

Article

Taxonomy and Distribution of the Gomphid Dragonfly *Orientogomphus minor* (Laidlaw, 1931) (Odonata: Gomphidae) in Thailand

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Abstract: The taxonomy and distribution of *Orientogomphus minor* (Laidlaw, 1931) were investigated in Thailand. Gomphid nymphs were collected from 28 sampling sites in streams in eastern, western, and southern Thailand. The nymph of *O. minor* is described for the first time and the male is re-described and illustrated based on a reared specimen. The taxonomic characteristics of the nymphs of the genus *Orientogomphus* are discussed. The nymph of *O. minor* differs from that of *O. armatus* Chao & Xu, 1987, the only other *Orientogomphus* species with a described nymphal stage, by the presence of lateral spines on abdominal segments six to nine and by a slender, stick-shaped third antennal segment. Multivariate analyses revealed a strong correlation between the distribution of *O. minor* and other three gomphid species with restricted distribution in Thailand (*Nychogomphus duaricus* (Fraser, 1924), *Onychogomphus louissiriusi* Fleck, 2020 and *Stylogomphus thongphaphumensis* Chainthong, Sartori & Boonsoong, 2020). Those species were recorded solely in streams in the western part of the country. Nymphs of *O. minor* were predominantly associated with stony substrates.



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Keywords: gomphid nymphs; *Orientogomphus*; Thailand

1. Introduction

The Gomphidae (clubtail dragonflies), a well-known family in the Odonata, comprise about 87 genera and 1000 species worldwide [1,2]. With the exception of the Libellulidae, the species diversity is likely higher for the Gomphidae than for any other family of Anisoptera [3,4]. The gomphid nymphs have several notable morphological features: (1) the antennae have four segments with the third larger than the others, and the fourth very small, (2) the prementum and palpal lobes of the labium are flattened (not scoop-shaped), and (3) the body is diverse in form, cylindrical, broad and slender to extremely flattened like a leaf. Most gomphid nymphs are lotic species that are commonly components of benthic communities and contribute to ecosystem services (e.g., they are highly predaceous and serve as food for humans and as indicators of environmental changes) [5,6]. In the past decade, taxonomic studies of the Gomphidae in Thailand have continued to increase, and many new taxa have been described. The discovery of gomphid dragonflies adds 54 species and 27 genera (e.g., *Anisogomphus* [7,8], *Burmargomphus* [9], *Stylogomphus* [10], *Onychogomphus* [11] and *Microgomphus* [12]) from Thailand to the known species.

To date, most studies of odonates in Thailand have focused on the taxonomy of the adult stage. So far, eight families (Aeshnidae, Chorogomphidae, Cordulegastridae, Corduliidae, Gomphidae, Libellulidae, Macromiidae and Synthemistidae), 97 genera and 207 species of dragonflies have been recorded in Thailand. Studies on their biology and ecology are scarce, and only limited data are available on the nymphal stages and their distributions in lotic ecosystems. However, gomphid nymphs have been continuously described from Thailand [12–18], and the number of nymphal descriptions of Gomphidae

species will steadily increase in the future because the diversity and taxonomy of the adult stage are well known.

The genus *Orientogomphus* was established by Chao & Xu [19], with species characterised as small to medium-sized, with divergent inferior appendages that are much shorter than the superior appendages (usually about half the length) and with apical margins shallowly concave. The superior appendages are long, bracket-like in dorsal view, and abruptly curved apically in lateral view, with a minute peg-like process at the tip. The prepuce is absent. The genus, distributed in Southeast Asia and China, currently comprises seven known species [20]. Of these, only *O. minor* (Laidlaw, 1931) has been recorded from Thailand. This small species is distributed throughout Thailand and extends to Peninsular Malaysia. A distribution map of adult specimens has been published [21]; however, knowledge of the distribution of the nymphal stage in Thai streams is sparse [21]. To date, *O. armatus* Chao & Xu, 1987 is the only species with a described nymph within the genera [22].

This paper provides the first description and illustration of the final stadium nymphs of *O. minor*, based on reared specimens, and compares and discusses the morphological characteristics of the nymphs of related species and genera. We also investigated the distribution and microhabitat of this species within lotic ecosystems.

2. Materials and Methods

2.1. Study Area and Sampling

The gomphid nymphs were collected from first order to third-order streams (28 sampling sites) in eastern, western, and southern Thailand (Figure 1). The nymphs were collected using a D-frame net in a variety of microhabitats, including sweepings of pool-litter, weeds, roots of riverside trees, mud and margin litter, or kick samples from riffles, sand, gravel, and pebbles. Gomphid nymphs were recorded at all microhabitats. Nymphs were identified to the species level using the published literature [10–18,23]. A distribution map was generated with SimpleMappr software (<https://simplemappr.net>) (accessed on 4 March 2022) [24].

