

Species composition of Sididae (Branchiopoda: Cladocera) in Vientiane Province and Vientiane City, Laos

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ABSTRACT: The species composition of the Sididae (Branchiopoda: Cladocera) of Laos (Vientiane Province and Vientiane City) was studied, based on 52 samples from 28 localities. Five species were recorded, with the genus *Diaphanosoma* represented by three. Two other genera, *Pseudosida* and *Sida*, had one species each (*Pseudosida szalayi* Daday, 1898 and *Sida* cf. *americana* Korovchinsky, 1979). The latter taxon, probably invasive, is new to Laos and to South-East Asia. In most cases two species of Sididae co-occurred but in eight localities combinations of three and four species were seen.

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KEY WORDS: Cladocera, Sididae, species composition, Laos, South-East Asia.

Видовой состав семейства Sididae (Branchiopoda: Cladocera) в провинции Вьентьян и городе Вьентьян, Лаос

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РЕЗЮМЕ: Впервые, на основании обработки 52 проб, собранных в 28 местонахождениях, подробно исследован видовой состав представителей семейства Sididae центрального района Лаоса (провинция Вьентьян и город Вьентьян). В целом обнаружено пять видов семейства, род *Diaphanosoma* был представлен тремя видами. Два других рода, *Pseudosida* и *Sida*, были представлены одним видом каждый (*P. szalayi* Daday, 1898 и *S. cf. americana* Korovchinsky, 1979, соответственно). Последний таксон, вероятно инвазивный, отмечен как новый для лаосской фауны, а также

и для Юго-Восточной Азии в целом. В большинстве случаев было отмечено сосуществование двух видов Sididae, но в восьми местонахождениях найдено вместе по три или четыре вида.

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КЛЮЧЕВЫЕ СЛОВА: Cladocera, Sididae, видовой состав, Лаос, Юго-Восточная Азия.

Introduction

Cladocera are freshwater microcrustaceans, monophyletic (Martin, Cash-Clark, 1995; Richter *et al.*, 2007), and an important component of aquatic ecosystems. They predominantly inhabit continental water bodies of different types all over the world and are especially abundant in stagnant waters (Dumont, Negrea, 2002; Forró *et al.*, 2008). They represent four orders of the Branchiopoda, one of which, the Ctenopoda, is dealt with here.

One family, the Sididae is widely distributed and is most diverse and abundant in tropical, subtropical, and southern temperate latitudes. It is present though less dominant in all climatic zones, and on all continents save Antarctica. Its representatives (e.g., *Sida* spp., *Diaphanosoma* spp.) often dominate the pelagic and littoral zooplankton communities. Analysis of novel information reveals that the world fauna of the family Sididae currently includes 64 valid taxa of at the species-group level (Korovchinsky, 2018).

Laos is one of the least explored countries of South-East Asia in respect of its Cladocera fauna (Korovchinsky, 2013). Heckman (1974) published the first faunistic list, that included seven species, of which only one, *Latonopsis australis* Sars, 1888, was of a Sididae family. In the 2000s, two faunistic reports were made but remained unpublished (see Kotov *et al.*, 2013). The next species record concerned the species *Diaphanosoma senegal isanensis* Korovchinsky et Sanoamuang, 2008, found in the southern Champasak Province of Laos (Korovchinsky, Sanoamuang, 2013). The most comprehensive

publication on Laotian Cladocera (Kotov *et al.*, 2013), prepared recently by the international research team cited 70 species, five of which were Sididae.

The present investigation focuses exclusively on the Sididae, which are sometimes especially numerous and play a significant role in both pelagic and littoral tropical freshwater communities (Korovchinsky, Sanoamuang, 2008, 2013). They were poorly surveyed in previous studies. Our aim here is to revise the Sididae of the central part of Laos (Vientiane Province and Vientiane City) based on an abundant material collected in water bodies of various types.

Study area, material and methods

Laos is a tropical country situated in South-East Asia that borders with China, Cambodia, Thailand, Myanmar, and Vietnam (Fig. 1). Samples were collected in the central part of the country (Vientiane Province and Vientiane City) (Fig. 2) where plenty of various water bodies are located. Each locality was abbreviated either VTP (Vientiane Province) or VTC (Vientiane City). Samples were collected qualitatively from February to April 2013 and from November to December 2014 using 60 µm plankton net from 28 localities. In total, 52 samples have been taken in the following water bodies of different types:

Large permanent water bodies with well-developed vegetation

1) VTC08, lake with abundant vegetation, Nakhanthoung village, 18.16056° N; 102.46187° E.

2) VTC09, large swamp, Nong Ngom, 18.13602° N; 102.49417° E.



Fig. 1. A map of Laos and neighboring countries of South-East Asia (the area of Vientiane Province and Vientiane City is highlighted).

Рис. 1. Карта Лаоса и соседних стран Юго-Восточной Азии (район провинции Вьентьян и города Вьентьян выделен).

3) VTC15, large lake, Nong Xeum, 18.07085° N; 102.39270° E.

4) VTC19, large irrigation reservoir, Nam Xuang, 18.14777° N; 102.27825° E.

5) VTP50, large swamp, Bankeun village, 18.21894° N; 102.37953° E.

6) VTC58, irrigation reservoir, Num Houm, 18.10414° N; 102.27945° E.

Small semi-permanent water bodies without abundant vegetation

7) VTC10, roadside channel, Nakhanthoung village 2, 18.15053° N; 102.48021° E.

8) VTC11, roadside channel, Nakhanthoung village 3, 18.15710° N; 102.46670° E.

