

An illustrated key to stonefly larvae (Plecoptera, Insecta) at Huai Nam Dung National Park, Thailand

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Abstract

An illustrated key to larvae of all genera of Plecoptera at Huai Nam Dung National Park is presented. The stonefly larvae were collected from seven streams of Huai Nam Dung National Park, Thailand. Four families have been reported for this region: Perlidae, Peltoperlidae, Nemouridae, and Leuctridae. For the family Perlidae, 11 genera including *Neoperla*, *Etrocorema*, *Togoperla*, *Kamimuria*, *Agnatina*, *Tetropina*, *Paragnetina*, *Phanoperla*, *Calineuria*, and *Caroperla* were identified. *Cryptoperla karen* and *Cryptoperla meo* of the family Peltoperlidae were also identified. The three genera *Indonemoura*, *Amphinemoura*, and *Sphaeronemoura* were identified from the family Nemouridae. In addition, *Rhopalopsale* of the family Leuctridae was identified.

Keyword: stonefly larvae, illustrated key, Huai Nam Dung National Park

บทคัดย่อ

การศึกษารังนี้เพื่อจัดทำคู่มือจัดจำแนกตัวอ่อนแมลงเกาะหินในทุกสกุลที่พบที่อุทยานแห่งชาติห้วยน้ำดัง โดยเก็บตัวอ่อนแมลงเกาะหินจากลำธารเจ็ดแห่งของอุทยานแห่งชาติห้วยน้ำดัง พบตัวอ่อนแมลงเกาะหินในพื้นที่ดังกล่าวทั้งหมดสี่วงศ์คือ Perlidae, Peltoperlidae, Nemouridae, และ Leuctridae ตัวอ่อนในวงศ์ Perlidae พบจำนวน 11 สกุลได้แก่ *Neoperla*, *Etrocorema*, *Togoperla*, *Kamimuria*, *Agnatina*, *Tetropina*, *Paragnetina*, *Phanoperla*, *Calineuria* และ *Caroperla* ส่วน *Cryptoperla karen* และ *Cryptoperla meo* เป็นชนิดที่พบในวงศ์ Peltoperlidae สามสกุลคือ *Indonemoura*, *Amphinemoura* และ *Sphaeronemoura* เป็นสกุลที่พบในวงศ์ Nemouridae ในขณะที่สกุล *Rhopalopsale* ของวงศ์ Leuctridae ก็พบในการศึกษานี้เช่นกัน

คำสำคัญ: ตัวอ่อนแมลงเกาะหิน, คู่มือจัดจำแนกชนิด, อุทยานแห่งชาติห้วยน้ำดัง

1. Introduction

Stoneflies appear to be a significant exception to the general pattern of higher biodiversity in the tropics. Normally, the diversity increases from the equator toward the pole (Fochetti & Tierno de Figueroa, 2008; Palma & Figueroa, 2008). The Northern Hemisphere possesses greater diversity than the Southern Hemisphere. The stonefly larvae are often restricted to highly oxygenated water and are intolerant of organic and thermal pollution; consequently, they have been chosen to be excellent bioindicators of water quality especially in pristine areas (McCafferty, 1998; Che, Amelia & Abu, 2001; Gullan & Cranston, 2005). Nowadays, the growing pollution and alteration of watercourses and to the high stenoccity of stoneflies, numerous stonefly species are reduced to small isolated populations and many others have already

gone extinct (Fochetti & Tierno de Figueroa, 2008). Stoneflies are probably one of the most endangered groups of insects (Fochetti & Tierno de Figueroa, 2008).

There are several good regional generic identification keys to larvae in North America (Pescador, Rasmussen & Richard, 2000; Stewart & Stark, 2008), China (Morse, Abu & Lixin, 1994), Australia (Hynes, 1978), and Europe (Hynes, 1984). However, these keys are of limited use in Thailand because the keys described the adults stage of the species, leaving the larvae yet to be depicted. Consequently, the stonefly larvae were identified only in genus level.