2.2. Rearing and Identification

Nymphs of *O. minor* were found in three sampling sites. Of these, nymphs were collected from a sandy substrate in one locality at Huai Khayeng, Thong Pha Phum district, Kanchanaburi Province, in western Thailand (Figure 2). Full-grown nymphs were transferred to the laboratory for rearing. The nymphs were reared in potable water in an earthenware pot (a rearing device for a single nymph with a netted cover) with a mixture of sand and gravel as substrate. Each rearing chamber was connected to an air supply via aquarium tubing. Chironomid larvae were offered as prey, which *Orientogomphus* nymphs fed on readily. The nymphs were reared in the laboratory until they emerged as adults. The exuviae were preserved in 80% ethanol, and the adults were pinned and dried 3 days after their emergence. The species identification was confirmed based on Asahina [25] and Wilson [21]. All drawings were illustrated with the aid of a camera lucida. Measurements (mm) and photographs were taken with a NIKON SMZ800 stereoscopic microscope (NIKON Corporation, Tokyo, Japan). All dragonfly specimens are deposited in the Zoological Museum, Kasetsart University (ZMKU), Bangkok, Thailand (Aquatic Insects Collection section). The terminology for the nymphal mandibular formula followed that of Watson [26].

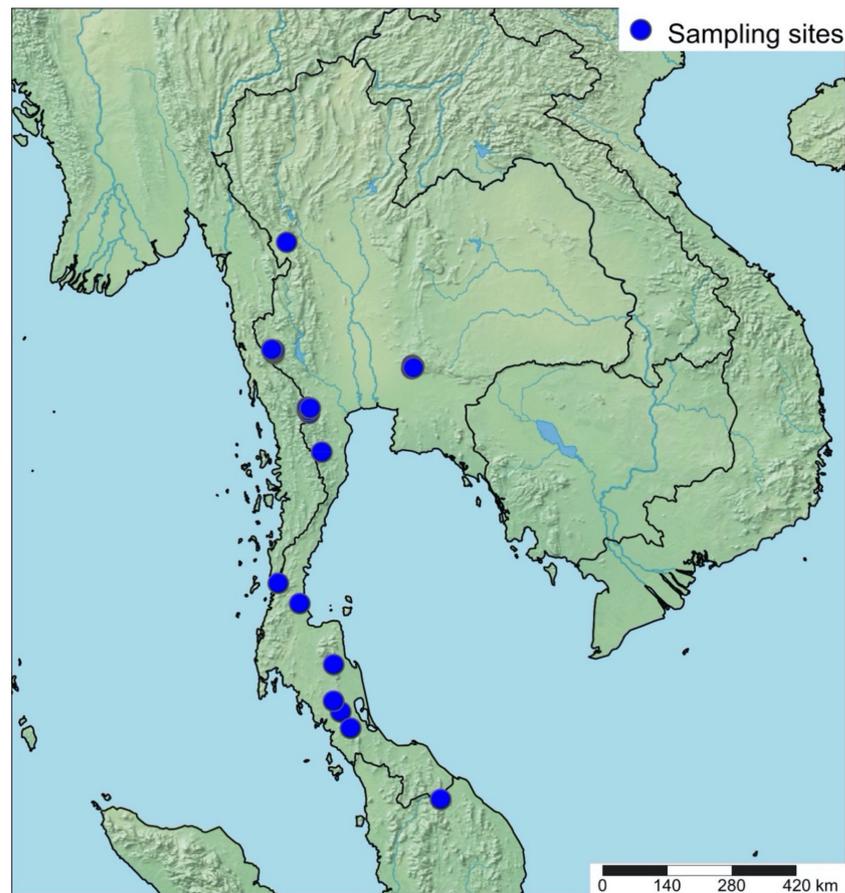


Figure 1. Map showing the sampling sites in eastern, western, and southern Thailand.

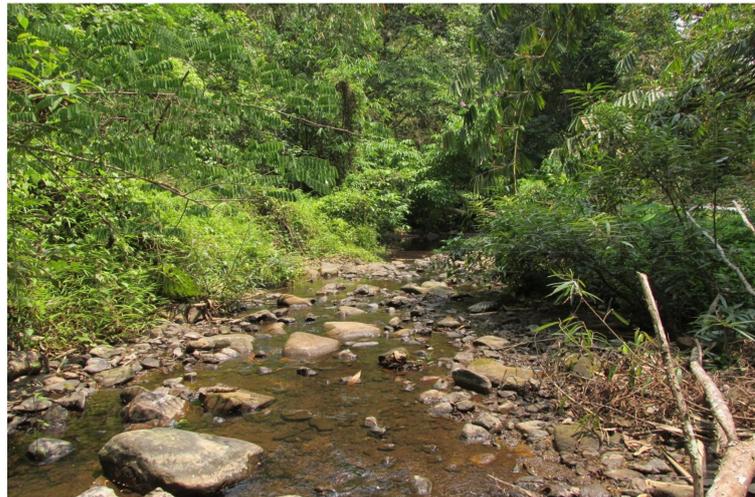


Figure 2. Nymphal habitat of *Orientogomphus minor* (Huai Khayeng, Thong Pha Phum district, Kan-
chanaburi Province).

