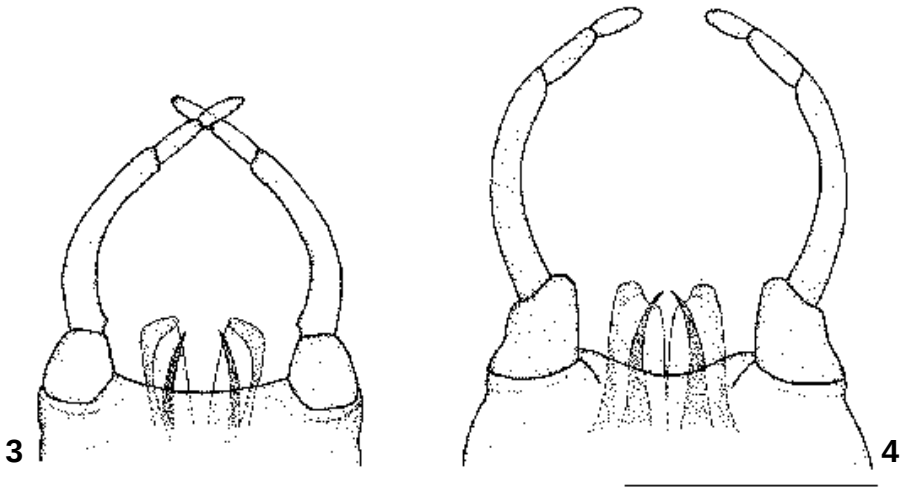
Ephemera lineata Eaton: Imanishi, 1940: 176 (as senior synonym of *Ephemera orientalis* McLachan).

Diagnosis. The adults and larvae of *E. orientalis* are similar to those of *E. sachalinensis* and *E. lineata* Eaton in general morphology, particularly in possessing three-paired stripes on the abdominal segments VI-IX (Figs. 1 and 2). However, those of *E. orientalis* and *E. sachalinensis* possess two pairs (sometimes one pair) of distinct lines on the abdominal tergum X (Figs. 1 and 2), while those of *E. lineata* lack such lines. The male adults of *E. orientalis* can be distinguished from those of *E. sachalinensis* by the shape of genitalia (Figs. 3 and 4). Although the forewing markings of the male adults of *E. orientalis* (Fig. 5) and *E. sachalinensis* (Fig. 6) are similar each other, the female adults of *E. orientalis* possess distinct markings in the forewings (Fig. 7), while those of *E. sachalinensis* lack such markings (Fig. 8). The head frontal process of the larvae of *E. orientalis* (Figs. 9, 11) are somewhat shallower and less pronounced than that of *E. sachalinensis* (Figs. 10, 12) and *E. lineata*. The foretarsi and foreclaws of *E. orientalis* are slenderer than those of *E. lineata*.