In Thailand, more than sixty species of stonefly have been recorded. However, most species of stonefly larvae could not be identified to the species level. Damrak (2006) studied the species of

stoneflies at Khao Yai National Park and found that there are four families of stoneflies namely; Leuctridae, Nemouridae, Ptiloperlidae and Perlidae which cover eight genera and 16 species as follows: *Rhopalopssole* sp., *Indonemoura jacobsoni* (Klapalek), *Cryptoperla* sp., *Neoperla thai* Stark, *Neoperla gordonae* Stark, *Neoperla fallax* Klapalek, *Neoperla* sp., *Chinoperla unidentata* Sivec & Zwick, *Phanoperla* sp., *Phanoperla* sp., *Phanoperla* sp. and *Kamimuria* sp. Chaisamsaeng (2003) found that there were nine genera of three families at Nan Nao National Park. The larva consists of Perlidae (*Neoperla*, *Phanoperla*, *Etrocorema*, and *Tetropina*), Nemouridae (*Amphinemura*, *Indonemoura*, and *Nemoura*), and Leuctridae (*Rhopalopssole*). Moreover, seven species of adults were found in this study. The identified taxa consisted of *Neoperla* sp., *N. gordonae* Stark, *N. mnong* Stark, *N. cavalieriei* (Narvas), *Etrocorema nigrogeniculatum* (Enderlein), *Amphinemura* sp., and *Rhopalopssole* sp. Watanasit (1999) reported that three families (Perlidae, Nemouridae, and Chloroperlidae) were found in southern Thailand.

Various species of Thai Plecoptera have been described in previous reports by many researchers. The species that have already been reported and described consist of *Caroperla longiseta* (Sivec & Stark, 2010a), *Chinoperla porntip*, *C. spinata*, *C. unidentata* (Sivec & Stark, 2010b), *Phanoperla doisuthep*, *P. huang*, *P. occipitalis*, *P. uchidai*, *P. wieng* (Sivec & Stark, 2010c), *P. mayalana* (Zwick, 1982; Stark, 1987; Sivec & Stark, 2010c), *P. simplex* (Zwick, 1982; Stark, 1987; Uchida & Yamasaki, 1989; Sivec & Stark, 2010c), *P. lao* (Stark, 1983; Sivec & Stark, 2010c), *P. sertispina* (Zwick, 1982; Stark, 1983; Sivec & Stark, 2010b), *P. lisu* (Stark, 1983; Uchida & Yamasaki, 1989; Sivec & Stark, 2010c), *Neoperla lahu* (Stark, 1983), *N. distincta*, *N. fallax* (Uchida & Yamasaki, 1989), *N. gordonae* (Stark, 1983; Uchida & Yamasaki, 1989), *N. leptophallus*, *N. saraburi*, *N. serrata* (Zwick, 1988), *N. asperata*, *N. banksi* (Zwick, 1988; Uchida & Yamasaki, 1989), *N. thai* (Zwick, 1988; Stark, 1983), *N. mnong*, *N. microtumida* (Stark, 1987), *Togoperla shan* (Stark & Sivec, 1991), *Indonemoura auberti*, *I. bilobata*, *I. chantaramongkolae*, *I. forcipata*, *I. horvati*, *I. javanica*, *I. malickyi*, *I. reducta*, *I. rostrilobata* (Sivec & Stark, 2010d), *Sphaeronemoura inthanonica*, *Protonemura filigera* (Kawai, 1969), *Cryptoperla karen*, *C. kosai*, *C. simplex* (Stark & Sivec, 2007), *C. akha*, *C. meo*, *C. bisaeta* (Stark,

1983), and *Peltoperlopsis sinensis* (Kawai, 1969). Huai Nam Dung National Park, which has had no previous stonefly research, was chosen as the sampling area for this study. Many rivers originate in Huai Nam Dung National Park, and this area has a large and varied geography. Consequently, this area was deemed suitable for this study.

In this study, the stonefly larvae were reared. By rearing, the larva can be associated with adult and then both larva and adult can be used for identification (Pescador et al., 2000). All of data were used to describe the morphological characteristic and construct the dichotomous key of stonefly at Huai Nam Dung National Park.

2. Objective

The aims of this study were to construct an illustrated key for stonefly identification at Huai Nam Dung National Park.

3. Materials and methods

3.1 Study area

Ministry of Natural Resources and Environment (2012) revealed that Huai Nam Dung National Park covers four districts: Mae Taeng, Chiang Dao, and Wiang Haeng in Chiang Mai Province and Pai District, Mae Hong Son Province, covering an area of approximately 1,247 square kilometers. The attraction for this National Park are the natural conditions and virgin forests which provided vital watersheds. The climate of this area is comfortable, with an average year-round temperature of 20°C, dropping to 8°C in October to February and soaring to 12-28°C in March to April. The wettest months are May to September.