2.3. Data Analysis

Gomphid nymph assemblages (presence/absence data) in response to spatial change were visualised by performing a principal component analysis (PCA), which identifies independent axes of variability and relates species samples to each axis. The relationship between gomphid nymphal species composition and microhabitat was investigated using two-way cluster analysis (Jaccard distance measure and the Group average linkage method). Multivariate analyses were performed using PC-ORD software version 7.01 [27].

3. Results

3.1. Taxonomy

3.1.1. Description of the Last Stadium Nymph

Material examined. THAILAND: 1 (exuvia) and 5 nymphs, Huai Khayeng, Thong Pha Phum district, Kanchanaburi Province, 14°36'20" N 98°34'38" E, 206 m a.s.l., 14.XII.2014, D. Chainthong leg; 3 nymphs, Huai Sat Lek; Kaeng Krachan district, Petchaburi Province, 12°38'14" N 99°30'59" E; 162 m a.s.l., 25.II.2018, D. Chainthong leg.

The general appearance and detailed structures are shown in Figures 3–5.

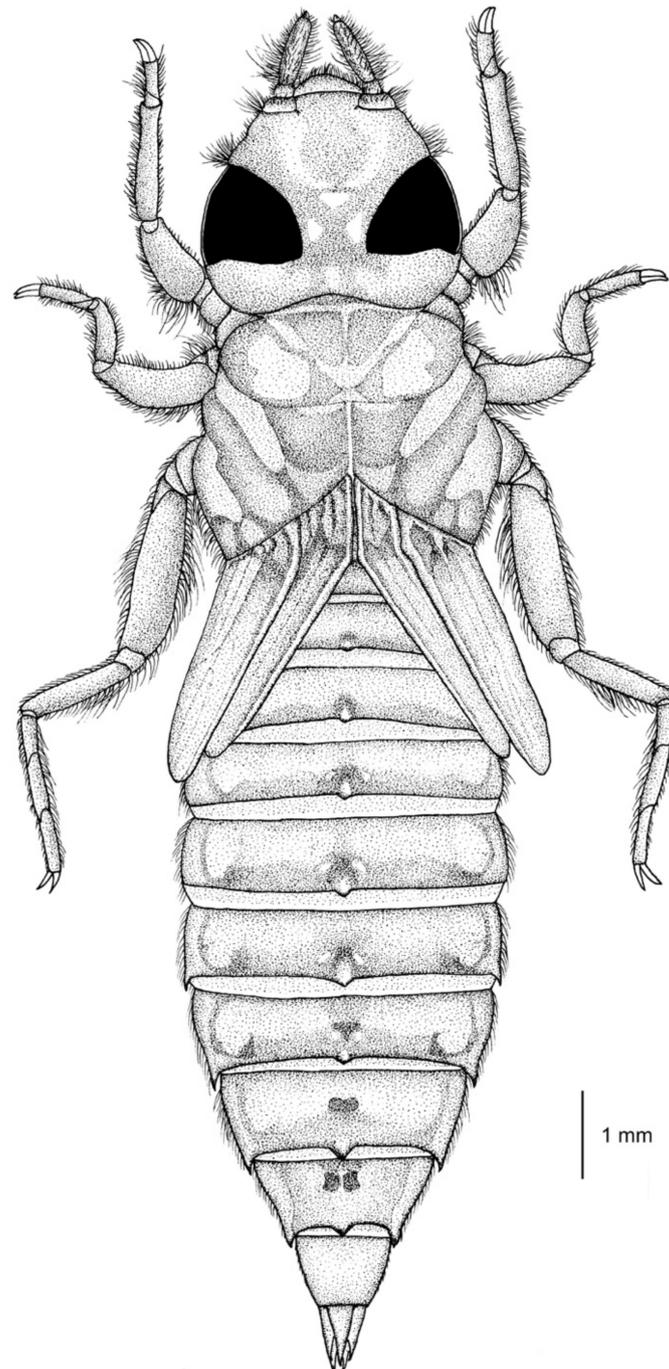


Figure 3. Dorsal view of nymph of *Orientogomphus minor*.



Figure 4. Habitus of *Orientogomphus minor* nymph.