9) VTP12, roadside channel, Haiyon village, 18.17266° N; 102.40641° E.

10) VTC16, roadside channel, Phonehaikham village, 18.14338° N; 102.41477° E.

11) VTC18, small irrigation dam, Phonexay village, 18.14924° N; 102.27979° E.

12) VTP43, roadside channel, Phonehong village, 18.27715° N; 102.24557° E.

13) VTP44, roadside channel, way to Hin Pa Pha waterfall, 18.17006° N; 102.44260° E.



Fig. 2. Map of sampling sites in Vientiane province (VTP) and Vientiane City (VTC).

Рис. 2. Карта места сбора материала в провинции Вьентьян (VTP) и в городе Вьентьян (VTC).

14) VTP46, roadside channel, Phonsavath village, 18.21791° N; 102.36359° E.

15) VTP49, roadside channel, Park hang village, 18.20009° N; 102.39793° E.

16) VTC54, roadside channel, Thong Mung village, 18.14310° N; 102.41485° E.

17) VTC55, roadside channel, Sikerud village, 18.02112° N; 102.32847° E.

Temporary pond and pools

18) VTP14, large temporary pool with abundant vegetation, Koudsambad village, 18.15710° N; 102.46670° E.

19) VTP51, pond, road to Mum Mung Dam, 18.20431° N; 102.41981° E.

20) VTC20, rock pool near a small artificial Nam Xuang water fall, 18.14501° N; 102.28240° E.

Forest streams and rivers

21) VTP01, small slowly flowing river without abundant vegetation (Namcheng River), 18.25667° N; 102.27699° E.

22) VTP03, small slowly flowing forest stream, 18.21624° N; 102.41466° E.

23) VTP04, large slowly flowing river with abundant vegetation (Nam Mang 1), 18.20691° N; 102.46457° E.

24) VTP05, large slowly flowing river with abundant vegetation (Nam Mang 2), 18.20439° N; 102.41980° E.

25) VTP06, river under the bridge on the road to Nam Mang Dam 3, 18.20439° N; 102.41980° E.

26) VTP13, small river with abundant vegetation, Napheng bridge, 18.19556° N; 102.40060° E.

27) VTP17, small Nam Phanai river with poor vegetation, 18.22937° N; 102.25486° E.

28) VTP52, small forest stream, Vang Heua village, 18.21100° N; 102.48908° E.

Environmental variables (water temperature, pH, conductivity, TDS) were measured in parallel. Samples were taken three times at each locality, including littoral and pelagic areas, and preserved by formaldehyde (4%). The taxonomic analysis was conducted at the Applied Taxonomic Research Center (Khon Kaen

Table 1. Species of Sididae found in Laos and their localities.
Таблица 1. Виды Sididae, найденные в Лаосе, и их местонахождения.

Taxa	Localities
<i>Diaphanosoma dubium</i> Manuilova, 1964	VTP01, VTP14, VTC15, VTP17, VTC20, VTP49, VTP51, VTC54
<i>Diaphanosoma excisum</i> Sars, 1885	VTP01, VTP03, VTP05, VTP06, VTC08, VTC10, VTC11, VTP12, VTP14, VTC15, VTC16, VTP17, VTC18, VTC20, VTP43, VTP44, VTP46, VTP51, VTP52, VTC54, VTC58
<i>Diaphanosoma sarsi</i> Richard, 1894	VTP01, VTP03, VTP04, VTC09, VTC10, VTC11, VTP12, VTP13, VTC15, VTC16, VTP17, VTC19, VTC20, VTP43, VTP46, VTP50, VTC55
<i>Pseudosida szalayi</i> (Daday, 1898)	VTC08, VTC16, VTP50, VTC55
<i>Sida</i> cf. <i>americana</i> Korovchinsky, 1979*	VTP01, VTP06, VTC08, VTP12, VTP13, VTP14, VTC16, VTP17, VTP44

Remarks: *new species to Laos; VTP — Vientiane province; VTC — Vientiane City.

University, Thailand). Figures were prepared using an Olympus CHD compound microscope with *camera lucida*. One species, *Sida* cf. *americana*, was studied in more detail with body parts measurements according to Korovchinsky (2004).

Results

Species richness and frequency distribution. In total, five species of the family Sididae have been found (Table 1); members of the genus *Diaphanosoma* Fischer, 1850 were most numerous being represented by three species.

Other two genera, *Pseudosida* Herrick, 1884 and *Sida* Straus, 1820 were represented by one species each: *P. szalayi* Daday, 1898 and *S. cf. americana* Korovchinsky, 1979. The latter was a new species to Laos fauna.

The frequency distributions of particular species is shown in Fig. 3. The most frequently encountered species always was *D. excisum* Sars, 1885, found in 75% of all localities. It was followed by *D. sarsi* Richard, 1894 (60.7%), *S. cf. americana* (32.1%), and *D. dubium* Manuilova, 1964 (28.6%). *P. szalayi* was rarest being found in 14.3% of localities.