Seven streams were selected from Huai Nam Dung National Park. All sampling sites were located in different ranges of hills. Coarse substrate types such as cobble, gravel, bedrock, leaf pack, and woody debris were found to be predominant at these sites. The detail of study sites was shown as following.

The first site was the Nam Dung Stream. It is located in Pai District, Mae Hong Son Province (S-ND: 19°19.370' N, 98°37.224' E, 1,163 m a.s.l.). It originates from the Nam Dung waterfall. It flows through forested areas, and drains to Pai River. Nam Dung has been undisturbed by human activity. The second site was the Mae Ping Stream (S-MP: 19°18.422' N, 98°35.627' E, 1,397 m a.s.l.). It is the headwater of the Mae Ping River, which is one of the important rivers in Pai District, Mae Hong Son

Province. Mae Jog Stream is located in Mae Taeng District, Chiang Mai Province (S-MJ: 19°16.827' N, 98°37.024' E, 1,210 m a.s.l.). It is the tributary of Mae Taeng River. It flows through forested areas, and it also has not been disturbed by human activity. The Mae Yen Stream (S-MY: 19°21.722' N, 98°27.841' E, 539 m a.s.l) is located in Pai District, Mae Hong Son Province. It originates from the Mae Yen Waterfall, and drains in to the Pai River. Huai Hea Stream is located in Pai District, Mae Hong Son Province (S-HH: 19°29.902' N, 98°30.574' E, 662 m a.s.l.). It is the tributary of Pai River. It flows through forest and rural areas with locations where agriculture and cattle are near the stream. The Chang Tao Stream (S-CT: 19°27.423' N, 98°28.610' E, 538 m a.s.l) is located in Pai District, Mae Hong Son Province. It is the tributary of the Pai River. The Mae Had Stream (S-MH: 19°39.900' N, 98°30.935' E, 1,274 m a.s.l) is located in Wiang Haeng District, Chiang Mai Province. This stream flows through forested and rural areas, and there are the agriculture and cattle near this stream as well (Figure 1).

3.2 Field methods

The stonefly larvae were sampled in February, April, June, August, October, and December in the year 2011. Stonefly larvae were collected by kick and pick sampling techniques, and samples were preserved in 4% formaldehyde solution. Insect specimens were sorted and stored in 70% ethanol.

3.3 Rearing

The species-unknown larvae were collected from the streams. All larvae were put into the watered plastic box, which was aerated at all times. Then, the living samples were immediately transported to the Freshwater Biomonitor Research Laboratory (FBRL), Faculty of Science, Chiang Mai University. All larvae were classified using the differences of morphotaxa, and described the morphological characteristic in each taxa. Afterward, the larvae in each taxa

were reared in the glass box (30x 20x 20 cm), which was covered by fabric mesh, under a natural photoperiod, with continuous aeration. The adults that emerged in the glass box were identified, and associated with their specific larvae.

3.4 Dichotomous key construction

The stonefly larvae were identified using available keys (Kawai, 1969; Baumann, 1975; Zwick, 1982; Stark, 1983; Stark, 1987; Zwick, 1988; Morse et al., 1994; Dudgeon, 1999; Pescador et al., 2000; Sangpradub & Boonsoong, 2006; Stark & Sivec, 2007; Sivec & Stark, 2008; Stewart & Stark, 2008; Stark & Sheldon, 2009; Sivec & Stark, 2010b; Sivec & Stark, 2010c; Sivec & Stark, 2010e; Stark & Sivec 2010). The identified specimens were drawn as illustrations in various magnifications from whole specimens.

4. Results

4.1 Diversity of stonefly larva at Huai Nam Dung National Park

Four families have been reported this region: Perlidae, Peltoperlidae, Nemouridae, and Leuctridae. For family Perlidae, 11 genera including *Neoperla*, *Etrocorema*, *Togoperla*, *Kamimuria*, *Agnatina*, *Tetropina*, *Paragnetina*, *Phanoperla*, *Calineuria*, and *Caroperla* were identified. *Cryptoperla karen* and *Cryptoperla meo* of the family Peltoperlidae were also identified. The three genera *Indonemoura*, *Amphinemoura*, and *Sphaeronemoura* were identified from the family Nemouridae. In addition, *Rhopalopsale* of the family Leuctridae was identified.

