Entomological Research Bulletin

Contents

Volume 28 2012

보문 Research paper

곤충의 다양성 Insect diversity

Proceedings of the 4th International Symposium on Aquatic Entomology in East Asia (AESEA), Khon Kaen, Thailand, 2009
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표지사진: 얼룩뱀잠자리 (*Neochauliodes formosanus*) 성충 (사진: 정상우)

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Sang Woo Jung and Yeon Jae Bae. 2012. Taxonomic Review of the Korean Megaloptera with Description of *Sialis koreana*, New Species. Entomological Research Bulletin 28: 3-13.

Kyungduk Han, Torben Kölkebeck and Hoonbok Yi. 2012. First Record of *Brachonyx pineti* (Paykull, 1792) (Coleoptera: Curculionidae) from Korea. Entomological Research Bulletin 28: 15-17.

Jeong Mi Hwang. 2012. First Record of *Torleya japonica* (Gose) (Ephemeroptera: Ephemerellidae) from Korea. Entomological Research Bulletin 28: 19-20.

대암산 용늪: 한국좀뱀잠자리 서식처

한국좀뱀잠자리 (*Sialis koreana*)

Entomological Research Bulletin **28**: 3-13 (2012)

Research paper

Taxonomic Review of the Korean Megaloptera with Description of *Sialis koreana*, New Species

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Abstract

Six species of Megaloptera in the families Sialidae and Corydalidae are recognized in Korea including one new species (*Sialis koreana*, n. sp.), two species (*Sialis annae* Vshivkova and *Sialis longidens* Klingstedt) new to Korea, and three species (*Neochauliodes formosanus* (Okamoto), *Parachauliodes asahinai* Liu, Hayashi & Yang, and *Protohermes xanthodes* Navás) previously recorded in Korea. Description of the new species, diagnoses of all known species, illustrations and photographs of diagnostic characters, photographs of habitats, key to the species for male adults, and taxonomic remarks are provided.

Key words: Corydalidae, description, Korea, Megaloptera, Sialidae, *Sialis koreana*

Introduction

The insect order Megaloptera is composed of two families, Sialidae and Corydalidae, wherein the family Corydalidae includes subfamiles Corydalinae and Chauliodinae. The order consists of 328 extant species worldwide including 81 Sialidae species, 131 Coydalinae species, and 116 Chauliodinae species (Cover & Resh, 2008). Because of their large body size and relatively low agility, members of this order are relatively well known (Glorioso, 1981; Whiting, 1994; Liu & Yang, 2006b; Liu *et al.*, 2007, 2008, 2010). In Korea, eight species of Megaloptera, *Parachauliodes continentalis, Parachauliodes asahinai, Protohermes grandis, Protohermes xanthodes, Neochauliodes formosanus, Neochauliodes koreanus, Sialis sibirica*, and *Sialis* KUa (unnamed larva) have been recorded (Weele, 1909, 1910; Doi, 1932, 1933; Kamijo, 1933; Kimmins, 1954; Kuwayama, 1962; Yoon, 1988; Liu *et al.*, 2006, 2007, 2008).

The adults of Corydalidae can be easily distinguished from those of Sialidae by the presence of ocelli, non-bilobed tarsomere 4, and relatively large body size; the larvae of Sialidae bear a terminal abdominal filament which is absent in Corydalidae (Whiting, 1994; Flint Jr. *et al.*, 2008).

The order has entirely aquatic larvae that found in diverse freshwater habitats. They generally have one or two year life cycles, and the biology is well known from the larvae and adults (Evans, 1972; Dolin & Tarter, 1981; Elliott, 1996; Hayashi, 1989, 1990, 1998). Most Coydalidae larvae occur in fast-flowing waters with substrates composed of gravel, pebble, cobble, and large stones, whereas Sialidae larvae are found in lotic and lentic habitats with soft sediments. They do not feed during the adult stage for one or two weeks, but the larvae of both Sialidae and Corydalidae are active predators on small invertebrates including other aquatic insects.

In this study, we reviewed previously known species of Megaloptera in Korea and provided description of one new species.

Materials and Methods

Adults of Corydalidae were frequently attracted by light traps and adults of Sialidae were collected using sweep nets near streams and lentic habitats such as reservoirs and wetlands. All examined materials, including the holotype of *Sialis koreana*, n. sp., are deposited in the Entomological Museum of Korea University (KU).

Adults were photographed with a digital camera (Nikkon D90, Japan) and genitalia were photographed and illustrated using a dissecting microscope with an image analyzer (Carl Zeiss Discovery V12 with AxioCam I Cc 1, Germany). The tip of the abdomen was dissected and cleared with 10% KOH for a few hours before examination, and then preserved in microtube with glycerin. Morphological terminology generally follows Glorioso (1981) and Liu & Yang (2006a). Province abbreviations used in this study are as follows: GG, Gyeonggi-do; GW, Gangwon-do; CB, Chungcheongbuk-do; CN, Chungcheongnam-do; GB, Gyeongsangbuk-do.

Taxonomic Accounts

Family Corydalidae 뱀잠자리과
Subfamily Chauliodinae 얼룩뱀잠자리아과
Genus *Neochauliodes* Weele, 1909: 259 얼룩뱀잠자리속

Type species: *Chauliodes sinensis* Walker, 1853

Neochauliodes formosanus (Okamoto), 1910 (Fig. 1A) 얼룩뱀잠자리
Chauliodes formosanus Okamoto, 1910: 263.
Chauliodes kawarayamanus Okamoto, 1910: 262.
Neochauliodes formosanus (Okamoto): Liu *et al.*, 2007: 35.

Diagnosis. Head subtriangular, entirely yellowish brown. Antennae pectinate in male, moniliform in female. Compound eyes prominent, gray in color. Ocelli present, yellow, with black marking. Wings hyaline, with many dark brown spots. Male sternum X strongly inflated apically in lateral view (Fig. 2B); basal margin V-shaped in ventral view (Fig. 2A). Female genitalia ventrally as in Fig. 2C and laterally as in Fig. 2D.
Material examined. 2♂, ♀, CN, Gongju-si, Sagok-myeon, Unam-ri, Magoksa (Temple), 28.vii.1986, YJ Bae (KU); ♀, GG, Gapyeong-gun, Daeseong-ri, Sudongcheon (Stream), 9. vii.1993, YJ Bae (KU); ♀, GG, Gapyeong-gun, Buk-myeon, Dodae-ri, 28.v.1998, YJ Bae (KU); ♀, GW, Samcheok-si, Miro-myeon, Hwalgi-ri, 30.viii.2011, SW Jung (KU); ♀, GG, Yangpyeong-gun, Danwol-myeon, Bomun-ri, Bomung-yo (Bridge), 21.vii.2012, SW Jung (KU).
Distribution. South Korea, China, Japan.
Remarks. *Neochauliodes formosanus* (Okamoto) was reported from Korea for the first time by Liu *et al.* (2007), and this species is widely distributed in East Asia.

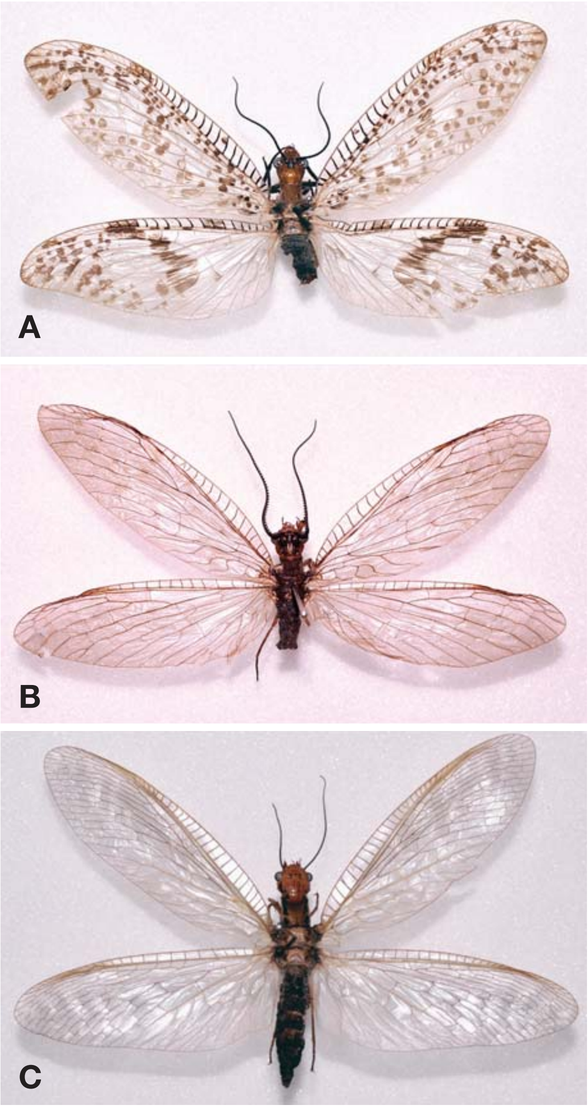

Fig. 1. Habitus photographs of family Corydalidae. A, *Neochauliodes formosanus* (Okamoto), female; B, *Parachauliodes asahinai* Liu, Hayashi & Yang, male; C, *Protohermes xanthodes* Navás, female.

Neochauliodes koreanus Weele, 1909 고려뱀잠자리
Neochauliodes koreanus Weele, 1909: 261; Weele, 1910: 65; Doi, 1933: 94; Kimmins, 1954: 437; Kimmins, 1970: 356; Liu *et al.*, 2007: 38.

Distribution. Korea.
Korean records. Seoul (South Korea), Gaeseong (North Korea).
Remarks. Weele (1909) described *Neochauliodes koreanus* from two female adults (syntypes) from Korea and indicated the type deposition in the British Museum. Weele (1910) redescribed *N. koreanus* using the same two female syntype adults in the British Museum with citation of the paler one labeled "Seoul, Korea, Hon. E. SCARLETT, Aug. 1900-351, Happy Valley, Hong Kong Peak," and the darker one with the only indication "Hong Kong, 97-261." Kimmins (1954), in the revision of the tribe Chauliodini (Megaloptera), reexamined the two syntype female adults and designated the paler one, labeled as Seoul, Korea, as holotype (=lectotype) of *N. koreanus* (see Fig. 16 in Kimmins, 1954); on the other hand, he regarded the additional label "Hong Kong Peak, Happy Valley" placed in the paler one (Korean specimen) was misplaced and it should belong to the darker Hong Kong specimen which was also illustrated in Weele (1910: Pl. IV, Fig. 39). Kimmins (1954) also found a second darker specimen in the McLachlan collection in the British Museum. Kimmins (1970) again provided information on the lectotype specimen, but listed it under the male (♂) symbol.

Liu *et al.* (2007) reiterated Kimmins' (1954) explanation of the type specimens but recognized the concept of this species based on the Kimmins' (1954) darker specimen (as paratype)

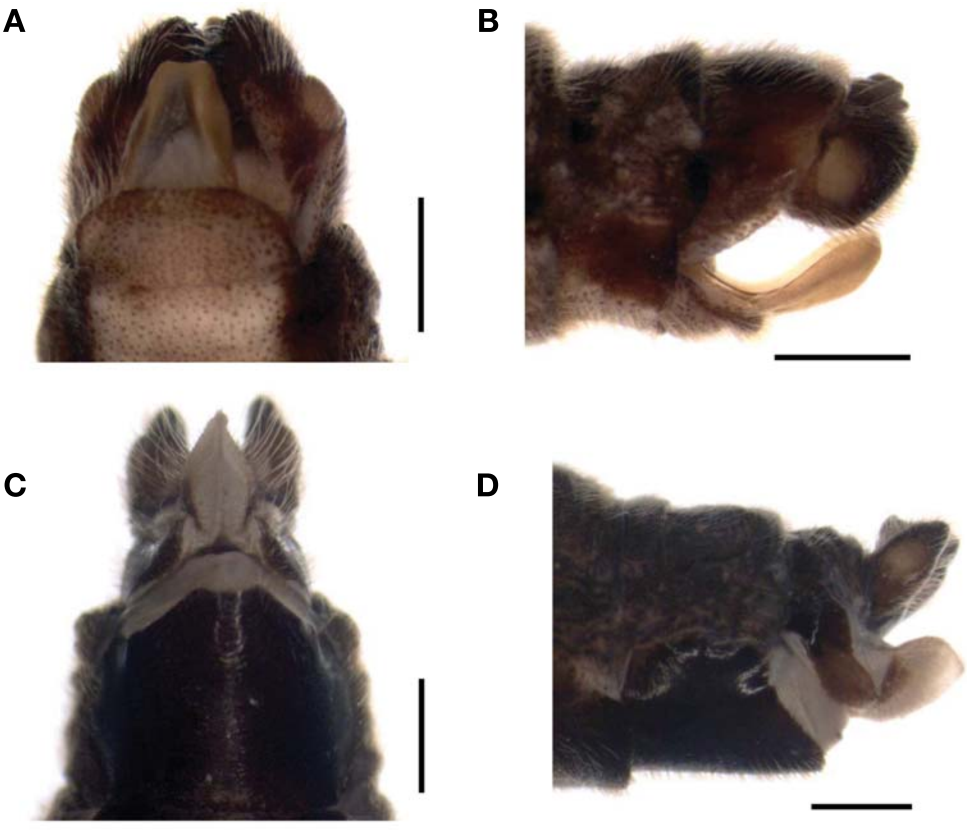

Fig. 2. *Neochauliodes formosanus*. A, male genitalia, ventral view; B, male genitalia, lateral view; C, female genitalia, ventral view; D, female genitalia, lateral view. Scale bars=1 mm.

as well as the type locality in Hong Kong. Liu *et al.* (2007) considered the type locality of the lectotype specimen, Seoul, Korea, is doubtful and excluded the locality from the distribution of this species. However, we find that the interpretation of the species concept of *N. koreanus* by Liu *et al.* (2007) is somewhat premature because the lectotype specimen designated by Kimmins (1954) as well as the type locality must be considered to re-establish the species concept of this species prior to further interpretation of this species. Kimmins (1954) did not designate paratype (=paralectotype) for the darker specimen from Hong Kong or for the second darker specimen; this darker specimen from Hong Kong can be identified as the same species of *N. koreanus* or different species after reexamination of the type specimens as well as the fresh materials from those two geographic areas.

Neochauliodes koreanus was reported by Doi (1933) from North Korea, but no specimens were available to confirm this report.

Genus *Parachauliodes* van der Weele, 1909: 257
뱀잠자리붙이속

Type species: *Chauliodes japonicus* McLachlan, 1867

Parachauliodes asahinai Liu, Hayashi & Yang, 2008
(Fig. 1B) 뱀잠자리붙이
Parachauliodes asahinai Liu, Hayashi & Yang, 2008: 563.

Diagnosis. Head subtriangular, yellowish brown with black mark dorsally. Antennae subserrate in male. Compound eyes prominent, gray in color. Ocelli present, yellow, with black marking. Wings slightly brownish color, narrowly elongated, with indistinctly brownish spots. Male tergum X (Fig. 3) flattened in dorsal view, with black spinous setae on dorsal and ventral lobes; median plate round apically.
Material examined. ♂, GG, Gapyeong-gun, Cheongpyeong-myeon, Cheongpyeong-ri, Cheongpyeong dam at street light near Bukhan River, 10.vi.1995, Y.J. Bae (KU); ♂, GG, Gapyeong-gun, Buk-myeon, Jeokmok-ri, 19.v.2012, SW Jung and YJ Bae (KU).
Distribution. South Korea, Japan.
Remarks. *Parachauliodes asahinai* was described by Liu *et al.* (2008) using adult material collected from Busan in South Korea. This species was also known in Chungcheongnam-do in South Korea and Kyushu in Japan (Liu *et al.*, 2008).

The genus *Parachauliodes* can be distinguished from other genera of the family by the subserrate antennae in both sexes,

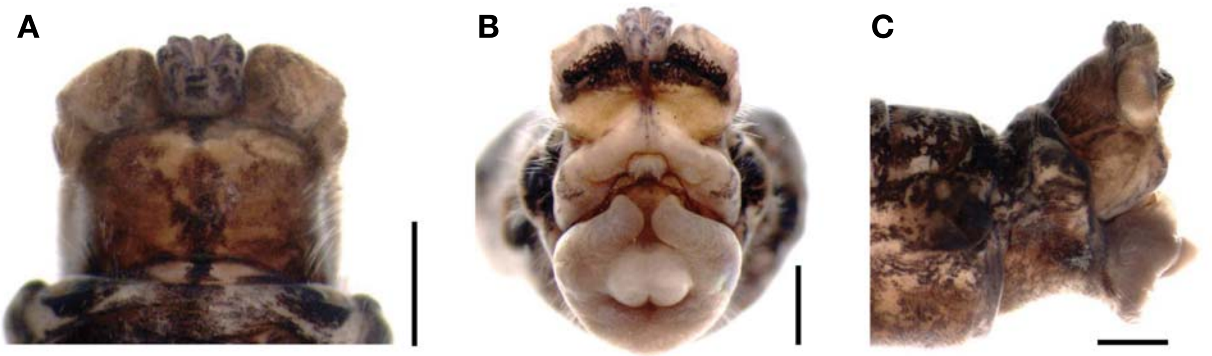

Fig. 3. *Parachauliodes asahinai*. A, male genitalia, dorsal view; B, male genitalia, caudal view; C, male genitalia, lateral view. Scale bars=1 mm.

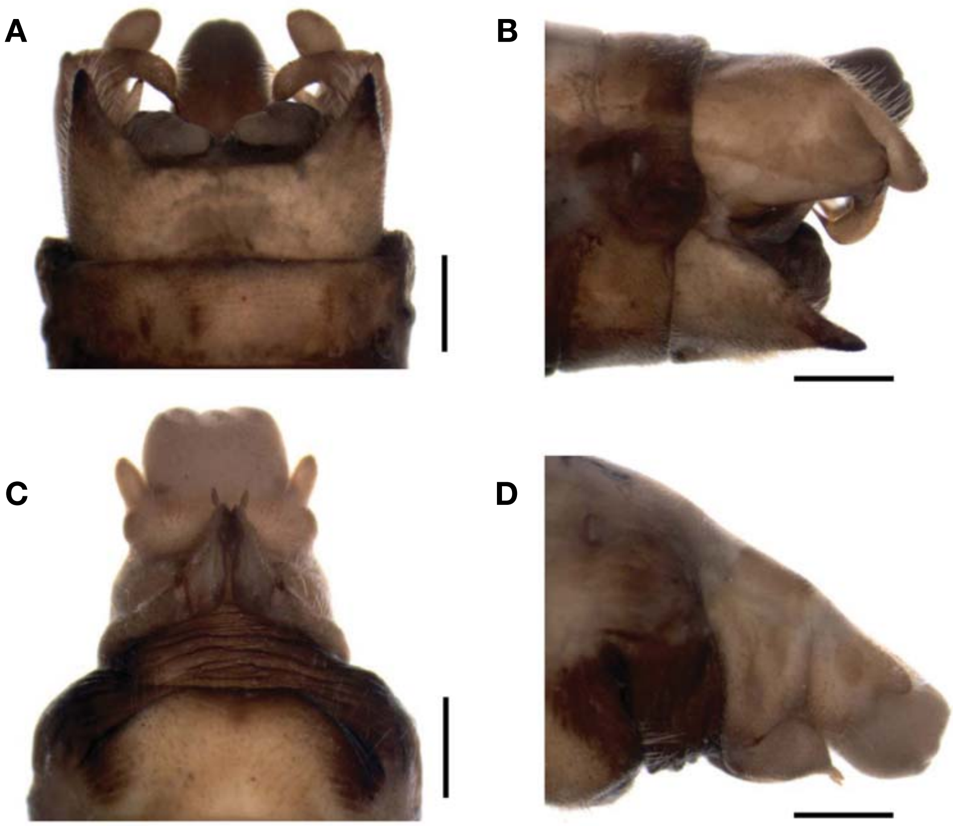

Fig. 4. *Protohermes xanthodes*. A, male genitalia, ventral view; B, male genitalia, lateral view; C, female genitalia, ventral view; D, female genitalia, lateral view. Scale bars=1 mm.

the bilobed tenth tergum in male, and the tenth sternum in male that is mostly enveloped by the ninth tergum (Kimmins, 1954). *Parachauliodes asahinai* is similar to *P. continentalis* Weele but can be distinguished by the tenth tergum that is flattened with the spinous setae on the dorsal and ventral lobes.

Weele (1909, 1910) described and reported the adult of *P. continentalis* from Tsushima Island indicating it belongs to Korea. Kimmins (1954) and Kuwayama (1962) reiterated the distribution of this species in Korea. Yoon (1988) recorded *P. continentalis* in Korea using larval material, but Liu *et al.* (2008) noted that *P. continentalis* is limited to Japan.

Subfamily Corydalinae 뱀잠자리아과
Genus *Protohermes* Weele, 1907: 243 뱀잠자리속

Type species: *Hermes anticus* Walker, 1853

Protohermes xanthodes Navás, 1913 (Fig. 1C)
노란뱀잠자리

Protohermes xanthodes Navás, 1913: 427; Liu *et al.*, 2006: 405.
Protohermes rubidus Stitz, 1914: 201.

Diagnosis. Head subquadrate, entirely yellowish brown, with three pairs of black marks. Thorax yellowish color, with a pair of black marks laterally on pronotum. Wings with yellowish marks, costal crossveins yellowish brown. Male tergum IX rectangular; sternum IX deeply incised posterior margin in ventral view (Fig. 4A); tergite X simple, claviform, with inner median margin incised, bearing one inner setal tuft on subdistal portion; male gonostylus IX (Fig. 4B) strongly developed with one apical claw. Female genitalia ventrally as in Fig. 4C and laterally as in, 4D.

Material examined. Korea: 2♂, 4♀, GW, Hongcheon-gun, Seo-myeon, Dumi-ri, Dumigyo (Bridge), Hongcheongang (River), 20.vi.2011, SW Jung (KU); ♀, CN, Gongju-si, Sagok-myeon, Unam-ri, Magoksa (Temple), 28.vii.1986, YJ Bae (KU); ♀, GG, Gapyeong-gun, Daeseong-ri, Sudongcheon (Stream), 9.vii.1993, YJ Bae (KU); ♀, GG, Gapyeong-gun, Gapyeong-eup, Eumnae-ri, Gapyeongcheolgyo (Bridge), 15.vii.1993, YJ Bae (KU); ♀, GB, Cheongsong-gun, Cheongsong-eup, 24.viii.2010, DH Lee (KU); 18♀, GW, Samcheok-si, Miro-myeon, Hwalgi-ri, 22.vii.2011, DH Lee (KU); 15♀, GB, Uljin-gun, Seo-myeon, Wangpi-ri, Yangjimaeul, 1.viii. 2012, JK Choi and HM Lim (KU).

Distribution. South Korea, China.

Remarks. This species is common and widely distributed in Korea. Previous records of the adults (Doi, 1933; Kamijo, 1933; Kuwayama, 1962) and larvae (Yoon, 1988) of *Protohermes grandis* (Thunberg) in Korea are probably misidentifications of this species. The adults of *P. xanthodes* can be distinguished from those of *P. grandis* by the thick ninth gonostylus in male and the tenth sternite that bears a spinous tip.

Liu *et al.* (2006) synonymized *Protohermes martynovae* Vshivkova, 1995 with *P. xanthodes* Navás, 1913, but Vshivkova & Dubatolov (2010) noted that these two species can be separated because wing venation and genital structure of the type specimen (Jakovlevsky, Primorsky Region, Russian Far East) of *P. martynovae* (as well as fresh material from the type locality) are significantly different from those of *P.*

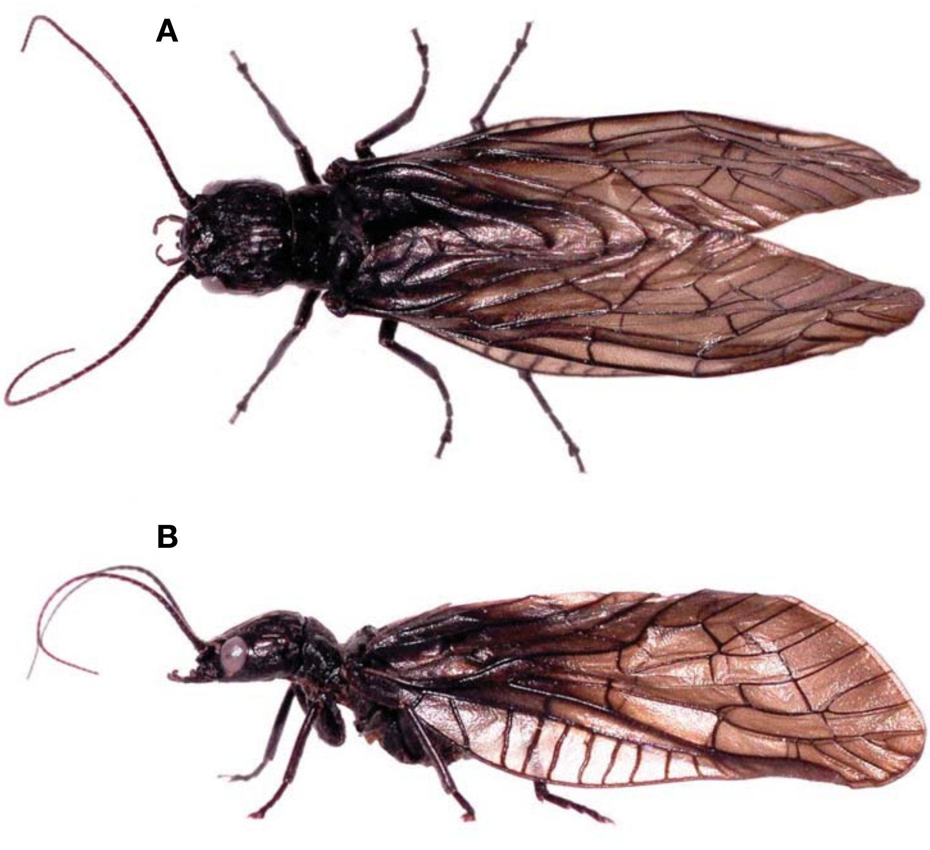

Fig. 5. *Sialis koreana*, n. sp. female paratype. A, habitus, dorsal view; B, habitus, lateral view.

xanthodes (type locality: Dali=Tali, Yunnan Province, Southern China).