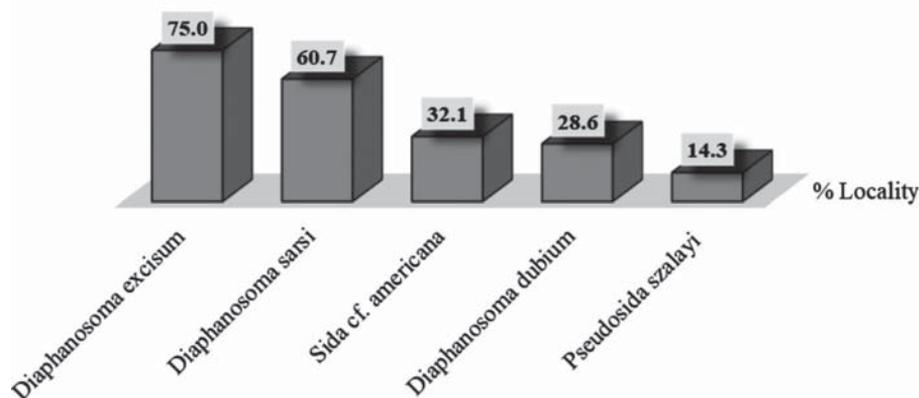


Fig. 3. The frequency distribution of Sididae species in studied area.

Рис.3. Частота встречаемости видов Sididae в исследованном районе.

Table 2. Measurement of body parts' proportions of adult females of *Sida cf. americana* (n=20) (in each column from top to down: Range, Mean, and SD).

Таблица 2. Измерения пропорций частей тела взрослых самок *Sida cf. americana* (n=20) (в каждой колонке сверху вниз: интервал значений, среднее арифметическое, среднее квадратичное отклонение).

HL: BL (%)	HH: BL (%)	DE: BL (%)	LSA: BL (%)	BaL: LSA (%)	LUAB: LSA (%)	LLAB:LSA (%)
27.8–42.8	21.6–39.7	7.1–10.3	44.5–64.3	43.9–58.3	47.5–54.9	47.5–55.0
37.5	29.2	8.6	57.6	53.0	51.1	51.1
5.5	6.0	1.2	6.5	3.8	2.5	2.5

BL — body length, HL — head length, HH — head height, DE — diameter of eye, LSA — length of swimming antennae, BaL — length of antennal basipodite, LUAB — length of upper antennal branch, LLAB — length of lower antennal branch.

Table 3. Type of water bodies and environmental variables at which Sididae species were found.

Таблица 3. Типы водоемов и параметры среды, при которых были найдены виды Sididae.

Species	Types of water body	pH	Conductivity (µS)	TDS (ppm)	Temperature (°C)
<i>Diaphanosoma dubium</i>	rivers, lake, roadside channels, swamp, pond, rock pool, temporary pool	5.8–8.7	4–201	2–74	21.3–34.9
<i>D. excisum</i>	lakes, rivers, streams, reservoirs, roadside channels, pond, temporary pool, rock pool	6.1–8.7	34–201	16–71	27.8–34.9
<i>D. sarsi</i>	rivers, stream, swamps, roadside channels, pond, reservoir, rock pool	5.6–7.2	6–489	2–249	21.3–43.1
<i>Pseudosida szalayi</i>	swamp, heavily vegetated lake, roadside channels	6.4–6.9	14–498	7–249	28.6–31.6
<i>Sida cf. americana</i>	rivers, lake, roadside channels, temporary pool	5.8–7.2	10–125	5–57	24.4–33.7

Notes on particular species. Data on water bodies and environmental variables for each species are shown in Table 3.

1) *Diaphanosoma dubium* (Figs 4, 5). This species is characterized by a large, dorsally protruding head with eye shifted ventrally, thin, hardly visible seta on distal basipodital outer end of swimming antennae, postero-ventral valve margin with a row of usually 12–29 slightly

curved denticles and a number of setules between them, absence of inner dorsal thorn(s) near posterior valve margin, and postabdomen usually prominent dorsally (see Korovchinsky (2018) for more details). It was found in a lake, rivers, swamp, roadside channels, pond, rock pool and ones especially abundantly in a temporary pool. In rainy season, the latter one turns into a large swamp surrounded by rice fields.

