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Cladocera (Crustacea: Branchiopoda) of South East Asia: history of exploration, taxon richness and notes on zoogeography

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ABSTRACT

The history of Cladocera studies in South-East Asia is reviewed, beginning from the early start of explorations in the end of the 19th century by J. Richard and T. Stingelin. In the first half of the 20th century, extensive research was carried out by V. Brehm, who investigated material collected by the Wallacea-Expedition and the Deutschen Limnologischen Sunda-Expedition. Later, in the 1970-1980s, C.H. Fernando and collaborators, besides a few other researchers, provided a new series of regional studies of the cladoceran faunas together with the systematic revisions of some taxa from tropical Asia. Then and up to present, investigations of the Cladocera have concentrated in Thailand and many species have been revised and described as new to science. In total, 298 taxa of species rank have been recorded in SE Asia but only comparatively few of them (67 taxa; 22.5%) can be regarded good *species, of which the valid status has been confirmed by recent studies, while others are synonyms (68; 22.8%) or taxa of uncertain taxonomic status, including those which definitely represent complexes of species (163; 54.7%). Most total taxa of species level and* good *species are known from Thailand (155 and 54, respectively), followed by Malaysia (plus Singapore), Indonesia, Philippines, Vietnam, and Cambodia in this respect (70-119 total taxa and 23-33* good *species respectively). Laos, Burma (Myanmar) and Brunei remain practically unexplored. Only* good *species were used for the zoogeographic analysis. Of them, about a quarter is known only in SE Asia but more species are distributed in tropical/subtropical/temperate Asia and Australia, others in tropics/subtropics of the eastern hemisphere (17.9%) or even wider. Tropical species, constituting the primary part of the cladoceran fauna of SE Asia, can penetrate the neighboring subtropical and southern temperate zones to a different degree. Only a small fraction of species (7 or 10.5%) here are of more or less northern origin, they are distributed predominantly in the subtropical/southern temperate or in the northern boreal latitudes. Few species are suggested to penetrate SE Asia from the north using the Mekong river and its tributaries. Generally, the cladocerans of SE Asia are poorly known and only continuous extensive taxonomic studies would improve this situation.*

Key words: Cladocera, South-East Asia, taxon richness, taxonomic status, zoogeography.

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INTRODUCTION

South-East (SE) Asia is a huge geographical region, which is almost fully, except small elevated part of northern Myanmar (Burma), located in tropical latitudes. It lies on the intersection of geological plates, with heavy seismic and volcanic activity. There are two main geographical regions: Mainland SE Asia also known as Indochina (Cambodia, Myanmar, Laos, Thailand, Vietnam, and West Malaysia) and Maritime SE Asia, comprising numerous islands of Indonesia, the largest archipelago of the world, Philippines, *etc.*

The climate of SE Asia is mainly monsoonal tropical-hot and humid with plentiful rainfall. An exception to this type of climate is the mountaneous areas in the north and some other regions, where high altitudes lead to milder temperatures and drier landscapes. The highest mountains are situated in northern Myanmar and in Borneo (up to 4000-5881 m asl). Historically, the SE Asian biota has been studied since the middle of the 19th century, especially by the outstanding zoologist Alfred Wallace, who traveled in particular to the Malay archipelago. He investigated abundant zoological collections, many collected by himself, which, however, mostly represented the terrestrial fauna which were the main focus of attention of most researchers of that time. As a result of these intensive zoological studies, some fundamental zoogeographical summaries have been composed and published (*e.g.*, Wallace, 1876). In particular, the Malay archipelago has been split by the so-called Wallace-, Weber-, *etc.* zoogeographical lines, which run along what is now known to be a tectonic plates boundary and largely separate the Asian and Australasian faunas. The islands between Java/Borneo and New Guinea form a mixed zone, where both types occur, known as *Wallacea*.