We temporarily identify Korean specimens of this species as *P. xanthodes* according to Liu *et al*. (2006), but it should be determined after comparisons with materials of *P. xanthodes* and *P. martynovae* (see Vshivkova & Dubatolov, 2010).

Family Sialidae 좀뱀잠자리과
Genus *Sialis* Latreille, 1802: 290 좀뱀잠리속

Type species: *Hemerobius lutarius* Linnaeus, 1758

***Sialis koreana*, n. sp.** (Fig. 5) 한국좀뱀잠자리

Description. Male adult (holotype). Body length 11.5 mm. Head black; vertex with median longitudinal yellow marking and round spots dorsally and several small elongate yellow markings laterally; frons with a pair of red markings. Labrum black and bilobed. Antennae dark brown and filiform. Mandibles narrow, strongly sclerotized and curved. Maxillary palp five-segmented; palpomere 1 short; palpomere 3 slightly longer than palpomeres 2, 4 or 5; terminal palpomere with sensory cone inside; galea two-segmented; basal segment long; terminal segment short with densely setae; lacinia narrow and more or less tapering with densely setae. Labial palp 3-segmented; palpomere 1 shorter than palpomeres 2 or 3; terminal palpomere with sensory cone inside. Compound eyes gray, less prominent. Ocelli absent. Thorax black. Legs blackish brown; tarsi 5-segmented; tarsomere 4 short and broad, bilobed; two claws shiny, with 1 tooth basally. Wings

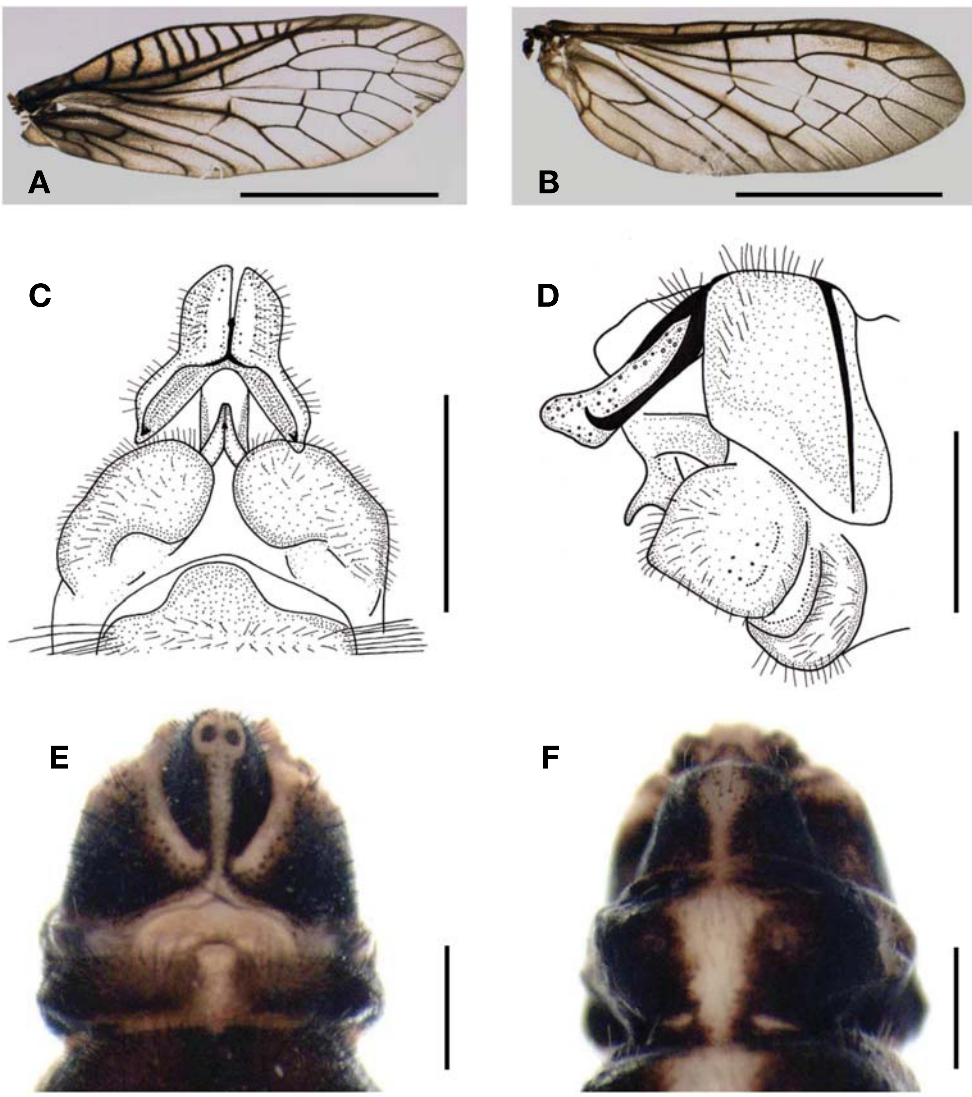

Fig. 6. *Sialis koreana*, n. sp. male holotype. A, right forewing, dorsal; B, right hindwing, dorsal; C, male genitalia, ventral view; D, male genitalia, lateral view; E, female genitalia, ventral view; F, female genitalia, dorsal view. Scale bars=5 mm (A, B), 0.5 mm (C-F).

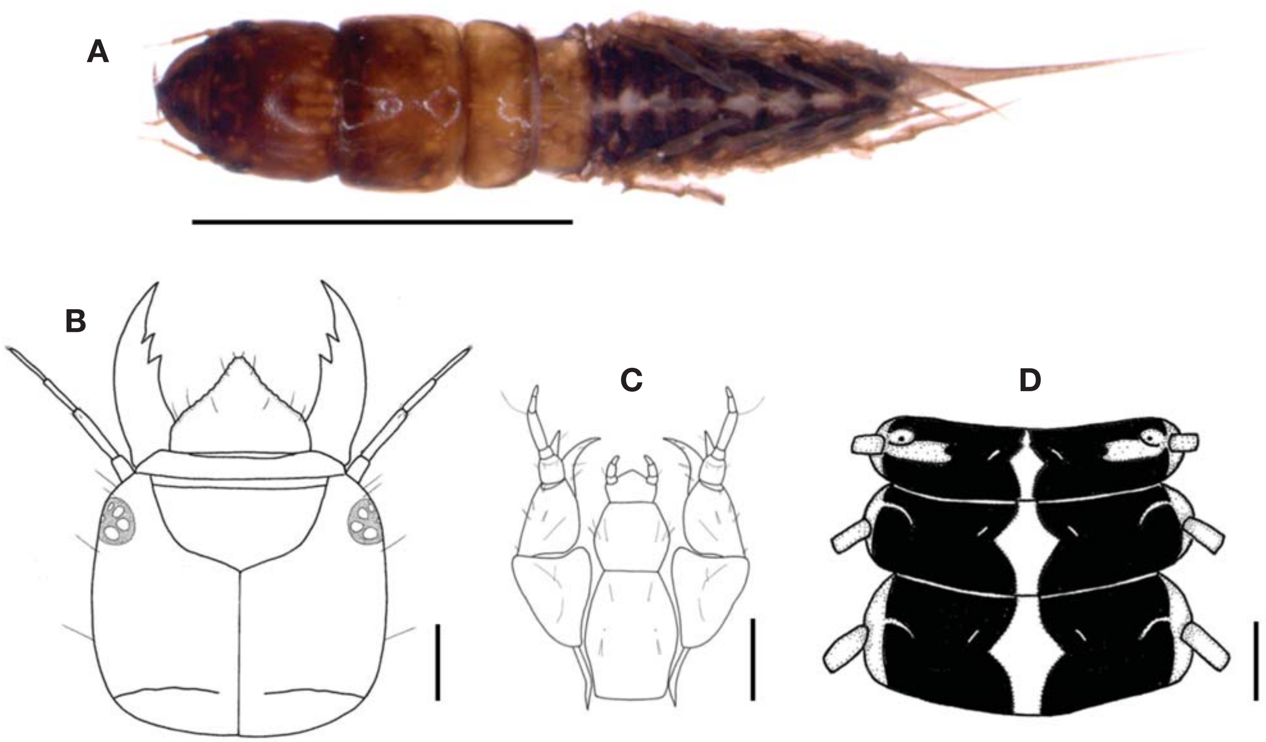

Fig. 7. *Sialis koreana*, n. sp. larva. A, habitus, dorsal view; B, head, dorsal view; C, mouth parts, ventral view; D, abdominal segments 1-3, dorsal view. Scale bars=5 mm (A), 0.5 mm (B-D).

dark in color; veins thick. Forewings (Fig. 6A) 11.5 mm in length, 4.0 mm in width, long and narrow, with 14 costal crossveins close each other; sc-r present; R_2 and R_3 2-branched. Hindwing (Fig. 6B) 10.6 mm in length, 4.0 mm in width. Abdomen black, with median longitudinal white line. Tergum IX broad, trapezoidal; tergum X long and prominent anteriorly in lateral view (Fig. 6D). Sternum IX narrow, with long setae laterally; sternum X short and slightly curved ventrally. Gonostylus IX (Fig. 6C) broad and subquadrate.

Female adult (Fig. 6E, F). Body 17.5 mm in length; forewings 15.5 mm in length, 6 mm in width; hindwings 13.8 mm in length, 6 mm in width. Abdominal sternum VII with a medial notch on posterior margin; sternum VIII narrow, divided at medial part. Ventral membranous plate of abdominal segment IX widely n-shaped.

Larva. Body length 11.2~12.0 mm (n=4); caudal filaments length 4.4~5.3 mm (n=4). Body elongate, more or less flattened (Fig. 7A). Head and thorax sclerotized, reddish brown, legs yellowish brown, abdomen soft and dark brown, with paler lateral filaments. Head (Fig. 7B) almost square, with several yellowish marks and spots; Y-shaped epicranial suture distinct; frons with indistinct transverse suture anteriorly; postoccipital suture slightly round, interrupted at coronal suture. Antennae slender, 4-segmented; antennomere 1 short and stout. Labrum subtriangular and protruding anteriorly with crenulate anterior margin. Mandibles well developed, with two teeth. Maxillae (Fig. 7C) with large cardo; stipes smaller than cardo; galea conical; lacinia falciform, with two strong long setae posteriorly and two strong small setae anteriorly; maxillary palp 5-segmented; palpomere 2 shortest; palpomere 3 slender and longest, with long seta anteriorly. Labium elongate; submentum large, widest at posterior 2/5 part; mentum small, widest at middle part, as long as half of submentum, with strong setae laterally; prementum short, subtriangular between palpi; labial palp short, 3-segmented.

Thorax reddish to yellowish brown; prothorax large, as long as meso- and metathorax combined; meso- and metathorax twice as wide as long. Legs long and slender, 6-segmented, with two claws in different length. Abdomen elongate, 10-segemented, with 7 lateral filaments. Abdominal segment X small and emarginated at apex, with caudal filament. Abdominal terga with median longitudinal light band, with two small lateral light spots (Fig. 7D). Sterna with transverse light band.

Material examined. Holotype: ♂, Korea, GW, Inje-gun, Seohwa-myeon, Seoheung-ri (38° 12′54.1″N, 128° 07′26.6″E, alt. 1,190 m), Yongneup (swamp), 1.vi.2012, YJ Bae and SW Jung (KU). Paratypes: 4♂, 2♀, same locality and data as holotype (KU). Other material: 3L, same locality as holotype, 16.viii.2011, DG Kim and MC Kim (KU); 8L, ditto but

Fig. 8. Habitat of *Sialis koreana*, n. sp. in Youngnup swamp land, Yanggu, Korea. A, landscape of collecting site; B, small swamp of preserved zone in peat beds; C, stream in swamp land.

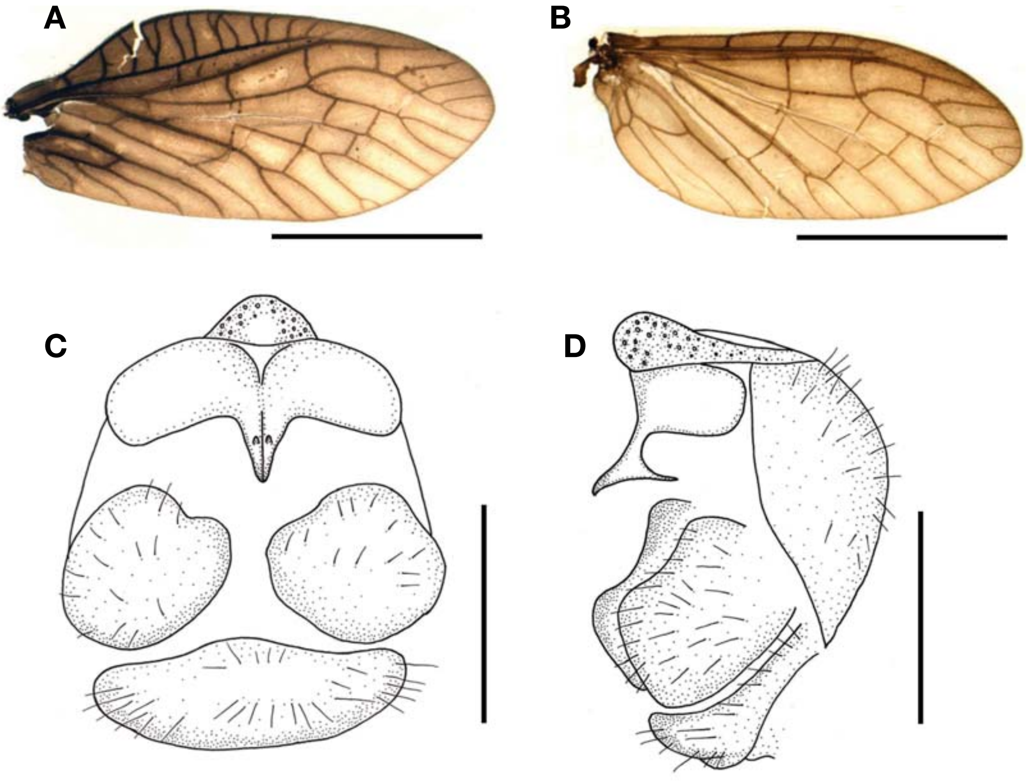

Fig. 9. *Sialis annae* Vshivkova. A, right forewing, dorsal; B, right hindwing, dorsal; C, male genitalia, ventral view; D, male genitalia, lateral view. Scale bars=5 mm (A, B), 0.5 mm (C, D).

1.vi.2012, YJ Bae, SW Jung, MC Kim, and HJ Park (KU).

Distribution. South Korea.

Etymology. This new species is presumably endemic to Korea.

Habitat. We collected larvae of *Sialis koreana* in a small headwater in the Youngnup (swamp) Naturae Protection Area (Fig. 8A~C), a basin type highland swamp on the top of the Daeamsan Mt. (1,304 m above sea level) in Gangwon-do, South Korea. This area is well protected as it was registered as the Ramsar wetland in 1997. Demilitarized zone (DMZ) is located beside the wetland area. Adults were collected using a sweep net on the vegetation beside the swamp.

Remarks. This new species is similar to *Sialis sibirica* McLachlan, but can be distinguished by the following morphological characters: body and wings are black in color and small sized; tenth tergum is thick and prominent anteriorly; sternum IX is broad with long setae laterally in ventral view; gonostylus IX is subquadrate in lateral view and widely round in ventral view.

In a fauna list of Korean insects, *Sialis sibirica* was report-

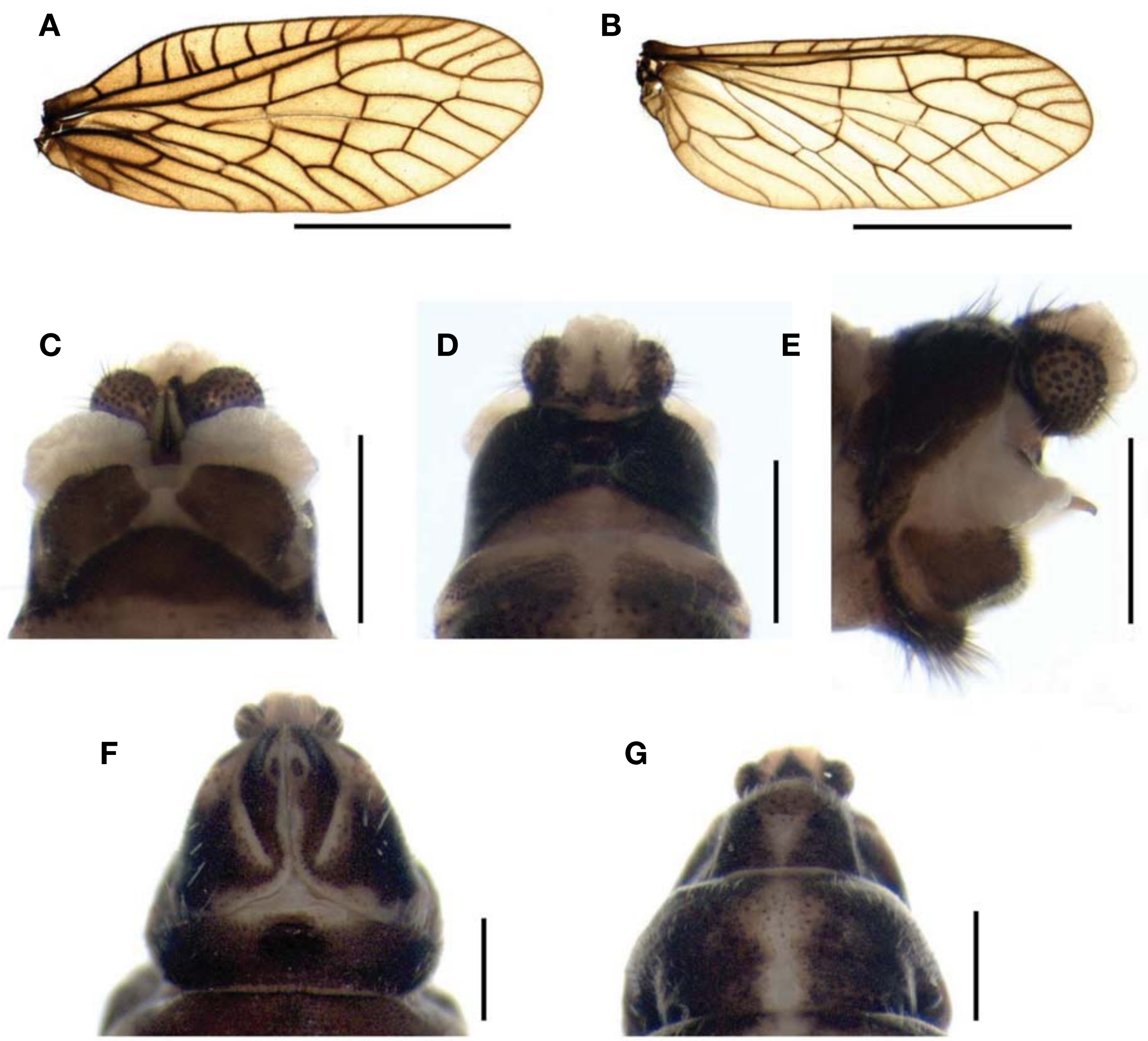

Fig. 10. *Sialis longidens* Klingstedt. A, right forewing, dorsal; B, right hindwing, dorsal; C, male genitalia, ventral view; D, male genitalia, dorsal view; E, male genitalia, lateral view; F, female genitalia, ventral view; G, female genitalia, dorsal view. Scale bars=5 mm (A, B), 0.5 mm (C-G).

ed from Hwanghae-do (North Korea) by Doi (1932, 1933). *Sialis* KUa (undetermined larva) was described by Yoon (1988) from Daeamsam Mt. area near holotype locality of *S. koreana*. However, we are unable to determine the larva because no specimens are preserved.

Sialis annae Vshivkova, 1979 (Fig. 9) 좀뱀잠자리

Sialis annae Vshivkova, 1979: 79; 1995: 33.

Diagnosis. This species can be distinguished from other male *Sialis* species by the following characters: head and thorax black color; wings (Fig. 9A, B) brown color and opaque, broad width; tenth tergum (Fig. 9C) short and slender; ninth sternum narrow; ninth gonostylus (Fig. 9D) broad, subtrapezodial in lateral view; tenth sternum short and pointed.

Material examined. 1♂, GG, Gapyeong-gun, Buk-myeon, Seungcheonsa, 20.v.2010, SW Jung (KU).

Distribution. South Korea (new record), Russia.

Remarks. This species is newly recorded from Korea. The single male was collected at the mountain of the northern area of South Korea.

Sialis longidens Klingstedt, 1932 (Fig. 10) 가는좀뱀잠자리

Sialis longidens Klingstedt, 1932: 1; Hayashi & Suda, 1995: 6; Vshivkova & Ito, 1993: 108; Vshivkova, 1995: 33; Liu & Yang, 2006a: 396.

Diagnosis. This species can be distinguished from other male *Sialis* species by the following characters: wings blackish brown color, slightly broad; tenth tergum (Fig. 10D) as long as 2/3 of width of ninth tergum, subquadrate in lateral view (Fig. 10E); tenth sternum elongate (Fig. 10C); ninth gonostylus subquadrate with ventroposterior corner angulately prominent (Liu & Yang, 2006a). Female is larger than male; ovipositor, seventh and eight sternum of ventral and dorsal view as in Fig. 10F, G.

Material examined. ♂, 2♀, GG, Namnyangju-si, Joan-myeon, Neungnae-ri, 24.iv.1986, YJ Bae (KU); ♀, GW, Yangyang-gun, Seo-myeon, Osaek-ri, Seoraksan (Mt.), 20.vi.1995, YJ Bae (KU); ♂, GG, Pocheon-si, Naechon-myeon, Eumhyeon-ri, 1.v.1996, YJ Bae (KU); 13♂, 3♀, CB, Yeongdong-gun, Hwanggan-myeon, Nangok-ri (36°14′50.96″N, 127°57′19.92″E), 13.iv.2011, SW Jung (KU); 2♀, GG, Namyangju-si, Wabu-eub (37°35′02.1″N, 127°14′16.7″E), Emergence trap, 28.iv.2012, CY Lee (KU).

Distribution. South Korea (new record), China, Japan, Russia.

Remarks. This species is newly recorded from Korea. The adults of this species were collected near the reservoir at the mountain area.

Sialis sibirica McLachlan, 1872 시베리아좀뱀잠자리

Sialis sibirica McLachlan, 1872: 55; Weele, 1910: 82; Kuwayama, 1936: 110; Kuwayama, 1962: 331; Kimmins, 1970: 357; Vshivkova, 1980: 75.

Sialis frequense Okamoto, 1905: 112.

Distribution. North Korea, China, Japan, Russia, northern Europe.

Korean records. Hwanghae-do.

Remarks. Doi (1932) recorded this species from North Korea (Hwanghae-do) under the name of *Sialis frequens* Matsumura which was later synonymized with *S. sibirica* McLachlan by Doi (1933).