4.2 An illustrated key to stonefly larvae at Huai Nam Dung National Park, Thailand

The stonefly collected from the sampling and rearing were used to create the illustrated key. The stonefly larvae were identified and described. The identified specimens were drawn, labeled as illustration to create the dichotomous key. The results are below.

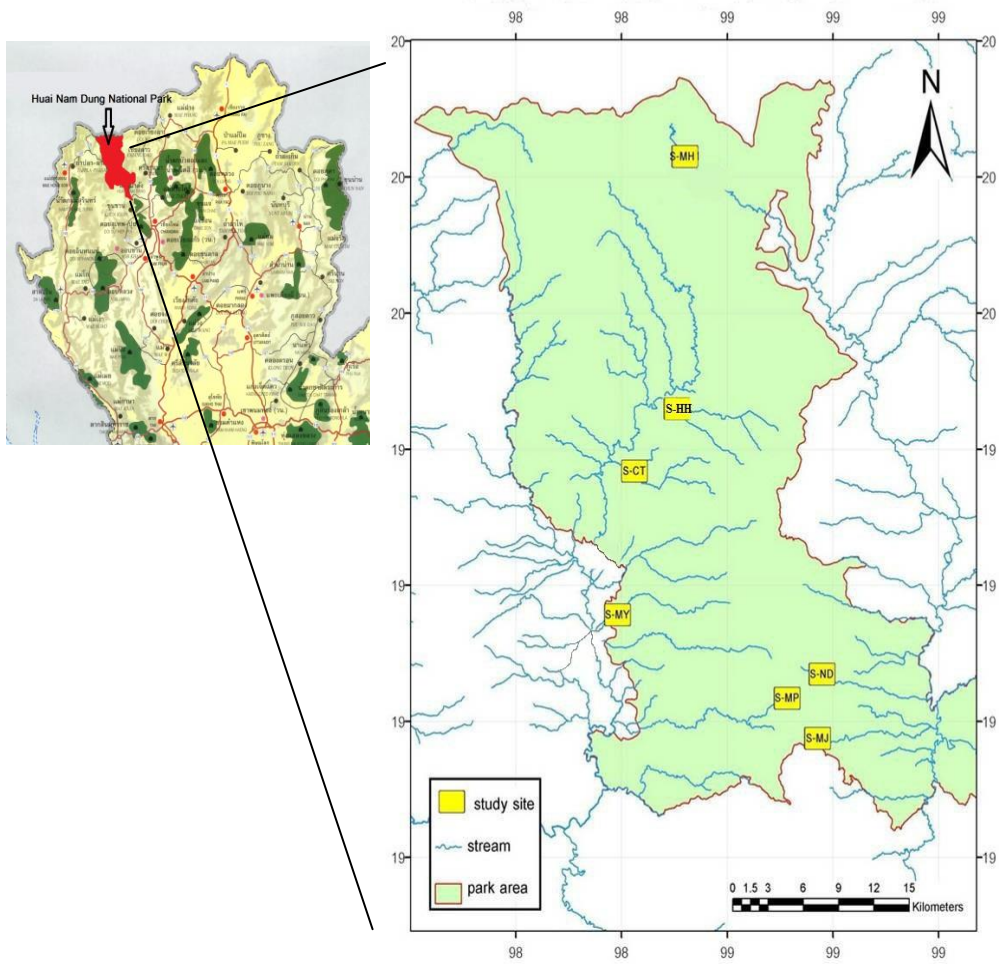


Figure 1 Seven sampling sites at Huai Nam Dung National Park (S-ND: Nam Dung Stream, S-MP: Mae Ping Stream, S-MJ: Mae Jog Stream, S-MY: Mae Yen Stream, S-HH: Huai Hea Stream, S-CT: Chang Tao Stream, and S-MH: Mae Had Stream)

Key to Families of Mature Larva of Stoneflies

(Modified from Morse et al., 1994; Sangpradub & Boonsoong, 2006)

1. (a.) Highly branched gill present on sides of all thoracic segment (Fig. 1); paraglossae longer than glossae (Fig. 2, 3).....**Perlidae**

