



ตัวเต็มวัยของแมลงช้ำกรามโต *Neochauliodes puntatolus* Liu and Yang, 2006 และชีวประวัติของ *Neochauliodes* sp. (Megaloptera: Corydalidae)

ในลำธารต้นน้ำ ประเทศไทย

Adult of *Neochauliodes puntatolus* Liu and Yang, 2006 and life history of *Neochauliodes* sp. (Megaloptera: Corydalidae) in headwater streams, Thailand

Fateemah Mahama¹, Chutima Hanjavanit² and Narumon Sangpradub^{1, 2*}

¹Department of Biology, Faculty of Science, Khon Kaen University, Muang District, Khon Kaen Province 40002

²Applied Taxonomic Research Center, Faculty of Science, Khon Kaen University, Muang District, Khon Kaen Province 40002

*Corresponding Author, E-mail: narumon@kku.ac.th

Received: 28 March 2018 | Revised: 14 October 2018 | Accepted: 17 October 2018

บทคัดย่อ

การศึกษาความหลากหลายและชีวประวัติของแมลงช้ำกรามโต วงศ์ย่อย Chauliodinae (อันดับ Megaloptera วงศ์ Corydalidae) โดยให้ความสนใจที่ระยะตัวอ่อนและตัวเต็มวัย ในลำธารต้นน้ำ 2 สายคือห้วยหญ้าเครือ และห้วยพรมแล้ง ระหว่างเดือน ตุลาคม พ.ศ. 2556 ถึงเดือนธันวาคม พ.ศ. 2557 พบตัวเต็มวัยของ *Neochauliodes puntatolus* Liu and Yang, 2006 ในเดือน ตุลาคม พ.ศ. 2556 และระหว่างเดือน มิถุนายน พ.ศ. 2556 ถึง กันยายน พ.ศ. 2557 คือ พบตัวผู้ จำนวน 12 ตัว และตัวเมีย 1 ตัวที่ ห้วยหญ้าเครือ และตัวผู้ 2 ตัวที่ห้วยพรมแล้ง ตัวเต็มวัยมีความแตกต่างระหว่างเพศ โดยตัวผู้มีขนาดแบบขนนก ตัวเมียมีขนาดแบบซี เลี้ย และตัวเมียมีขนาดใหญ่กว่าตัวผู้ จากข้อมูลการพบตัวเต็มวัยในสองลำธารนี้ดูเหมือนว่าการเป็นตัวเต็มวัยของตัวผู้มีจำนวนมากกว่า ตัวเมีย พบตัวอ่อนพบสกุล *Neochauliodes* ที่มีลักษณะสัณฐานแบบเดียวกันทั้งหมดแต่ไม่สามารถระบุชนิดได้จำนวน 88 ตัวที่ห้วย หญ้าเครือ และ 6 ตัวที่ห้วยพรมแล้ง ห้วยหญ้าเครือมีปริมาณออกซิเจนละลายต่ำกว่า แต่มีค่าการนำไฟฟ้าของน้ำและปริมาณของแข็ง ละลายทั้งหมดสูงกว่าห้วยพรมแล้งอย่างมีนัยสำคัญ ($p < 0.05$) ตัวอ่อนของ *Neochauliodes* sp. มีท่อหายใจยาวจำนวน 1 คู่ที่ปล้อง ท้องที่ 8 ซึ่งช่วยให้สามารถใช้ออกซิเจนจากบรรยากาศได้แม้ว่าตัวอ่อนยังคงอยู่ในน้ำที่มีปริมาณออกซิเจนละลายต่ำ จากความกว้างของ ส่วนหัวแสดงว่า *Neochauliodes* sp. มีตัวอ่อน 11 ระยะและมีชีวประวัติแบบหนึ่งรุ่นต่อปีและไม่เป็นฤดูกาล

ABSTRACT

Diversity and life history of fishflies (Megaloptera: Corydalidae: Chauliodinae) were explored, which focusing on larval and adult stages at two headwater streams (Yakruae and Phromlaeng streams) during October 2013 to December 2014. Fifteen adults of *Neochauliodes puntatolus* Liu and Yang, 2006 were found in October 2013 and during June to September 2014 which consisted of 12 males and a female at Yakruae stream and two males at Phromlaeng stream. Adult showed sexual dimorphism, the male had pectinated antenna and the female had sub-serrated antenna, body size of female was larger than male. It seemed that emergence of *N. puntatolus* tend to be more males than females from these two headwater streams. Only one morphospecies of *Neochauliodes* larvae was found. *Neochauliodes* sp. larvae had more abundance at Yakruae stream (n=88) than those of Phromlaeng stream (n=6). Even though Yakruae stream had less dissolved oxygen and higher electrical conductivity and total dissolved solid than those of Phromlaeng stream ($p<0.05$). *Neochauliodes* sp. larvae have a pair of elongated respiratory tube which allowed them to utilize atmospheric oxygen while they remain submerged in low dissolved oxygen. Measurement of larval head capsule width showed *Neochauliodes* sp. has 11 larval size classes and a non-seasonal, univoltine life history pattern.