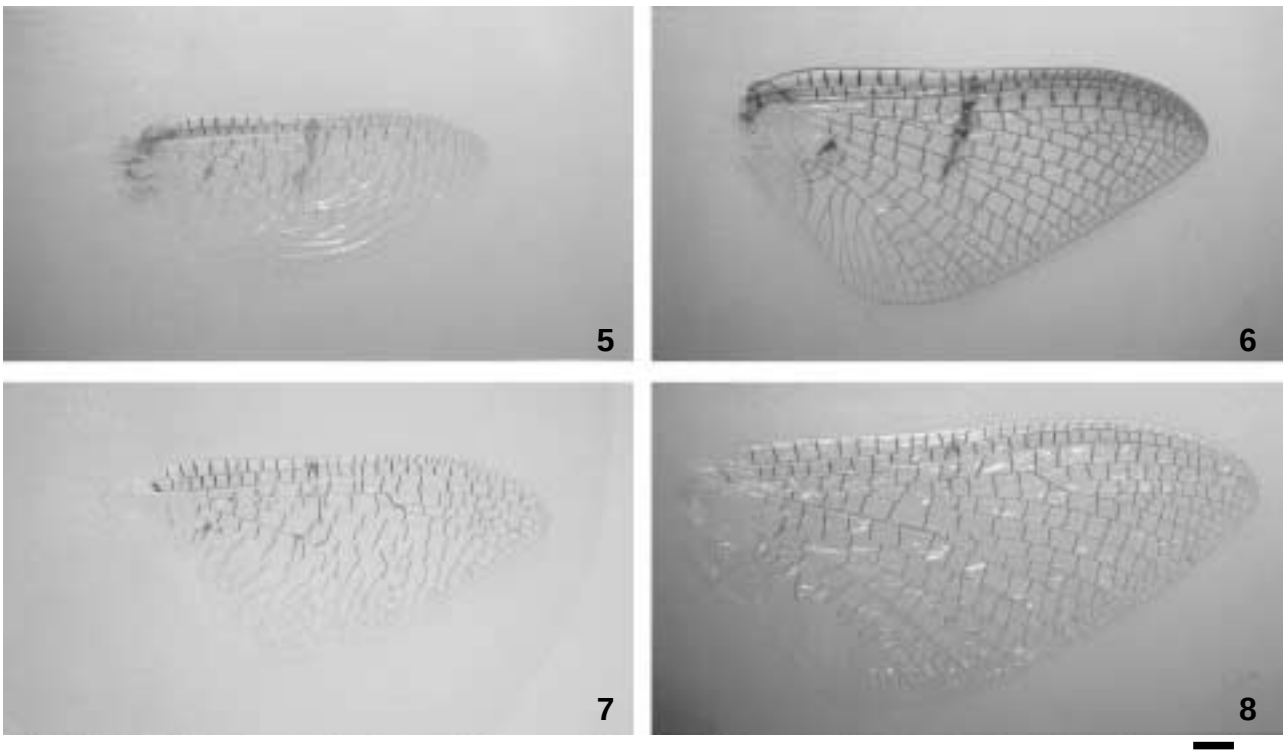
Distribution. Japan, Russia, China, Korea.



Figs. 1-2. Adult abdominal terga VI-X, scale 0.1 mm: 1. *Ephemera orientalis*; 2. *E. sachalinensis*.



Figs. 3-4. Male adult genitalia, scale 0.1 mm: 3. *Ephemera orientalis*; 4. *E. sachalinensis*.