Key to the Korean Megaloptera male adults

1. Ocelli present; tarsomere 4 non-bilobed; large species (Fig. 1) .... Corydalidae 2
− Ocelli absent; tarsomere 4 bilobed; small black species (Fig. 5) .... Sialidae 4
2. Head subquadrate; antenna filiform; head and thorax with black marks on lateral part; wings hyaline without spots (Fig. 1C) .... *Protohermes xanthodes*
− Head subtriangular, antenna pectinate or subserrate; wings with spots (Fig. 1A) 3
3. Head dark; antenna subserrate; wings narrowly elongated with spots indistinctly (Fig. 1B) .... *Parachauliodes asahinai*
− Head yellowish brown; antenna pectinate; wings with many dark brown spots distinctly (Fig. 1A) .... *Neochauliodes formosanus*
4. Wings dark color, narrow (Fig. 6A, B); tenth tergum long and prominent anteriorly .... *Sialis koreana*
− Wings yellowish brown, wide (Fig. 9A) 5
5. Tenth tergum and sternum short (Fig. 9D) ... *Sialis annae*
− Tenth tergum and sternum long (Fig. 10E) .... *Sialis longidens*

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Short communication

First Record of *Brachonyx pineti* (Paykull, 1792) (Coleoptera: Curculionidae) from Korea

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Abstract

A weevil species *Brachonyx pineti* (Paykull, 1792) is identified for the first time from Korea. Redescription, illustrations of diagnostic characters and biological notes are provided.

Key words: *Brachonyx pineti*, Coleoptera, Curculionidae, Korea, newly recorded

Introduction

The genus *Brachonyx* Schoenherr, 1825 (Coleoptera: Curculionidae) is a common weevil group in Europe. The genus *Brachonyx* is monotypic, with the only known species *Brachonyx pineti*. The species is a pest of pine tree because its larvae are mining in needles of pine tree (Rheinheimer and Hassler, 2010). In Korea, *Brachonyx* group include two other genera, *Anthonomus* and *Bradybatus*.

Brachonyx is distinguished by the combinations of the following features from other related genera: antennal funicle with 7 or 6 segments; antennal scape reaching middle of eye or not; body slender, elytra longer than 2 times of its width or shorter than 1.7 times of its width; clavate part of femur with teeth or 2 tooth or without, and host plants.

This paper provides redescription for *Brachonyx pineti* with photo, illustrations of diagnostic characteristics, biological notes and key to the *Brachonyx* group in Korea. Specimen is deposited in Korea University (KU), Seoul, Korea.

Taxonomic Accounts

Order Coleoptera
Family Curculionidae
Subfamily Curculioninae
Tribe Anthonomini
Genus *Brachonyx* Schoenherr, 1825
솔잎바구미속(신칭)

Brachonyx Schoenherr, 1825: 583. (Type species. M; *Curculio indigena* Herbst, 1795=*Curculio pineti* Paykull, 1792.

Brachonyx pineti (Paykull, 1792) (Figs. 1, 2A, 2B, 3A, 4)
솔잎바구미 (신칭)

Curculio pineti Paykull, 1792. Monographia Curculionum Sveciae. Upsaliae, I-VIII: 61-62 (type-locality: West Sweden, upland).

Brachonyx pineti : Schoenherr, 1825: 583; Reitter, 1916: 195; Hoffman, 1954: 1101; Lohse, 1983: 105.

Redescription. Body length 2.5 mm, body width 0.85 mm. Body color reddish brown to dark brown. Head, pronotum, underside and legs dark brown. Elytra and antenna reddish brown. Body covered with short slender light brownish bamboo leaf-like hairs densely. Head much broader than length, almost 2 times of the length. Rostrum slender, and more than 4 times longer than width, both sides almost parallel, dorsal surface covered with small punctures sparsely. Epistome small V-shape. Antennal sockets located a little behind of middle of rostrum. Eyes dorso-lateral position, a little convex. Antennal scape slender, its distal part clavate slightly. Antennal funicle with 7 segments, segment 1 thicker and bigger than segment 2, from segment 3 to segment 6 moniliform, segment 7 much wider than segment 6. Pronotum a little broader than length, basal margin slightly bisinuate and wider than anterior margin, sides slightly rounded. Scutellum small U-shape, covered with tiny whitish brown hairs. Elytra very long, more than 2 times of width, sides almost parallel, widest hindquarter part very slightly wider than base. Each elytral interval with granules and hairs in a row, a hair on a granule, except hind part of first interval. Punctures between intervals forming a stria. Femur without a tooth on the inside of the clavate part. Tarsal segment 3 long and bi-lobed, segment 5 slightly longer than segment 3, shorter than 1.5 times of segment 3. Grooves (=junctions) between ventrites straight horizontally.

Material Examined. Korea: 1 male, Gangwon-do, Taebaek-si, Sodo-dong, 28.iv.2012, Torben Kölkebeck (KU).

Distribution. Korea (Central), Europe, West Siberia.

Fig. 1. Habitus of *Brachonyx pineti*: A, Dorsal view; B, Lateral view. Scale bar=1.0 mm.

Biological note. *Bradybatus* group lives in Middle Europe only on maple trees (*Acer* spp.), *Brachonyx pineti* lives monophagous on *Pinus silvestris*, in contrary to *Anthonomus*, which can be found on a wide base different plants (Lohse, 1983). The beetle can fly well and follow the spreading of the important horticultural tree also in high altitudes. The species was found in the Bulgarian Rhodopen mountain at an altitude level of 1,700 m. The beetles are laying eggs on the sheath of the needles from the end of April, and the larva are drilling from this place to the base of the needle, where it also reach its pupae state, the inhabited needles degenerate or die. The beetle is hatching in July and feeding on the needles up to the autumn. The species has a tendency to be invasive (Dieckmann, 1988). Parasitoids of the species as follows, Ichneumidae: *Pimpla turionella* (Linnaeus), *Scambus sagax* (Hartig); Eulophidae: *Tetrastichus* sp.; Eupelmidae: *Eupelmus vesicularis* (Retzius), *E. urozonus* Dalman; Eurytomidae: *Eurytoma curculionum* Mayr; Pteromalidae: *Pteromalus semotus* (Walker), *P. vaginulae* Ratzebrug, *Trichomalus helvipes* (Walker) (Rheinheimer and Hassler, 2010).

Remarks. *Brachonyx* - in comparing with *Anthonomus* spp. (*Anthonomus bisignifer*, *Anthonomus rectirostris, Anthonomus rubi*) - can be easily distinguished by the following features: *Brachonyx* shows lack of tooth structure on all legs (Fig. 2B) in contrary to distinguished species of *Anthonomus* (Fig. 2C, D). The *Anthonomus* species shows two types of femoral teeth: one type with 2 teeth on the clavate part of femur just found by *Anthonomus* subgenus *Furcipus* (Fig. 2C) and the other type with a simple tooth testified by the species *Anthonomus rubi* and *Anthonomus bisignifer* (Fig. 2D). Tarsal

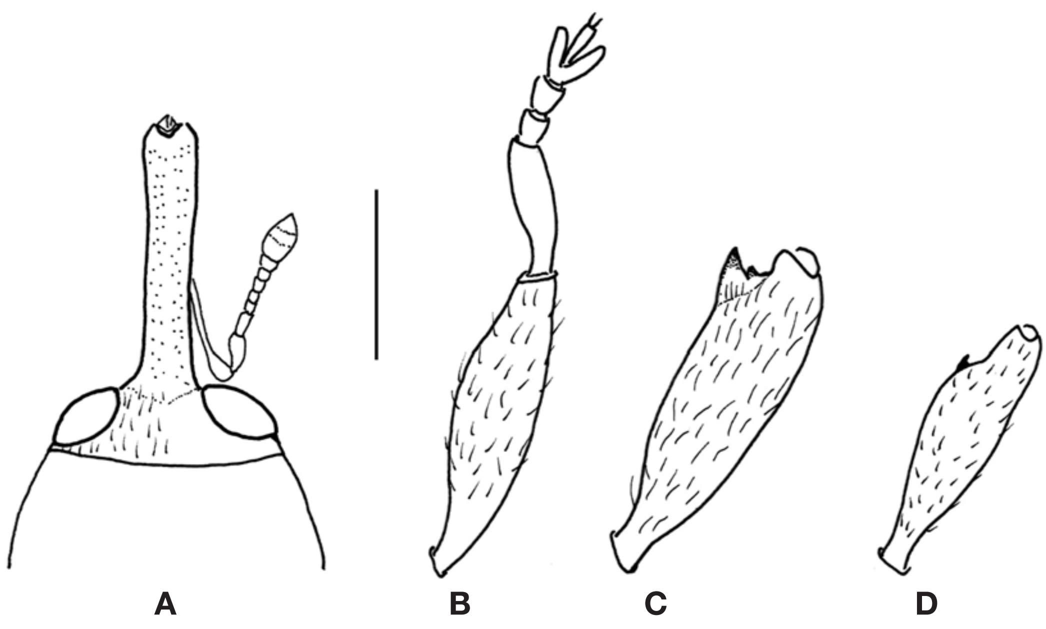

Fig. 2. Illustrations of diagnostic characters: A, Head and rostrum of *Brachonyx pineti*; B, Front leg of *Brachonyx pineti*; C, Front femur of *Anthonomus* (*Furcipus*) *rectirostris*; D, Front femur of *Anthonomus bisignifer*. Scale bar=0.5 mm.

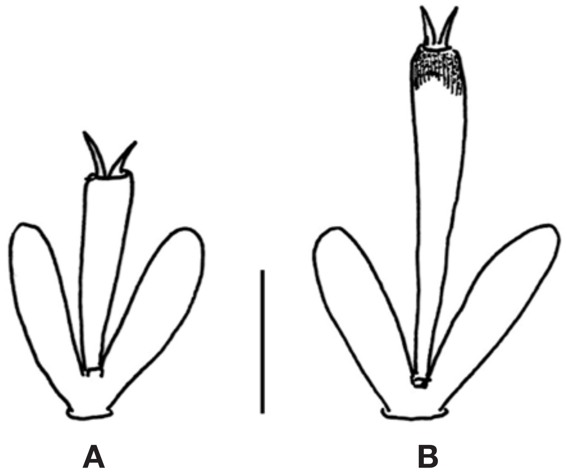

Fig. 3. Tarsal segment 3 and 5: A, *Brachonyx pineti*; B, *Anthonomus* spp. Scale bar=0.1 mm.

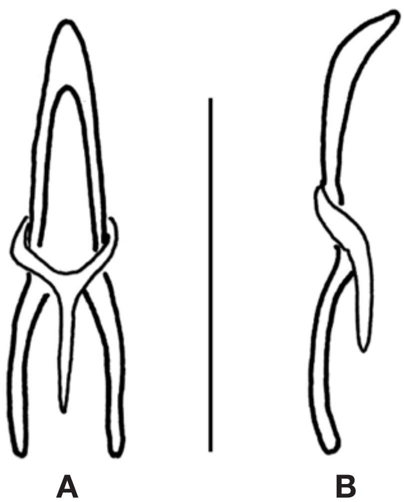

Fig. 4. Male genitalia of *Brachonyx pineti*: A, *Ventral* view; B, Lateral view. Scale bar=0.5 mm.

segment 5 of *Brachonyx pineti* slightly shorter than segment 3 (Fig. 3A); Fifth tarsal segment of *Anthonomus* 2 times longer than segment 3 (Fig. 3B).

Key to the Korean *Brachonyx* group in Korea

1. Antennal funicle with 6 segments. Antennal scape is reaching the middle area of an eye ··· *Bradybatus* Germar
– Antennal funicle with 7 segments ································· 2
2. Body more compact. Elytra widened to the end, not longer than 1.7 times of width. Front femur with 1 or 2 teeth. Fifth tarsal segment is 2 times longer than segment 3. Antennal scape is reaching the anterior margin of an eye. Host plants are not limited to only coniferous trees ··· *Anthonomus* Germar
– Body elongate. Elytra not widened to the end, around double as long as wide. All femur without teeth. Fifth tarsal segment is 1.5 times shorter than segment 3. Antennal scape is almost reaching the middle area of an eye. Host plants limited to coniferous trees ··· *Brachonyx* Schoenherr

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Short communication

First Record of *Torleya japonica* (Gose) (Ephemeroptera: Ephemerellidae) from Korea

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Abstract

The genus and species *Torleya japonica* (Gose, 1980) in the family Ephemerellidae is recorded for the first time in Korea. Diagnosis and larval photograph are provided.

Key words: Ephemerellidae, Ephemeroptera, Korea, new record, *Torleya japonica*

Introduction

Torleya Lestage, 1917 (Ephemerellidae, Ephemeroptera) is a Palearctic and Oriental genus of the subfamily Ephemerellinae (Jacobus and McCafferty, 2008). In East Asia, 2 species of *Torleya* were recorded from the Russian Far East (Tiunova, 2009); 3 species from Japan (Ishiwata, 2001); and 3 species from China (Jacobus *et al.*, 2004).

The larva of *Torleya* has semi-operculate dorsal gill lamellae on the 3rd abdominal segment, bifurcate ventral gill lamellae on the 6th abdominal segment, paired or absent abdominal tergal spines, and claws with at least a basal set of denticles (Jacobus *et al.*, 2004).

This study provides diagnostic characters for *Torleya japonica* with a photograph of the larva. All specimens used in this study are deposited in the Entomological Museum of Korea University (KU) in Seoul and the National Institute of Biological Resources (NIBR) in Incheon, Korea.

Taxonomic Accounts

Order Ephemeroptera
Family Ephemerellidae Klapalek
Genus *Torleya* Lestage, 1917
Torleya Lestage, 1917: 366. Type species: *Torleya belgica* Lestage

Torleya japonica (Gose, 1980) (Fig. 1)
Ephemerella (*Torleya*) *japonica* Gose, 1980: 286.
Torleya japonica (Gose, 1980) Gose, 1985: 25.

Fig. 1. Larva of *Torleya japonica* in dorsal view. Scale bars=0.5 mm.

Diagnosis. Maxillae with few distal hairlike setae; palp absent; spinous processes hooked distally. Mandibles external margin with cilialike setae. Labium with cilialike setae on ventral surface; palp segment 3 approximately one-half length segment 2. Pronotum pale medially, darker laterally, with pale anterolateral and posterolateral corners. Mesonotum brown with medial pale spot on anterior margin, flank-

ed by two dark brown spots laterally, pale between forewing-pads. Claws with two to four basal denticles, one to four subdistal denticles, and with subdistal setae. Dorsal lamella gills 3 operculate, without apical notch, pale with brown trilobed pattern. Sterna with few faint brown sublateral maculae, with few setae. Caudal filaments pale with brown bands.
Remarks. Jacobus *et al.* (2004) provided full description.
Materials examined. Korea: 1 Larva, Gangwon-do, Cheorwon-gun, Seo-myeon, Wasu-ri, Hakpogyo, 15 Sep. 2007, Chun YC; 1 Larva, Gyeongsangbuk-do, An-dong, Imha-myeon, Sindeok-ri, Sindeokgyo, 16 Sep. 2010, Baek MJ and Hwang JM.
Distribution. Korea (new record), Japan

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Edited by S. Narumon & S.W. Jung

4th AESEA Meeting
at Charoenthanee Princess Hotel, Khon Kaen, Thailand

Field trip to Lam Takhong
Stream from Khao Yai National Park, Thailand

Report from the AESEA Meeting Committee upon the Reformation of AESEA

Asian countries are experiencing the unprecedented economic growth and industrial development as is well known. Consequently the problems from various anthropogenic disturbances will cause a serious impact on ecosystems, especially on aquatic ecosystems: rapid degradation of water quality and shortage of freshwater resources in the Asian region. Under this critical moment of fast growing fields in aquatic sciences and the rapid increase in young scientist communities as well, all members of the AESEA Meeting Committee, on behalf of delegates of the Aquatic Entomologists Societies in East Asia (AESEA), agreed that the scope of the society should be extended in various fields regarding topics, taxa, and geographic areas. Consequently the Committee recommended that AESEA should be reformed as a more advanced organization, as follows:

1. Change of the title of AESEA: The Benthological Society of Asia (BSA).
2. BSA will succeed major philosophies, traditions, and policies of AESEA.
3. The upcoming meeting of BSA should be: The 5th Symposium of the Benthological Society of Asia (BSA: formerly AESEA).
4. The Committee unanimously recommended that Professor TANIDA Kazumi (Osaka Prefecture University, Japan) should be brought forward as the 1st President of BSA (term: 3 years, 2009.1.1～2011.12.31) upon consent of the delegates of AESEA, by considering his life-time contribution to the field of benthology including the well known book "Aquatic Insects of Japan".
5. Publication of the official academic journal of BSA will be launched. Distinguished aquatic scientists will be invited by BSA as editor(s) and editorial board members accordingly.
6. The establishment of BSA will be completed by the end of 2009. The place and time of the upcoming symposium of BSA (year 2011) will be announced by BSA by the end of 2009.
7. Professor BAE Yeon Jae (Korea University, Korea) will serve as Secretary General of BSA.

Charoenthanee Princess Hotel, Khon Kaen, Thailand
January 2009

AESEA Meeting Committee
Dr. BAE Yeon Jae (Organizer of the 1st AESEA Meeting, Korea, 2000)
Dr. TOJO Koji (on behalf of the Organizer of the 2nd AESEA Meeting, Japan, 2002)
Dr. WANG Xinhua (Organizer of the 3rd AESEA Meeting, China, 2005)
Dr. SANGPRADUB Narumon (Organizer of the 4th AESEA Meeting, Thailand, 2009)

The 4th International Symposium on Aquatic Entomology in East Asia (AESEA), Khon Kaen, Thailand
5–8 January 2009

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Insect diversity

Origin of Parthenogenesis in the Geographically Parthenogenetic Mayfly *Ephoron shigae* (Ephemeroptera: Polymitarcyidae) - Potential for Parthenogenesis of Females in a Bisexual Population -

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Abstract

The burrowing polymitarcyid mayfly *Ephoron shigae* is widely distributed across Japan. Some populations are bisexual, and others are unisexual, *i.e.*, geographically parthenogenetic. Moreover, the distribution of the bisexual and unisexual populations overlap broadly in their respective geographic ranges. *Ephoron shigae* provides a good model to study the differentiation of unisexual and bisexual populations, the establishment of parthenogenesis, and the dispersal of parthenogenetic individuals. In the previous study for this mayfly, obligatorily diploid thelytoky appears in unisexual populations. However, the potential for parthenogenesis or parthenogenetic ability of females in a bisexual population is still not clearly understood. From this background, we examined the parthenogenetic ability of virgin females in the bisexual populations. As a result, it is revealed that females of this population potentially have parthenogenetic ability. The parthenogenetic individuals of bisexual population were also indicated to be of the same diploid thelytokous type as found in the other examined unisexual populations.

Key words: *Ephoron shigae*, geographic parthenogenesis, mayfly, parthenogenesis, Polymitarcyidae, thelytoky

Introduction

The burrowing polymitarcyid mayfly *Ephoron shigae* (Takahashi) is distributed widely in Japan. Some populations are bisexual, and others are unisexual (solely females), so that *E. shigae* is a geographically parthenogenetic mayfly (Watanabe and Ishiwata, 1997; Tojo *et al.*, 2006; Sekiné and Tojo, 2007; Fig. 1). In general, parthenogenetic populations are often found under that extreme environments such as at high latitudes and altitudes, in xeric as opposed to mesic conditions (e.g., Suomalainen *et al.*, 1987), in isolated habitats such as islands and island-like areas, and at the peripheral regions of the taxon's range (Cuellar, 1977). In *E. shigae*, however, the distribution of the bisexual and unisexual populations overlap broadly in their respective geographic ranges. Therefore, *E. shigae* provides a uniquely well-suited model to study the differentiation of unisexual and bisexual populations, the establishment of parthenogenesis, and the dispersal of parthenogenetic individuals.

In the previous study on *E. shigae*, obligatory parthenogenesis (the normal mode of reproduction) appears in unisexual populations (Tojo *et al.*, 2006). Furthermore, it is revealed that all individuals reproduced by parthenogenesis are diploid females (2n=12), indicating the occurrence of thelytokous parthenogenesis (Sekiné and Tojo, 2007). However, the parthenogenetic ability of females in the bisexual populations has not been thoroughly studied. Although it was reported that twenty of the females examined in the Asahi-gawa River population (a bisexual population) showed no parthenogenetic ability (Tojo *et al.*, 2006), it is still unclear whether this parthenogenetic potential is peculiar to the unisexual populations or not. From this background, we examined the parthenogenetic potential of virgin females in the bisexual populations.

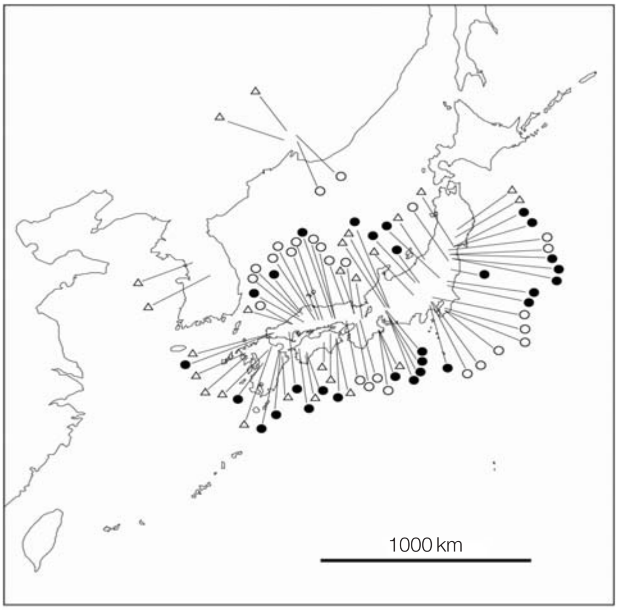

Fig. 1. Distribution of *Ephoron shigae*. Data from the present study added to that from Sekiné *et al.* (2006) and Tojo *et al.* (2006). Open and solid circles indicate bisexual and unisexual populations, respectively. Open triangles indicate the populations in which the sex ration was not determined.

Materials and Methods

Development Rate of Fertilized and Unfertilized Eggs of *Ephoron shigae*

Three bisexual populations of *Ephoron shigae* were examined; from Hino-yosui flume (irrigation canal; Hino, Tokyo Prefecture: 36° 24′N, 138° 15′E), Ara-kawa River (Konosu, Saitama Prefecture: 36° 05′N, 139° 26′E), and Asahi-gawa River (Okayama, Okayama Prefecture: 34° 41′N, 133° 56′E). In the Hino-yosui, Ara-kawa, and Asahi-gawa populations, many males as well as females were observed: the ratio of males to females almost one to one. On the other hand, a unisexual Chikuma-gawa population (Chikuma, Nagano Prefecture: 36° 32′N, 138° 6′E) was examined. Wherein no males were found indicating a fully unisexual population (Tojo *et al.*, 2006).

We collected ten final instar female nymphs from the Hino-yosui population (Sep. 1, 2006) and reared them individually in the laboratory until the subimaginal stage to ensure all were virgin females. Thereafter unfertilized eggs were collected from these ten virgin females. In the Ara-kawa and the Asahi-gawa populations, we dissected final instar female nymphs and obtained their unfertilized eggs (five female nymphs from the Ara-kawa River population: Sep. 1, 2006, and also five female nymphs from the Asahi-gawa population: Sep. 19, 2006). As a control, fertilized eggs were obtained from six mated females in the Hino-yosui population (bisexual) and unfertilized eggs were obtained from twenty four virgin females in the Chikuma-gawa population (unisexual).

These fertilized and unfertilized eggs were incubated separately in batches at 20±0.5°C. At about three months of incubation, successful development rates were analyzed for each female's egg batch of fertilized or unfertilized eggs collected from the four different populations. During embryogenesis of this mayfly, diapause commences during the last embryonic stage (Watanabe *et al.*, 1993; Nakamura *et al.*, 1999; Nakamura and Endo, 2001): equivalent to "stage 13" in embryos of a closely related burrowing mayfly *Ephemera japonica* (cf. Tojo and Machida, 1997a, b), and release of diapause (*i.e.*, hatching) requires a change in environmental conditions like water temperature and light conditions (under the incubated conditions in the laboratory, a long incubation time was required for completion of hatching). Differences were observed in developmental and successful hatching rates during short-term experiments over a range of several months to a half-year. Under natural conditions, several years may be required for hatching, in rare cases (Sekiné *et al.*, 2007). Consequently, the development rate of eggs was focused upon in this study rather than the hatching rate. Judging as to whether an egg was developing or not was relatively simple because the developing and undeveloped eggs are clearly differing in color (Tojo *et al.*, 2006).

Chromosome Number Analysis

Upon hatching of the nymphs, chromosome preparations were made and chromosomes were counted for each of the respective offspring. The nymphs were prepared on slides wounded with a needle and forceps and incubated for 30 minutes in ion-exchange water containing 0.005% colcemide. The nymphs were then fixed with fixative solution I (acetic acid : ethanol : ion-exchange water=1 : 1 : 2). A drop of fixative solution II (acetic acid : ethanol=1 : 1) was placed on each nymph before it was macerated with a needle and forceps while fixative solution I was spreading over the slide. After one minute, glacial acetic acid was dropped onto the slides which were then air-dried. These air-dried chromosome preparations were stained with 3% Giemsa solution (Nacalai Tesque) in phosphate buffer (Sigma-Aldrich Japan; pH 6.4) for 30 minutes. The slides were then dipped in the water for one second, and air-dried. Chromosome spreads on the slides were mounted in a mounting agent (Entellan New, Merck) and photographed under a microscope at 1000× magnification.