คำสำคัญ: แมลงช้ำงครามโต ลำธารต้นน้ำ หนึ่งรุ่นต่อปี

Keywords: Fishflies, Headwater streams, Univoltine

INTRODUCTION

Aquatic insects are important in energy flow in aquatic systems, since they constitute of an important link between the algal/detrital food base and the higher trophic level, including benthivorous fish. The Megaloptera is a minority of aquatic insect group and larvae of this order are important as active predators. They are valuable components in aquatic ecosystems especially for fisheries and angling in North America and are consumed as local food and medicine in some Asian countries, as well as widely used in freshwater bio-monitoring for stream health (Liu and Winterton, 2016). The Megaloptera is composed of two families, Corydalidae and Sialidae. The adults of Corydalidae easily separated from those of Sialidae by presence of ocelli, non-bilobed fourth tarsomere 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 Corydalidae consists of two subfamilies, Corydalinae and

Chauliodinae. The Corydalinae are restricted to North and South America, South Africa and Asia while the Chauliodinae occur in Australia and New Zealand (Glorioso, 1981). Larvae of the Megaloptera are association with cool, well-oxygenated waters (Gullan and Cranston, 2010). Although they are found throughout the world, the distributions are discontinuous, which is characteristic of a relict fauna (Anderson, 2009). The Megaloptera considered as holo-metabolous aquatic insects which go from egg to larva to pupa to adult and the larvae look very different than the adults (Flint Jr. et al., 2008). Knowledge of the number of immature stages and the patterns of growth and development throughout the year is an important component of this basic information (Becker, 2005). Life history information is of fundamental importance for virtually all ecological studies of freshwater invertebrates and may vary between populations, depending on abiotic factors such as temperature and biotic factors such as feeding, growth, development, dormancy, dispersal and

reproduction (Butler, 1984). Basic information on a species life history is essential for understanding its adaptation to its environment as well as the functions and interactions of biological communities (Roff, 1992; Stearns, 1992). Collections of adults from particular localities will be invaluable as clues to recognition of larvae that likely to be found in local rivers and streams (New, 2004).

In Thailand, diversity studies of the Megaloptera are scarce compared to other orders of aquatic insects and are mostly reported as the familial level of larvae. Recently, only 11 species in six genera of megalopterans consisted of *Neoneuromus sikkimensis*, *Neurhermes sumatrensis*, *Neurhermes tonkinensis*, *Nevromus aspock*, *Nevromus exterior*, *Protohermes furcatus*, *Protohermes tenellus*, *Protohermes triangulates*, *Neochauliodes moriutii*, *Neochauliodes punctatolus* and *Indosialis bannaensis* (Yang and Liu, 2010; Liu et al. 2015; 2010, 2012; 2008; 2007a; Liu and Yang, 2006; Bowles and Contreras-Ramos, 2016) were reported from Thailand. Since diversity of the Megaloptera has been little known in Thailand and no study of life history of the Megaloptera has been reported. This study is focused on adults of *Neochauliodes punctatolus* Liu and Yang, 2006 and life history of *Neochauliodes* sp. from head water streams, Yakruae and Phromlaeng streams, Petchabun and Chaiyaphum Provinces, Thailand.

RESEARCH METHODOLOGY

1. Study site

Two locations of study sites are shown in Figure 1 Yakruae stream (YK) (latitude 16°44'27.92"N, longitude

101°34'46.52"E and altitudes 807-840 m above sea level (m a. s. l.)) is located at Phetchabun Province and Phromlaeng stream (PL) (latitude 16°38'24.02" N, longitude 101°34'52.9"E and altitude 764-800 m a.s.l.) is located at Chaiyaphum Province, where are situated at Nam Nao National Park, Thailand.

Yakruae stream (Figure 2A) is the 2nd order stream of the Cheun River and is approximate 100 m far from the Visitors' Center. It is slightly disturbed by anthropogenic activities (guest houses, rest rooms closed to camping ground, small cafeterias and staff's accommodation). Riparian vegetation is mainly bamboo (*Bambusa* spp.). The stream has slow running water and is heavily shaded. Canopy coverage is approximate 70%, thus light penetrated to the stream is approximate 30%. Substrates consist of mainly bedrocks (60%), scraps of woods and leaves (20%), boulders and cobbles (10%) and gravel, sand and silt (10%), respectively. Some substrates are also covered by sediment, algae and mosses. Phromlaeng stream (Figure 2B) is the 3rd order stream of the Phrom River. It is approximate 10 km far from the Visitors' Center and there was no disturbance by anthropogenic activity. The stream possess more open canopy where is partially shaded by *Bambusa* spp. and *Syzygium* spp. Thus, the stream is slightly covered by shaded approximate 20% and the light penetration to the stream is more than 80%. The substrate types are dominated by bedrocks (70%), boulders (15%), cobbles and gravels (10%), scraps of woods and leaves (5%), respectively. Each stream is composed of four stations.

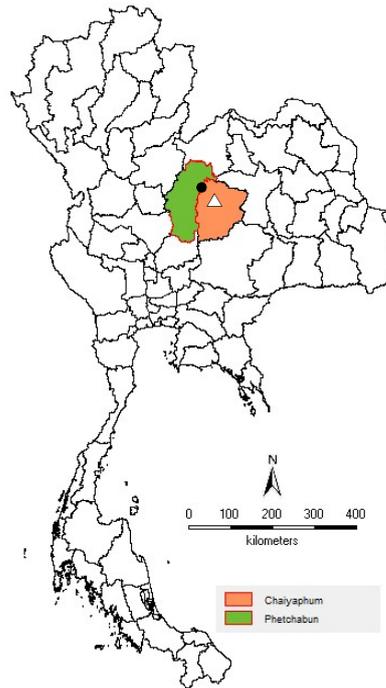


Figure 1 Locations of study sites, Yakruae (●) and Phromlaeng (△) streams, Thailand.



Figure 2 Habitats of *Neochauliodes* sp. larvae A: Yakruae stream, B: Phromlaeng stream.