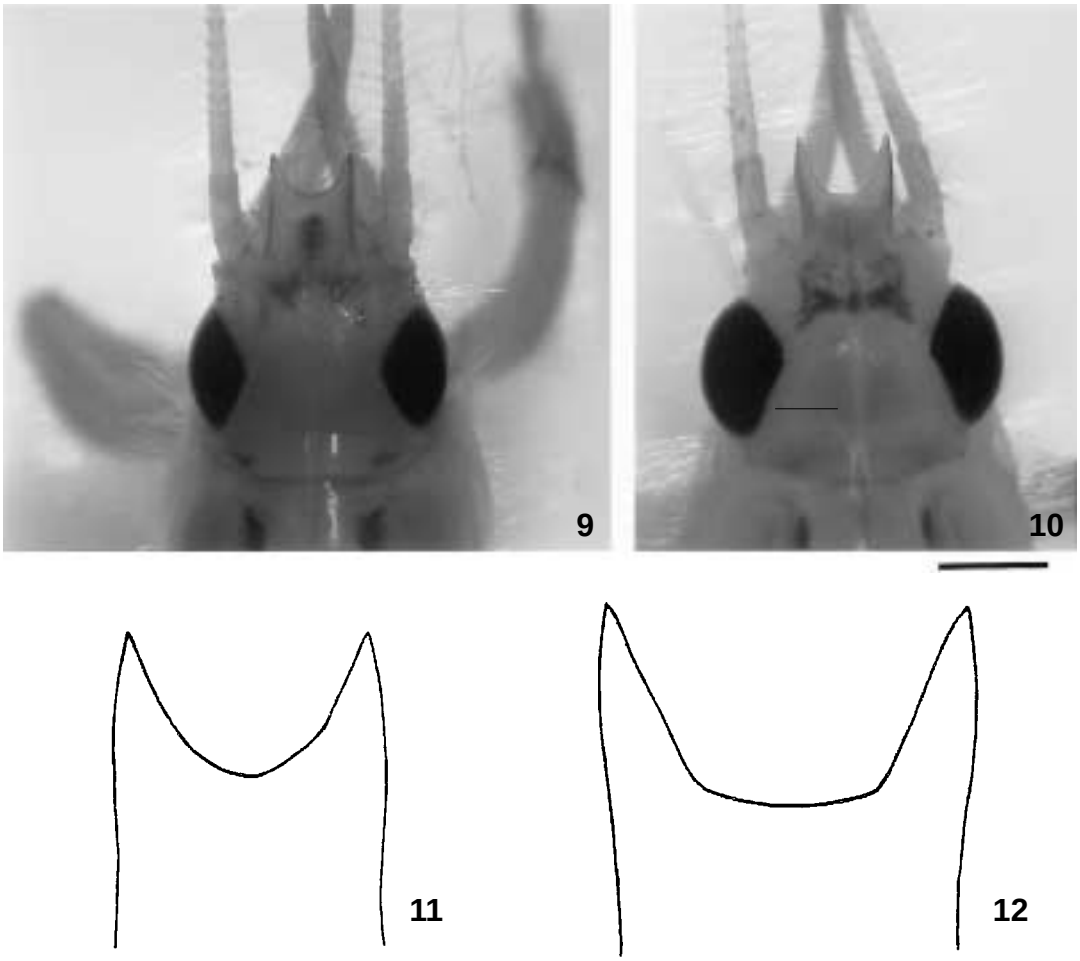


Figs. 5-8. Adult forewings, scale 0.1 mm: 5. *Ephemera orientalis*, male; 6. *E. sachalinensis*, male. 7. *E. orientalis*, female; 8. *E. sachalinensis*, female.

Ephemera sachalinensis Matsumura
사할린하루살이

Ephemera sachalinensis Matsumura, 1931: 1469; Tshernova, 1973: 226; Bae and Soldán, 1997: 148; Bae and Andrikovics, 1997: 157.

Diagnosis. *E. sachalinensis* and *E. orientalis* are similar each other, but the body length of *E. sachalinensis* (mean±sd male adult 18.44±0.70 mm, female adult 21.46±0.46 mm) is larger than that of *E. orientalis* (male adult 13.92±0.04 mm, female adult 15.27±0.48 mm). In adults, the



Figs. 9–10. Larval head, scale 0.1 mm: 9. *Ephemera orientalis*; 10. *E. sachalinensis*
Figs. 11–12. Frontal process of larval head: 11. *E. orientalis*; 12. *E. sachalinensis*.

abdominal terga 6–9 of *E. sachalinensis* possess more thickened stripes (Fig. 2) than those of *E. orientalis* (Fig. 1). The male adults of *E. sachalinensis* (Fig. 4) can be distinguished from those of *E. orientalis* (Fig. 3) by the shape of penes. The female adults of *E. sachalinensis* lack distinct median and basal markings in the forewings (Fig. 8), while those of *E. orientalis* possess such markings (Fig. 7). The male and female subimagos of *E. sachalinensis* and *E. orientalis* also can be separated each other by the body size and markings as in their adults. The mature larvae of *E. sachalinensis* (Figs. 10, 12) differs from *E. orientalis* (Figs. 9, 11) in possessing a deeper and more divergent head frontal process.

Distribution. Japan, Russia, China, Korea.

Material examined. 1 Ms, 2 F & 1 Fs: Seoul, Jamsil, Han R., 1993–VIII–5; 2 L: GG, Hanam, Paldang, Han R., 1998–II–17, 1998–V–17; 1 F & 16 L: GG, Namyangju, Wangsuk Cr., 1998–IV–29, 1998–VII–16, 1999–II–25, 1999–III–25, 1999–IV–8, 1999–VI–17, 2003–VI–10; 6 Fs: GG, Namyangju, Sudong Cr., 1993–V–27, 1993–VI–11, 1993–VII–5; 1 Ms & 2 Fs: GG, Gapyeong, Bukhan R. at Guamdongsan, 1992–VI–13, 1994–VII–20; 11 M, 7 Ms, 9 F &11 Fs: GG, Gapyeong, Jojong Cr., 1985–IX–5, 1993–VII–4, 1994–VII–20, 2003–VII–04; 11 Ms, 18 F, 10 Fs & 12 L: GG, Gapyeong, Gapyeong Cr., 1997–V–30, 1997–X–16, 1997–XI–8, 2003–VI–22, 2003–VII–04; 3M & 3F: GG, Yangpyeong, Yongmunsan, 2000–VII–28; 17 L: GW, Gangreung, Okgye–myeon, Chunnam–ri, Namyeonggyo (Br.), 2003–V–26; 3 L: GW, Gangreung, Okgye–myeon, Wolcheon–dong, 2003–V–26; 1 L: CB, Danyang, Eosangcheon, 1993–VII–26; 3 L: CB, Oksan–myeon, Dandong