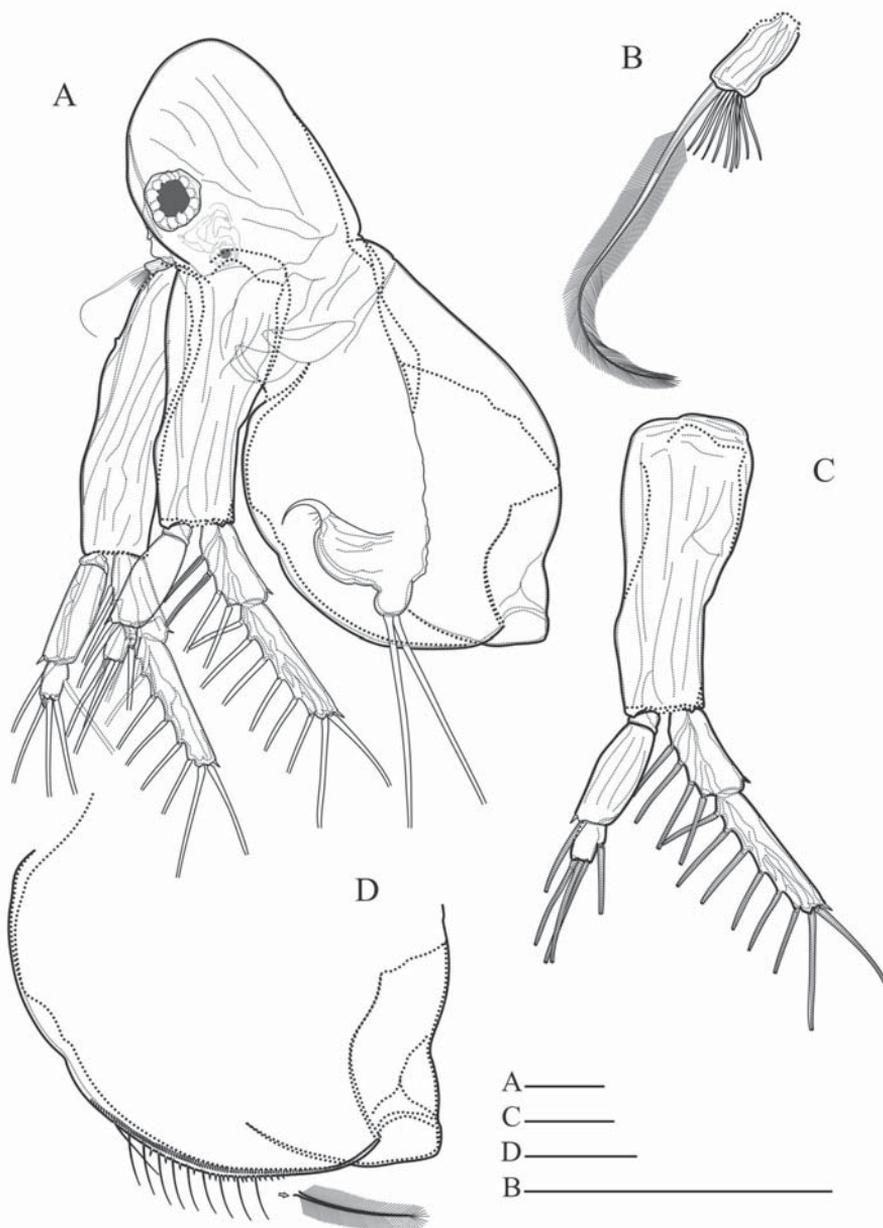


Fig. 4. *Diaphanosoma dubium* Manuilova, 1964, ♀ (VTP14): A — general lateral view; B — antennula; C — swimming antenna, lateral view; D — shell valve, outer side. Scale bars: 0.05 mm.

Рис. 4. *Diaphanosoma dubium* Manuilova, 1964, ♀ (VTP14): A — общий вид сбоку; B — антеннула; C — плавательная антенна, вид сбоку; D — створка раковинки с внешней стороны. Масштаб: 0,05 мм.

2) *Diaphanosoma excisum*. This species is characterized by a relatively large rectangular head with a fairly large dorsal part and eye situated closer to its anterior-ventral side, pres-

ence of a sharp spine on distal basipodital outer end of swimming antennae, rather wide flap gradually tapering distally without depression, 4–18 large, sharp denticles without setules be-