Results

Table 1 summarizes the developmental rate of fertilized and unfertilized egg batches of *Ephoron shigae* collected from

Table 1. Developmental rate of fertilized or unfertilized eggs of *Ephoron shigae*

	No. of females examined	No. of eggs examined	Percentage of embryos developing to the final embryonic stage	
			Mean±SD	Minimum-Maximum
Hino-yosui Irrigation Canal[a]				
fertilized eggs	6	32289	98.1±1.9	94.8-99.9
unfertilized eggs	10	23956	14.1±13.5	0.3-34.7
Chikuma-gawa River[b]				
unfertilized eggs	23	66698	89.2±4.6	76.2-96.9
Ara-kawa River[a]				
unfertilized eggs	5	7425	21.5±27.5	0-53.3
Asahi-gawa River[a]				
unfertilized eggs	5	5881	3.0±4.0	0-8.0

[a]Bisexual population
[b]Unisexual population: no males were found

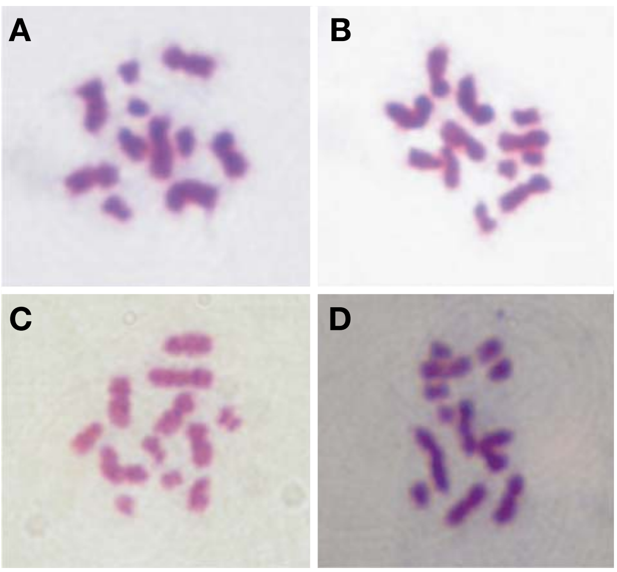

Fig. 2. The mitotic metaphase chromosomes prepared from nymphs of the mayflies, *Ephoron shigae*. A, Chromosomes of 2n=11, obtained from a fertilized nymph in the bisexual population (*Ephoron shigae*; Hino-yosui), B, Chromosomes of 2n=12, obtained from a fertilized nymph in the bisexual population (*Ephoron shigae*; Hino-yosui), C, Chromosomes of 2n=12, obtained from a parthenogenetic nymph in the bisexual population (*Ephoron shigae*; Hino-yosui), D, Chromosomes of 2n=12, obtained from a parthenogenetic nymph in the unisexual population (*Ephoron shigae*; Chikuma-gawa).

four different populations. In the bisexual population (Hino-yosui flume) of *E. shigae*, the fertilized eggs from six mated females developed almost to the final embryonic stage in three months. The percentage of embryos developing to the final stage was 98.1±1.9% (mean of three egg batches±SD). Whereas the development rate of embryos to the final stage in the unfertilized egg batches was 14.1±13.5% (ten batches; there were no batches with a developmental rate of zero). The developmental rates of unfertilized egg batches in Ara-kawa River and Asahi-gawa River populations were 21.5±27.5% (five batches) and 3.0±4.0% (five batches), respectively. In the unisexual Chikuma-gawa River's population, the developmental rate of unfertilized egg batches was 87.8±7.0% (twenty four batches; this data included prior data collected in Tojo *et al*. [2006], 89.0±4.6% for twenty batches).

For nymphs hatched from fertilized eggs in the Hino-yosui *E. shigae* population, either eleven or twelve mitotic metaphase chromosomes were counted. However, amongst nymphs parthenogenetically hatched from unfertilized eggs in the Hino-yosui *Ephoron shigae* population, only 12 chromosomes were observed (Fig. 2, Table 2).

Table 2. Chromosome numbers of *Ephoron shigae*

Population	Mode of reproduction	Number of specimens examined		
		Total	2n=11 (♂)	2n=12 (♀)
Hino-yosui	Sexual	6	2	4
Hino-yosui	Parthenogenetic	33	0	33
Chikuma-gawa	Parthenogenetic	8	0	8

Discussion

In the present study, the parthenogenetic ability of virgin females in bisexual populations of *E. shigae* is investigated for the first time, and the parthenogenetic development rates of unfertilized eggs were considerably lower than that of virgin females in the unisexual populations (Table 1). In Hino-yosui population, although the parthenogenetic development rates varied widely, parthenogenetic ability was recognized in all of the individuals examined (n=10). In Ara-kawa population, the parthenogenetic development rates of two egg batches were relatively high (53.3% and 49.8%), while two other egg batches failed to develop at all. For these egg batches, we obtained eggs from final instar nymphs (female), rather than obtaining and dissecting matured and unfertilized eggs from winged (subadult) virgin females. Therefore, the parthenogenetic abilities of the Ara-kawa and the Asahi-gawa populations may be higher than indicated in the above results.

In *Ephoron shigae*, Sekiné and Tojo (2007) indicated that all parthenogenetic offspring from the unisexual populations were female (2n=12), and that the reproductive mode of the unisexual populations is a diploid thelytokous parthenogenesis. The present result also indicates that all of the parthenogenetic offspring from bisexual population are females (2n=12; Fig. 2, Table 2), similar to parthenogenetic mode of the unisexual populations. Consequently, the parthenogenetic ability of bisexual populations would be relevant in the evolutionary path to parthenogenetic evolution of unisexual populations.

Thelytokous parthenogenesis is divided into two main types from a cytogenetic standpoint as follows (White, 1973); (1) automixis or meiotic thelytoky, in which completely meiosis occurs in oogenesis, but is compensated for by a doubling of the chromosome number at some stage in the life cycle, and (2) apomixis or ameiotic thelytoky, in which meiosis has been entirely suppressed, where the maturation division or divisions in the oocyte is mitotic in character (*i.e*., without any formation of bivalents). However, the process and mechanisms of egg maturation and parthenogenetic recovery of diploidy have not been studied, as to whether this mayfly's parthenogenesis is of the automictic or apomictic type. Hereafter, it is need that we will observe and describe the oogenesis and early embryogenesis of this mayfly.

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Insect diversity

Aquatic Insect Fauna of Bidoup-Nui Ba National Park in Lam Dong Province, Southern Vietnam

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Abstract

Aquatic insect fauna of Bidoup-Nui Ba National Park in Lam Dong Province, Southern Vietnam, was investigated in February 2006. Aquatic insects were quantitatively collected from 6 stream sites using Surber sampler (50 cm × 50 cm, riffle and pool) as well as qualitatively using hand net. As a result, 153 species belonging to 101 genera, 49 families, and 9 orders were identified: Ephemeroptera 55 species (35.95%), Plecoptera 24 species (15.69%), Trichoptera 23 species (15.03%), Odonata 18 species (11.76%), Coleoptera 15 species (9.8%), Diptera 12 species (7.84%), Hemiptera 4 species (2.61%), Megaloptera 1 species (0.66%), and Lepidoptera 1 species (0.66%). The EPT-group (Ephemeroptera, Plecoptera, and Trichoptera) was predominant in terms of species richness and diversity. This is the first investigation of aquatic insect fauna in Bidoup-Nui Ba National Park in Southern Vietnam.

Key words: aquatic insects, Bidoup-Nui Ba National Park, biodiversity, Southern Vietnam, tropical stream

Introduction

Bidoup-Nui Ba National Park belongs to Lam Dong Province, Southern Vietnam, with the location of N: 12°00′00″∼12°52′00″ and E: 108°17′00″∼108°42′00″ (Fig. 1). It contains high mountain areas including Mt. Lang Bian (2,189 m), Mt. Bidoup (2,278 m), and Mt. Cong Troi (2,272 m) and is called the roof of the Indochinese Peninsula. The climate is tropical with rainy and dry seasons. The yearly average temperature is around 16∼18°C with high humidity over 80%. Owing to its geographical location, topography and climate, and protected tropical rain forest, the park possesses a higher degree of biodiversity including many endemic and rare species. Consequently, this area is considered as biological “hot spot” in Vietnam. This is the first comprehensive investigation of aquatic insect fauna in Bidoup-Nui Ba National Park in Southern Vietnam.

Materials and Methods

Field survey was conducted during February 17∼19, 2006 at 6 collecting sites from major streams in Bidoup-Nui Ba National Park as shown in Fig. 1. Aquatic insects were quantitative sampled using a Surber sampler (50×50 cm, riffle and pool), and were also qualitatively sampled from diverse habitats using hand nets. Sampled aquatic insects were preserved in plastic vials with 80% ethanol. They were identified to species or higher taxonomic categories based on available references such as Merritt & Cummins (1996) for families and genera, Nguyen (2003) and Nguyen & Bae (2003, 2004a, b) for Ephemeroptera, Cao (2002) and Cao *et al.* (2008) for Plecoptera, and Hoang (2005) and Hoang & Bae (2006) for Trichoptera. Studied materials are housed in the Department of Invertebrate Zoology, Faculty of Biology, Hanoi University of Science in Hanoi and in the Entomological Museum of Korea University in Seoul.

Results and Discussion

The habitats along the streams were dominated by the riparian forest, consisting of a variety of vegetation, including bamboos, palms, herbs, and vines. The bottom of the streams was covered mainly by cobble and boulder-sized stones mixed with various substrates such as pebbles, gravel, sand, leav-

Table 1. Environmental parameters of the study sites

Sites	Altitude (m)	River width (m)	Water width (m)	Depth (cm)		Air temp. (°C)	Water temp. (°C)	pH
				Riffle	Pool			
St.1	1705	25	10	13	36	23	18.2	7.02
St.2	1738	50	35	21	23	23	17.8	7.01
St.3	1639	30	13	28	42	23	19.3	7.00
St.4	1543	20	13	20	24	23	16.9	7.04
St.5	1225	25	5	11	17	22	17.3	7.02
St.6	1119	15	13	14	39	31	19.3	6.99
Mean±SD	1495±261	28±12	15±10	18±6	30±10	24±3	18±1.0	7±0.02

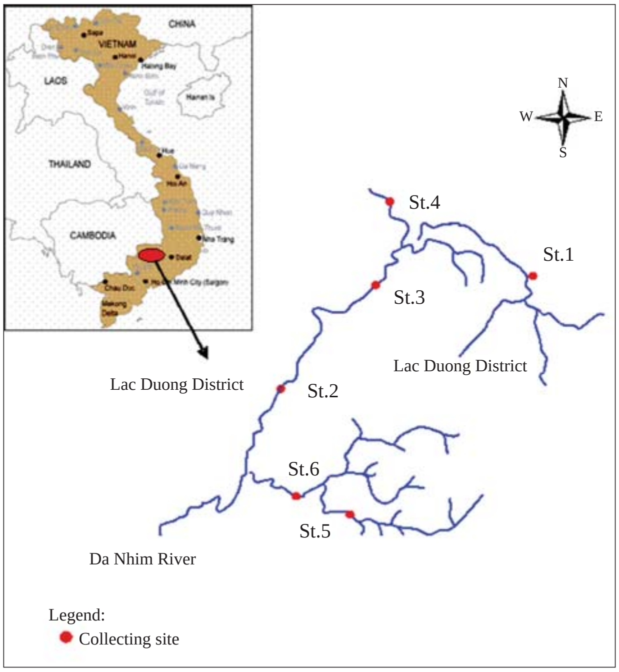

Fig. 1. Study sites in Bidoup-Nui Ba National Park in Lam Dong Province, Southern Vietnam.

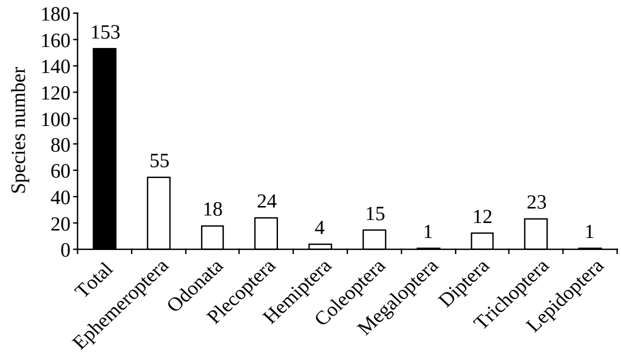

Fig. 2. Species richness of aquatic insects in the study sites.

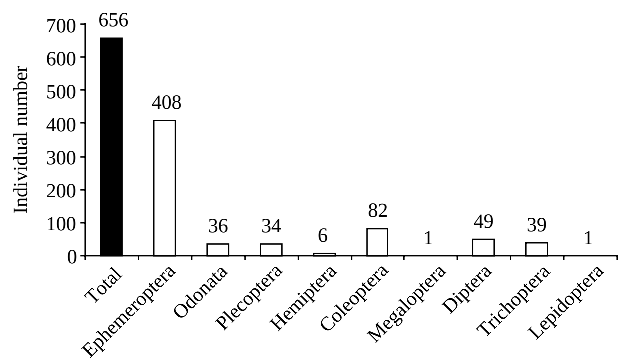

Fig. 3. Individual abundance of aquatic insects in the study sites.

es, mosses, and attached algae. The environmental parameters at the sampling sites, such as habitat topology, water width, water temperature, pH, and other conditions showed a gradual change along the sites (Table 1). Typically, the average water temperature was about 18°C, reaching the maximum at Site 3 (19.3°C) and the minimum at Site 6 (16.9°C). The values of pH varied around 7, showing a neutral condition of the stream water.

As a result of the investigation, a total of 153 species of aquatic insects belonging to 101 genera, 49 families, and 9 orders (Fig. 2). The EPT-group predominated the aquatic insect fauna: Ephemeroptera 55 species (35.95%), Plecoptera 24 species (15.69%), and Trichoptera 23 species (15.03%). Other orders showed a lower degree of species diversity including Odonata (18 species, 11.76%), Coleoptera (15 species, 9.8%), Diptera (12 species, 7.84%), Hemiptera (4 species, 2.61%), Megaloptera (1 species, 0.66%), and Lepidoptera (1species, 0.66%).

Ephemeroptera

Ephemeroptera showed the highest species richness and individual abundance at all the study sites (Figs. 2, 3). The families Leptophlebiidae and Heptageniidae were relatively more abundant compared to other families due to the 2 dominant species, *Choroterpes trifurcata* (Leptophlebiidae) and *Iron martinus* (Heptageniidae) (Table 2). *Baetis* sp.1 (Baetidae) and *Thalerosphyrus vietnamensis* (Heptageniidae) were

Table 2. First and second dominant species of aquatic insects from the study sites

Sites	1st dominant species	2nd dominant species
St.1	*Choroterpes trifurcata*	*Isca* sp.
St.2	*Iron martinus*	*Choroterpes trifurcata*
St.3	*Iron martinus*	*Baetis* sp.1
St.4	*Iron martinus*	*Choroterpes trifurcata*
St.5	*Chironomus* sp.	*Baetis* sp.1
St.6	*Chironomus* sp.	*Choroterpes trifurcata*

limited only to the lower streams. The genus *Torleya* was rarely found.

Plecoptera

The second predominant order was the Plecoptera with 24 species occurred from the study area. The family Perlidae was abundant throughout the study sites. *Acroneuria* sp. and *Phanoperla* sp. (Perlidae) were found only in riffle habitats.

Trichoptera

Trichoptera was the third predominant order, consisting of 23 species, and showed a wide range of occurrence from various types of habitats. Net-spinning caddisflies such as *Cheumatopsyche*, *Ceratopsyche*, and *Hydropsyche* were abundant in the riffle habitats.

Diptera

Diptera occurred in all available habitats, and the lower stream reaches and pools were probably more favorable for them. The families Tipulidae and Athericidae were particularly abundant.

Coleoptera

Fifteen species from the larvae and adults were identified in this order. *Stenocolus* sp. (Ptilodactylidae) and *Ordobrevia* sp. (Elmidae) occurred only in the riffles, while Psephenidae was found in both riffles and pools. The larvae of Dytiscidae and Gyrinidae were rarely found.

Odonata

Eighteen species of Odonata were identified in this study. The species richness and abundance of Odonata were relatively low in most study sites except for the family Gomphidae. *Anisopleura* sp. (Euphaeidae) and *Stylogomphus* sp. (Gomphidae) were found only in the riffles.

Hemiptera

Only 4 species belonging 4 families were found in this study. *Microvelia* sp. (Veliidae) occurred only in pools, while *Rhyacobates* sp. (Gerridae) occurred only in riffles. *Trephotomas* sp. (Helotrephidae) was rare.

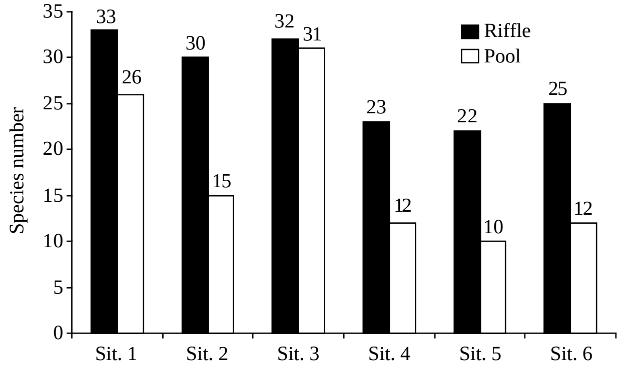

Fig. 4. Species richness of aquatic insects between riffle and pool habitats.

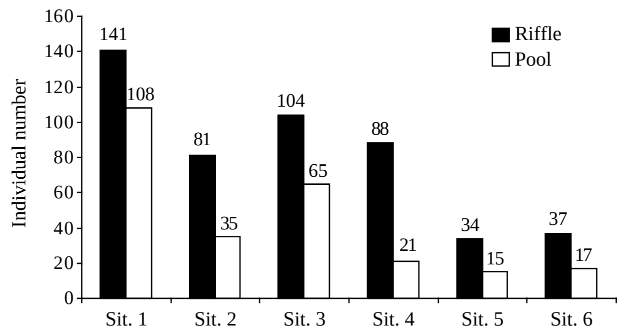

Fig. 5. Individual abundance of aquatic insects between riffle and pool habitats.

Megaloptera

One species, *Neochanliodes* sp. (Corydalidae), commonly occurred in the riffles of the study sites.

Lepidoptera

The larvae of *Elophila* sp. (Pyralidae) rarely occurred from the study area.

Based on the quantitative analysis, 3 major orders, Ephemeroptera, Coleoptera, and Diptera, represented 81.2% of the total individual abundance, whereas other orders were relatively less abundant (Fig. 3). The result also showed that Ephemeroptera (62.2%) was the most abundant order represented by the 2 dominant species *Iron martinus* and *Choroterpes trifurcata*. Chironomids (Diptera) also predominanted at the lower reaches of the study streams (Site 5 and Site 6).

Dominance indices (DI), richness indices (RI), and diversity indices (H′) are shown in Table 3. The average values of DI, RI, and H′ are 0.26, 8.16, and 2.56, respectively, with the highest values at the Site 3. In general riffle habitats con-

Table 3. Dominance indices (DI), richness indices (RI), and diversity indices (H′) from the study sites

Sites	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Average
Altitude (m)	1705	1738	1639	1543	1225	1119	1495±261
DI	0.27	0.26	0.36	0.26	0.14	0.24	0.26±0.07
RI	8.26	7.94	8.93	8.92	6.36	8.54	8.16±0.96
H′	2.74	2.67	3.12	2.13	2.58	2.63	2.56±0.32

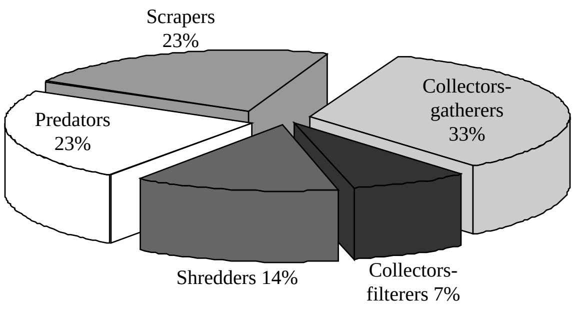

Fig. 6. Functional feeding groups of aquatic insects in the study sites.

tain a larger species richness, whereas pool habitats a larger individual abundance (Figs. 4, 5). Collector-gatherers (33%) represented the largest portion of functional feeding groups followed by predators (23%), scrapers (23%), shredders (14%), and collectors-filters (7%) (Fig. 6).

Acknowledgements

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Appendix 1. Aquatic insect taxa in Bidoup-Nui Ba National Park in Lam Dong Province, Southern Vietnam, in February 2006

Order Ephemeroptera
Family Leptophlebiidae
1. *Choroterpes proba*
2. *Choroterpes trifurcata*
3. *Choroterpides major*
4. *Habrophlebiodes prominens*
5. *Isca fascia*
6. *Isca janiceae*
7. *Isca* sp.

Family Ephemeridae
8. *Ephemera serica*
9. *Ephemera* sp.1

Family Ephemerellidae
10. *Cincticostella gosei*
11. *Cincticostella insolta*
12. *Cincticostella* sp.1
13. *Cincticostella* sp.2
14. *Drunella perculta*
15. *Epharacella commodema*
16. *Epharacella longicaudata*
17. *Serratella albostriata*
18. *Serratella* sp.
19. *Torleya arenosa*
20. *Torleya* sp.1
21. *Torleya* sp.2

Family Teloganodidae
22. *Teloganodes tristis*

Family Caenidae
23. *Caenis* sp.1
24. *Caenoculis* sp.

Family Heptageniidae
25. *Afronurus mnong*
26. *Afronurus philippinensis*
27. *Afronurus* sp.1
28. *Asionurus primus*
29. *Compsoneuria thienenmanni*
30. *Ecdyonurus cervina*
31. *Ecdyonurus landai*
32. *Epeorus aculatus*
33. *Epeorus bifurcatus*
34. *Epeorus carinatus*
35. *Epeorus hieroglyphicus*
36. *Epeorus tiberius*
37. *Iron longitibus*
38. *Iron martinus*
39. *Paegniodes* sp.
40. *Rhithrogena parva*
41. *Rhithrogeniella tonkinensis*
42. *Thalerosphyrus vietnamensis*
43. *Trichogenia maxillaris*

Family Baetidae
44. *Acentrella* sp.
45. *Baetiella* sp.1
46. *Baetis* sp.1
47. *Baetis* sp.2
48. *Baetis* sp.3
49. *Centroptella* sp.1
50. *Labiobaetis* sp.1
51. *Labiobaetis* sp.2
52. *Nigrobaetis* sp.1
53. *Nigrobaetis* sp.2
54. *Plattybaetis bishopi*
55. *Plattybaetis edmundsi*

Order Odonata
Zygoptera
Family Chlorolestidae
56. *Sinolestes* sp.1

Family Calopterygidae
57. *Mnais* sp.1

Family Chlorocyphidae
58. *Rhinocypha* sp.

Family Euphaeidae
59. *Anisopleura* sp.
60. *Bayadera* sp.1
61. *Bayadera* sp.2
62. *Bayadera* sp.3

Anisoptera
Family Aeshnidae
63. *Boyeria* sp.1
64. *Planaeschna* sp.1

Family Cordulegastridae
65. *Anotogaster* sp.1
66. *Cordulegaster* sp.1

Family Gomphidae
67. *Lamelligomphus* sp.1
68. *Lamelligomphus* sp.2
69. *Lamelligomphus* sp.3
70. *Melligomphus* sp.
71. *Stylogomphus* sp.1

Family Amphipterygidae
72. *Philoganga* sp.1

Family Macromiidae
73. *Macromia* sp.1

Order Plecoptera
Family Nemouridae
74. *Amphinemoura* sp.1
75. *Amphinemoura* sp.2
76. *Nemoura* sp.
77. *Protonemura* sp.
78. *Sphaeronemura* sp.

Family Leuctridae
79. *Paraleuctra* sp.
80. *Perlomyia* sp.
81. *Rhopalopsole subnigra*

Family Peltoperlidae
82. *Cryptoperla bisaeta*
83. *Cryptoperla meo*
84. *Cryptoperla* sp.1

Family Perlidae
85. *Acroneuria* sp.
86. *Etrocorema nigrogeniculatum*
87. *Etrocorema* sp.1
88. *Kamimura* sp.
89. *Kiotina* sp.
90. *Neoperla lushana*
91. *Phanoperla* sp.1
92. *Phanoperla* sp.2
93. *Tetropina* sp.
94. *Togoperla noncoloris*
95. *Togoperla* sp.1
96. *Togoperla* sp.2
97. *Togoperla* sp.3

Order Hemiptera
Family Gerridae
98. *Rhyacobates* sp.1

Family Helotrephidae
99. *Trephotomas* sp.1

Family Notonectidae
100. *Anisops* sp.1

Family Veliidae
101. *Microvelia* sp.1

Order Coleoptera
Family Gyrinidae
102. *Gyrinus* sp.1
103. *Orectochilus* sp.1

Family Dytiscidae
104. *Hyphydrus* sp.1
105. *Copelatus* sp.