-ri, 1998-IV-21; 1 L: GB, Daegu, Yeongcheon, Keumho R., 1992-IV-28.

DISCUSSION

The species of *Ephemera* in Northeast Asia which possess paired multi-striped markings on the abdominal terga (see Figs. 1 and 2) have been historically confused. This species group, *E. orientalis*-group, includes *E. orientalis* McLachlan, *E. lineata* Eaton, *E. sachalinensis* Matsumura, *E. formosana* Eaton, etc. This confusion started with Imanishi (1940) when he identified the larval materials from Northeast China as *E. lineata* Eaton which is originally known in Europe. At that time, Imanishi (1940) synonymized *E. orientalis* with *E. lineata*. Since then the populations of *E. orientalis*-group found in Korean streams have been frequently confused either with *E. lineata* or with *E. orientalis*.

Tshernova (1973) reviewed the Russian species of *Ephemera* and revalidated the species concepts of *E. orientalis* and *E. sachalinensis* which were poorly defined in the original descriptions. Tshernova (1973) noted that the foreleg length of the male adults of *E. sachalinensis* is shorter than that of *E. orientalis*, but *E. sachalinensis* is actually longer than *E. orientalis* in the body length as well as in the foreleg length based on our materials.

The species of *Ephemera* were reviewed in Japan (Gose, 1981), in Russia (Tshernova *et al*., 1986), and in Korea (Bae *et al*., 1994; Bae, 1995; Bae and Yoon, 1997). Imanishi's (1940) taxonomic work was reviewed and corrected by Bae *et al*. (2000). There are a number of species of *E. orientalis*-group known in tropical Asia whose