2. Physico-chemical parameters of water quality

Three replicates of some physico-chemical parameters of water quality from Yakruae and Phromlaeng streams were measured *in situ* before collected the Megaloptera. They are composed of (1) depth of streams (cm, tape measure and ruler), (2) water temperature ($^{\circ}\text{C}$, YSI 550A; USA dissolved oxygen meter and Temperature Tester), (3) air temperature ($^{\circ}\text{C}$, Thermometer), (4) pH of water (Index ID1000, pH meter), (5) current velocity (m/s, Gurley Precision Instruments, Model 1100; USA flow velocity indicator), (6) total dissolve solid (TDS, mg/L, Hanna HI 98129, Mauritius pH/ Conductivity/ TDS and Temperature Tester), (7)

electrical conductivity (EC, $\mu\text{S}/\text{m}$, Hanna HI 98129, Mauritius pH/ Conductivity/ TDS and Temperature Tester) and (8) dissolved oxygen (DO, mg/L, YSI 550A; USA dissolved oxygen meter and Temperature Tester).

3. Collecting samples

Benthic macroinvertebrates were collected using a D-frame net (450 μm mesh size) by 20 sweeps. Samples and sediment were put in plastic bag, preserved with 95% ethanol and returned to the Department of Biology, Faculty of Science, Khon Kaen University for further study. In the laboratory, larvae were sorted to morphospecies as possible and each larval specimen was preserved separately with 95%

ethanol in vial. Samples of aquatic insect adults were collected using an ultraviolet light trap (15-W fluorescent, powered by a 12-volt DC battery) which was set up adjacent to the stream that has been turned on since 17.30 p.m. The insect adults were collected the next morning, preserved in 95% ethanol and transported to the Department of Biology, Faculty of Science, Khon Kaen University for further investigation.

4. Identification

Megalopteran larvae were examined to the genus level under the compound microscope (Olympus model CH 30RF200, Japan) and the stereo-microscope (Nikon model C-LEDS, China) according to Ding and Chikun (1994), New (2004). Megalopteran adults were examined to the genus level under the stereo-microscope with taxonomic keys of Flint Jr. et al. (2008), New (2004), Liu and Yang (2005). The specimens were deposited at Freshwater laboratory, Department of Biology, Faculty of Science, Khon Kaen University.

5. Preparation of megalopteran adult genitalias

Genitalia of each megalopteran was dissected under the stereo-microscope and cleared in hot 10% KOH (60 °C) for 30 min, which was modified from Liu and Yang (2006) then it was transferred to glycerin for further examination. After the examination, it was moved to fresh glycerin and stored in a microvial and placed back in the vial of its adult body. Genitalia were examined and identified to the species level according to Liu et al. (2007b; 2010), Liu and Yang (2006). Photographs of megalopteran larvae, adults and the genitalia were taken with the Canon digital camera (EOS 70D (W), Japan) attached to the stereo-microscope.

6. Life history analyses

Head capsule width (HCW) of megalopteran larvae was measured using a micrometer of binocular compound microscope (0.01 mm accuracy), in a case of large sized larvae, the HCW was measured using

vernier caliper and then recorded data. The total data was established the graph for illustrating frequency distribution of width of head larvae. Dyar's Rule, the rule proposes a linear dimension increase in successive instar with a geometric progression factor of 1.2 was used to estimate instar size range (Dyar and Rhinebeck, 1890). The percentage of individual frequency distribution of larval size class in each month chart was established. These established charts can be defined (1) a period of each larval size class, (2) percentage of each larval size class and (3) frequency distribution in each size class of larvae. In addition, data about megalopteran adults were also evaluated.

RESULTS

1. Physico-chemical parameters of water quality

Values of physico-chemical parameters of water quality from each stream are shown in Tables 1. Mann-Whitney U test revealed that pH of water in Yakruae stream did not differ from Phromlaeng stream ($p > 0.05$). Depth, water temperature, water velocity and Dissolved Oxygen in Phromlaeng stream were significant higher than those of Yakruae stream, whereas electrical conductivity and total dissolved solid were significantly higher in Yakruae stream than those of Phromlaeng stream ($p < 0.05$).

2. Abundance of adults *Neochauliodes punctatolus* Liu and Yang, 2006 and larvae of *Neochauliodes* sp.

Table 2 shows monthly distribution of adults *Neochauliodes punctatolus* Liu and Yang, 2006 and larvae of *Neochauliodes* sp. Abundances of the adults and larvae were greater at Yakruae stream (adult, $n = 13$, larvae, $n = 88$) than those at Phromlaeng stream (adult, $n = 2$, larvae, $n = 6$). No pre pupae or pupae were collected during this study.

3. Morphological characters of adult *Neochauliodes punctatolosus* Liu and Yang, 2006

Figure 3 shows morphological characters of *Neochauliodes punctatolosus* adult male and female. Body slender, male (n=14) body length 21.0-29.0 mm, fore wing length 26.5-32.7 mm, hind wing length 23.1-29.2 mm; female (n=1) body length 33.0 mm, fore wing length 38.1 mm, hind wing length 35.0 mm (Figure 3A and B).

Head: head yellow, broad and flattened, compound eyes large bulge; three ocelli white, margin black, male antenna long blackish brown pectinate (Figure 3C), female antenna dark brown sub serrate (Figure 3D), chewing mouthparts yellow, apical mandible reddish brown, maxillary palps and labial palps dark brown.