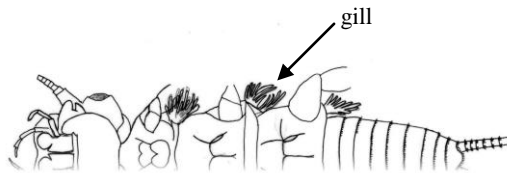


Fig. 1

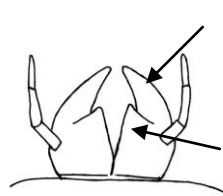


Fig. 2

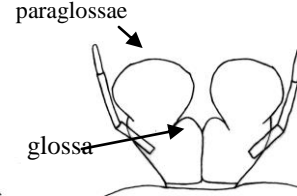


Fig. 3

(b.) Highly branched gill absent (Fig. 4); praglossae and glossae subequal in length (Fig. 5).....2



Fig. 4



Fig. 5

2. (a.) Habitus cock roach- like; thoracic sterna plates overlapping (Fig. 6); conical gills behind coxae of middle and hindlegs (Fig. 7).....**Peltoperlidae**

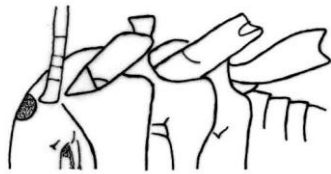
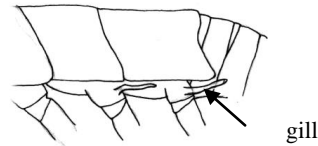


Fig. 6



gill

Fig. 7

(b.) Habitus not cockroach- like; thoracic sterna do not overlap (Fig. 8).....3

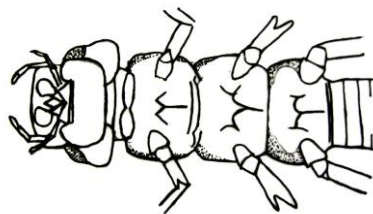
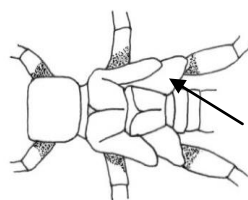


Fig. 8

3 (a.) Hindlegs when extended reaching to apex of abdomen; wingpads strongly divergent from body axis (Fig. 9).....**Nemouridae**



wingpads

Fig. 9

- (b.) Hindlegs when extended not reaching to apex of abdomen; wingpads not strongly divergent and hind wingpads longer than width (Fig. 10).....**Leuctridae**

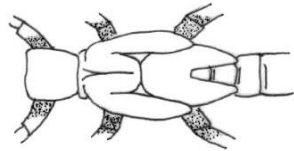


Fig. 10

Key to Genera and Species for Mature Larva of Perlidae
(Modified from Morse et al., 1994)

- 1 (a.) Two ocelli (Fig. 11).....2

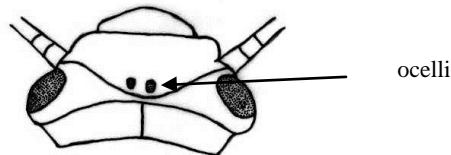


Fig. 11

- (b.) Three ocelli (Fig. 12).....6

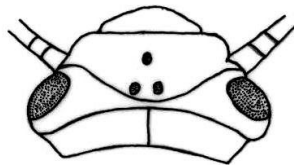


Fig. 12

2. (a.) Occipital ridge with complete row of short bristle (Fig. 13); anal gills absent (Fig.14)....*Tetropina*

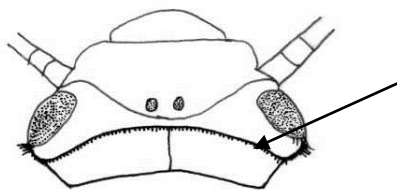


Fig. 13

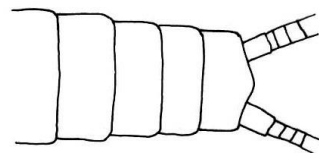


Fig. 14

(b.) Occipital ridge with incomplete row of short bristle or absent (Fig. 15).....3

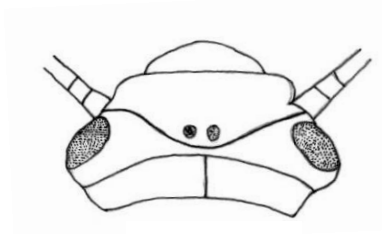


Fig. 15

3. (a.) Anal gills absent; lateral margin of pronotum with short setae (Fig. 16); posterior setal fringe of abdominal sternum 7 incomplete (Fig. 17).....*Etrocorema*.....4