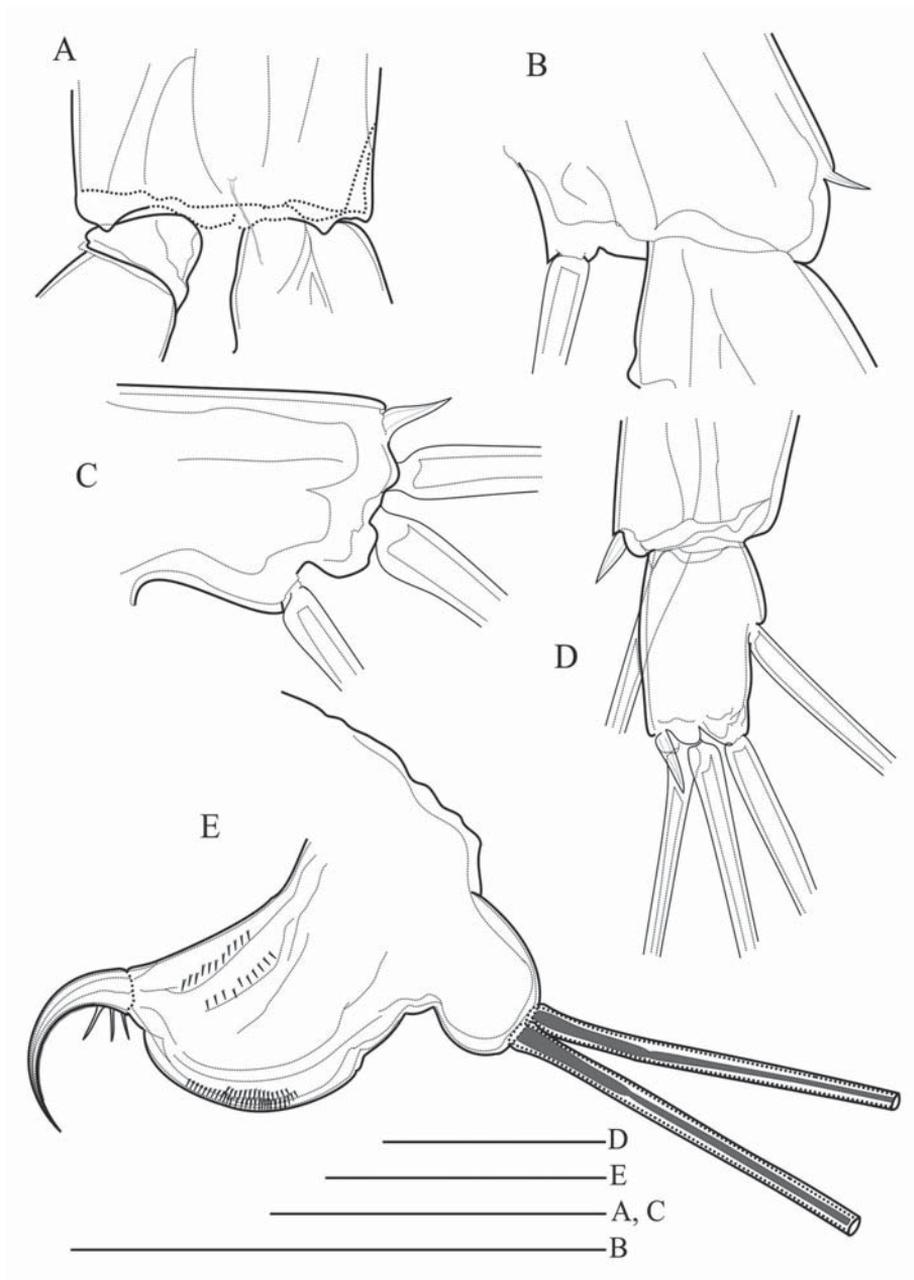


Fig. 5. *Diaphanosoma dubium* Manuilova, 1964, ♀ (VTP14): A — distal part of basipodite of swimming antenna, outer view; B — distal part of first segment of upper antennal branch; C — distal part of second segment of upper antennal branch; D — distal part of lower 3-segmented antennal branch; E — postabdomen, lateral view. Scale bars: 0.05 mm.

Рис. 5. *Diaphanosoma dubium* Manuilova, 1964, ♀ (VTP14): A — дистальная часть плавательной антенны, вид сбоку; B — дистальная часть первого членика верхней ветви антенны; C — дистальная часть второго членика верхней ветви антенны; D — дистальная часть нижней ветви антенны; E — постабдомен, вид сбоку. Масштаб: 0,05 мм.

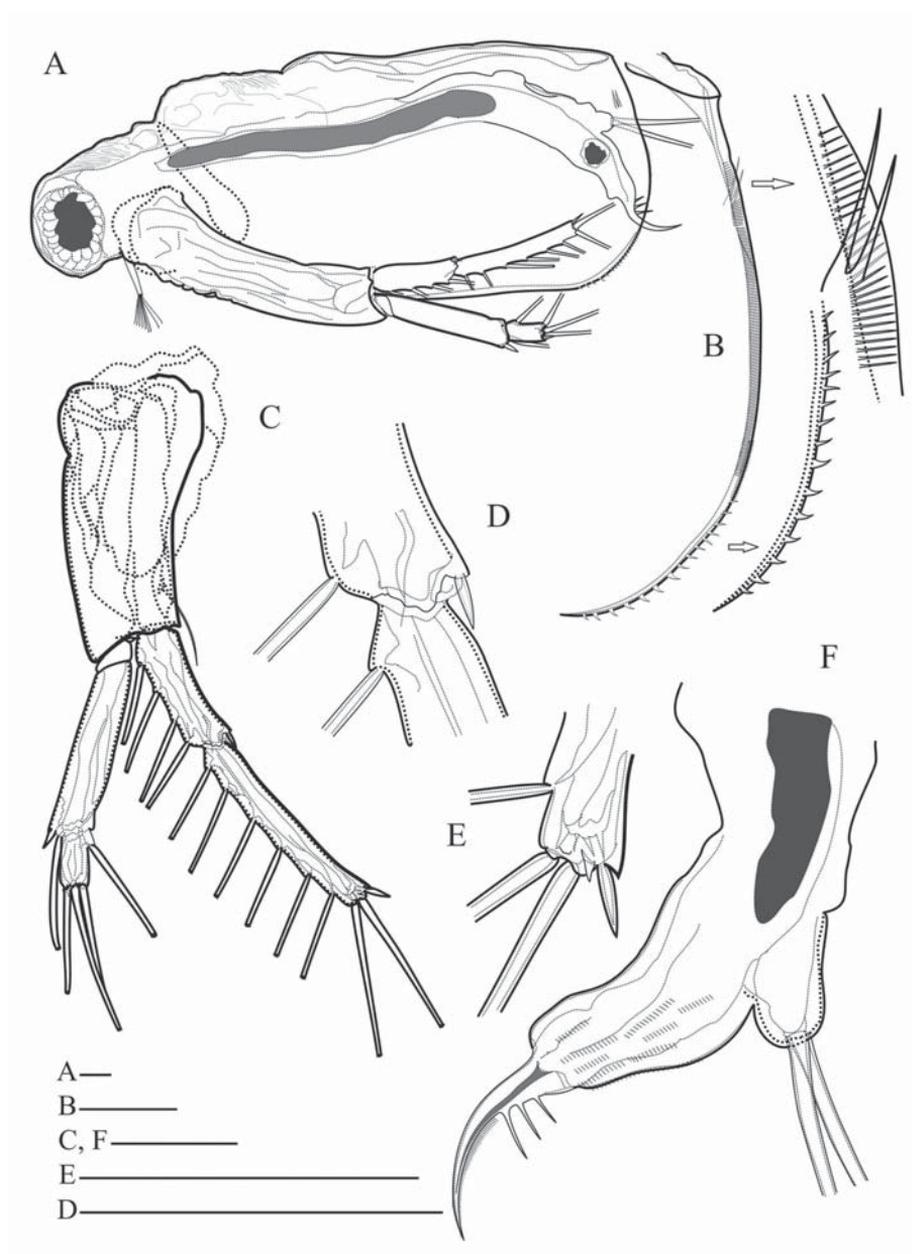


Fig. 6. *Diaphanosoma sarsi* Richard, 1894, ♀ (VTP09): A — general lateral view; B — postero-ventral valve margin and denticles near posterior valve margin; C — swimming antenna, lateral view; D — distal part of first segment of upper antennal branch; E — apical end of upper antennal branch; F — postabdomen, lateral view. Scale bars: 0.025 mm.