Thorax: prothorax yellow with smooth dorsal surface, mesothorax and metathorax with dorsally central pale yellow stigma like a star, margin black, wings membranous, fore wings with pale brown patches scattered and long brownish pterostigma on costal area (Figure 3E), hind wings with small brownish patches on upper margin and apical 2/3 of wing except at basal 1/3 of wing (Figure 3F), veins brown, C straight, Sc2 branched, Rs4 branched, R2 four branched, r3 and R4 curved backward at tip, M2 branched, Cu1 two branched, Cu2 curved, A1 two branched, J1 two branched, J2 curved and J3 near basal portion, leg with dense pale yellow setae, coxa brown, trochanter pale

yellow, femur brown, tibia dark brown, tarsus 5 segments with 2 reddish brown apical tarsal claws.

Abdomen: abdomen dark brown and black, 10 segments with eight pairs of spiracles, no cerci, Male genitalia: genitalia on abdominal IX and X terga; in lateral view upper plate sub-quadrate with dense long pale setae at apex, lower plate slender curved upward with distinctly inflated apex (Figure 3G); in ventral view slender, sub-oblong plate with larger basal part incised deeply like V-shaped, apical margin shallowly incised (Figure 3H); in dorsal view apex with two inflated, globose, outer edge with long blackish brown setae, inner edge with many horizontal rows of short black setae (Figure 3I).

Female genitalia: genitalia on abdominal IX - X terga; in lateral view upper plate sub-quadrate and curve apical margin, lower plate gonapophyses membranous sub-oblong shape with slightly oblique apical margin (Figure 3J); in dorsal view two strongly plates globose with long setae and one vertical central plate without setae (Figure 3K); in ventral view flame-like shape plate with long pale yellow setae (Figure 3L).

4. Life history of *Neochauliodes* sp.

Morphological characters of *Neochauliodes* sp. larvae (Figure 4A): larvae campodeiform, chewing mouthparts, pronathous head; prothorax cylindrical dark brown, mesothorax and metathorax brown, lateral filament on abdominal segment I - VIII (Figure 4B), pair of long respiratory tube on dorsal of abdominal segment VIII.

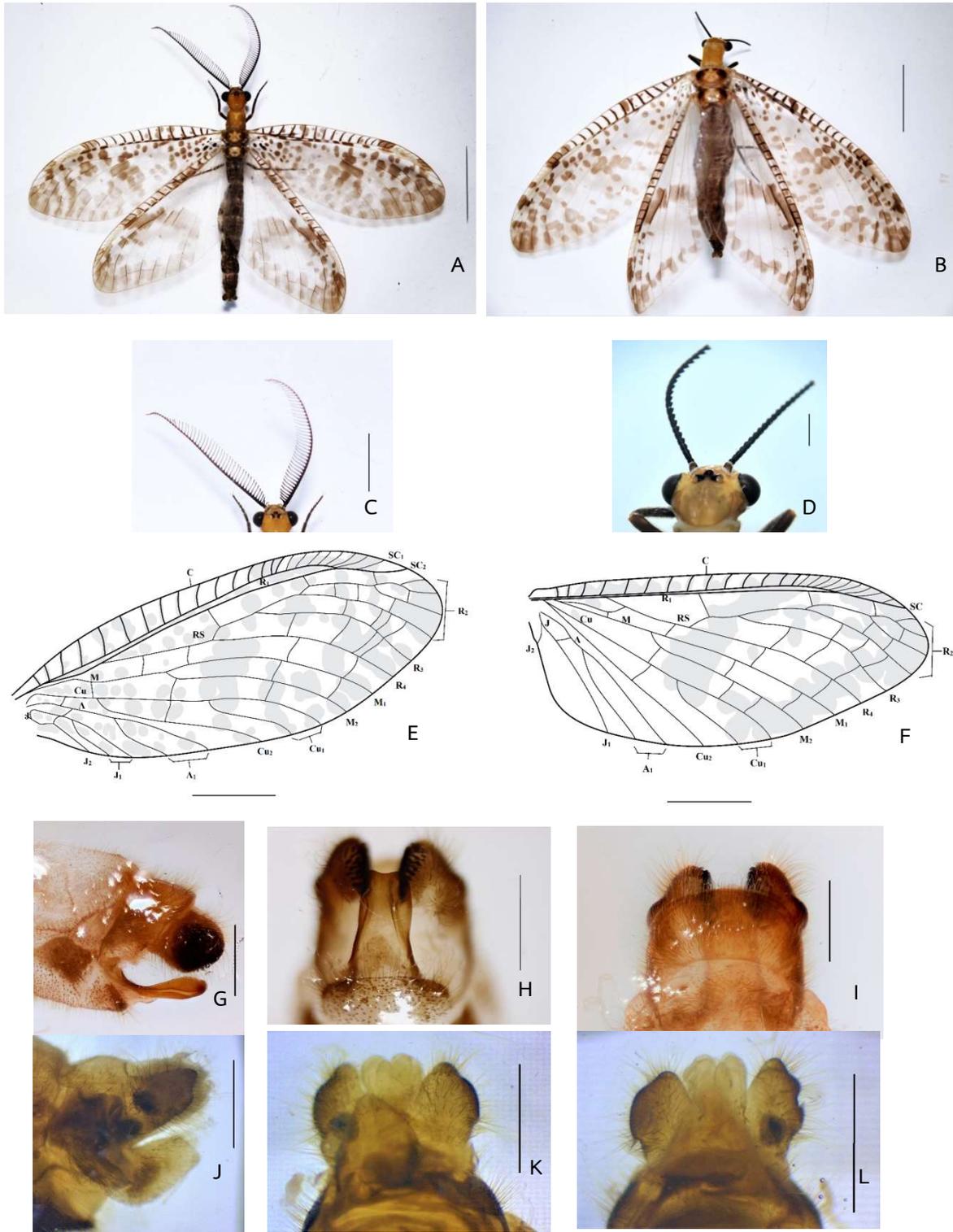


Figure 3 Morphological characters of *Neochauliodes punctatolus* adult (A) male (scale=10 mm), (B) female (scale=10 mm); antenna (C) male (scale=5 mm), (D) female (scale=1 mm); (E) male fore wing (scale=5 mm), (F) male hind wing (scale=5 mm); male genitalia (G) lateral view, (H) ventral view, (I) dorsal view; female genitalia (J) lateral view, (K) ventral view, (L) dorsal view (G-L scale=1 mm)



Figure 4 (A) Morphological characters of *Neochauliodes* sp. larva (scale = 10 mm), (B) respiratory tubes (arrow) (scale = 5 mm).