Fig. 16

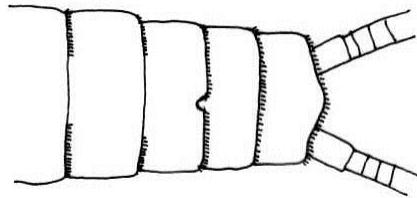


Fig. 17

(b.) Anal gills present (Fig. 18).....5

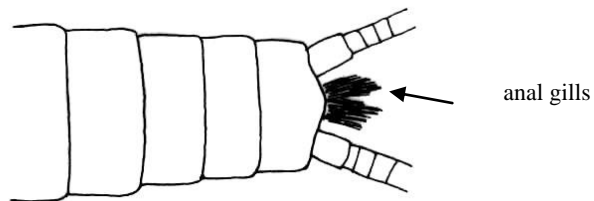


Fig. 18

4. (a.) Compound eyes with pale area (Fig. 19).....*Etrocorema belumensis*

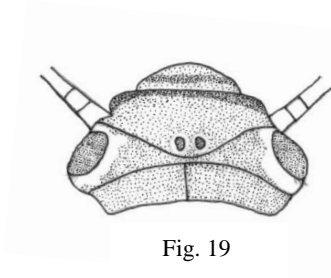


Fig. 19

(b.) Compound eyes without pale area (Fig. 20)..... *Etrocorema nigrogeniculatum*

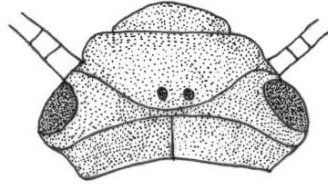


Fig. 20

5. (a.) Anterior and posterior margin of meso and metasternum with fringe of setae (Fig.21).....*Phanoperla*

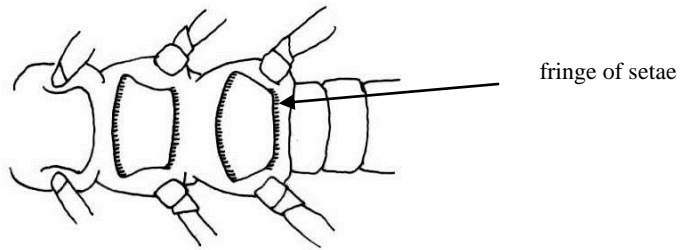


Fig. 21

(b.) Anterior and Posterior margin of thoracic sternum without fringe of setae.....*Neoperla*

6. (a.) Anal gills absent (Fig. 22).....7

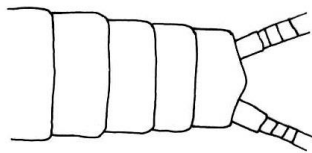


Fig. 22

(b.) Anal gills present (Fig. 23).....9

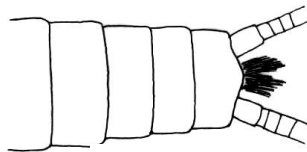


Fig. 23

7. (a.) Occipital ridge with incomplete row of short bristle or absent.....*Calineuria*
 (b.) Occipital ridge with complete row of short bristle; posterior supracoxal gills on thoracic segment
 2- 3 double (Fig. 24).....8

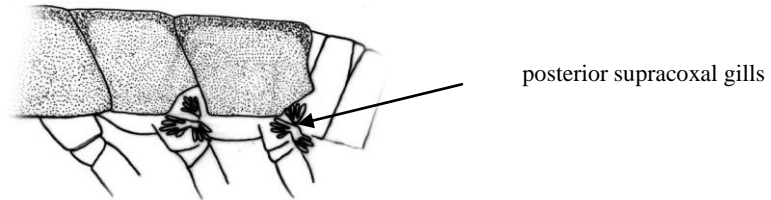


Fig. 24

8. (a.) Thorax and abdomen with median row of silky hair (Fig. 25).....*Kamimuria*

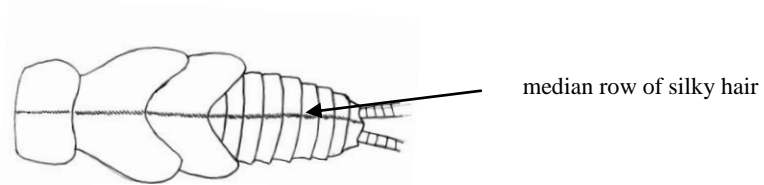


Fig. 25

- (b.) Thorax and abdomen without median row of silky hair.....*Togoperla*

9. (a.) Occipital ridge with incomplete row of short bristle or absent; prothorax without supracoxal gills
*Caroperla*
 (b.) Occipital ridge with complete row of short bristle.....10