Рис. 6. *Diaphanosoma sarsi* Richard, 1894, ♀ (VTP09): A — общий вид сбоку; B — задне-нижний край створки и шипики у заднего края створки; C — плавательная антенна, вид сбоку; D — дистальная часть первого членика верхней ветви антенны; E — апикальный конец верхней ветви антенны; F — постабдомен, вид сбоку. Масштаб: 0,025 мм.

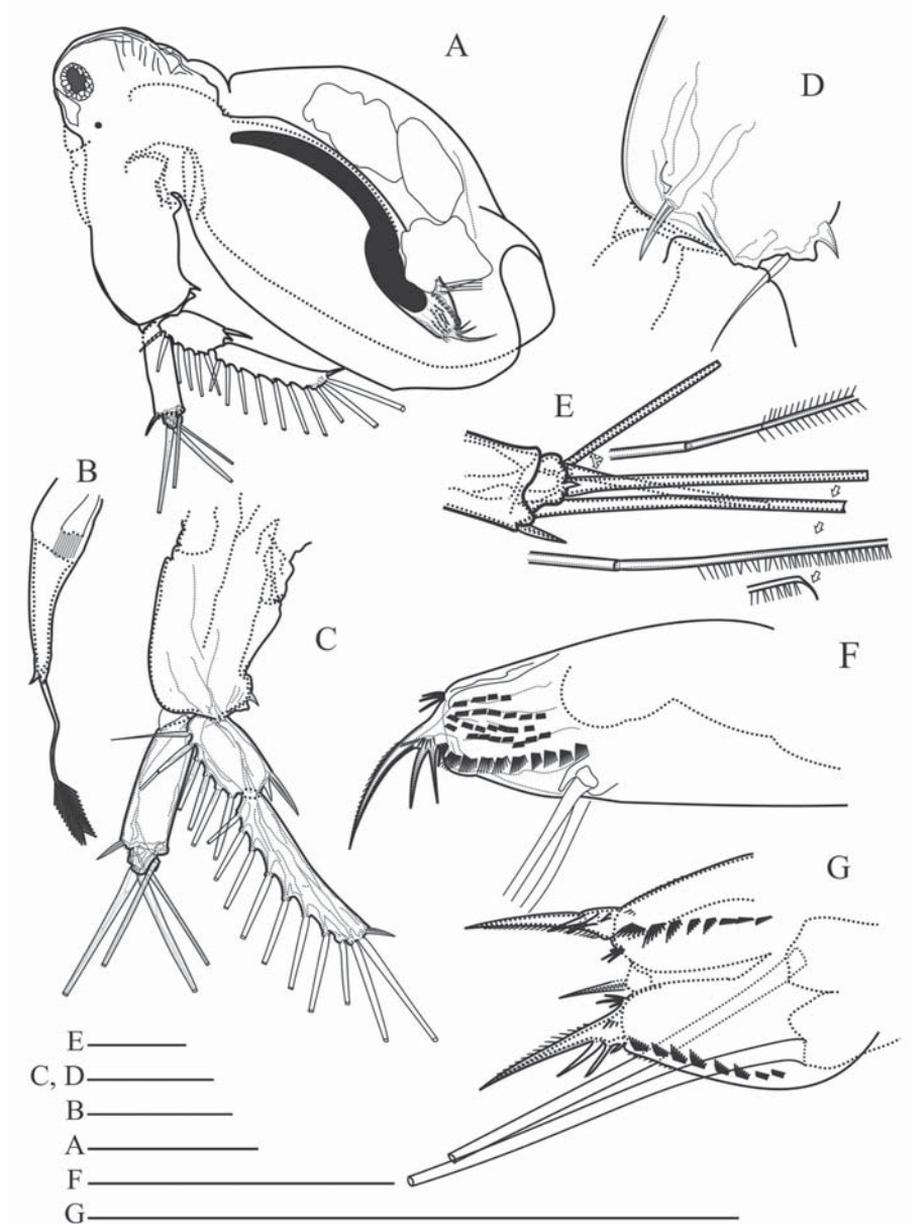


Fig. 7. *Pseudosida szalayai* (Daday, 1898), ♀ (VTP55) (A, B, C, D, E) and VTP54 (F, G): A — general lateral view; B — antennula; C — swimming antenna; D — distal outer end of antennal basipodite; E — distal part of lower antennal branch and armament of distal setae; F — postabdomen, dorsal view. Scale bars: 0.05 mm.

Рис. 7. *Pseudosida szalayai* (Daday, 1898), ♀ (VTP55) (A, B, C, D, E) и VTP54 (F, G): A — общий вид сбоку; B — антеннула; C — плавательная антенна; D — дистальный конец базиподита плавательной антенны с внешней стороны; E — дистальный членик нижней ветви плавательной антенны и вооружение дистальных щетинок; F — постабдомен, вид сбоку; G — дистальный конец постабдомена, вид с дорсальной стороны. Масштаб: 0,05 мм.

tween them on postero-ventral valve margins, and two inner dorsal thorns on posterior valve margins (see Korovchinsky (2018) for more details). It was distributed especially broadly inhabiting almost all types of studied water bodies.

3) *Diaphanosoma sarsi* (Fig. 6). This species is characterized by a round-rectangular head with large eye, ventral flap-shaped inflexion of valves with a rather narrow cut near its junction with the postero-ventral margin, so that the roundish distal part of the ventral valve inflexion hardly projects backwards, and postero-ventral valve margins with a row of usually 16–28 small denticles diminishing dorsally (see Korovchinsky (2018) for more details). The representatives of the species have been found in various types of water bodies such as a large lake, large swamp, rivers, forest stream, roadside channels, reservoir, pond and a rock pool.