Larvae of *Neochauliodes* sp. were found in Yakruae stream (n=88) and Phromlaeng stream (n=6). Only larvae of Yakruae were use on the study of life history. The head capsule width frequency histogram from Yakruae stream suggested that *Neochauliodes* sp. had 11 size classes (n=88) as shown in Figure 5. Eggs were not obtained in the study sites because of limited

collecting effort. So, it did not know actual size of larval instar I. In this study, “larval size class” was used instead of “larval instar”. Based on illustration on percentage individual and frequency distribution of larval size class in each month, the population of *Neochauliodes* sp. exhibited a non-seasonal, univoltine life history (Figure 6).

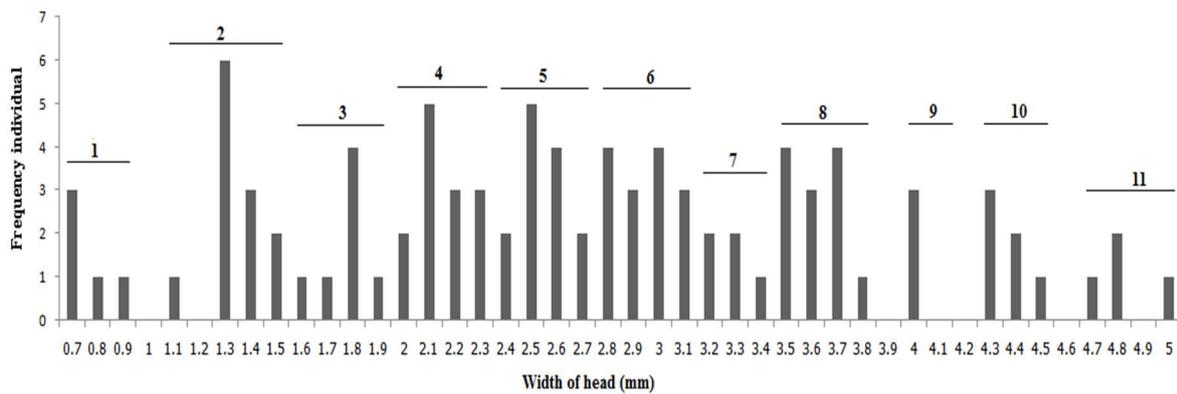


Figure 5 Head capsule width (mm) and frequency individual of megalopteran larvae, *Neochauliodes* sp.