10. (a.) Posterior margin of abdominal sternum 7 with complete row of bristle (Fig. 26).....*Agetina*

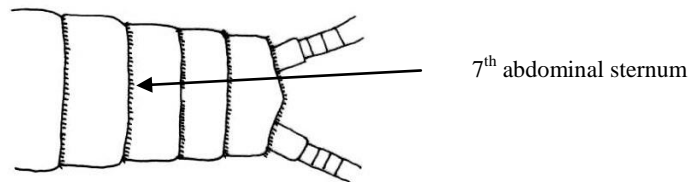


Fig. 26

- (b.) Posterior margin of abdominal sternum 7 with incomplete row of bristle (Fig. 27).....*Paragnetina*

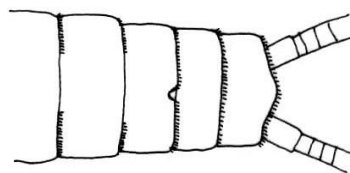


Fig. 27

Key to Genera and Species for Mature Larva of Peltoperlidae
(Modified from Morse *et al.* (1994))

1. (a.) Posterior infracoxal gills on thoracic segments 1-2 single (Fig. 28, 29)*Peltoperlopsis*

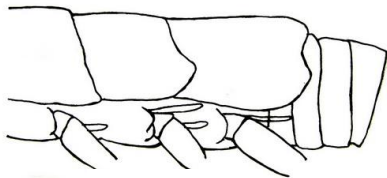


Fig. 28

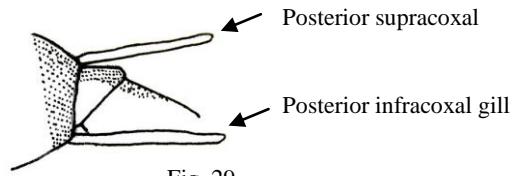


Fig. 29

- (b.) Posterior infracoxal gills absent (Fig. 30).....*Cryptoperla*.....2

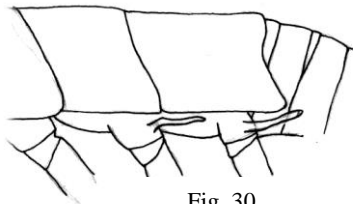


Fig. 30

2. (a.) Body without distinctive markings; all of thoracic sterna without posterior fringes (Fig. 31).....*Cryptoperla karen*

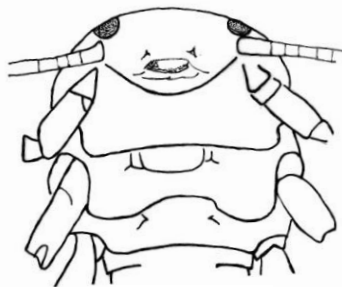


Fig. 31

- (b.) Body with distinctive markings (Fig. 32); Pro and mesosternal plates with three fringe of setae, metasternum plates with one fringe of setae (Fig. 33).....*Cryptoperla meo*

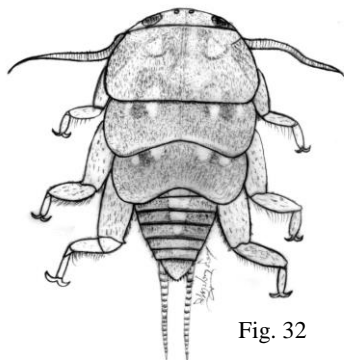


Fig. 32

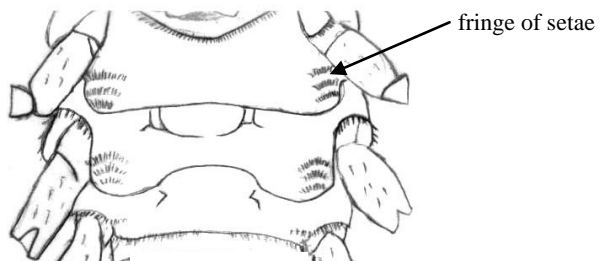


Fig. 33

Key to Genera for Mature Larva of Nemouridae
(Modified from Sangpradub and Boonsoong (2006))