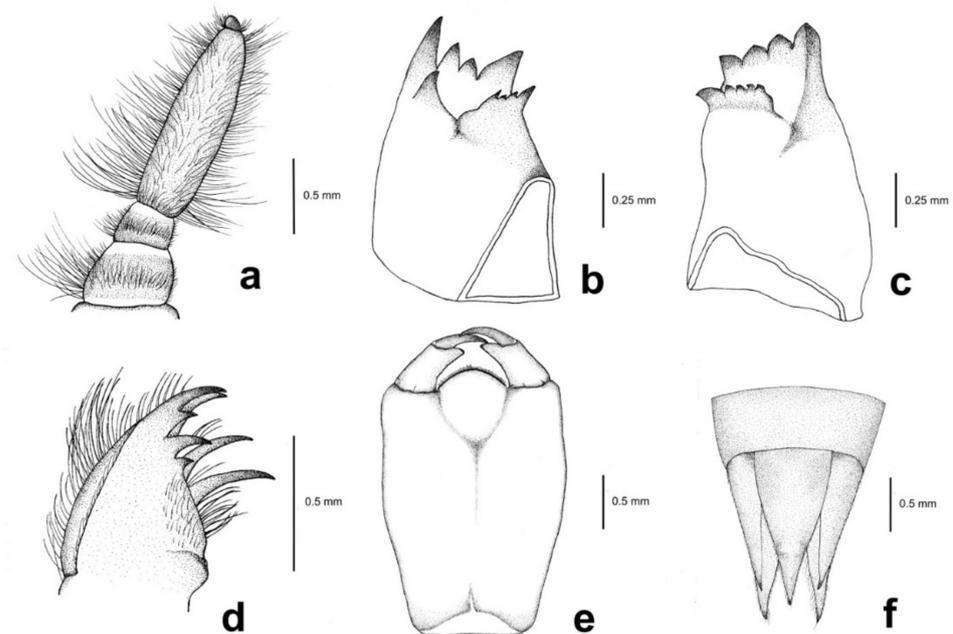


Figure 5. Morphological features of *Orientogomphus minor* nymph: (a) dorsal view of antenna; (b) ventral view and internal view of right mandible; (c) ventral view and internal view of left mandible; (d) ventral view of right maxilla; (e) ventral view of prementum; (f) dorsal view of anal appendages.

Colouration. Nymphs uniformly bright yellow. Body broadly lanceolate and covered with hair-like setae, dorsal surface strongly convex, ventral surface flat (Figure 4).

Head. Head broad and flat, frontal part with triangular appearance in dorsal view, posterior lobe of the head shorter than the eye length; eyes large and broadest across, with three large ocelli. Antennae four-segmented, first two segments small and rather circular; third segment slender, stick-shaped, slightly dorso-ventrally flattened and slightly upcurved; fourth segment vestigial, knob-like. All four segments bear long and dense hairs (Figure 5a). Mandibles as in Figure 5b,c, with mandibular formula: L 1234 0 a(m1–3)b/R 1234 y a(m1–2)b with $a > b$ in both mandibles (Figure 5b,c). Maxillae: galeolacinia with seven moderately incurved teeth, three dorsal teeth nearly equal in length, four ventral teeth of different sizes, apical one largest; stipes and palp setose (Figure 5d).

Labium. Flat and not protruding when at rest (Figure 5e). Prementum–postmentum articulation reaching the posterior margin of the procoxa. Prementum subrectangular, longer than wide, in a ratio of 3:2, sides convex, convergent basally, with small teeth and minute setae at lateral margins; apical margin convex, with ventral row of 45–50 short, subquadrate reddish brown teeth, and dorsal rows of whitish piliform setae on apical border; labial palp with uniformly inflexed inner edge, yellowish brown, apical lobe reddish, rounded, internal margin arched inward, feebly serrulate. Movable hook reddish brown, sharp and moderately incurved.

Thorax. Small; prothorax narrower than head, dorsal portion raised at sides forming two mushroom-shaped ridges. Wing sheaths strongly divergent, reaching S4 (inner wing pad length 4.25 mm, outer wing pad length 3.75 mm). Legs short and stout, fore and middle legs strongly curved; protibia (length 2.0 mm) decidedly longer than profemora (length 1.25 mm); mesotibia (length 2.25 mm) slightly longer than mesofemora (length 1.75 mm); metafemur slightly longer than metatibia. Tarsal formula 2-2-3, tarsi yellowish. Rows of minute setae scattered along the femur, tibia, and tarsus of all six legs.

Abdomen. Broadly lanceolate, uniformly bright yellow, mid-dorsal black markings on S7–9. Mid-dorsal spines, absent on S1 and most prominent on S2–9, largest mid-dorsal spine on S8 (Figure 3). Lacking lateral spines on S2–5. Lateral edges of abdomen serrated, with spine projections that become more protrusive on S6–9 (Figure 3). Anal appendages elongated. Epiproct and cerci subequal in length; paraprocts longer than the other appendages (Figure 5f).

Measurements (in mm, $n = 9$): Length of total body 19.86–20.38; abdomen length 11.06–11.54; abdominal maximum width 4.90–5.08; head maximum width 4.08–4.23; length of hind femur 2.26–2.53; length of antennae third segment 1.50–1.69; length of antennae fourth segment 0.10–0.14; length of epiproct 1.26–1.44; length of cerci 1.18–1.23; length of paraprocts 1.48–1.56.

3.1.2. Taxonomy of the Adult

Material examined. THAILAND: 1 male adult (reared), Huai Khayeng stream, Thong Pha Phum district, Kanchanaburi province, 14°36′20″ N 98°34′38″ E, 206 m a.s.l., nymph collected on 14 July 2014, adult emerged on 18 February 2015, D. Chainthong leg.