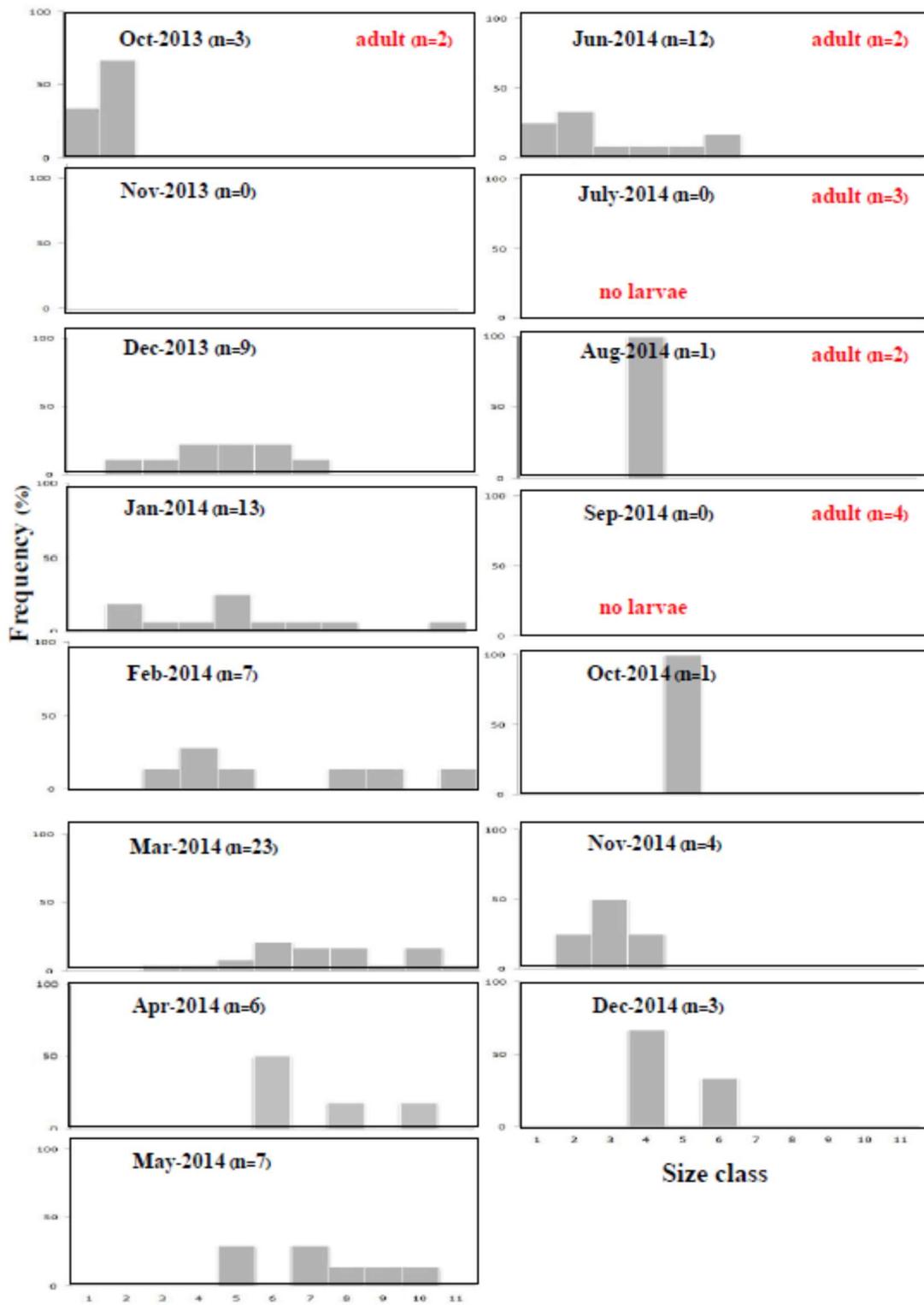


Figure 6 Percentage individual and frequency distribution in each month of *Neochauliodes* sp. larvae I-XI size classes from Yakrae stream and individual of *N. punctatolusus* adults.

DISCUSSION

Prepupae and pupae of *Neochauliodes* were not found in this study because pitfall trap was not used to collect final instars that existing the water and burrow in sandy or muddy soil around the banks. Takeuchi and Hoshiba (2012, 2013) succeed to catch the final instar of *Sialis yamatoensis*, *S. japonica* (Family Sialidae) and *Parachauliodes continentalis*, *Pa. japonicus* and *Protohermes grandis* (Family Corydalidae, Subfamily Corydalinae) by using pitfall traps, while these final instar larvae were climbing from water to search for a suitable location for pupation on a bank side. Final instar larvae of *S. yamatoensis* and *S. japonica* climbed at night and approximately 50 percent occurred during or after rainy nights while almost (99%) *Pa. continentalis*, *Pa. japonicus* and *Pr. grandis* climbed during or after rainy night to dig pupal chamber in wet ground (Takeuchi and Hoshiba, 2012). Both *Sialis* species pupated closed to margin of pond (Takeuchi and Hoshiba, 2013). *Pa. continentalis* pupate in 50 cm to 10.5 m (Hayashi, 1989; Takeuchi, 2010) and 10 m in *Pr. grandis* (Takeuchi and Hoshiba, 2012) away from the rivers. Locklin et al. (2006) used pitfall trap to collect prepupae of many sialid species in central Texas.

The occurrence of *N. punctatolus* is a new record at Nam Nao National Park and it is one out of 11 species of megalopterans which is reported from Thailand (Liu et al., 2007a; 2008; 2010; 2012; 2015; Bowes and Contreres-Ramos, 2016). Only one female adult was found at Yakruae stream in June 2014, whereas 12 male adults were found at Yakruae stream in October 2013 and two individuals from Phromlaeng streams during June to September 2014. Characteristics of male and female *N. punctatolus* in this study followed characters of *N. punctatolus* in Yunnan described by Liu and Yang (2006). Adults of *N. punctatolus* have been reported from many

locations at altitude between 200-1710 m a.s.l. in Yunnan Province, China (Liu and Yang, 2006). They were found in Lao PDR, Vietnam and Thailand, but most had no detailed data (Liu, et al., 2010). They were also found in Lao PDR at 650 and 1,200 m a.s.l. in Louang Nam Tha and Xieng Khong Provinces, respectively. In Thailand, they were reported at 400 m a.s.l. in Chantaburi Province (Khao Soi Dao) and at 450 m a.s.l. in Fang district, Chiang Mai Province (Liu, et al., 2010). In this study, it may be concluded that *N. punctatolus* distributed between 764-840 m a.s.l. which is in the range of 200-1710 m a.s.l. as described by the previous studies (Liu and Yang, 2006; Liu et al., 2010). *Neochauliodes* sp. larvae were found marked higher (n=88) at Yakruae stream than those of Phromlaeng stream (n=6). Even though Yakruae stream had less dissolved oxygen and higher electrical conductivity and total dissolved solid than those of Phromlaeng stream. This may be due to larvae of *Neochauliodes* sp. have a pair of respiratory tube located on the dorsal side of the abdominal segment VIII to obtain oxygen from atmosphere. In addition, larvae of *Neochauliodes* sp. preferred to cling underneath the cobbles and inhabited leaf litter decomposition where Yakruae stream has more cobbles and leaf pack accumulation along the margin of stream bank for providing more microhabitat to *Neochauliodes* sp. larvae. Hayashi and Nakane (1989) and Hayashi (1989) used radio transmitters to explore the relationship between microhabitat selection and respiratory mode in 3 species of corydalid larvae. They found that respiratory tube of Chauliodinae larvae are used as snorkels when they need to obtain oxygen from the atmosphere and the larvae are often found along the margin of rivers when the current is slow (Takeuchi and Hoshiba, 2012). Whenever the aquatic dissolved oxygen is inadequate, the larvae can raise their snorkels to the water surface

and shift from aquatic respiration to aerial respiration (Hayashi, 1989). In contrast, Corydalinae larvae inhibit in riffle areas of rivers (Takeuchi and Hoshiba, 2012). Somnak (2018) found larvae of Corydalinae only in riffle areas, while larvae of Chauliodinae occurred in both riffle and pool areas of Yakruae and Phromlaeng streams.