- 1. (a.) Cervical gills absent or reduced2
- (b.) Cervical gills present3
- 2. (a.) No cervical gills (Fig. 34).....*Nemoura*

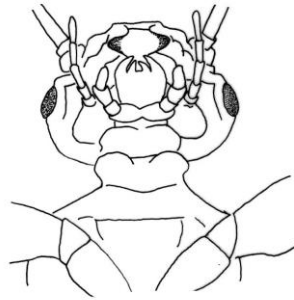


Fig. 34

- (b.) Cervical gills reduced to stubbly or triangular projection (Fig.35).....*Indonemoura*

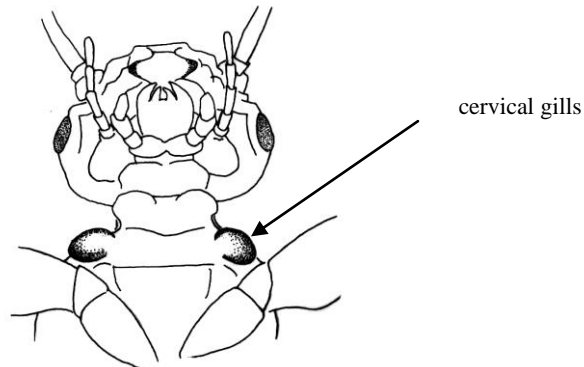


Fig. 35

- 3. (a.) Cerci forming uniquely bulb- shaped segments (Fig. 36); four cervical gills with sausage- like segments (Fig. 37).....*Sphaeronemoura*

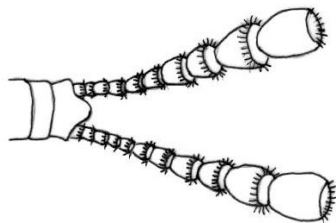


Fig. 36

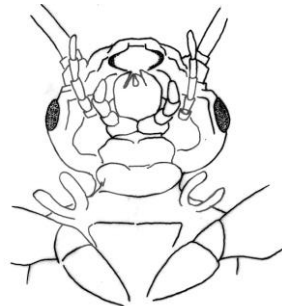


Fig. 37

(b.) Cerci not forming uniquely bulb- shaped segments (Fig. 38); cervical gills branched or sausage-like.....4

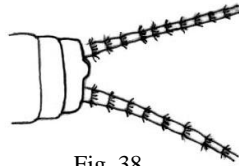


Fig. 38

4. (a.) Cervical gills highly branched (Fig. 39).....*Amphinemoura*

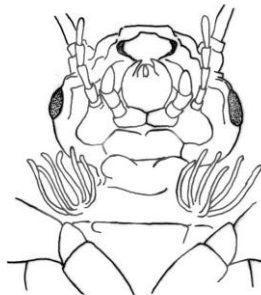


Fig. 39

(b.) Six cervical gills, sausage- like (Fig. 40).....*Protonemoura*

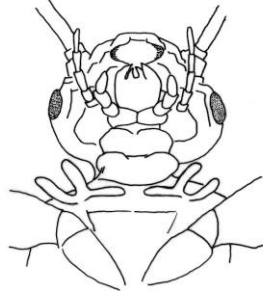


Fig. 40

Key to Genera for Mature Larva of Leuctridae
(Modified from Morse *et al.* (1994))

1. (a.) Pronotum without such tuft, at most a few strong setae on anterior and posterior margin; body nearly glabrous; membranous fold on abdominal segment 1- 6 (Fig. 41) *Rhopalopsole*

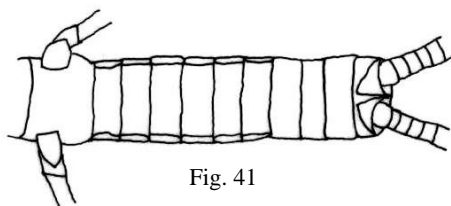


Fig. 41

(b.) Not as above.....*Not found in Thailand*

5. Discussion

The identified larval and adult plecopteran species were used to create the dichotomous key of Plecoptera of Thailand. From previous reports, the Thai stoneflies were identified by various keys (Morse et. al., 1994; McCafferty, 1998; Dudgeon, 1999; Sangpradub & Boonsoong, 2006; and Stewart & Stark, 2008) without a specific key for Thai species. Some Thai species of stonefly could not be identified by keys from different regions. Therefore, this key was constructed to be suitable for all species of stonefly of Thailand.

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