In this study, we reared the *Orientogomphus* nymph until emergence of the male adult. The identification as a male adult of *O. minor* was confirmed based on Wilson [21], using the following diagnostic characters: head, pterothoracic, and caudal appendages (Figure 6a–d). A brief description of the male adult is presented based on our reared specimen following Wilson [21].

Diagnosis. Wilson [21] revised the known *Orientogomphus* specimens from northern Myanmar, China, Vietnam and Thailand as four species (*O. armatus*, *O. circularis* (Selys, 1894), *O. minor* and *O. naninus* (Förster, 1905), respectively). A distributional map has been provided by Wilson [21]. In Thailand, the adults of *O. minor* were recorded in Sakon Nakhon, Chiang Mai, Tak, Phatthalung, Krabi and Songkhla provinces [21,28,29].

Head (Figure 6a). Black with yellow markings; labrum with a pair of transverse ellipsoid yellow spots; genae black; anteclypeus yellow; postclypeus black, with a large yellow spot laterally; postfrons with a broad yellow band, antefrons black.

Thorax. Pattern of colouration as shown in Figure 6b. Prothorax black with yellow laterally; pterothorax dorsal suture with a yellow streak; mesothoracic collar yellow, except on middle; black stripe along first lateral suture disconnected to humeral, mesepimeron ventral margin yellow; legs black.

Wing. Hyaline, venation dark brown, pterostigmata very dark brown, anal triangle 4-celled with the smallest cell a well-defined rectangle; anal field 2-celled, with A2 arising from the subtriangle rather than directly from anal vein between cu-a and the subtriangle.

Abdomen. Abdomen predominantly black, with bright yellow markings; S1 mostly yellow laterally, S2 yellow around auricle, dorsal yellow spots on S2–S6, S4–S7 with dorso-

lateral yellow markings at base, S8–S9 with yellow lateral markings, epiproct black, cerci yellow outside and brownish to the proximal 2/3 and yellowish to the distal 1/3 (Figure 6c–d).

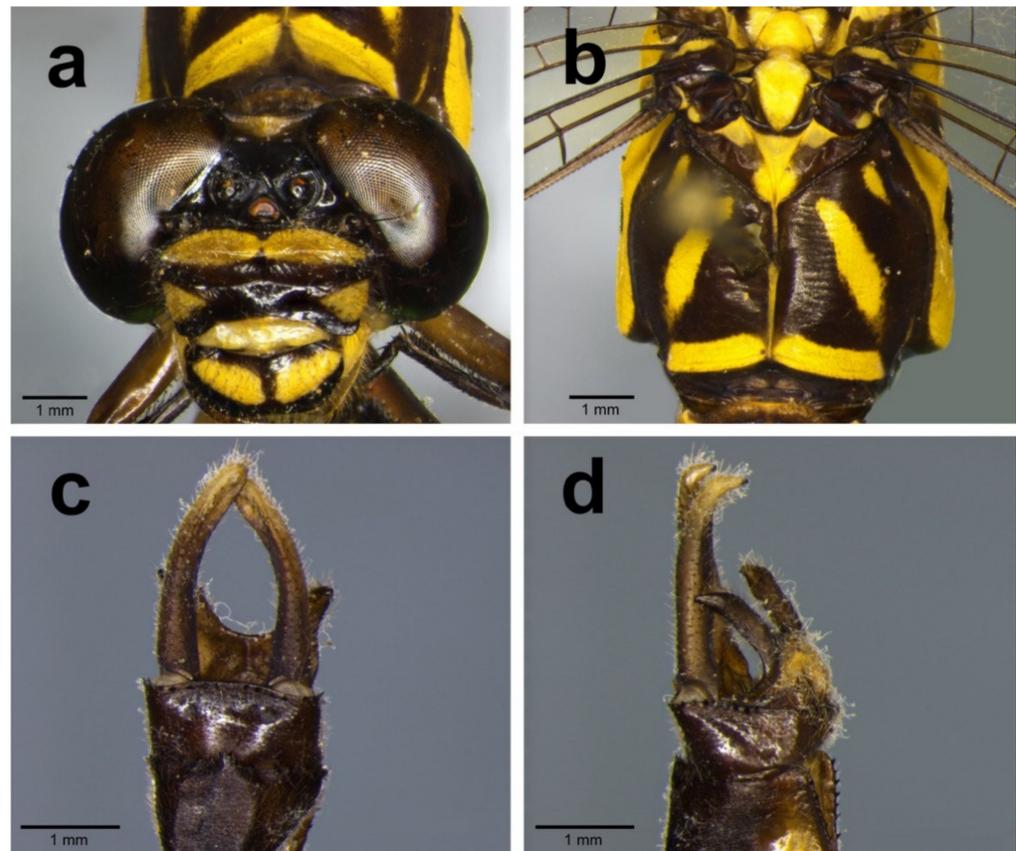


Figure 6. Morphological features of *Orientogomphus minor* adult male: (a) frontal view of head; (b) dorsal view of pterothoracic pattern; (c) dorsal view of caudal appendages; (d) lateral view of caudal appendages.