Based on head capsule width frequency, 11 larval size classes of *Neochauliodes* sp. were suggested. In western United State, *Neohermes* was estimated to have nine to 12 larval instars and the female may have one more larval molt than male in order to gain on the larger size (Anderson, 2009). Brown and Fitzpatrick (1978) reported that 11 larval instars of *Corydalus cornutus* in north-central Texas, while 10 larval instars of *Sialis itasca* and *S. valata* were observed in central Texas (Locklin et al., 2006).

In this study, many size classes of *Neochauliodes* sp. larvae, especially early size classes, occurred in several months. Its life history showed a non-seasonal univoltine pattern. *Sialis* (Sialidae) showed an annual life cycle (Dall, 1989; Locklin et al., 2006). Whereas, corydalids were usually reported as semivoltine growth pattern which took 2-4 years to complete life cycle (Hayashi, 1988; Cover et al., 2015). The life cycle of corydalid megalopteran is temperature dependent. *Corydalus cornutus* from a stream in north-central Texas with high water temperature in summer (20-30 °C) and low in winter (5-15 °C) showed univoltine life history pattern. However, northern population may have a life cycle of 2-3 years and one larger as adults (Anderson, 2009). Hayashi (1988) reported that the life cycle of *Pr. grandis* in four streams in central Japan and found that annual temperature regime and prey availability affected on life history. In the warmer river, larvae took 2 years and small adults emerged, but the larvae took 3 years to develop in lower temperature

and large adults emerged. Larger prey available affected the time larvae left the stream to pupate.

The present study, the combined result of adults from both streams, males of *N. punctatolus* (n=14) were found more than females (n=1) and both sexes were found together in June 2014. This finding may suggest that emergence of *N. punctatolus* tend to be more males which was supported by Liu and Yang (2006) who found more *N. punctatolus* males (n=41) than females (n=12) from Yunnan, China as well as Liu et al. (2010) also found more *N. punctatolus* males than females from Thailand (male, n=9; female, n=1) and Lao PDR (male, n=6; female, n=4), respectively. According to Takeuchi and Hoshiba (2012), two emergent patterns were observed in the Megaloptera. The first pattern is a synchronous emergence behavior which optimizes mating opportunities. The second pattern is protandrous or male-first emergence behavior which makes a reproductive advantage for male to develop a relatively large spermatophore.

In this study, it could not be identified larvae of *Neochauliodes* into the species level. New (2004) stated that larvae and adults of megalopterans were likely to be found in the same localities. However, molecular studies among the larvae and adults will be further investigated to fulfill this gap.

CONCLUSION

Here is the first record of adults of *N. punctatolus* Liu and Yang, 2006 and larvae of *Neochauliodes* sp. from Yakruae and Phromlaeng streams, Nam Nao National Park. In this study, it is possible to identify the larvae in only the generic level because no keys to separate them from the area beyond the generic level. According to New (2004), identification to the generic and species levels relies entirely on adult features. In order to associate the

unknown larvae of *Neochauliodes* sp. with taxonomically identified adults *N. punctatolus*, molecular investigation among the larvae and adults are needed for further study, which will be able to provide keys to the known larvae of the Megaloptera. Therefore, the presence of genus *Neochauliodes* make Yakruae and Phromlaeng streams interesting places for the study of megalopteran fauna.

ACKNOWLEDGEMENTS

The research was supported by Khon Kaen University, Thailand (grant No. 58008) and Center of Excellence on Biodiversity (BDC-PG4-160020). Authors wish to thank the Department of National Parks, Wildlife and Plant Conservation, Ministry of Natural Resources and Environment for permitting us to study at Nam Nao National Park. We are grateful to the project for promotion of science and mathematics talent teacher (PSMT) for grant to the first author.