Family Hydrophilidae
106. *Berosus* sp.

Family Ptilodactylidae
107. *Stenocolus* sp.1
108. *Stenocolus* sp.2

Family Psephenidae
109. *Mataeopsephus* sp.1
110. *Mataeopsephus* sp.2
111. *Eubrianax* sp.1
112. *Eubrianax* sp.2

Family Chrysomelidae
113. *Prodonacia* sp.1
114. *Prodonacia* sp.2

Family Elmididae
115. *Ordobrevia* sp.

Family Scirtidae
116. *Cyphon* sp.

Order Megaloptera
Family Corydalidae
117. *Neochanliodes* sp.

Order Diptera
Family Tipulidae
118. *Hexatoma* sp.
119. *Pedicia* sp.1
120. *Pedicia* sp.2
121. *Tipula* sp.1
122. *Tipula* sp.2
123. *Tipula* sp.3

Family Ephydridae
124. *Ephydra* sp.1

Family Athericidae
125. *Atherix* sp.1
126. *Atrichops* sp.

Family Chironominae
127. *Chironomus* sp.1
128. *Chironomus* sp.2

Family Ceratopogonidae
129. *Bezzia* sp.

Order Trichoptera
Family Hydropsychidae
130. *Arctopsyche* sp.1
131. *Arctopsyche* sp.2
132. *Ceratopsyche* sp.1
133. *Ceratopsyche* sp.2
134. *Diplectrona* sp.1
135. *Hydropsyche* sp.1
136. *Hydropsyche* sp.2
137. *Macrosternum* sp.1

Appendix 1. Continued

138. *Potamyia* sp.1
139. *Stenopsyche* sp.1

Family Rhyacophilidae
140. *Rhyacophila* sp.1
141. *Rhyacophila* sp.2

Family Limnephilidae
142. *Pseudostenophylax* sp.1

Family Dipseudopsidae
143. *Pseudoneureclipsis* sp.1

Family Phryganeidae
144. *Ptilostomis* sp.1
145. *Ptilostomis* sp.2

Family Stenopsychidae
146. *Stenopchus* sp.
147. *Stenopsyche* sp.

Family Hydroptilidae
148. *Ugandatrichia* sp.1

Family Leptoceridae
149. *Leptocerus* sp.

Family Lepidopstomatidae
150. *Lepidopstoma* sp.

Family Calamoceratidae
151. *Anisocentropus* sp.1
152. *Anisocentropus* sp.2

Order Lepidoptera

Family Pyralidae
153. *Elophila* sp.

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Insect diversity

Aquatic Insect Fauna of Vang Vieng Area in Northern Laos

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Abstract

Aquatic insect fauna was investigated from the Vang Vieng area (Nam Xong River, Pamom Stream, Naxeng Stream, and Bahn Don Wetland) in northern Laos. Quantitative (Surber sampler 30 × 30 cm, mesh size 0.2 mm) and qualitative (hand net, sweep net) sampling was conducted from 6 sites (St.1 ~ 6: 221 ~ 477 m in altitude) in the area, including 5 stream sites and 1 wetland site, in October 2008. As a result, a total of 149 species (most of them undetermined) belonging to 118 genera, 60 families, and 9 orders were identified: Ephemeroptera 38 species (25.5%), Odonata 29 species (19.46%), Coleoptera 24 species (16.11%), Trichoptera 20 species (13.42%), Diptera 17 species (11.41%), Hemiptera 11 species (7.38%), Plecoptera 7 species (4.7%), Lepidoptera 2 species (1.34%), and Megaloptera 1 specie (0.67%). Ephemeroptera, Odonata, Coleoptera, and Trichoptera were the most abundant aquatic insect groups in the stream sites, whereas Coleoptera and Odonata contributed to the higher degree of aquatic insect diversity in the wetland site. This is the first comprehensive investigation of aquatic insect fauna in northern Laos.

Key words: aquatic insects, fauna, northern Laos, tropical streams, Vang Vieng

Introduction

Lao PDR is a landlocked country in Southeast Asia surrounded by Vietnam, China, Thailand, and Cambodia. It has a high conservation value with the highest biodiversity in peninsular Southeast Asia (IUCN, 2002). The land is composed of high mountain areas with thick tropical forest such as the highest peak Phou Bia (2,819 m). The Mekong River forms a large part of the western boundary with Thailand. The Vang Vieng area is located in 160 km north of Vientiane, the capital city of Lao PDR. This area belongs to the limestone karst region and the climate is typical of the tropical monsoon with a rainy season extending from May to October (Vientiane, 1,700 mm in annual precipitation). Although streams, rivers, lakes and wetlands of Laos are known to constitute rich habitats for diverse groups of freshwater organisms, the aquatic insect fauna remains poorly studied and only some aquatic insect taxa have been taxonomically studied (e.g., Peschet, 1921; Jäch, 1997; Wooldridge, 1977; Mey, 2001; Yochitomi, 2003; Yoshitomi & Satô, 2003a, b). In previous faunistic studies on aquatic insects in tropical Southeast Asia, Nguyen *et al.* (2001) conducted "Aquatic insects from Tam Dao National Park in northern Vietnam," Hoang and Bae (2006) "Aquatic insect diversity in tropical stream in southern Vietnam," Cao *et al.* (2008) "A faunisitic study of aquatic insects in Bach Ma National Park in central Vietnam," and Jung *et al.* (2008) "Aquatic insect faunas and communities of Sapa Highland in northern Vietnam." This is the first comprehensive investigation of aquatic insect fauna in northern Laos.

Materials and Methods

Six sites (St.1 ~ 6) were sampled in the Vang Vieng area (Nam Xong River, Pamom Stream, Bahn Don Stream, and Naxeng Wetland) in northern Laos as follows (Fig. 1).

St.1 (19° 07′14.2″N, 102° 20′43.2″E): Pamom Stream (477 m in altitude)
St.2 (19° 06′24.2″N, 102° 22′24.0″E): Pamom Stream (340 m in altitude)
St.3 (19° 03′13.9″N, 102° 25′45.1″E): Nam Xong River (241 m in altitude)
St.4 (18° 55′02.9″N, 102° 26′42.4″E): Nam Xong River (236 m in altitude)

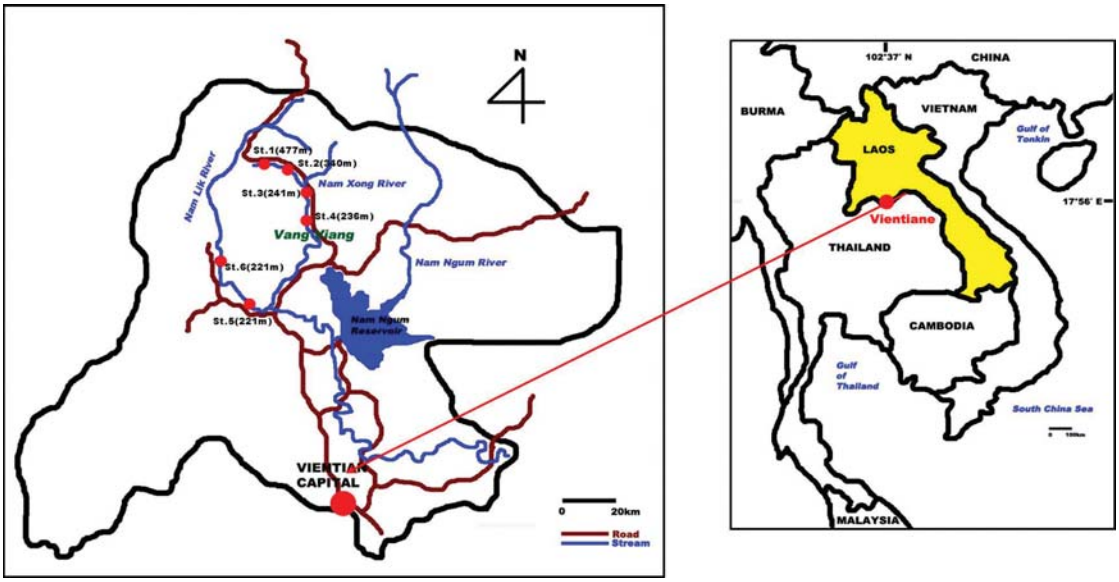

Fig. 1. Study sites (St.1-St.6) in the Vang Vieng area in northern Laos.

Table 1. Number of aquatic insect taxa in the Vang Vieng area in northern Laos

Order	Family	Genera	Species
Ephemeroptera	9	27	38
Odonata	11	23	29
Plecoptera	3	6	7
Hemiptera	8	11	11
Coleoptera	8	20	24
Megaloptera	1	1	1
Diptera	10	13	17
Trichoptera	9	15	20
Lepidoptera	1	2	2
Total	60	118	149

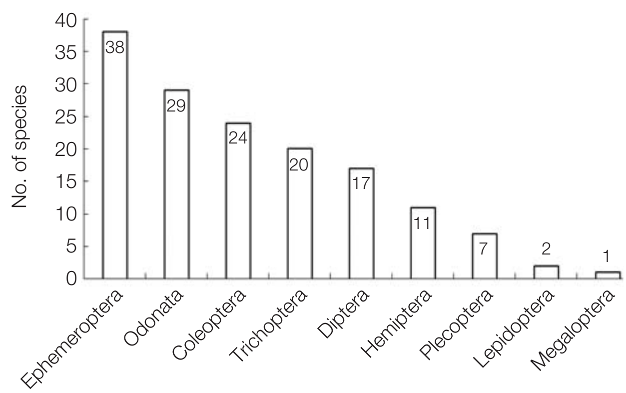

Fig. 2. Species richness of aquatic insect orders in the Vang Vieng area in northern Laos.

St.5 (18° 38′51.1′′N, 102° 11′25.3′′E): Bahn Don Stream (221 m in altitude)
St.6 (18° 47′15.9′′N, 102° 07′46.3′′E): Naxeng Wetland (221 m in altitude)

Aquatic insects were quantitatively sampled using a Surber sampler (30 × 30 cm, mesh size 0.2 mm) and using a hand net and a sweep net for qualitative purposes. Aquatic insects were identified to species or higher taxonomic levels using available references (Wiederholm, 1983; Morse *et al.*, 1994; Jäch and Ji, 1995, 1998, 2003; Merritt and Cummins, 1996; Wiggins, 1998; Dudgeon, 1999; Jill, 2001; Cao, 2002, 2008; Nguyen, 2003; Sangpradub and Boonsoong, 2004; Yule and Sen, 2004; Chen *et al.*, 2005; Hoang, 2005; Kawai and Tanida, 2005; Bedjanič *et al.*, 2007; Tungpairojwong, 2007). Larvae were preserved in 80% ethanol and adults were pinned in insect boxes. They were housed in the Entomological Museum of Korea University (KU).

Results

The quatic insect taxa sampled from the Vang Vieng area is listed in Appendix 1. A total of 149 species (most of them unidentified) belonging to 118 genera, 60 families, and 9 orders were identified (Table 1 and Fig. 2): Ephemeroptera 38 species (25.5%), Odonata 29 species (19.46%), Coleoptera 24 species (16.11%), Trichoptera 20 species (13.42%), Diptera 17 species (11.41%), Hemiptera 11 species (7.38%), Plecoptera 7 species (4.7%), Lepidoptera 2 species (1.34%), and Megaloptera 1 species (0.67%). Ephemeroptera, Odonata, Coleoptera, and Trichoptera were the most abundant aquatic

Fig. 3. Habitats of aquatic insects. a-b: Pamom stream (477 m in alt.), St.1. a, macrohabitat; b, microhabitat: c-d: Pamom stream (340 m in alt.), St.2. c, macrohabitat; d, microhabitat: e-f: Nam Xong River (241 m in alt.), St.3. e, macrohabitat; f, microhabitat: g-h: Nam Xong River (236 m in alt.), St.4. g, macrohabitat; h, microhabitat: i-j: Bahn Don stream (221 m in alt.), St.5. i, macrohabitat; j, microhabitat: k-l: Naxeng Wetland (221 m in alt.), St.6. k, macrohabitat; l, microhabitat.

insect ordres in the stream sites (St.1~5), whereas Coleoptera and Odonata contributed to the higher degree of aquatic insect diversity in the wetland site (St.6). We herein describe the aquatic insect fauna, and provide macrohabitat and microhabitat characteristics (Fig. 3) and species photographs (Fig. 4).

Ephemeroptera

Ephemeroptera is one of the most diverse aquatic insect orders in streams and rivers (St.1~5). Baetidae was the most species-rich and abundant mayfly family in all study sites, whereas Austremerellidae (*Vietnamella* sp.), Ephemeridae (*Ephemera* sp.), and Teloganellidae (*Teloganella* sp.) were rarely found in St.2 and St.5. *Rhithrogena* sp., *Thalerosphyrus* sp. (Heptageniidae) and *Procloeon* sp. (Baetidae) occurred only in the wetland site (St.6).

Odonata

Twenty-nine species of Odonata belonging to 11 families

Fig. 4. Aquatic insects. a-c Ephemeroptera: a, Baetidae, *Baetis* sp.; b, Ephemerellidae, *Ephacerella* sp.; c, Neoephemeridae, *Potamanthellus edmundsi*: d-k Odonata: d, Calopterygidae, *Neurobasis chinensis*; e, Chlotocyphidae, *Heliocypha perforata perforata*; f, Euphaeidae, *Euphaea* sp.; g, Gomphidae, *Trigomphus* sp.; h-k Libellulidae: h, *Neurothemis theminata*; i, *Trithemis aurora*; j, *Brachythemis* sp; k, *Orthetrum* sp.: l, Plecoptera, Perlidae, *Neoperla* sp.: m-o Hemiptera: m, Naucoridae, *Ctenipcoris* sp.; n, Belostomatidae, *Lethocerus* sp.; o, Nepidae, *Ranatra* sp.: p, Diptera, Stratiomyidae, *Ptecticus* sp.: q-r Trichoptera: q, Hydropsychidae, *Hydropsyche* sp.; r, Stenopsychidae, *Stenopsyche* sp.

were found (Fig. 4d~4k). Most species inhabited the wetland (Fig. 3k, 3l). However, *Brachythemis* sp. (Libellulidae) was found in a riffle area in a stream site (Fig. 3a). Gomphidae and Libellulidae were relatively more diverse than other families. In adults, *Neurobasis chinensis* (Linnaeus, 1758), *Heliocypha perforata perforata* (Percheron, 1835), *Neurothemis terminata* (Ris, 1911), and *Trithemis aurora* (Burmeister, 1839) were reported from other regions in tropical Asia (Sri Lanka, Thailand, Vietnam, Philippine, Malaysia, China) (Steinmann, 1997; Bedjanič *et al.*, 2007; Orr and Hämäläinen, 2007; Dow and Reels, 2008).

Plecoptera

Species richness and abundance of Plecoptera were relatively low, and only 7 species were found in the stream sites, particularly in the NamXong River. Perlidae was the most diverse Plecoptera family as in other tropical streams (Nguyen *et al.*, 2001; Hoang and Bae, 2006; Cao *et al.*, 2008; Jung *et al.*, 2008). The wetland site (St.6) lacked Plecoptera.

Hemiptera

Eleven species of Hemiptera were identified from the streams, rivers, and wetlands. *Gestroiella* sp. and *Ctenipcoris* sp. (Naucoridae) were found from the riffle areas and submerged roots and other families were found from the pool areas.

Coleoptera

Majority Coleoptera species were found in the wetland site. Elmidae and Psephenidae were found in the riffle areas in the river site (NamXong), while Dytiscidae, Noteridae, and Hydrophilidae were found in the pool areas of streams with aquatic plants and in the wetland site (St.6).

Megaloptera

One species, *Protohermes* sp. (Corydalidae) occurred in the riffle areas in streams and rivers.
The substrate was composed of cobble (30%), pebble (40%), gravel (20%), and coarse sand (10%).

Diptera

Seventeen species occured throughout the sampling sites. Chironomidae was the most diverse and abundant group of Diptera. Simulidae occurred in the riffle area of streams, whereas *Ptecticus* sp. (Stratiomyidae) (Fig. 4p) was found only in the wetland site (St.6).

Trichoptera

Twenty species occurred throughout the study sites. The net-spinning caddisflies Hydropsychidae (*Amphipsyche*, *Ceratopsyche*, *Cheumatopsyche*, *Hydropsyche*, and *Potamyia*), are the most diverse and abundant group of Trichoptera in streams. Leptoceridae was frequently found in the pool area of streams, while Helicopsychidae was found in the shallow run area with coarse sand and gravel.

Lepidoptera

Two species of Crambidae, *Ecoophyla* sp. and *Paracymoriza* sp., were found from the riparian area in rivers.

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Appendix 1. Aquatic insect taxa in the Vang Viang area in northern Laos

Order Ephemeroptera
- Family Leptophlebiidae
  - 1. *Choroterpides* sp.
  - 2. *Choroterpes* sp.
  - 3. *Habrophlebiodes* sp.1
  - 4. *Habrophlebiodes* sp.2
  - 5. *Thraulus* sp.
- Family Ephemeridae
  - 6. *Ephemera* sp.
- Family Ephemerellidae
  - 7. *Ephacerella* sp.
  - 8. *Torleya* sp.
  - 9. *Uracanthella* sp.
- Family Neoephemeridae
  - 10. *Potamanthellus edmundsi*
- Family Austremerellidae
  - 11. *Vietnamella* sp.
- Family Caenidae
  - 12. *Caenoculis* sp.1
  - 13. *Caenoculis* sp.2
  - 14. *Caenis* sp.1
  - 15. *Caenis* sp.2
- Family Heptageniidae
  - 16. *Afronurus* sp.
  - 17. *Compsoneuria* sp.
  - 18. *Ecdyonurus* sp.
  - 19. *Rhithrogena* sp.
  - 20. *Thalerosphyrus* sp.
- Family Baetidae
  - 21. *Acentrella* sp.
  - 22. *Baetis* sp.1
  - 23. *Baetis* sp.2
  - 24. *Baetis* sp.3
  - 25. *Baetis* sp.4
  - 26. *Baetiella* sp.1
  - 27. *Baetiella* sp.2
  - 28. *Centroptella* sp.1
  - 29. *Centroptella* sp.2
  - 30. *Heterocloeon* sp.
  - 31. *Labiobaetis* sp.1
  - 32. *Labiobaetis* sp.2
  - 33. *Labiobaetis* sp.3
  - 34. *Labiobaetis* sp.4
  - 35. *Nigrobaetis* sp.
  - 36. *Platybaetis* sp.
  - 37. *Procloeon* sp.
- Family Teloganellidae
  - 38. *Teloganella* sp.

Order Odonata
- Family Calopterygidae
  - 39. *Neurobasis chinensis*
  - 40. *Neurobasis* sp.
- Family Chlorocyphidae
  - 41. *Heliocypha perforata perforata*
  - 42. *Phinocrypha* sp.
- Family Coenagrionidae
  - 43. *Ceriagrion* sp.
  - 44. *Cercion* sp.
  - 45. *Coenagrion* sp.
- Family Platystictidae
  - 46. *Copera* sp.
- Family Protoneuridae
  - 47. *Prodasineura* sp.
- Family Euphaeidae
  - 48. *Euphaea* sp.
- Family Lestidae
  - 49. *Indolestes* sp.
- Family Aeshnidae
  - 50. *Aeschnophlebia* sp.
- Family Gomphidae
  - 51. *Labrogomphus* sp.1
  - 52. *Lamelligomphus* sp.1
  - 53. *Lamelligomphus* sp.2
  - 54. *Davidius* sp.
  - 55. *Nihonogomphus* sp.
  - 56. *Trigomphus* sp.
- Family Corduliidae
  - 57. *Ephideca* sp.
- Family Libellulidae
  - 58. *Brachythemis* sp.
  - 59. *Neurothemis theminata*
  - 60. *Orthetrum* sp.1
  - 61. *Orthetrum* sp.2
  - 62. *Crocothemis* sp.1
  - 63. *Crocothemis* sp.2
  - 64. *Libellula* sp.1
  - 65. *Libellula* sp.2
  - 66. *Trithemis aurora*
  - 67. *Trithemis* sp.

Order Plecoptera
- Family Peltoperiidae
  - 68. *Cryptoperla* sp.
- Family Perlidae
  - 69. *Neoperla* sp.1
  - 70. *Neoperla* sp.2
  - 71. *Paragnetina* sp.
  - 72. *Phanoperla* sp.
  - 73. *Togoperla* sp.
- Family Nemouridae
  - 74. *Amphinemura* sp.

Order Hemiptera
- Family Aphelocheridae
  - 75. *Aphelocheirus* sp.
- Family Naucoridae
  - 76. *Gestroiella* sp.
  - 77. *Ctenipcoris* sp.
- Family Belostomatidae
  - 78. *Lethocerus* sp.
- Family Nepidae
  - 79. *Ranatra* sp.
  - 80. *Cercotmetus* sp.
- Family Corixidae
  - 81. *Micronecta* sp.
- Family Helotrephidae
  - 82. *Hydrotrephes* sp.
- Family Gerridae
  - 83. *Cylindrostehus* sp.
  - 84. *Ptilomera* sp.
- Family Veliidae
  - 85. *Baptista* sp.

Order Coleoptera
- Family Gyrinidae
  - 86. *Orectochilus* sp.
- Family Dytiscidae
  - 87. *Cybister* sp.
  - 88. *Copelatus* sp.
  - 89. *Hydroporus* sp.
  - 90. *Leiodytes* sp.
  - 91. *Microdytes* sp.
  - 92. *Llybius* sp.
- Family Noteridae
  - 93. *Notomicus* sp.
- Family Hydrophilidae
  - 94. *Amphiops* sp.
  - 95. *Enochrus* sp.1
  - 96. *Enochrus* sp.2
  - 97. *Laccobius* sp.1
  - 98. *Laccobius* sp.2
- Family Scirtidae
  - 99. *Cyphon* sp.
- Family Dryopidae
  - 100. *Elmomorphus* sp.
- Family Psephenidae
  - 101. *Eubrianax* sp.
  - 102. *Psephenoides* sp.
- Family Elmidae
  - 103. *Leptelmis* sp.
  - 104. *Stenelmis* sp.
  - 105. *Optioservus* sp.
  - 106. *Ordobrevia* sp.1
  - 107. *Ordobrevia* sp.2
  - 108. *Zaitzevia* sp.1
  - 109. *Zaitzevia* sp.2

Order Megaloptera
- Family Corydalidae
  - 110. *Protohermes* sp.

Order Diptera
- Family Tipulidae
  - 111. *Antocha* sp.
  - 112. *Hexatoma* sp.
- Family Blephariceridae
  - 113. *Blepharicera* sp.
- Family Simuliidae
  - 114. *Simulium* sp.
- Family Chironomidae
  - 115. Chironominae sp.1
  - 116. Chironominae sp.2
  - 117. Chironominae sp.3
  - 118. Chironominae sp.4
  - 119. Tanypodinae sp.1
  - 120. Tanypodinae sp.2

Appendix 1. Continued

Family Athericidae
121. *Asuragina* sp.
Family Dolichopodidae
122. *Hemerodromia* sp.
Family Stratiomyidae
123. *Ptecticus* sp.
Family Ceratopogonidae
124. *Bezzia* sp.
Family Culicidae
125. *Anopheles* sp.
126. *Topomyia* sp.
Family Tabanidae
127. *Tabanus* sp.
Order Trichoptera
Family Helicopsychidae
128. *Helicpsyche* sp.
Family Hydropsychidae
129. *Amphipsyche* sp.
130. *Cheumatopsyche* sp.1
131. *Cheumatopsyche* sp.2
132. *Cheumatopsyche* sp.3
133. *Ceratopsyche* sp.1
134. *Ceratopsyche* sp.2
135. *Ceratopsyche* sp.3
136. *Ceratopsyche* sp.4
137. *Hydropsyche* sp.
138. *Potamyia* sp.
Family Stenopsychidae
139. *Stenopsyche* sp.
Family Hydroptilidae
140. *Hydroptilia* sp.
Family Lepidostomatidae
141. *Lepidostoma* sp.
Family Leptoceridae
142. *Mystacides* sp.
143. *Oecetis* sp.
144. *Setodes* sp.
Family Odontoceridae
145. *Marilia* sp.
Family Calamoceratidae
146. *Ganonema* sp.
Family Psychomyiidae
147. *Psychomyia* sp.
Order Lepidoptera
Family Crambidae
148. *Eoophyla* sp.
149. *Paracymoriza* sp.