Accessory genitalia. The anterior hamulus is only slightly hooked; the posterior one does not bend caudad, but the anterior one is as high as the posterior one.

3.2. Distribution

3.2.1. Spatial Distribution of Gomphidae Species

Sixteen genera and 18 species of gomphid nymphs were found among the 28 sampling sites in eastern, western, and southern Thailand. PCA analysis revealed that most gomphid nymphs were strongly correlated with axis 1 (20% of the total variance explained). Among the gomphid species, the distribution of *O. minor* was strongly associated with the distribution of *Nychogomphus duaricus* (Fraser, 1924), *Onychogomphus louissiriusi* Fleck, 2020 and *Stylogomphus thongphaphumensis* Chainthong, Sartori & Boonsoong, 2020 (Figure 7). Those species were recorded solely in streams in the western part of Thailand.

3.2.2. Substrate Preference of *O. minor* Nymphs

A two-way cluster analysis showed two groups (I and II) of substrate types (microhabitat) and two groups (A and B) of gomphid species (Figure 8). Gomphid species (group A) *Megalogomphus sumatranus* (Krüger, 1899), *Phaenandrogomphus asthenes* Lieftinck, 1964, *Lamelligomphus castor* (Lieftinck, 1941), *Paragomphus capricornis* (Förster, 1914), *O. minor*, *Nepogomphus walli* (Fraser, 1924), *N. duaricus*, *O. louissiriusi*, *S. thongphaphumensis* and *S. malayanus* Sasamoto, 2001 were found predominantly associated with stony (pebble, gravel, and sand) substrates. In contrast, gomphid species (group B) *Heliogomphus selysi*

Fraser, 1925, *Microgomphus svihleri* (Asahina, 1969), *Gomphidia abbotti* Williamson, 1907, *Gomphidictinus perakensis* (Laidlaw, 1902), *Burmagomphus williamsoni* Förster, 1914, *B. divaricatus* Lieftinck, 1964, *Merogomphus paviei* Martin, 1904 and *Macrogomphus kerri* Fraser, 1932 were associated with litter (pool/marginal) and mud substrate types. The nymphs of *O. minor* were found in a substrate with mixture of sand and gravel, together with *P. asthenes*, *L. castor*, *P. capricornis*, *N. walli*, *N. duaricus* and *O. louissiriusi*.