REFERENCES

- Anderson, N.H. (2009). Megaloptera. In Encyclopedia of Insects. 2nded. V.H. Resh and R.T. Cardé (eds). London: Elsevier, Inc. pp. 620-623.
- Becker, G. (2005). Life cycle of *Agapetus fuscipes* (Trichoptera, Glossosomatidae) in a first-order upland stream in central Germany. *Limnologica* 35: 52-60.
- Bowles, D.E. and Contreras-Ramos, A. (2016). First record of the family Sialidae (Megaloptera) from Thailand and description of the female and putative larva of *Indosialis bannaensis*. *Zootaxa* 4114(4): 485-491.
- Brown, A.V. and Fitzpatrick, L.C. (1978). Life history and population energetics of the dobsonfly, *Corydalus comutusi*. *Ecology* 59(6): 1091-1108.
- Butler, M.G. (1984). Life histories of aquatic insects. In The ecology of aquatic insects. V.H. Resh and D.M. Rosenberg (eds.). London: Praeger Publishing. pp. 24-55.
- Cover, M.R., Resh, V.H. and Seo, J.H. (2015). Life history, burrowing behavior, and distribution of *Neohermes filiconis* (Megaloptera: Corydalidae), a long-lived aquatic insect in intermittent streams. *Western North American Naturalist* 75(4): 474-490.
- Dall, P. (1989). The life history and occurrence of *Xicrlis zutcria* L. (Megaloptera) in the littoral zone of Lalie Esrørr, Denmark. *Internationale Revue der gesamten Hydrobiologie und Hydrographie* 74(3): 273-281.
- Ding, Y. and Chikun, Y. (1994). Megaloptera and aquatic Neuroptera. In Aquatic insects of China useful for monitoring water quality. J.C. Morse, L. Yang and L. Tian (eds.). Nanjing: Hohai University Press. pp. 250-259.
- Dyar, H.G. and Rhinebeck, N.Y. (1890). The number of molts of Lepidoptera larvae. *Phyche* 5: 420-422.
- Flint Jr., O.S., Evans, E.D. and Neunzig, H.H. (2008). Megaloptera and aquatic Neuroptera. In An introduction to the aquatic insects of North America. 4th ed. R.W. Merritt, K.W. Cummins and M.B. Berg (eds.). Dubuque, Iowa: Kendall Hunt Publishing Company. pp. 425-437.
- Glorioso, M.J. (1981). Systematics of the dobsonfly subfamily Corydalinae (Megaloptera: Corydalidae). *Systematic Entomology* 6: 253-290.
- Gullan, P.J. and Cranston, P.S. (2010). The insects: an outline of entomology. 4th ed. Malaysia: Willey-Blackwell.
- Hayashi, F. (1988). Life history variation in a dobsonfly, *Protohermes grandis* (Megaloptera: Corydalidae): effects of prey availability and temperature. *Freshwater Biology* 19: 205-216.
- Hayashi, F. (1989). Microhabitat selection by the fishfly larva, *Parachauliodes japonicus*, in relation to its mode of respiration. *Freshwater Biology* 21: 489-496.
- Hayashi, F. and Nakane, M. (1989). Radio tracking and activity monitoring of dobsonfly larvae, *Protohermes grandis* (Megaloptera: Corydalidae) *Kontyu Oecologia* 78: 468-472.
- Liu, X., Hayashi, F., Viraktamath, C.A. and Yang, D. (2012). Systematics and biogeography of the dobsonfly genus *Nevromus* Rambur (Megaloptera: Corydalidae: Corydalinae) from the Oriental realm. *Systematic Entomology* 37: 657-669.
- Liu, X., Hayashi, F. and Yang, D. (2007a). The *Protohermes assamensis* species-group (Megaloptera: Corydalidae: Corydalinae), with descriptions of two new species. *Annales Zoologici (Warszawa)* 57(4): 833-840.

- Liu, X. , Hayashi, F. and Yang, D. (2007b). Revision of the *Neochauliodes sinensis* Species-Group (Megaloptera: Corydalidae: Chauliodinae). Zootaxa 1511: 29-54.
- Liu, X. , Hayashi, F. and Yang, D. (2008). The *Protohermes guangxiensis* species-group (Megaloptera: Corydalidae), with descriptions of four new species. Zootaxa 1851: 29-42.
- Liu, X., Hayashi, F. and Yang, D. (2010). The genus *Neochauliodes* van der Weele (Megaloptera: Corydalidae) from Indochina, with description of three new species. Annales Zoologici (Warszawa) 60(1): 109-124.
- Liu, X. , Hayashi, F. and Yang, D. (2015). Systematics and biogeography of the dobsonfly genus *Neurhermes* Navás (Megaloptera: Corydalidae: Corydalinae). Arthropod systematic and Phylogeny 73(1): 41-63.
- Liu, X. and Winterton, S.L. (2016). A new fishfly species (Megaloptera: Corydalidae: *Neohermes* Banks) discovered from North America by a systematic revision, with phylogenetic and biogeographic implications. Plos One 1371(10): 1-17.
- Liu, X. and Yang, D. (2005). Notes on the Genus *Neochauliodes* Weele (Megaloptera: Corydalidae) from Henan, China. Entomological Science 8: 293-300.
- Liu, X. and Yang, D. (2006). Revision of the species of *Neochauliodes* Weele, 1909 from Yunnan (Megaloptera: Corydalidae: Chauliodinae) 56(1): 187-195.
- Locklin, J.L., Arsuffi, T.L. and Bowles, D.E. (2006). Life history of *Sialis* (Megaloptera: Sialidae) in a lentic and lotic ecosystem in central Texas. The American Midland Naturalist 155: 50-62.
- New, T. R. (2004). Insecta: Neuropteroidea. In Freshwater invertebrates of the Malaysian region. H.S. Yong and C.M. Yule. Kuala Lumpur: Akademi Sains Malaysia. pp. 491-500.
- Roff, D.A. (1992). The evolution of life histories. Theory and analysis. New York: Chapman and Hall. 537 pp.
- Somnark, R. (2018). Community structure of freshwater benthic macroinvertebrates, phonology of some species of aquatic insects and leaf litter breakdown in Nam Nao National Park, Phetchabun Province. Ph. D. Thesis, Khon Kaen University.
- Stearns, S.C. (1992). The evolution of life histories. Canada: Oxford University Press. 249 pp.
- Takeuchi, Y. (2010). Pupation of the fishfly *Parachauliodes continentalis* (Megaloptera: Corydalidae) in Yumessaki River, Hyogo Prefecture, Japan. Hyogo Freshwater Biology 61/62: 55-66 (in Japanese with English abstract).
- Takeuchi, Y. and Hoshihara, H. (2012). The life histories of three species of Corydalidae (Megaloptera) from Japan. Aquatic Insects 34 (1): 55-63.
- Takeuchi, Y. and Hoshihara, H. (2013). The life histories of two species of Sialidae (Megaloptera) from Japan. Aquatic Insects 34 (3-4): 205-216.
- Yang, D. and Liu, X. (2010). Fauna sinica insecta vol. 51, Megaloptera. Beijing: Science Press. pp. 420-435.
- Whiting, M.F. (1994). Cladistic analysis of the alderflies of America north of Mexico (Megaloptera: Sialidae). Systematic Entomology 19: 77-91.