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Insect diversity

A Burrowing Mayfly, *Anagenesia minor* (Eaton) in the Mekong River

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Abstract

An annual massive swarm of burrowing mayfly, *Anagenesia minor* (Eaton) occurred in hot season along the bank of the Mekong River. This occurrence was well known by Thai local people. Objective of this study was to investigate some biological aspects of *A. minor*. Nymphs were sampled by a D-frame dip net (450 μm mesh) from mud, sand, and clay along the shoreline of the Mekong river reaches between Nakhon Phanom and Mukdahan provinces, northeast of Thailand during April 13~14, 2007. Adults were collected by hand picking from the massive swarm on April 16, 2007. The result showed that it was successful to associate nymphs with adults by male genitalia. The highest density of nymphs sampled were in site I which is clean site and lowest density sampled was in site III which is the polluted site. Body sizes of female nymphs and adults were larger than those males. Abdomens of gravid female nymphs were full of numerous eggs. Mean of fecundity±SD was 3,824.63±1,836.00 (n=8). Sex ratios between male: female nymphs and adults were 1.32 : 1 and 1.85 : 1, respectively. Gut content analysis of nymphs (n=5) resulted mainly of minerals (90%), detritus (9.99%) and diatoms (0.01%).

Key words: *Anagenesia minor*, burrowing mayfly, Mekong River

Introduction

Mayfly belonging to the genus *Anagenesia* was established by Eaton (1883). So far, there were 15 species described under this genus (Kluge, 2004; Barbel-James *et al*., 2008). Fourteen species, *Anagenesia albescens* (Demoulin), *A. ampla* (Eaton), *A. birmanica* (Navas), *A. javanica* (Eaton), *A. lata* (Walker), *A. leucoptera* (Navas), *A. lontona* (Hafiz), *A. minor* (Eaton), *A. nana* (Demoulin), *A. nanoides* (Demoulin), *A. picta* (Gravely), *A. robusta* (Eaton), *A. spodiocephala* (Demoulin), and *A. tenera* (Eaton), were distributed in the Oriental region whereas only one species, *A. paradoxa* (Buldovsky), was found from the Palaearctic region (Kluge, 2004). The burrowing mayfly *A. minor* was widely distributed over the Indian Empire, Burma, and spread over to Borneo and Sarawak of Indonesia (Chopra, 1927). This species was also distributed along the Mekong river between Thailand and Lao People's Democratic Republic. Massive swarm emergence of of *A. minor* is reported annually in hot season especially April at Mukdahan province, northeast of Thailand. This phenomenon caused nuisance to the local residents living along the river and interference with road traffic (Komchadluek News, 2007; Mukdahan Health Care, 2007). The distribution and morphology of adult of *A. minor* have been reported (Chopra, 1927), however some biological aspects of the nymphs are not well known. The objectives of this study were to determine density, body size, sex ratio, fecunfity and gut content of mature nymphs and also density and body size of adults.

Methods

Study Area

The study area consisted of five sampling sites situated along the Mekong River bank 127 km between Nakhon Phanom and Mukdahan Provinces, northeast of Thailand. The locations of sampling sites are shown in Fig. 1. Site I is adjacent to Tha U Then water supply station, Tha U Then District, Nakhon Phanom province. Site II is Art Samart village, upstream Muang District, Nakhon Phanom province. Site III is near Thad Phanom District with intensive activities such as pier, fish culture, restaurants and recreation. Site IV is near Ban Nam Kam, Nakhon Phanom province. Lastly, site V is upstream the Thai-Laos Friendship Bridge, Mukdahan province. Substrata of all sampling sites were mud, sand, and clay.

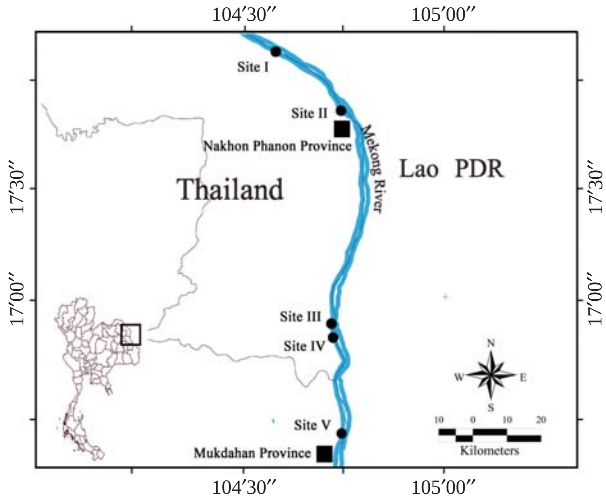

Fig. 1. Location of sampling sites.

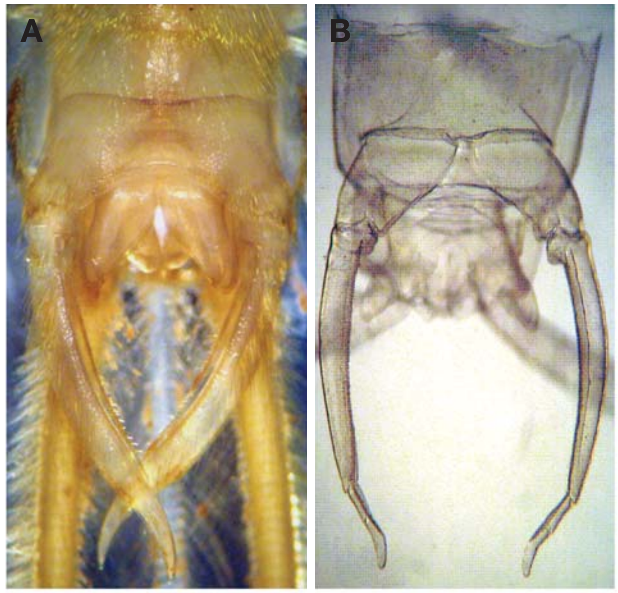

Fig. 2. Genitalia of (A) *A. minor* nymph, (B) adult.

Sampling and Laboratory Procedures

Benthic samples were collected on April 13~14, 2007 using a D-frame dip net (450 μm mesh, $20 \times 20 \times 30$ cm^3). Five samples were collected per site. Invertebrates were stored into labeled vials containing 70% ethanol. Individuals were later sorted, identified and counted for density in the laboratory. In addition, mayfly adults were collected on April 16, 2007 (19:30~20:00) from a massive swarm falling down on the road by hand picking at Ban Bang Sai Noi, 300 m downstream site V. Specimens were preserved in 70% ethanol and transported to the laboratory. Nymphs and adults were associated using male genitalia. The identification keys to species were according to Gravely (1920); Lestage (1923); Chopra (1927); Hafiz (1937); Kimmins (1960); Demolin (1965). Numbers and sexes of nymphs and adults were counted under stereo microscope to calculate density and sex ratios.

Body Sizes

Width of head capsule, body length from the frontal process of head to the end of 10th abdominal segments, widths of the pronotum and mesonotum of nymphs were measured (n=12). The width of head, the lengths of body, fore wing, and hind wing of adults (n=10) were also measured using an ocular micrometer under the stereo microscope (10~70 ×).

Fecundity

Fecundity estimates were based on gravid females nymphs (n=8) from preserved samples. Ovaries of some gravid specimens were stained with methylene blue to facilitate egg counting.

Gut Analysis

Nymphs with dark wing pads were selected as the mature nymphs as described by Edmunds and McCafferty (1988). Guts of the mature nymphs (n=5) were isolated. The gut contents were diluted in glycerin and then placed on microscopic slides (one nymph/slide) according to the methods of Landolt *et al.* (1995). The diet contents were determined to the lowest possible taxa level and quantified as a percentage of the total stomach content per sample. The percentage of diet composition has been obtained by pooling the data of individual nymph.

Data Analysis

T-test was used to determine the significant differences of body sizes of females and males. Pearson correlation was used to analyze egg numbers and body sizes.

Results and Discussion

From the present study, it was successful to associate nymphs and adults by male genitalia (Fig. 2) of *A. minor* (Eaton) (Figs. 3, 4).

Density

As shown in Table 1, the highest density of nymphs occurred at site I (34.67%), followed by site II (33.50%), site IV (18.75%), and then site V (11.51%). The lowest density was found at Site III (1.55%), which may be due to intensive activities such as sand dredging services, pier, fish cultures, restaurants and recreation which caused water pollution and disturbed microhabitats of benthos (Edsall *et al.*, 2005).

Fig. 3. *A. minor* nymphs (scale bar=5 mm).

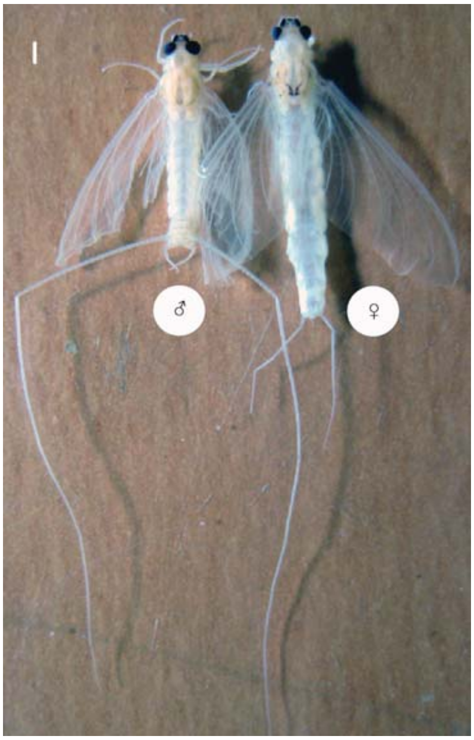

Fig. 4. *A. minor* adults (scale bar=2 mm).

Table 1. Density of *A. minor* nymphs along the Mekong River

Sites	No. of nymphs	Density (Ind. m^{-3})	No. of ♂ : ♀	Sex ratio ♂ : ♀
I	268	2,138	26 : 22	1.18 : 1
II	259	2,066	79 : 51	1.54 : 1
III	12	96	4 : 2	2.00 : 1
IV	145	1,157	30 : 28	1.07 : 1
V	89	710	13 : 13	1.00 : 1
Total	773	1,234	152 : 115	1.32 : 1

Table 2. Range (Mean ± SD) of body sizes of *A. minor* nymphs from the Mekong River

Body sizes (mm)	♂ (n=10)	♀ (n=12)
Head width	3.0-3.2 (3.09 ± 0.7)**	3.2-3.4 (3.28 ± 0.9)**
Body length	21.1-29.0 (27.06 ± 28.1)	28.8-32.6 (30.75 ± 13.7)
Pronotum width	3.6-4.0 (3.8 ± 1.2)*	3.9-4.3 (4.14 ± 1.3)*
Mesonotum width	3.8-4.1 (3.99 ± 0.8)**	4.2-4.7 (4.35 ± 1.6)**

**$p < 0.01$, *$p < 0.05$

Table 3. Range (Mean ± SD) of body sizes of *A. minor* adults from the Mekong River

Body sizes (mm)	♂ (n=10)	♀ (n=10)
Head width	22.0-26.0 (24.05 ± 1.42)	21.0-29.0 23.9 ± 2.23
Body length	131.0-185.0 (161.6 ± 17.66)	147.0-210.0 (170.3 ± 21.40)
Fore wing length	131.0-140.0 (125.40 ± 7.90)**	140.0-175.0 (154.10 ± 12.04)**
Hind wing length	49.0-68.0 (57.30 ± 5.20)*	57.0-75.0 (64.30 ± 6.29)*

**$p < 0.01$, *$p < 0.05$

Body Sizes

Body sizes of the nymphs are presented in Table 2. It showed that the head and mesonotum widths as well as the pronotum widths of female nymphs were significantly larger in females than in males ($p < 0.01$ and $p < 0.05$, respectively). However, body lengths of the female nymphs were not significantly different from those of male nymphs ($p > 0.05$).

As presented in Table 3, the head widths and the body lengths of female adults were not significantly different from those of male adults ($p > 0.05$). Whereas the fore wing lengths of the female adults were highly significant longer ($p < 0.01$), and the hind wing length of the female adults were significantly longer ($p < 0.05$) than those of male adults. However,

Table 4. Pearson correlation and p value of egg numbers and body sizes of nymphs

Body sizes (mm)	r	p
Head width	0.81	0.013
Body length	0.56	0.149
Pronotum width	0.65	0.079
Mesonotum width	0.85	0.007

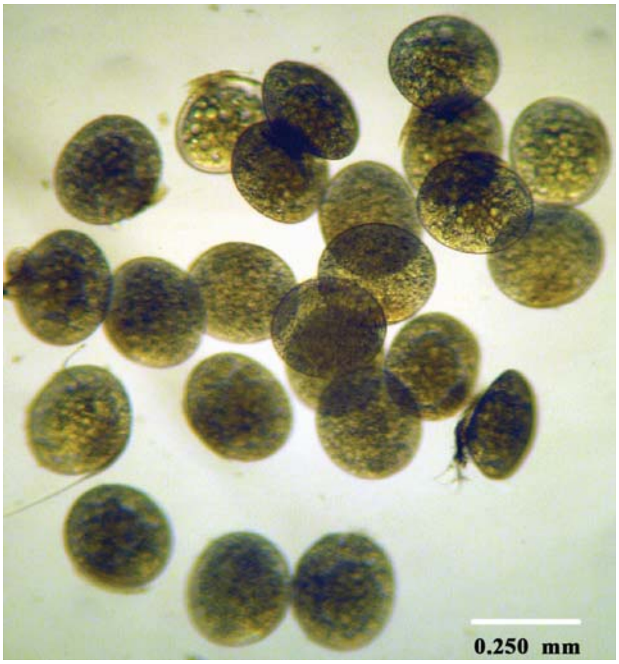

Fig. 5. Eggs of *A. minor* nymph.

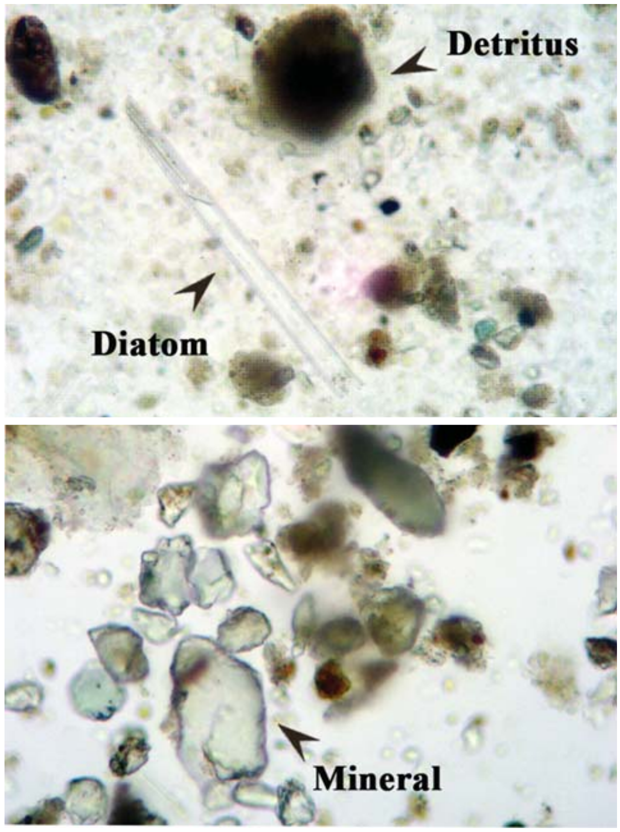

Fig. 6. Food contents of *A. minor* nymph.

the body measurements of both female nymphs and adults were larger than the male nymphs and adults. This result is similar to the study done by Chopra (1927) showing that *A. minor* adult females are larger than the adult males.

Sex Ratio

Sex ratios between male: female nymphs were 1.32 : 1 (152/115), whereas the sex ratios of male:female adults were 1.85 : 1 (280/151) (Table 1). It showed that ratios of adult males were higher than females, which may be due to the collecting time, 19:30~20:00 wherein more male adults usually emerged. This result is similar to the study done by Watanable *et al.* (1989) reporting that more male subimagoes will emerge 1-2 hours earlier than the female subimagoes.

Fecundity

Ranges and mean ± SD of eggs numbers counted from gravid female nymphs were 1,691~7,197 and 3,824 ± 1,836, respectively. It was found that body sizes of female nymphs were strongly correlated with number of eggs (Table 4). Eggs were oval-shaped with numerous globular yolk granules scattered (Fig. 5) which was similar to the report of Chopra (1927).

Gut Analysis

As shown in Fig. 6, the main food items of the mature nymphs (n=5) were minerals (90%), followed by detritus (9.99%) and then diatoms (0.01%), which was corresponded to the substrate. Gut analysis showed that *A. minor* nymphs are collector-gatherers which was similar to the study of Edmunds and Waltz (1996) showing that burrowing mayflies (superfamily Ephemeroidea included *A. minor*) are collectors-gatherers.

This is the first report of some biological aspects of *A. minor* nymphs from Thailand.

Acknowledgements

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Insect diversity

Meiofaunal Community in Different Substrate Types of Headwater Streams of Nam Nao National Park, Thailand

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Abstract

Research on lotic meiofauna in Thailand is very scarce. This pioneer study was conducted in Phromsong and Phromlaeng streams, Nam Nao National Park, Petchabun province during October 2004 to June 2005. Organisms and sediment samples were collected from upper 10 cm streambed by a 4 cm diameter PVC standing-pipe within two month intervals. Sediment characteristics, subsurface water physico-chemistry, taxa richness and abundance were measured. A total of 15,345 individuals were found wherein different sites have different meiofauna group composition. Tardigrades and acari were the dominant organisms in Phromsong stream. Whereas gastrotrichia and monogonont rotifer were the dominant organisms in Phromlaeng streams. Molluscs such as *Corbicula* species and Coleoptera larvae such as Elmidae were found only in Phromsong stream. Result of multivariate analysis showed that substrate type and physico-chemistry of water affects the meiofauna distribution in these headwater streams

Key words: lotic meiofauna, meiofaunal community, Nam Nao National Park

Introduction

Meiofauna are mobile invertebrates that have been defined as benthic animal passing through a 500 μm and retained on 63 μm sieve (Giere, 1993). There are many metazoan phyla that could be examined by this definition and represented by Robertson *et al.* (2000a). They were grouped into two categories: permanent meiofauna which range within meiofaunal size throughout their life cycle and temporary one which is immature stage of many macrofauna (Higgins and Thiel, 1988). Hakenkamp *et al.* (2002) and Robertson (2000) described meiofaunal role on ecological functioning such as increasing microbial activity and particulate organic matter dynamics by consumption and bioturbation, contribution to total stream biomass and production and maintaining lotic population by succession and recolonization. They also contribute to the diversity of lotic ecosystem because of their diversity (Robertson *et al.*, 2000b). Schmid-Araya and Schmid (1995) found 300 meiofauna species in Oberer Seebach stream. Stead *et al.* (2003) found meiofauna species reaching to 66~81% of the total 168 taxa in Lone Oak stream. In addition, their density could reach 906 and 3166 individuals per 10 cm^2 in Körsch and Kröhenbach streams, respectively (Beier and Traunspurger, 2003). Silver *et al.* (2002) discussed the influence of small-scale spatial pattern such as predation, food quality, substratum characteristics and local flow dynamics on lotic meiofaunal community and reviewed that water flow and substrata overwhelmingly affect faunal distribution pattern. Swan and Palmer (2000) stated that oxygen replenishment was limited by small particle size at low flow. This situation can reduce meiofaunal abundance and/or change species composition. So, it possible that difference of substratum grain size and heterogeneity can cause the difference of meiofaunal community in both composition and abundance. However, most of this knowledge came from many areas in Europe, while the meiofaunal study was very scarce in other regions and in Thailand as well. So this investigation in lotic meiofauna aims to prove whether the studies done before in other areas will also be applicable in Thailand streams given that there were many different environmental conditions in the area.

Materials and Methods

Subsurface Water Physico-chemical Parameters and Sediment Characteristic Analysis

Subsurface water and sediment samples at 10 cm depth were collected for 3 times in each sampling occasion[HP1] using pore water lance and a 4 cm diameter PVS standing-pipe,

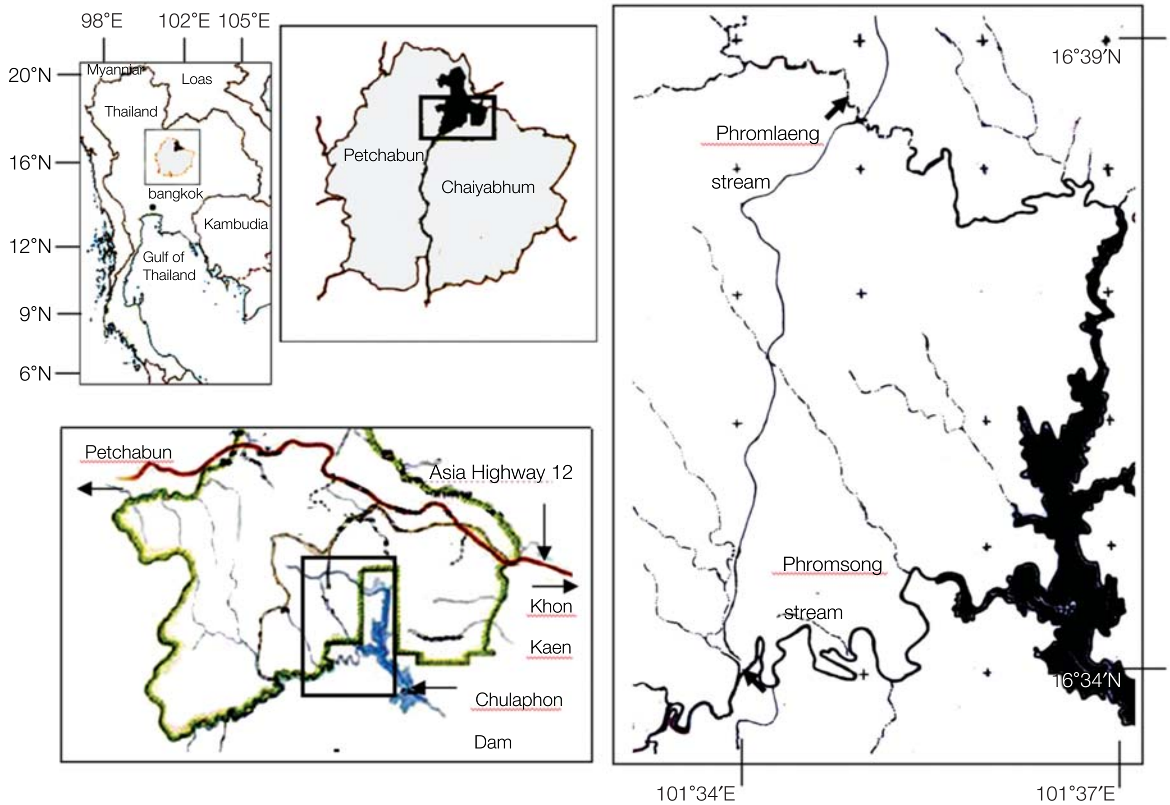

Fig. 1. Location of Phromsong and Phromlaeng streams of Nam Nao National Park, Thailand. Sampling locations were point by black arrows (⬅).

Table 1. Mean±standard errors (n=4) of environmental variables are compared using Mann-Whitney *U*-test (*=P<0.05; **=P<0.01; ***=P<0.001; NS=not significant; n.d.=cannot detected by instrument)

Parameters		PS	PL	*U*-test
Water physico-chemistry				
Water velocity	m sec.$^{-1}$	0.13±0.10	n.d.	–
Water temperature	°C	23.20±1.89	20.81±1.96	NS
pH	–	7.10±0.23	7.11±0.18	NS
Dissolved oxygen (DO)	mg/L	3.42±0.22	2.26±0.31	*
Total dissolved solid (TDS)	μS/cm	134.18±12.00	304.42±41.20	***
Sediment characteristics				
Median particle size (MD)	mm	7.20±1.19	4.05±0.72	*
Coefficient of Uniformity (CU)	–	40.10±6.31	10.16±2.42	***
Fine particle content	g cm^{-3}	0.55±0.03	0.59±0.08	NS
Gravel content	g cm^{-3}	0.20±0.03	0.32±0.04	**
Coarse particle content	g cm^{-3}	1.02±0.10	0.64±0.08	**
Organic matter content	% W/W	1.37±0.07	2.83±0.15	***

respectively. Median particle size diameters were analyzed by sieve analysis (Giere *et al.*, 1988). Coefficient of Uniformity (CU; sediment sorting) was calculated equal to D_{60}/D_{10}. Fine particle (<2 mm), gravel (2~4 mm) and coarse particle (>4 mm) content were calculated in weight per volume of sediment sample. Ash-free dry weight analysis was proceeded to examine total organic matter (Greiser and Faubel, 1988). Mean physico-chemical parameters of water, water flow velocity and sediment characteristics were calculated (Table 1). However, the parameters on the last occasion were not computed and analyze because they were disturbed by spate.

Meiofaunal Community

The organisms were collected by a 4 cm diameter PVS standing-pipe for 3 times in each occasion and preserved in 4%

formalin. They were extracted from sediment samples by decantation. Sorting and identification proceeded under stereomicroscope and biological microscope, respectively. Taxa richness and density were also examined.