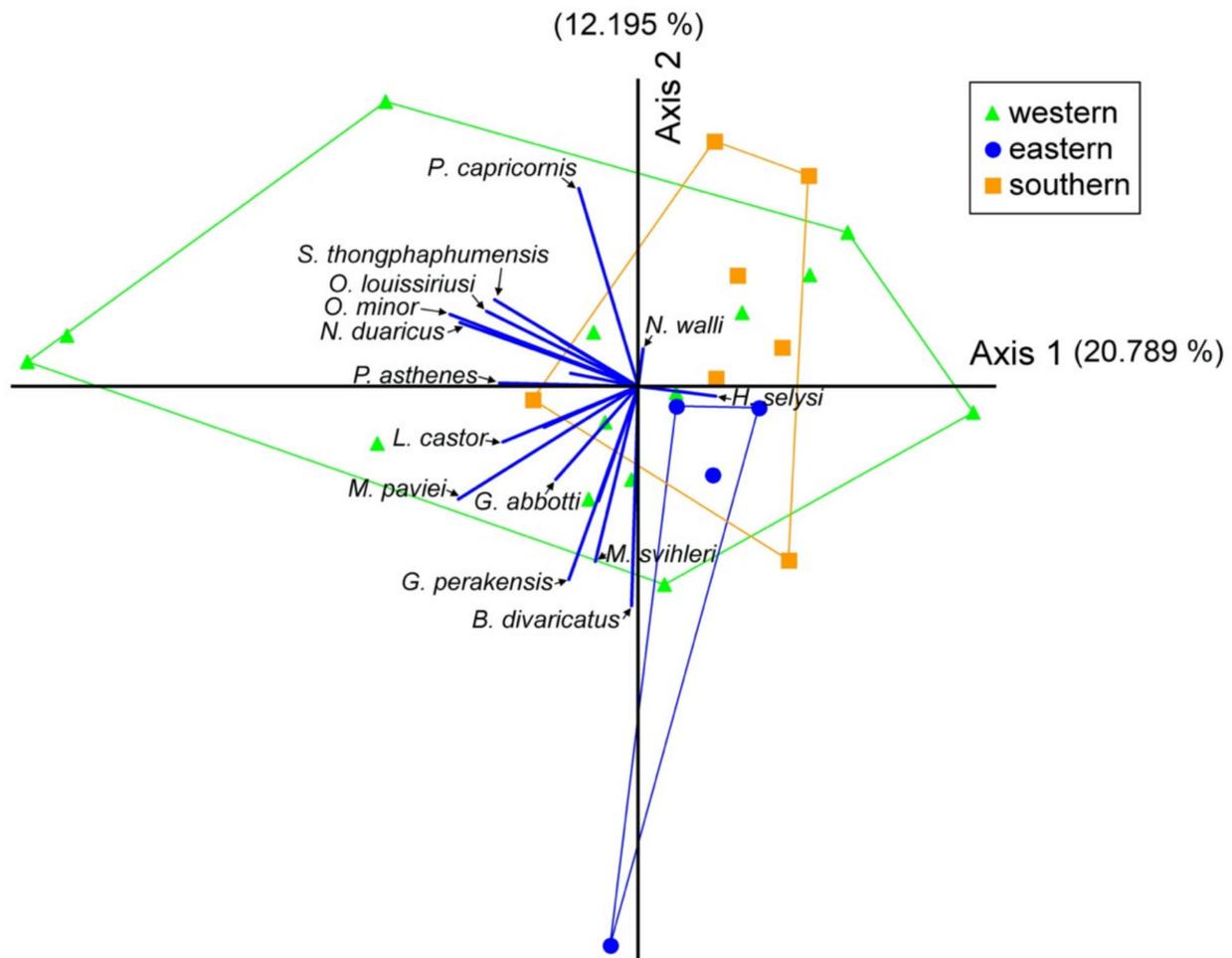


Figure 7. Principal component analysis (PCA) ordination biplots with sample and species scores of Gomphidae species (vectors of *S. thongphaphumensis*, *O. louissiriusi* and *N. duaricus* are related to *O. minor*). Percentages of variance explained on the first two axes are indicated.

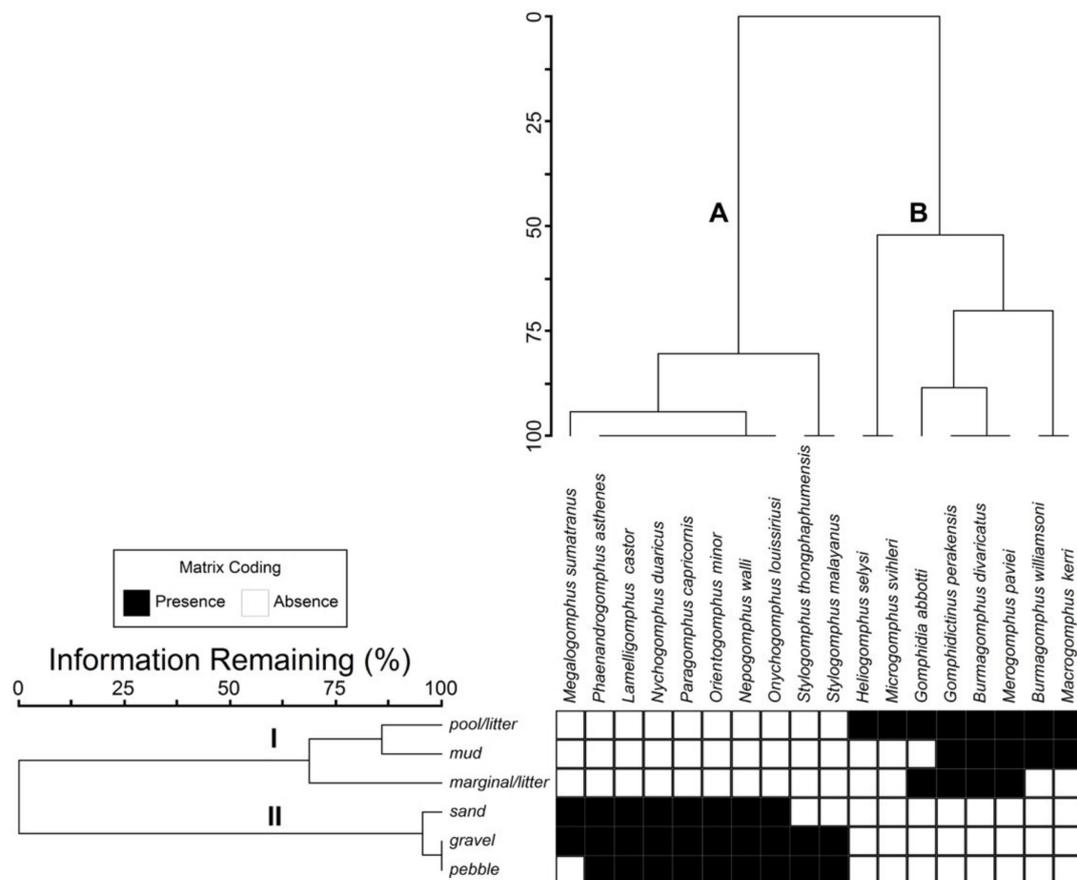


Figure 8. Two-way cluster analysis dendrogram of six microhabitats and 18 Gomphidae species. The two groups (I and II) of microhabitats and the two groups (A and B) of Gomphidae species are indicated.