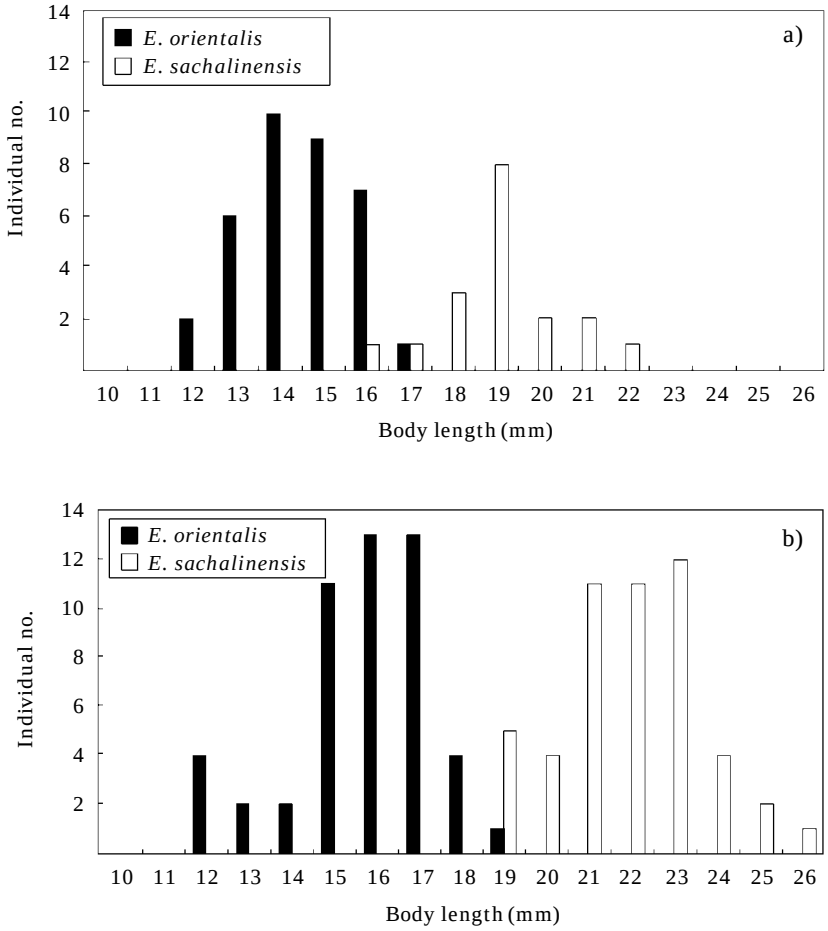


Fig. 13. Body size distributions of the adults of *Ephemera orentalis* and *E. sachalinensis*. a) Male (*E. orientalis* n = 35; *E. sachalinensis* n = 18); b) Female (*E. orientalis* n = 50; *E. sachalinensis* n = 50).

taxonomic revision is needed.

The adults and larvae of *E. sachalinensis* can be distinguished from those of *E. orientalis* by their larger body size and other morphological characters presented above. Their macro-distributions and microhabitats are quite similar each other. Both species occur in the downstream section of lowland streams and rivers where the current is relatively slow and the substrate consists of sand, gravel, and organic matter. A large number of populations are also found in reservoirs and large rivers. *E. sachalinensis* tends to be found in relatively clean water streams in northern parts in Northeast Asia, but there are no quantitative data to support this tendency.

When the two species occur in a stream watercourse, the adults of both species are simultaneously collected at lights along the stream reaches. Although not quantified, females are always more abundant and two body size groups are more distinctly separated in late summer (August and September) when the adults are collected at lights. Based on larval and adult materials sampled in a Korean stream, Gapyeong stream, the body size groups of the larvae of the two species are not well distinguishable although those of male and female adults are well separated (Fig. 13). Other advanced techniques such as molecular systematics may be useful to distinguish those immature larvae.

ACKNOWLEDGEMENT

This work was supported by the grant from the research project "Eco-technopia 21" of the Ministry of Environment of Korea in 2003.

REFERENCES

Bae, Y.J. 1995. *Ephemera separigata*, a new species of Ephemeridae (Insecta: Ephemeroptera) from Korea. *Korean J. Syst. Zool.* **11**: 159-166.

Bae, Y.J. 1997. A historical review of Ephemeroptera systematics in Northeast Asia. p. 405-417. In: Ephemeroptera & Plecoptera: Biology-Ecology-Systematics (P. Landolt and M. Sartori, eds.). MTL, Fribourg, Switzerland.

Bae, Y.J. and W.P. McCafferty. 1995. Ephemeroptera tusks and their evolution. p. 377-405. In: Current Directions in Research on Ephemeroptera (L. Corkum and J. Ciborowski, eds.). Canadian Scholar's Publishing, Inc., Toronto.

Bae, Y.J., I.B. Yoon and D.J. Chun. 1994. A catalogue of the Ephemeroptera of Korea. *Entomol. Res. Bull.*, Korean Entomol. Inst., Seoul **20**: 31-50.

Bae, Y.J. and T. Soldán. 1997. Mayfly (Ephemeroptera) fauna of North Korea (1). *Insecta Koreana*, Korea **14**: 137-152.

Bae, Y.J. and S. Andrikovics. 1997. Mayfly (Ephemeroptera) fauna of North Korea (2). *Insecta Koreana*, Korea **14**: 153-160.

Bae, Y.J. and I.B. Yoon. 1997. A revised catalogue of the Ephemeroptera of Korea. *Entomol. Res. Bull.*, Korean Entomol. Inst., Seoul **23**: 29-39.

Bae, Y.J., J.E. Lee and I.B. Yoon. 2000. Northeast Asian Ephemeroptera in Imanishi's 1940 report. *Entomol. Sci.* **3**: 391-397.

Gose, K. 1981. A revision of the genus *Ephemera* in Japan. *Biol. Inl. Wat.* (Japan) **2**: 11-14 (in Japanese).

Hubbard, M.D. 1990. Mayfies of the World. A Catalog of the Family and Genus Group Taxa (Insecta: Ephemeroptera). Sandhill Crane Press, Gainesville, Florida.