4) *Pseudosida szalayii* (Fig. 7). It is characterized by a rounded head with eye situated frontally. Swimming antennae long with massive basipodite, their upper branch bears numerous setae whereas lower branch always bears four setae two distal of which are especially long, massive, and having hooked ends. Postabdomen with prominent terminal outgrowth between base of claws, its anal teeth are grouped in 10–12 clusters, postabdominal claws with three basal spines, the proximal of which is much smaller than others (see Korovchinsky (2018) for more details). This species was found in a large swamp, heavily vegetated lake, and in roadside channels.

5) *Sida cf. americana* (Fig. 8). The body measurements of 20 adult parthenogenetic females are shown in Table 2. Head large, oblong-oval with anchoring dorsal organ and rostrum (Fig. 8A, B). Rostrum is relatively long and straight with tip directed backwards. Eye large situated close to ventral side of head. Both branches of swimming antennae (Fig. 8D) consist of three segments. Shell rectangular with small denticles of different size along ventral valve margins (Fig. 8G). Postabdomen with long, slightly curved row of anal teeth gradually decreasing in size proximally. Terminal claws

with four basal spines the proximal of which is rather large (Fig. 8H, I). Proximal part of postabdomen's dorsum is strongly prominent. The species was found in rivers, lake, roadside channels, and in a temporary pool.

The features of the Laotian specimens are largely consistent with the diagnosis of the species but proximal spine of their postabdominal claws is unusually large, amounting about two-thirds of the length of the neighboring spine. For this reason, the taxonomic status of these specimens requires further clarification.

The pairwise co-occurrence of Sididae

Monospecific occurrences of Sididae species were observed in few localities (8), most of them (7) were occupied by *D. excisum* and *D. sarsi* and one by *D. dubium* (Table 4). It is clear from the table that the most common species (*D. excisum*, *D. dubium*, *D. sarsi*, *S. cf. americana*) especially often co-occurred. Comparatively rare species (*S. cf. americana*, *P. szalayii*) have never been found alone. All this probably suggests mostly random character of distribution of such common eurytopic species.

In most cases (12) two species of Sididae co-occurred but in eight localities combinations of three and four species were seen (Table 5). Again, the most common species (*D. excisum*, *D. sarsi*, *S. cf. americana*) were especially prominent. Among others, the *Diaphanosoma* species, close in their space partitioning and ecology, formed three-species assemblages in four localities.

Discussion

In a comprehensive publication on Laotian Cladocera (Kotov *et al.* 2013), five Sididae have been recorded: *Diaphanosoma dubium*, *D. excisum*, *D. sarsi*, *Latonopsis australis* s.l., and *Pseudosida szalayii*. Here, we encountered the same species except *L. australis* s.l. *S. cf. americana* represents new genus and species for the country and even for all South-East Asia in general. In larger scale, this is the first record of the species on the Eurasian continent! Before, the identification of the representatives of