4. Discussion

Based on the description of the nymph of *Amphigomphus hansonii* Chao, 1954 by Xu [30] and comparison with the nymphs of *Nihonogomphus lieftincki* Chao, 1954 and *O. armatus*, Xu [30] concluded that the nymphal morphological characters of the genus *Amphigomphus* are closer to those of *Orientogomphus* than of *Nihonogomphus*. Therefore, we selected two species of the genus *Amphigomphus* for comparison in this study. The evidence afforded by the characters of four gomphid nymphs species listed in Table 1 shows that the nymphs of *O. minor* can be distinguished from those of the other three species by a front margin of the median lobe furnished with about 50 finger-shaped serrations and the presence of lateral spines on S6–9. We also found that the *O. minor* nymph is similar to the *O. armatus* nymph only in the prementum length-to-width ratio, wing length, and mid-dorsal spines on the abdomen. The nymphs of *O. minor* share similarities with *Amphigomphus* nymphs in terms of wing pad length, mid-dorsal position on the abdomen and the shape of the third antennal segment [18,30].

We showed that *O. minor* nymphs were distributed in the western streams of Thailand and associated with other gomphid species (*N. duaricus*, *O. louissiri* and *S. thongphaphumensis*), which are restricted in their geographic distributions [10,11,16]. The nymphs of *O. minor* were usually found together with those of *Lamelligomphus*, *Nepogomphus*, *Onychogomphus*, *Paragomphus* and *Phaenandrogomphus*. These nymphs burrow deeply into the pebble, gravel, and sand substrates in streams. The nymphal microhabitat preference varies for Gomphidae [6], resulting in related morphological adaptations (e.g., burrowers in sand and mud (*Anisogomphus*, *Burmagomphus* and *Onychogomphus*) and in detritus accumulations (*Heliogomphus* and *Microgomphus*)).

Table 1. Comparison of morphological characters of four gomphid species (two *Orientogomphus* and two *Amphigomphus*, modified from [18,30]).

Characters/Species	<i>O. minor</i>	<i>O. armatus</i>	<i>A. somnuki</i> Hämäläinen, 1996	<i>A. hansonii</i>
Third antennal segment of nymph	slender, stick-shaped, longer than antennal S1 + 2	spindle-shaped, shorter than antennal S1 + 2	cylindrical, parallel-sided, longer than antennal S1 + 2	stick-shaped, longer than antennal S1 + 2
Prementum length-to-width ratio	about 3:2	about 3:2	about 1:0.83	about 3:2
Front margin of median lobe	furnished with about 50 finger-shaped serrations	furnished with about 60 finger-shaped serrations	furnished with about 27 or 28 small teeth	furnished with about 40 finger-shaped serrations
Wing pads length	strongly divergent, reaching middle of S4	strongly divergent, reaching middle of S4	reaching basal half and posterior margin of S4,	strongly divergent, reaching middle of S4
Mid-dorsal spines on abdomen	present on S2–9	present on S2–9	present on S2–9	present on S2–9
Lateral spines on abdomen	present on S6–9	present on S7–9	present on S7–9	present on S7–9

Anthropogenic threats, such as deforestation, erosion, riparian vegetation removal, channelisation, and flow regulation, have effects on macroinvertebrate communities, including the odonate species composition [6]. Disturbance of the forest status is causing a decline in dragonfly species diversity, community composition, and structure [31]. The spatial distribution is influenced mainly by the presence of coarse detritus and by sediment particle size [32]. Removal of riparian vegetation also has a strong effect on odonate species composition and is associated with the loss of some species (*Dicterias atrosanguinea* Selys, 1853 and *Chalcopteryx scintillans* McLachlan, 1870) in Amazonia [33]. In Thailand, the need of protecting rivers and streams is increasing due to increasing human activities. For example, alterations in water flow by damming have affected the characteristics of stream ecosystems, resulting in altered microhabitats, water flows, and even changes from running water to standing water. The changes in microhabitat composition due to check dams also affect the community of dragonflies by changing the types and numbers of prey species, thereby affecting the food chain [34]. Therefore, knowledge of the microhabitat preferences of gomphid genera, which contain one or a few species (e.g., *Amphigomphus*, *Anisogomphus*, *Asahinagomphus*, *Asiagomphus*, *Davidius*, *Ethygomphus*, *Heliogomphus*, *Mattigomphus*, *Nihonogomphus*, *Siebodius*, *Stylogomphus*, *Sinictiogomphus*) can provide insight into the conservation issues of gomphid dragonfly nymphs in Thailand.

5. Conclusions

The taxonomic characteristics of *O. minor* are presented, and the nymph is described and illustrated for the first time from a reared specimen collected in streams of western Thailand. Morphological characteristics and distribution of *Orientogomphus* nymphs were discussed and compared to the related species and genera. The geographic distribution of *O. minor* is restricted to the western streams of Thailand and is associated with several other gomphid species with restricted distribution in the country (i.e., *N. duaricus*, *O. louissiriusi* and *S. thongphaphumensis*). Nymphs of the studied species burrow deeply into the pebble, gravel, and sandy substrates in streams.

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Conflicts of Interest: The authors declare no conflict of interest.

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