Imanishi, K. 1940. Ephemeroptera of Manchoukuo, Inner Mongolia and Chôsen. p. 169-263. In: Report of the Limnobiological Survey of Kwantung and Manchoukuo (T. Kawamura, ed.). Public Works Section, Kwantung State-agency, Sinkyo (in Japanese).

Lee, S.J., I.B. Yoon and Y.J. Bae. 1995. Altitudinal distribution of *Ephemera strigata* Eaton and *E. orientalis* McLachlan (Ephemeroptera: Ephemeridae). *Korean J. Entomol.* **25**: 201-208.

Lee, S.J., Y.J. Bae, I.B. Yoon and N.C. Watanabe. 1999. Comparisons of temperature-related life histories in two ephemerid mayflies (*Ephemera separigata* and *E. strigata*: Ephemeridae, Ephemeroptera, Insecta) from a mountain stream in Korea. *Korean J. Limnol.* **32**: 253-260.

Matsumura, S. 1931. Ephemerida. p. 1456-1480. In: 600 Illustrated Insects of the Japanese Empire. Tokyo (in Japanese).

McCafferty, W.P. 1975. The burrowing mayflies (Ephemeroptera: Ephemeroidea) of the United States. *Trans. Am. Entomol. Soc.* **101**: 447-504.

McCafferty, W.P. 1991. Toward a phylogenetic classification of the Ephemeroptera (Insecta): A commentary on systematics. *Ann. Entomol. Soc. Am.* **84**: 343-360.

McLachlan, R. 1875. A sketch of our present knowledge of the neuropterous fauna of Japan (excluding Odonata and Trichoptera). *Trans. Entomol. Soc. London*. p. 167-190.

Tshernova, O.A. 1973. On Palaearctic species of Mayflies of the genus *Ephemera* L. (Ephemeroptera, Ephemeridae). *Entomol. Obozr.* **52**: 324-339 (in Russian).

Tshernova, O.A., N.Ju. Kluge, N.D. Sinitshenkova,

and V.V. Belov, 1986. 5. Order Ephemeroptera. p. 99-142. In: Identification of Insects of Far East USSR (P.A. Ler, ed.). Vol. 1. Leningrad Press, Leningrad. (in Russian).

Watnanabe, N.C. 1985. Distribution of *Ephemera* nymphs in Kagawa Prefecture, Japan, in relation to altitude and gradient. *Kangawa Seibutsu* **13**: 1-7.

Yoon, I.B. and Y.J. Bae. 1985. The classification of the Ephemeroidea (Ephemeroptera) in Korea. *Entomol. Res. Bull.*, Korean Entomol. Inst., Seoul **11**: 93-109.

Yoon, I.B. and Y.J. Bae. 1988. I. Order Ephemeroptera. p. 95-184. In: Illustrated Encyclopedia of Fauna & Flora of Korea. Vol. 30. Aquatic Insects. Ministry of Education of Korea (in Korean).

(Manuscript received 3 November 2003,
Revision accepted 18 December 2003)

<국문적요>

한국 하천의 동일 서식처에 서식하는 2종의 굴파는 하루살이인 동양하루살이와 사할린하루살이 (하루살이목: 하루살이과)

황 정 미 · 이 성 진 · 배 연 재*

(서울여자대학교 생물학과)

이 논문에서는 한국 하천의 동일한 서식처에 서식하는 2종의 굴파는 하루살이(하루살이목, 하루살이과)인 동양하루살이와 사할린하루살이(남한 미기록종)에 대하여 성충 및 유충의 차이점을 밝혔다. 사할린하루살이는 성충에 있어서 몸의 크기(평균체장±표준편차 수컷성충 18.44±0.70 mm, 암컷성충 21.46±0.46 mm)가 동양하루살이(수컷성충 13.92±0.04 mm, 암컷성충 15.27±0.48 mm)에 비하여 크고, 수컷 생식기, 앞날개 무늬, 6-9배마디 등판의 줄무늬에 있어서 차이가 난다. 성숙 유충에 있어서 사할린하루살이는 동양하루살이에 비하여 다소 깊게 패이고 밖으로 퍼진 형태의 전두부 돌출기를 가진다. 두 종의 체장 분포와 부수적인 생태적 특징을 기록하였다.