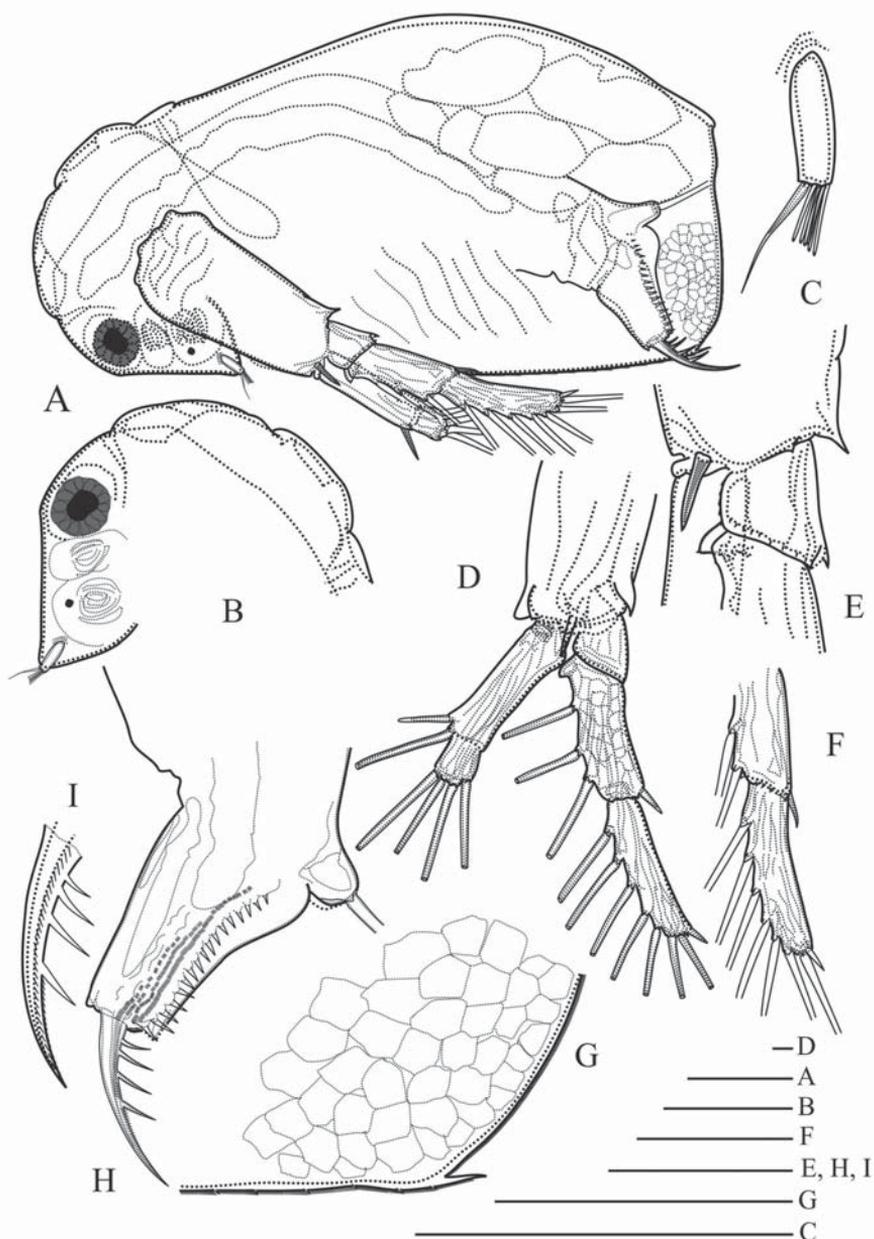


Fig. 8. *Sida* cf. *americana* Korovchinsky, 1979, ♀ (VTP13): A — general lateral view; B — head, lateral view; C — antennula; D — swimming antenna; E — distal part of antennal basipodite and proximal part of upper branch, outer side; F — second segment of upper antennal branch; G — postero-ventral portion of shell valve; H — postabdomen, lateral view; I — postabdominal claw. Scale bars: 0.05 mm.

Рис. 8. *Sida* cf. *americana* Korovchinsky, 1979, ♀ (VTP13): А — общий вид сбоку; В — голова с боковой стороны; С — антеннула; D — плавательная антенна; E — дистальная часть базиподита антенны и проксимальная часть верхней ветви с внешней стороны; F — второй членик верхней ветви плавательной антенны; G — задне-нижняя часть створки раковинки; H — постабдомен, вид сбоку; I — коготок постабдомена. Масштаб: 0,05 мм.

Table 4. Matrix of pairwise co-occurrence of Sididae species (cells with the number of monospecific occurrences are shaded).

Таблица 4. Матрица попарного сосуществования видов Sididae (ячейки с присутствием одного вида затушеваны).

Species	<i>D. dubium</i>	<i>D. excisum</i>	<i>D. sarsi</i>	<i>P. szalay</i>	<i>S. cf. americana</i>
<i>D. dubium</i>	1	7	4	0	3
<i>D. excisum</i>	7	4	7	2	5
<i>D. sarsi</i>	4	7	3	2	1
<i>P. szalay</i>	0	2	2	0	1
<i>S. cf. americana</i>	3	5	1	1	0

Table 5. Co-occurrence of three-four species of Sididae.

Таблица 5. Примеры сосуществования трех-четырех видов Sididae.

<i>D. excisum</i>	<i>D. dubium</i>	<i>D. sarsi</i>	<i>P. szalay</i>	<i>S. cf. americana</i>	No. of species	No. of localities
X		X		X	3	1
X			X	X	3	1
X	X			X	3	1
X	X	X			3	2
X	X	X		X	4	2
X		X	X	X	4	1

the genus in South-East Asia was mostly generalized (“*Sida crystallina*”) (e.g., Shirota, 1966; Tanaka, Ohtaka, 2010), only later they were specified as *S. ortiva* Korovchinsky, 1979 (= *S. crystallina ortiva* Korovchinsky, 1979) (Korovchinsky, Sanoamuang, 2008; Korovchinsky, 2013). This species is widely distributed all over Eastern Asia and readily penetrates South-East Asia, especially along the Mekong River basin (Korovchinsky, Sanoamuang, 2008). The unexpected presences of *Sida cf. americana* in Laos can be provisionally evaluated as species invasion which might have occurred during the military conflicts in the country in 1960–1970s. The taxon *Sida americana* Korovchinsky, 1979 remains poorly understood, its representatives in Laos require verification, especially their morphological difference from typical American specimens. The lack of the native species, *S. ortiva*, in the samples remains unclear.

Other species, *D. excisum*, *D. sarsi*, *P. szalay*, found in Vientiane City and in its vicinity during present investigation are common tropical species widely distributed in the tropics of Eastern Hemisphere. At the same time, *D. dubi-*

um is a species more characteristic for subtropical-southern temperate and even more northern latitudes of Eastern Asia (Korovchinsky, 2000). *P. szalay*, being basically tropical, can penetrate far to the north up to the Amur River basin (Korovchinsky, 2010). The lack of *L. australis* s.l. remains unclear because this species was listed in Laos previously (Heckman, 1974; Kottov *et al.*, 2013) as well as in the neighboring North-East Thailand where this species was quite prominent being encountered in 27% of samples (see Korovchinsky, Sanoamuang, 2008).

Of the presently recorded *Diaphanosoma* species, *D. excisum* predictably occupies the first position by frequency occurrence (75%) as it was the case in water communities of Thailand (see Korovchinsky, Sanoamuang, 2008, 2013). The second position in this respect occupies *D. sarsi* being found in 60.7% of localities whereas in Thailand it was present only in 4–10% of them.

In total, seven species of Sididae have proved to be known in Laos, *S. cf. americana*, *D. excisum*, *D. sarsi*, *D. dubium*, *D. senegal*, *P. szalay* and *L. australis* s.l., which is half of the

known number of species of the family in the mainland South-East Asia (see Korovchinsky, Sanoamuang, 2008, 2013; Korovchinsky, 2013). Further detailed investigations are needed to reveal true species richness of Sididae and other Cladocera families in the country.

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