Statistics

Due to less number of samples (1 station × 3 corers × 4 occasions × 2 streams=24), so, non-parametric Mann-Whitney *U*-test was used for analysis (Siegel, 1956) testing the significant differences of physic-chemical parameters of water, sediment characteristics parameter, and meiofauna density among streams using SPSS (version 11.0). Multivariate analysis was conducted to ordinate the variables and abundance of meiofauna taxa using non-metric multidimentional scaling (NMS) which calculated by Bray-Curtis similarity index in PC-ord software. The NMS was carried out on $\log_{10}(x+1)$ transformed meiofauna data (to down-weight abundant taxa).

Results and Discussion

Subsurface Water Physico-chemical Parameters and Sediment Characteristics

DO, TDS, gravel, fine particles and total organic matter content were higher in Phromlaeng than Phromsong sampling location significantly ($p<0.05$) (Table 1). This could be explained by the sampling location of Phromlaeng situating upstream of a weir which causes an accumulation of small particles and organic matter (Boulton and Block, 1998). They clogged interstitial space and reduce oxygen concentration by intense microbial activity at high water retention time (Boulton *et al.*, 1998). Contrastingly, MD, CU and higher coarse particle content indicated that particle size in Phromsong were larger and more heterogeneous than Phromlaeng. In addition, water flow was not limited by any obstacle in stream channel. This situation contributed to the exchange of oxygen between surface and subsurface water.

Meiofaunal Community

A total 15,345 individuals were found. Taxa composition of meiofauna among streams was very different (Table 2). Temporary meiofauna was more abundant and diverse in Phromsong like other heterogeneous streams (Minshall, 1984). Molluscs such as *Corbicula* species and Coleoptera larvae such as Elmidae were found only in Phromsong stream where the substrate is suitable for bivalves (Smith, 2001) while relative high oxygen requirement and substrate stability may be the factors restricting elmid distribution. Total permanent meio-

Table 2. Mean ± standard errors (n=4) of meiofaunal density (individual/10 cm^2) are compared using Mann-Whitney *U*-test (*=P < 0.05; **=P < 0.01; ***=P < 0.001; NS=not significant)

Taxa	PS		PL		*U*-test
	Density	%	Density	%	
Permanent meiofauna					
Bdelloidea (Rotifera)	114.48 ± 43.87	38.3	263.96 ± 201.09	67.4	NS
Nematoda	45.21 ± 7.12	15.1	30.95 ± 11.60	7.9	NS
Monogononta (Rotifera)	2.65 ± 0.99	0.9	36.26 ± 26.08	9.3	***
Crustacea (Arthropoda)	12.99 ± 3.41	4.3	12.79 ± 5.48	3.3	NS
Gastrotricha	0.86 ± 0.25	0.3	12.79 ± 5.44	3.3	***
Hydrachinidia	8.75 ± 1.97	2.9	0.60 ± 0.38	0.2	**
Tardigrada	3.38 ± 1.14	1.1	0.13 ± 0.17	0.03	*
Other		1.5		2.57	-
Temporary meiofauna					
Ephemeroptera	9.41 ± 1.53	3.1	2.52 ± 1.49	0.6	**
Trichotera	1.92 ± 0.31	0.6	0.33 ± 0.17	0.08	**
Ceratopogonidae (Diptera)	3.31 ± 1.00	1.1	4.04 ± 0.74	1.0	NS
Chironomidae (Diptera)	47.66 ± 5.74	15.9	9.08 ± 8.12	2.3	**
Elmidae (Coleoptera)	10.21 ± 1.53	3.4		–	–
Cobicula (Mollusca)	23.66 ± 0.07	7.9		–	–
Other	–	1.0	–	0.12	–
Oligochaeta (Annelida)	7.82 ± 2.51	2.6	7.36 ± 2.28	1.9	NS
Total permanent meiofana	192.77 ± 53.07	64.4	368.43 ± 293.06	94.0	NS
Total temporary meiofana	98.57 ± 11.10	33.0	16.11 ± 8.65	4.1	**
Total meiofana	299.16 ± 60.66	100	391.89 ± 236.80	100	NS
Permanent meiofauna richness	27		35		–
Temporary meiofauna richness	39		18		–
Total taxa richness	66		53		–

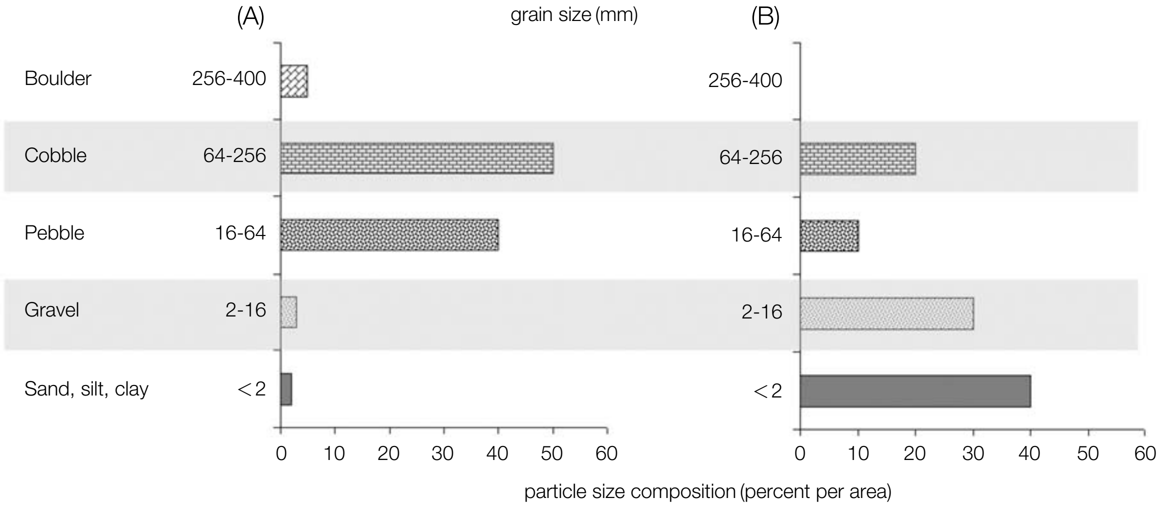

Fig. 2. Percentage of grain size fractions of the sampling locations in the stream (A) Phromsong and (B) Phromlaeng.

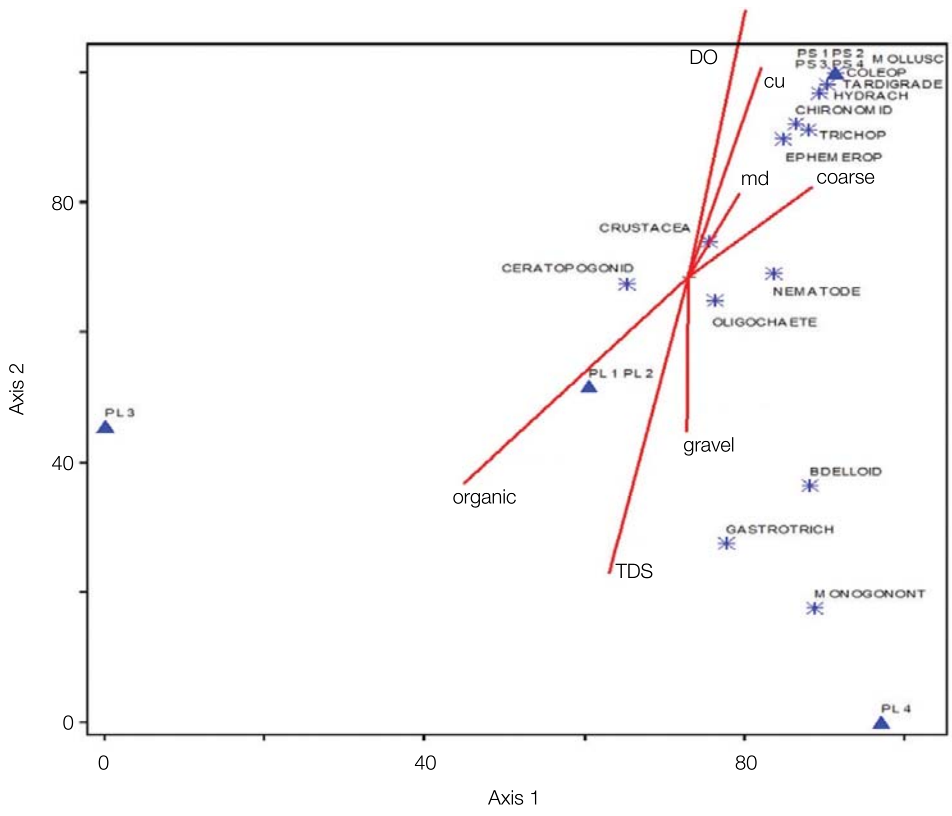

Fig. 3. Non-multidimensional scaling analysis of community composition, abiotic factors and sites.

fauna density was relative higher in Phromlaeng but result showed that the differences across the two locations were not significant. Abundance of permanent meiofauna showed their difference in environmental preference. Tardigrade and acari were more significantly abundant in Phromsong stream whereas gastrotrich and monogonont rotifer were more abundance in Phromlaeng. Like many streams, rotifer and nematode usually are the most abundant permanent meiofauna (Beier and Traunspurger, 2003) and chironomid larva is the aquatic insect that can be probably encountered in freshwater habitats (Huryn and Perimutter, 1988).

Non-matric Multidimentional Scaling

The results of multivariate analysis indicated that difference of substrate types and water physico-chemistry affected the meiofauna distribution in these headwater streams (Fig. 3). The station where there is higher DO, CU, MD and coarse particle content is composed mainly of temporary meiofauna; tardigrade and hydrachinidia. In contrast, bdelloid rotifer, monogonont rotifer and gastrotrich dominated in relatively high organic matter, TDS and gravel content. Lastly, crustacean, ceratopogonid, oligochaete and nematode distribution was rarely affected by measured parameters.

Acknowledgements

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Insect diversity

Adult Caddisfly Fauna and Physico-chemical Parameters of Pasak Jolasit Dam, Central Thailand

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Abstract

Adult caddisfly fauna and physico-chemical parameters of stream inlets and outlets of Pasak Jolasit dam were investigated from July to November 2008. Three sites were sampled in the said river system; first site was 1 km above the inlet, second was in Wang Ghan Leung waterfall which drains into the main river, and last was 50~100 m below the outlet. A total of 19 species belonging to seven families of caddisfly were found in this preliminary survey. Outlet streams were dominated by the hydropsychids; *Amphipsyche meridiana* (Ulmer, 1909), *Cheumatopsyche cognita* (Ulmer, 1951), and *Macrostemum indistinctun* (Banks, 1911). Whereas, dam inlets were dominated by *Chimarra chiangmaiensis* (Chantaramongkol and Malicky, 1989), *Ecnomus volovicus* (Malicky and Chantaramongkol, 1993), and *Cheumatopsyche naumanni* (Malicky, 1986). The correlation between the diversity of adult Trichoptera and water quality were analyzed. Water and air temperature and orthophosphates showed strongly influenced by the caddisfly presence at the dam.

Key words: caddisflies, Pasak Jolasit Dam, physico-chemical parameters, Thailand

Introduction

In Thailand, many studies were done using adult caddisflies as bioindicator of water quality (Chiabu, 2000; Laudee, 2001; Cheunbarn, 2002). Caddisflies were chosen for study because they are usually more numerous and diverse than other aquatic insect orders (Wiggins, 1996). Adults are being studied widely because they are easily collected in light traps and can be used as a useful tool for bioassessment (de Moor, 1999; Greenwood *et al.*, 2001). Light traps have been used extensively by various workers to survey caddisfly populations. Light traps are the sampling tools that are used to collect insect from both terrestrial and aquatic systems. The methods applied in light traps, which are catching tools in aquatic insects, have been of benefit especially in sampling the Trichoptera species (Chantaramongkol, 1983; Waringer, 2003). Knowledge of the taxonomy and ecology of the species has proven valuable in biomonitoring programs because of very different susceptibilities of the various species to pollutants and other types of environmental disturbances. Genus or species level identifications of adult caddisflies are possible and clearly produce more accurate results than family level identification, thereby giving better ability to assess the water quality. The aim of this paper is to investigate the diversity of adult caddisflies in inlets and outlets of Pasak Jolasit Dam. Physico-chemical parameters such as pH, water temperature, Dissolved oxygen (DO), conductivity, and total dissolved solids (TDS) The ammonia nitrogen (NH_4-N), sulfate (SO_4^{2-}), nitrate-nitrogen (NO_3-N), orthophosphate (PO_4^{3-}) and turbidity were measured to determine their effects, if any, on the diversity of adult caddisfly.

Materials and Methods

Study Area

Investigations were carried out at the inlet and the outlet of Pasakchonlasit Dam which was constructed across the Pasak River, including Wang Ghan Lueng waterfall that drains into that main river. The source of the Pasak River (N 14°21′44″~17°06′02″, E100°34′40″~101°32′56″, area: 15,779 km^2, length of main stream: 1,039 km) is in the highlands of Phetchaboon Province and flows through hundreds of kilometers on the central plain of Lopburi and Saraburi, and joins the Chao Phraya River at Ayutthaya Province. This river flows from northern mountainous area to the south wherein short tributaries are located from east and west area draining to Chai Phraya river.

Table 1. Male Trichoptera collected by light traps during July to November 2008 at Pasak Jolasit Dam

Taxa	WGL WF	Inflow	Outlet*
Philopotamidae			
Chimarra chiangmaiensis Chantaramongkol and Malicky 1989	112		
Psychomyiidae			
Paduniella sampati Malicky and Chantaramongkol 1993	22		
Psychomyia kaiya Malicky and Chantaramongkol 1993			1
Psychomyia samanaka Malicky and Chantaramongkol 1993	7		
Dipseudopsidae			
Dipseudopsis robustior Ulmer 1929		1	
Ecnomidae			
Ecnomus atevalus Malicky and Chantaramongkol 1993			1
Ecnomus mammus Malicky and Chantaramongkol 1993		1	4
Ecnomus puro Malicky and Chantaramongkol 1993	4		
Ecnomus volovicus Malicky and Chantaramongkol 1993	39		
Ecnomus votticius Malicky and Chantaramongkol 1993			1
Xiphocentronidae			
Abaria guatila Malicky and Chantaramongkol 1992	4		
Hydropsychidae			
Cheumatopsyche banksi Mosely 1942		7	
Cheumatopsyche cognita Ulmer 1951	1	1	119
Cheumatopsyche naumanni Malicky 1986	36		
Macrostemum indistinctum Banks 1911			129
Amphipsyche meridiana Ulmer 1909		2	3781
Leptoceridae			
Ceraclea hypsipyle Malicky 2005		1	1
Oecetis laodike Malicky and Chantaramongkol 2005		1	
Triaenodes narkissos Malicky 2005	5		

*Light traps were operated only in 10 minutes.

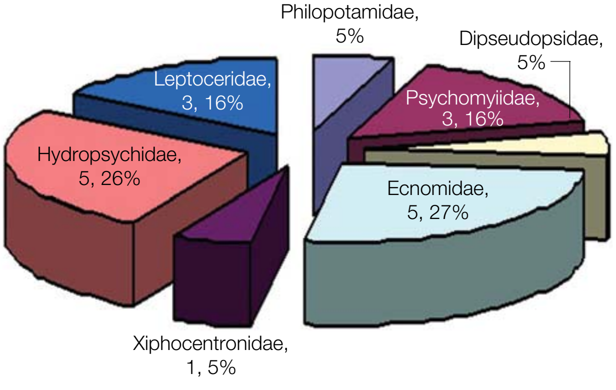

Fig. 1. Percentage of caddisflies species collected from each family in Pasak Jolasit dam during July to November 2008.

Adult Caddisflies Collection

At each collection site, adults were collected using portable black light traps (10 Watts fluorescent, 12 Volts DC batteries) suspended across a black pan containing a detergent solution. These were timed to operate simultaneously from one hour before sunset to 1.5 hours after sunset near the stream margin. Insects attracted to the black light were collected in trays filled with water and a few drops of liquid detergent. They were transferred into 80% ethanol the next morning and transported back to the laboratory. Light traps were set once each month from July to November 2008.

Table 2. Some physico-chemical parameters of the Pasak Jolasit Dam during sampling of adult caddisflies

Parameters	Study sites		
	Wang Ghan Lueng WF	Inflow	Outlet
Air temperature (°C)	24	25	37
Water temperature (°C)	24	25	32.8
pH	6.95	7.39	8.1
DO (mg L^{-1})	5.3	5.6	5.7
NO_3-N (mg L^{-1})	4.4	1	1.4
NH_3-N (mg L^{-1})	0.19	0.66	0.55
PO_4 (mg L^{-1})	0.04	0.27	0.27
SO_4^{2-} (mg L^{-1})	16	28	35
Turbidity (FTU)	5	195	74

Specimen Identification

Specimens were identified and counted under a stereo-microscope. Analysis was performed using family and species level identification of male specimen since it was easier to identify as compared to females. Identification of species was done by using pictorial keys by Malicky (2010).

Table 3. Pearson's correlations between some physico-chemical parameters on adult caddisflies from Pasak Jolasit Dam during July to November 2008

Species	Physico-chemical parameters		
	Air temperature	Water temperature	Orthophosphate
Chimarra chiangmaiensis Chantaramongkol and Malicky 1989			−−
Psychomyia kaiya Malicky and Chantaramongkol 1993	+	++	
Psychomyia samanaka Malicky and Chantaramongkol 1993			−−
Paduniella sampati Malicky and Chantaramongkol 1993			−−
Abaria guatila Malicky and Chantaramongkol 1992			−−
Ecnomus atevalus Malicky and Chantaramongkol 1993	+	++	
Ecnomus votticius Malicky and Chantaramongkol 1993	+	++	
Ecnomus volovicus Malicky and Chantaramongkol 1993			−−
Ecnomus puro Malicky and Chantaramongkol 1993			−−
Amphipsyche meridiana Ulmer 1909	+	++	
Cheumatopsyche cognita Ulmer 1951	+	++	
Cheumatiosyche naumanni Malicky 1986			−−
Macrostemum indistinctum Banks 1911	+	++	
Ceraclea hypsipyle Malicky 2005			++
Triaenodes narkissos Malicky 2005			−−

++, −−: Correlation is significant at the 0.01 level, positive (+) and negative (−).
+: Correlation is significant at the 0.05 level, positive (+).

Physico-chemical Survey

Physico-chemical parameters of the streams were measured once at each site in each month. These includes pH which was measured using a pH-meter, water temperature and air temperature which were measured using a hand thermometer, and Dissolved Oxygen (DO) which was measured using DO meter HACH® Model sensION 6. In the laboratory, nitrate-nitrogen (NO_3-N), ammonia nitrogen (NH_4-N), orthophosphate (PO_4^{3-}), sulfate (SO_4^{2-}), and turbidity (FTU turbidity) were analyzed using a spectrophotometer following the cadmium reduction method for nitrate-nitrogen, Nessler method for ammonia-nitrogen, ascorbic acid method for orthophosphate and sulfaVer 4 method for sulfate.

Data Analysis

Differences in trichoptera species community structure across sample sites, in relation to environmental variables, were analyzed by Pearson's correlation in SPSS software program version 13.0.

Results and Discussion

Adult Caddisfly Survey

[0]Nineteen species belonging to seven families of caddisflies were sampled using light trapping in this preliminary survey (Table 1). The most species rich families were Ecnomidae (27%) followed by Hydropsychidae (26%), Leptoceridae and Psychomyiidae (16%), Philopotamidae, Dipseudopsidae, and Xiphocentronidae (5%) (Fig. 1). From these results *Chimarra chiangmaiensis, Ecnomus volovicus* and *Cheumatopsyche naumanni* were most common and widely distributed in the stream from Wang Ghan Leung waterfall. River inlets with less variety of habitats had reduced numbers and taxonomic richness.

Net spinning caddisflies, particularly hydropsychids, commonly occur in high densities at lake outlets (Barnard, 1984; Harding, 1997). Their abundance has been associated with the presence of high food quality (Perterson, 1987; Harding, 1997), stable water flow and stable substrata common in these habitats (Georgian and Thorp, 1992). As in this study, the numerous numbers of adult hydropsychids, *Amphipsyche meridiana*, *Cheumatopsyche cognita*, and *Macrostemum indistinctum*, are generally found in fast-flowing rivers on a stony substrate and below lake outlets, and only few were found at river inlets because of less variety of habitats. Taxa represented by one specimen were *Psychomyia kaiya*, *Dipseudopsis robustior*, *Ecnomus atevalus*, *Ecnomus votticius*, and *Oecetis laodike*.

Physico-chemical Survey

The physico-chemical parameters did not differ significantly at all sampling sites, except in terms of air and water temperature (Table 2). Air and water temperatures were generally higher in lake outlet than inlet and waterfall. The highest air and water temperatures at the sampling sites ranged between 24~37°C. The pH levels at all sampling sites ranged from 6.95 to 8.1. DO concentration values showed no clear tends among sites (5.3~5.7 mg L^{-1}).

Dissolved nutrients, NH_3-N and PO_4 concentrations were considerably higher at the inlet and outlet, than at the waterfall. The NO_3-N concentration reached up to 4.4 mg L^{-1} in the stream from the waterfall. The SO_4^{2-} tended to be higher in the outlet of the dam, because the sugar-cane factory is located near that outlet and released air pollution. The turbidity was higher at the inlet than in other sites during flood.

The Correlation between Caddisfly Species and Physico-chemical Parameters

Analysis of trichoptera species data and some physico-chemical parameters indicated that *Psychomyia kaiya*, *Ecnomus atevalus*, *Ecnomus votticius*, *Amphipsyche meridiana*, *Cheumatopsyche cognita*, and *Macrostemum indistinctum* were positively correlated with air and water temperatures ($p < 0.01$ and $p < 0.05$, respectively). Higher air and water temperatures at outlets than inlet rivers may also favor increased production of some species as found for several hydropsychids (Harding, 1992). The *Chimarra chiangmaiensis*, *Paduniella sampati*, *Psychomyia samanaka*, *Abaria guatila*, *Cheumatopsyche naumanni*, and *Ecnomus volovicus* were negatively correlated with PO_4 ($p < 0.01$), whereas *Ceraclea hypsipyle* was positively correlated with PO_4 ($p < 0.01$). Correlation coefficients between caddisflies species data and some water quality parameters are given in Table 3.

The present study shows that most of the caddisfly species that were found in this area are indicator species that are always present in the river and therefore have potential as water quality bioindicators for this river and its watershed (Chaibu, 2000; Cheunbarn, 2002).

The results of this study will be valuable baseline information for monitoring environmental change in the area in the future and the study will be continued at a later date.

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Insect diversity

Light-trapping of Caddisflies (Insecta: Trichoptera) at Champathong Waterfall, Northern Thailand with Reference to Local Climate

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Abstract

The adult caddisfly fauna of Champathong waterfall in northern Thailand was sampled monthly using portable black light traps from February to October 2008. A total of 762 male individuals were sampled, belonging to 72 species of 14 families. *Chimarra monorum* (Chantaramongkol and Malicky, 1989), *Cheumatopsyche copia* (Malicky and Chantaramongkol, 1997), and *Hydromanicus serubabel* (Malicky and Chantaramongkol, 1993), were the most common species in the research area. Apart from specimen collection, air temperature and precipitation were also recorded and analyzed. Results showed that trichoptera species was highest in richness and abundance during February through to April, which was also the end of the dry season in the region

Key words: caddisflies, Champathong waterfall, light-trapping, Thailand, trichoptera

Introduction

Most studies of trichoptera in Thailand have focused mainly on lotic habitat. The methods applied in light traps, which are used as a catching tool in aquatic insects, have been of benefit especially in sampling the Trichoptera species (Waringer, 2003). Although they are selective and the caught ones are affected by the meteorological parameters,light traps are still commonly used (Schmera and Kiss, 2004).

Adult trichoptera seasonality in Thailand is poorly known, although several investigations at Doi Suthep-Pui have been conducted e.g., Chantaramongkol *et al.* (1999), and Prommi and Chantaramongkol (2003). The abundance of Trichoptera adults was associated to the three seasons in that region. The study of adult trichoptera's seasonal activity patterns for the two seasons: dry (December~April) and wet (May~November) were obtained in southern Thailand (Prommi *et al.*, 2005).

The investigation presented here assesses the seasonal flight activity patterns of Trichoptera at a stream from Champathong waterfall in northern Thailand, which is the one of the few remaining virgin rain forests in northern Thailand as well as related to the presence of specimens within the local climates.

Materials and Methods

Study Area

This study was conducted at a stream from Champathong waterfall (Fig. 1), in the Doi Lueng National Park, Phayao Province, northern Thailand. The study area is located at 19° 13′N, 99° 44′E and is 620 m above sea-level. The substrate consisted of large exposed rocks with little movable intervening substrate.

The climate is monsoonal, with a mean annual rainfall of about 1158.3 mm; the rainy season is from May to October; the cool-dry season is from November to January (minimum temperatures 10.5°C); and the hot dry season is from February to April, (maximum temperatures 38.2°C) (Fig. 2) (Source: Muang Phayao Station, 2008).

Adult Trichopteran Survey

The Trichoptera adults were attracted with 10-watt ultraviolet lights operated from a 12-volt DC battery, suspended across a black pan containing a detergent solution. At the sampling site, the pan was placed in the vegetation near the water's edge and. This procedure was done consistently to the sampling sites. Lights were set on timers to run simultaneously from one hour before sunset to $1^1/_2$ hours after sun-

Fig. 1. Location of sampling site in stream from Champathong waterfall, northern Thailand.

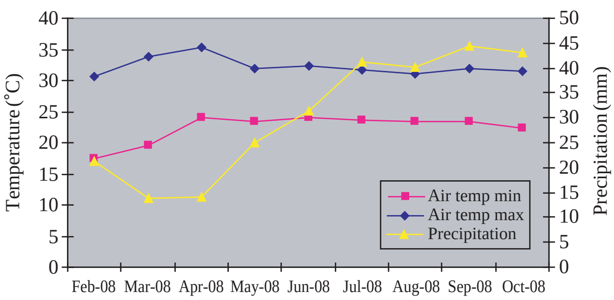

Fig. 2. Total monthly rainfall and air temperature in Champathong waterfall (February~October 2008) (source: Muang Station Records for 2008).

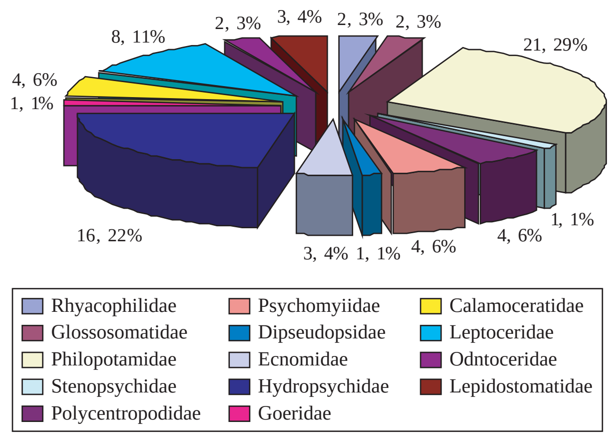

Fig. 3. Percentage of caddisflies species collected in each family in a stream from Champathong waterfall during February to October 2008 (clockwise from 12 o'clock).

set. After which the pan's contents were placed in a container and transported back to the laboratory. Light traps were set once each month from February to October 2008.

Specimens Identification

Samples were sorted and specimens were identified using stereomicroscope. Adult males caddisfly species were primarily used for making species determinations. The last two abdominal segments of adult male genitalia were cut and cleared by heating in 10% NaOH at 70°C for 30 minutes. Specimen identifications were carried out to the species level. Specimen identification was carried out on the species level using Malicky (2010).

Analysis

The correlations between the Trichoptera species community structure from amongst sample sites and local climate data were analyzed using SPSS software program version 13.

Results and Discussion

Diversity of Adult Caddisflies

A total of 762 male individuals belonging to 72 species of 14 families were sampled. The percentage of trichoptera species collected in each family (Fig. 3) and the flight graphics of the 10 most common species in terms of individuals, and time of collection of 72 species, were plotted from the monthly count results of species in the traps (Fig. 4).

Taxa represented by fewer specimens and found just once were Philopotamidae - *Chimarra meorum, C. rama, C. shiva, C. schwendingeri, Gunungiella traiafiazga, G. fiarafiazga, Kisaura verecunda*; Stenopsychidae - *Stenopsyche siamensis*; Polycentropodidae - *Polyplectropus anakgugus*; Psychomyiidae - *Psychomyia kuni, Tinodes ragu*; Dipseudopsidae - *Dip-*

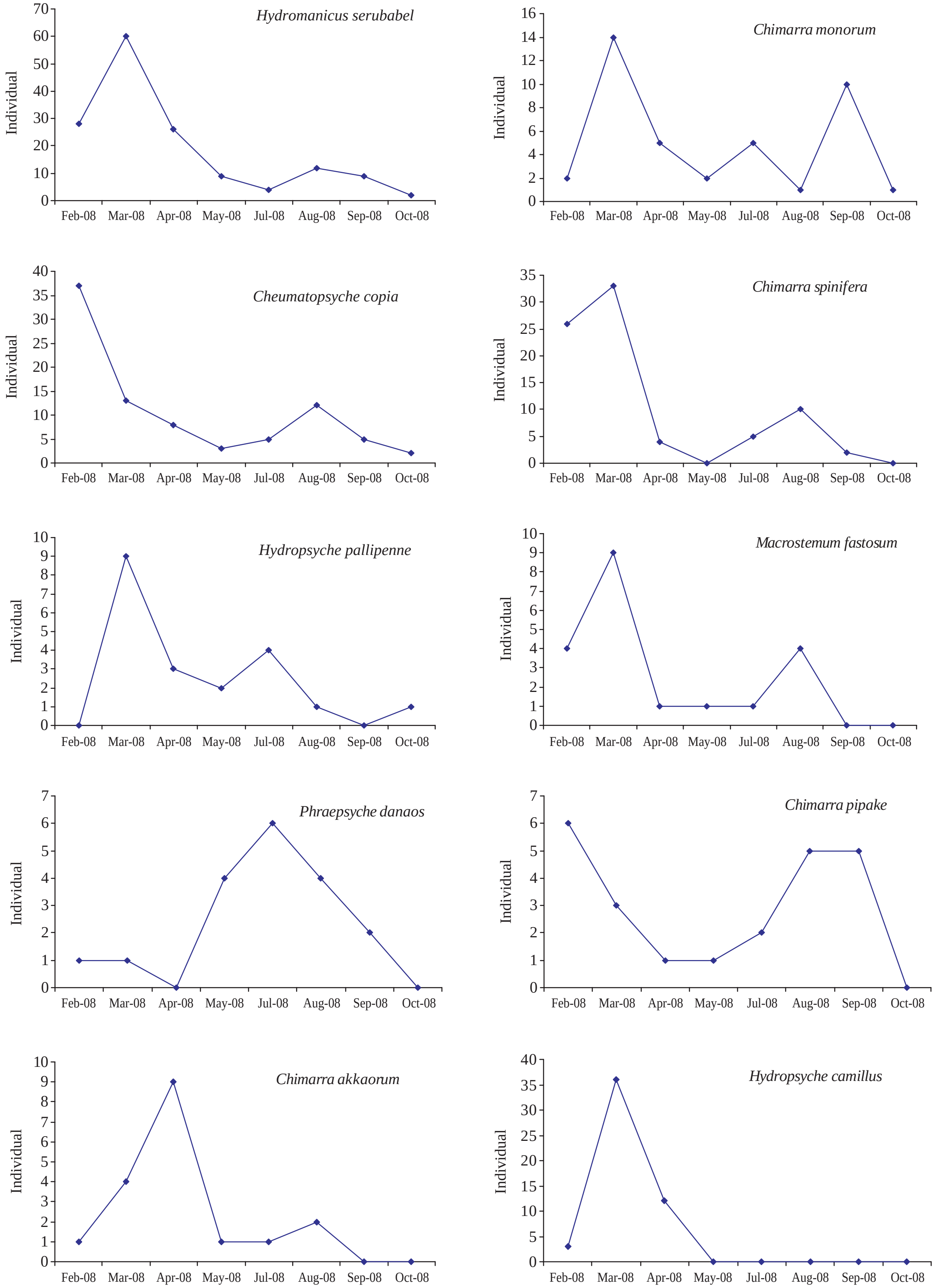

Fig. 4. The seasonal flight distribution of the 10 most common species of 72 Trichoptera species in a stream from Champathong waterfall.

Table 1. Pearson's correlations between local climate data on Trichoptera adults in a stream from Champathong waterfall

Species	Local climate data		
	Minimum air temperature (°C)	Maximum air temperature (°C)	Rainfall mm
Rhyacophila tosagan Malicky and Chantaramongkol 1993	−0.779*		
Agapetus dangorum Olah 1942			−0.878**
Agapetus lalus Malicky and Chantaramongkol 1992		0.930**	−0.769*
Chimarra akkaorum Malicky and Chantaramongkol 1989		0.892**	−0.709*
Chimarra devva Malicky and Chantaramongkol 1993	−0.779*		
Chimarra meorum Chantaramongkol and Malicky 1989	−0.809*		
Chimarra spinifera Kimmins 1957	−0.845**		
Chimarra suadulla Malicky and Chantaramongkol 1993	−0.797*		
Dolophilodes truncata Kimmins 1955	−0.749*		
Pseudoneureclipsis philemon Malicky and Prommi 2000		0.930**	−0.769*
Dipseudopsis robustior Ulmer 1929		0.788*	
Ecnomus mammus Malicky and Chantaramongkol 1993		0.788*	
Cheumatopsyche carna Malicky and Chantaramongkol 1997	−0.921**		
Cheumatopsyche copia Malicky and Chantaramongkol 1997	−0.849**		
Pseudoleptonema supalak Malicky and Chantaramongkol 1998		0.743*	−0.849**
Anisocentropus brevipennis Ulmer 1906		0.788*	
Setodes endymion Malicky and Chibu 2000		0.788*	
Setodes sarapis Malicky 2005		0.788*	
Tagalopsyche orisis Malicky 2005	−0.809*		
Marilia sumatrana Ulmer 1951		0.788*	

**p < 0.05, *p < 0.01

seudopsis robustior; Ecnomidae - *Ecnomus mammus, E. venimar*; Hydropsychidae - *Cheumatopsyche globosa, Hydropsyche dolosa, Macrostemum dohrni*; Goeridae - *Goera matuilla*; Calamoceratidae - *Anisocentropus brevipennis, Ganonema extensum, G. fuscipenne*; Leptoceridae - *Adicella evadne, A. hero, Oecetis miletos, Setodes endymion, S. sarapis, Tagalopsyche orisis, Triaenodes dusra*; Odontoceridae - *Marilia sumatrana*; Lepidostomatidae - *Dinarthrum pratetaiensis*.

Taxa found to be present twice were Glossosomatidae - *Agapetus lalus*; Philopotamidae - *Chimarra bimbltona, C. lannaensis, C. suthepensis, C. suadulla, Kisaura surasa*; Polycentropodidae - *Polyplectropus nahor, Pseudoneureclipsis philemon*; Hydropsychidae - *Cheumatopsyche carna, C. chrysothemis, Diplectrona eurydike*; Leptoceridae - *Adicella koronis*; Lepidostomatidae - *Georodes doligung*.

Taxa present three times were Rhyacophilidae - *Rhyacophila suthepensis, R. tosagan*; Glossosomatidae - *Agapetus dangorum*; Philopotamidae - *Chimarra atnia, C. chiangmaiensis, C. devva*; Polycentropodidae - *Polyplectropus admin*; psychomyiidae- *Psychomyia lak*; Ecnomidae - *Ecnomus tinco*; Hydropsychidae - *Diplectrona aurovittata, Hydatomanicus klanklini, Hydromanicus truncatus, Hydropsyche camillus, Pseudoleptonema supalak*; Calamoceratidae - *Anisocentropus pan*; Lepidostomatidae - *Adinarthrum moulmina*. Only one species, *Psychomyia lak*, in Psychomyiidae, were found at four times.

Taxa present five times were Philopotamidae - *Dolophilodes truncate, Gunungiella segsafiazga*. Taxa present six times were Philopotamidae - *Chimarra akkaorum, C. spinifera*; Hydropsychidae - *Hydropsyche pallipenne, Macrostemum fastosum*; Odontoceridae - *Phraepsyche danaos*. Only one species in Philopotamidae was present seven, the *Chimarra pipake*. The philopotamid species (*Chimarra monorum*), and the hydropsychid species (*Cheumatopsyche copia*, and *Hydromanicus serubabel*) were the dominant taxa and found in all sampling dates. Of the 72 species collected, 18 were represented by only a single specimen over collecting periods. Some of these species might either be rare or, in the case at least of *Polyplectropus anakgugus*, was not attracted to black lights. Therefore, phenological data of species represented by relatively few specimens over the collecting date can be misleading.

The local climate in the area i.e. minimum and maximum air temperatures and rainfall was evaluated by Pearson's correlation test. Many species of Trichoptera were significantly related to the effects of local climate according to the data (Table 1).

Microclimatic conditions experienced during the adult phase have an impact on survival and longevity. Air temperature and relative humidity are of particular importance, with higher temperatures and lower humidity reducing the adult lifespan of aquatic groups (Collier and Smith, 2000). Microclimate also influences the flight activity of aquatic species (Waringer, 1991; Briers *et al.*, 2003). In common with terrestrial groups, the flight activity of aquatic adults appears to be affected primarily by air temperature and humidity showed an effect also in some groups.

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Insect diversity

'Origin of Insect Wings' – An Embryological Approach of the Mayfly *Bleptus fasciatus* Eaton (Ephemeroptera, Heptageniidae)

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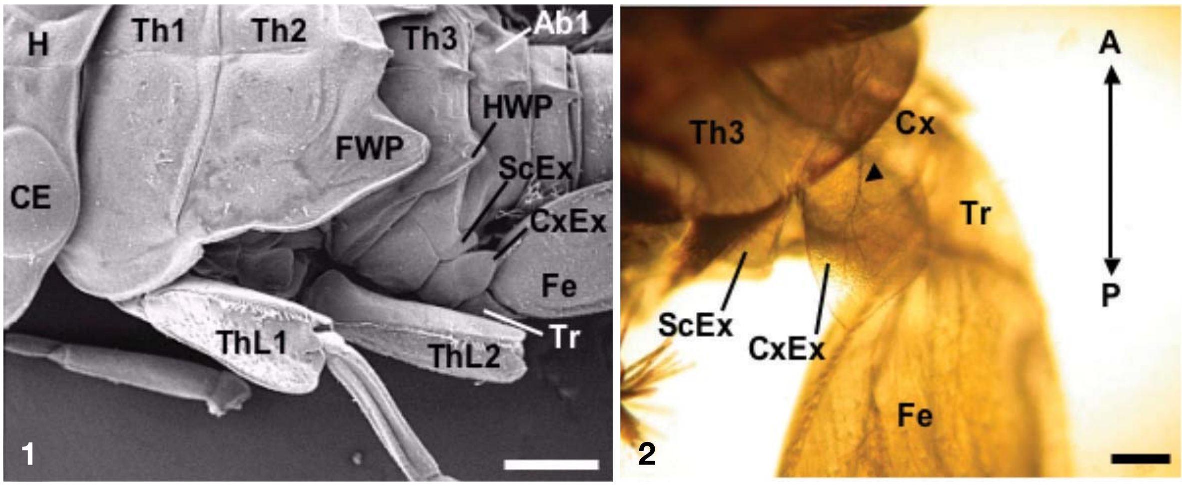
Abstract

With regards to the 'origin of wings', which has been argued over a long period, various hypotheses have been proposed. Of these hypotheses, 'epicoxal exite theory' is the most widely accepted. According to this theory, the gill itself is a modified epicoxal exite of a hypothetical, basal leg podite. The articulating epicoxal exite of the most proximal appendicular segment then became modified into a gill and then into a wing. Recently, we could find the remaining structures of subcoxal and coxal exites in the modern heptageniid mayfly *Bleptus fasciatus* belonging to the most basal pterygote group. Furthermore, in this coxal exite, tracheation can be clearly observed. The remains of these structures are a new discovery amongst present Pterygotans. Through this discovery amongst present winged insects, long required research has become possible into the verification of the serial homology between the 'coxal exite - subcoxal exite - epicoxal exite (*i.e.*, wing)', and the 'epicoxal exite (*i.e.*, wing) - gill' with various newly available approaches. We are not limited to only external morphological study, but can also use methods of, comparative embryology, developmental genetics, and others.

Key words: comparative morphology, epicoxal exite, evolution, radiation, subcoxal exite

Insects account for three quarters of all animal species, and more than 99 percent of them are wing-acquired insects, *i.e.*, Pterygota. Pterygote type insects have achieved spectacular prosperity and radiation, and elucidating their evolution, their morphogenesis and groundplans is one of the most interesting subjects not only in entomology but also animal phylogeny (Janzen, 1977; Daly *et al.*, 1978; Wooton, 1986; Wilson, 1988, 1992; Kingsolver and Koehl, 1994). Particularly because, insects were the first organisms to have developed powered flight, perhaps from within the Devonian or even the Early Carboniferous periods (e.g., Engel and Grimaldi, 2004; Grimaldi and Engel, 2005). The most obvious effect of wings is the organism's ability to disperse. A flying insect can readily exploit new habitats, and when the local environment becomes unfavorable, it can more effectively seek better habitats. Utilizing its flying capabilities, it has access to a broader range of biological niches.

With regards to the 'origin of wings', which has been argued over a long period, various hypotheses have been proposed, such as the 'paranotal lobe theory' (Snodgrass, 1935; Hamilton, 1971; Quartau, 1986) and the 'epicoxal exite (outer lobe or podite of the most basal leg segment) theory' (Kukalová-Peck, 1978, 1987, 1991). Of these hypotheses, the latter is the most widely accepted. Furthermore, the epicoxal exite hypothesis of wing origin can be reconciled with another recurring view: that wings derive from tracheal gills of an ancestral aquatic "protopterygote". The abdominal winglets (or gills) of the protopterygote may be serially homologous with thoracic wings (Kukalová-Peck, 1991). According to this theory, the gill itself is a modified epicoxal exite of a hypothetical, basal leg podite. The articulating epicoxal exite of the most proximal appendicular segment then became modified into a gill and then into a wing. On the other hand, the movable abdominal gills of the modern aquatic mayfly nymphs may be homologous with the abdominal winglets of the protopterygote, and be serially homologous with thoracic wings (Kukalová-Peck, 1991). Indeed, the gills of some mayflies look like tiny wings, and the tracheation in the gills resembles the venation in the wings. In addition, recent developmental biological evidence has also supported the 'exite



Figs. 1-2. External futures of the heptageniid mayfly *Bleptus fasciatus* nymph. Fig. 1. SEM micrographs. A. Dorso-lateral view. Note the coxal exite (CxEx), the subcoxal exite (ScEx) and the hind wing pad (HWP='epicoxal exite'?). B. Enlargemat of the base of left hind leg (lateral view). Fig. 2. A photograph under a light microscopy of the base of right hind leg (dorsal view). The tracheae (arrowhead) clearly observed in the coxsal exite. A-P: anterior-posterior axis. CE: compound eye, A-P: anterior-posterior axis. Cx: coxa, CxEx: coxal exite, Fe: femur, FWP: fore wing pad, H: head, HWP: hind wing pad, ScEx: subcoxal exite, Th1-3: pro, meso and metathorax, ThL1-3: pro, meso, metaleg, Tr: trochanter. Scales=1A: 1 mm; 1B: 500 µm; 2: 300 µm.

or gill theory' by comparing the expression of genes found in 'crustacean gills' with the two genes found in wings of the hypothesised derived insect species (Averof and Cohen, 1997).

When verifying direct homology of wing to epicoxal exite, it becomes important to compare the serial homology between wing (or epicoxal exite) with other proximal exites of appendages (e.g., subcoxal, coxal, trochanteral and prefemural exites). Unfortunately, the significant 'exite structures' of proximal appendicular podites do not remain in present pterygote insects (Kukalová-Peck, 1991). Those are only recognized in the Paleozoic fossil insects (Carboniferous to Permian; about 350～250 million years ago). Because according to each insect habitat, under the effect of phylogenetic evolution, each of their appendages adapted and modified according to their functionality (sometimes with the accompanying structural simplification or degeneration of non-functional structures).

However, we could find the remaining structures of subcoxal and coxal exites in the headwater-specific heptageniid mayfly *Bleptus fasciatus* belonging to the most basal pterygote group (Ephemeroptera, Heptageniidae) (Fig. 1A, B). This species is endemic to mountain areas of Japan (except Hokkaido Island and Ryukyu islands) and Korea (Miyairi and Tojo, 2007). Furthermore, in this coxal exite, tracheation can be clearly observed (Fig. 2). The remains of these structures are a new discovery amongst present Pterygotans. Through this discovery amongst present winged insects, long required research has become possible into the verification of the serial homology between the 'coxal exite - subcoxal exite - epicoxal exite (*i.e*, wing)', and the 'epicoxal exite (*i.e.*, wing) - gill' with various newly available approaches. We are not limited to only external morphological study, but can also use methods of, comparative embryology, developmental genetics, and others.

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곤충연구지 투고규정

1. 목적

본 곤충연구지는 곤충학의 이론과 실제에 관한 학술적 논문을 게재함을 목적으로 한다.

2. 대상

본 곤충연구지는 한국의 곤충학자(Biography), 곤충학 논단(Review), 보문(Research paper), 곤충의 다양성(Insect diversity), 단보(Short communication) 및 기타 분야의 학술 논문을 대상으로 하며, 다른 출판물에 발표되지 않았거나, 발표될 예정이 없는 논문에 한한다.

3. 원고의 작성

1) 원고는 반드시 워드프로세스를 이용하여 국문 또는 영문으로 작성한다.
2) 보문은 표지(Cover page), 초록(Abstract), 검색어(Key words), 서론(Introduction), 재료 및 방법(Materials and methods), 결과(Results), 고찰(Discussion), 사사(Acknowledgements), 참고문헌(Reference), 도표(Table), 그림제목(Figure legends), 그림(Figure)의 순으로 작성한다.
3) 다른 성격의 원고는 보문에 준하여 작성하되 특성에 따라 소제목 및 형식을 달리할 수 있다.
4) 제출 원고의 표지에는 제목, 저자, 소속, 주소 및 교신저자의 연락처(E-mail) 등을 기재한다.
5) 논문 제목, 저자 및 소속은 국문 또는 영문으로 작성하고, 소속기관이 다른 공저자일 경우에는 해당 연구자의 이름 우측에 위첨자 1, 2, 3….로 표시하고 그 주소를 명시한다. 교신저자(Correspondence)의 성명, 소속, 주소, 이메일 주소를 따로 기입한다.
6) 국, 영문 요약은 300자 이내로 하며, 6단어 이내의 검색어(Key words) 및 난외 제목(Running title)은 국문 또는 영문으로 기재한다. 검색어는 가나다 또는 알파벳순으로 작성한다.
7) 학명(속명, 종명)은 반드시 이탤릭체로 쓴다.
8) 한글지명의 로마자 표기는 가장 최근의 표기 지침을 따른다.
9) 도량형의 단위는 국제단위체계(System of International Units: S.I.U.)를 사용하며, 분모가 있는 경우 음의 지수를 사용한다(예: μgL^{-1}). 숫자와 도량형의 사이는 한칸을 띄운다(예: 10 cm). 단, 온도, 위도, 경도, % 등을 표시하는 단위는 숫자에 붙여 쓴다.
10) 참고문헌은 국문과 영문의 순서로 작성하며, 국문 참고문헌은 저자명의 가나다순으로, 영문은 저자명의 알파벳과 출판연도의 순서에 따라 아래와 같이 작성하며, 학회지의 명칭은 정식명칭(Full name)으로 작성하는 것을 원칙으로 한다.

① 논문의 인용

Webb JM, McCafferty WP (2008) Heptageniidae of the world. Part II. Key to the genera. *Canadian Journal of Arthropod Identification* **7**: 1-55.

② 책의 인용

Chapman RF (1971) The Insects. Structure and Function. 3rd ed. Elsevier, New York.

③ 책의 일부분을 인용하는 경우

Ishiwata S, Takemon Y (2005) Ephemeroptera. In: Kawai T, Tanida K (eds). Aquatic Insects of Japan: Manual with Keys and Illustrations. Tokai Univiversity Press, Kanagawa, Japan. pp. 31-128. (in Japanese).

11) 기타 원고의 작성과 형식은 한국곤충학회의 "Entomological Research"와 본 곤충연구지의 최근호를 참고하여 작성한다.

4. 원고 제출 및 심사

1) 원고는 e-mail로 투고하는 것을 원칙으로 한다. 원고 제출 주소 (E-mail) entoko@korea.ac.kr
2) 원고는 수시로 접수하며, 이메일의 발신일을 접수일로 한다.
3) 원고는 해당분야 편집위원이 지정한 2인이 심사한다.
4) 심사의 결과는 게재 가, 수정 후 게재 가, 게재 불가로 판정한다.
5) 원고의 채택여부는 최종적으로 편집위원회에서 결정하고, 게재 불가로 판정된 원고는 저자에게 반송한다.

5. 교정

교정은 편집자 및 출판사의 의견을 참고하여 저자가 직접 교정하는 것을 원칙으로 하며, 교정 중 내용과 형식을 대폭 수정하는 것은 불허한다.

6. 저작권

본 곤충연구지에 게재되는 모든 원고에 대한 저작권은 저자 및 한국곤충연구소가 소유한다.

7. 위임 사항

기타 본 규정에 명시되지 않은 사항은 편집위원회의 결정에 따른다.

8. 규정의 발효

이 규정은 2010년 1월 1일부터 시행한다.