The inland freshwater fauna of SE Asia, especially invertebrates, attracted the researchers' attention later. It was explored significantly less intensely than the terrestrial biota (Lim, 1980; Fernando, 1980; Dussart *et al*., 1984; Ho, 1995). In particular, a detailed overview of the Cladocera fauna of the region has never been made. Only Fernando (1980) attempted to do this in the context of his review of all freshwater zooplankton of the Oriental Region, but his data, containing interesting facts and conclusions, are preliminary. The subsequent review publications were regional, containing brief summary data (Idris and Fernando, 1981; Idris, 1983), and most concerned the fauna of Thailand (Boonsom, 1984; Sanoamuang, 1998, especially detailed in Maiphae *et al*., 2005, 2008). It should be noted, however, that the latter studies did not distinguish adequately from poorly studied taxa, thus preventing taxonomic and zoogeographic analysis.

The aim of this paper is to present an overview of studies of Cladocera, one of the main group of crustaceans of inland waters in SE Asia, to estimate their known taxon richness and validity, and outline some zoogeographical peculiarities.

APPROACHES AND DEFINITIONS

The present work required a comprehensive analysis of published data on cladoceran taxa recorded in SE Asia from the early beginning of these studies to now. The list of taxa has been compiled and presented in Tab. 1. The closer analysis of literature sources (Tab. 1) clearly showed quite a different quality of the taxa presented. From the modern point of view, many of them were described inadequately, thus having an unclear taxonomic status. For this reason, it was important to select the credible taxa of species rank, thus creating the basis for further faunistic and zoogeographical analysis.

The only reliable criterion to select such taxa was to evaluate them with consideration of principles of the modern cladoceran taxonomy, developed in last decades (Frey, 1982, 1987b; Korovchinsky, 1996). These principles require the detailed morphological study of the material favoring the description of real biological units (species, genera, *etc.*). The effectiveness of this method was confirmed by the following genetic analysis of taxa, sometimes provided together with morphological descriptions (Kotov *et al*., 2006; Elias-Gutierrez and Valdez-Moreno, 2008). Our approach was that the only credible or *good* species, were those recently described or redescribed on the basis of such studies or at least, of which validity was confirmed by recent taxonomic revisions (Van Damme *et al*., 2010), have been chosen for further analysis (Tab.1, taxa marked in bold). The list of these taxa was supplemented by some species with peculiar taxonomic traits (*e.g*., *Latonopsis australis* Sars, *Scapholeberis kingi* Sars, *Daphnia lumholtzi* Sars), which have not yet been comprehensively revised but which were originally described from SE Asia or from the neighboring regions (Australia, India, Sri Lanka) and whose valid taxonomic status and occurrence in SE Asia seem quite probable.

HISTORICAL OVERVIEW

Studies of the Cladocera of SE Asia started in 1890s and the beginning of the 1900s, when J. Richard and T. Stingelin published their pioneer papers on zooplankton of the region, collected in a few localities in Sumatra, Celebes (Sulawesi), and Tonkin (Northern Vietnam) (Richard, 1891, 1894a, 1894b; Stingelin, 1900). In total, 17 forms were recorded, among which four *good* species were described. Among others, the honeycombed *Chydorus* was recorded in SE Asia for the first time (Richard, 1894b). Slightly later, more extensive explorations were provided by G.O. Sars (1903) and especially by Stingelin (1905), who recorded zooplanktonic animals (41 species, subspecies, and varieties) from Sumatra, Java, Siam (Thailand), Singapore, and Cochinchina (Saigon) (now in the south of Vietnam). Among them, three *good* species were described, some initially described as new variety of a known species (*e.g*., *Diaphanosoma sarsi* var. *volzi* Stingelin=*D. volzi* Stingelin). Also *Daphnia* (*D. longispina* O.F. Müller), rare in the tropics, was recorded first from Java by Sars (1903).

After the pioneer studies, the investigations on the mainland were abandoned for a long time, up to the 1960s, while they were more steadily continued on the islands. For example, Grochmalički (1915) described 12 species from Java, including three new ones, but all of them seem to be invalid (see Smirnov, 1971). Heberer (1923) found a population of *Daphnia cephalata* Schödler in Flores Island, and Spandl (1925) provided the first study of the Cladocera from Borneo (Sarawak). Surprisingly, the latter author recorded exclusively temperate species from the genera *Daphnia, Simocephalus,* and *Moina*. The late 1920-1930s was a period of extensive surveys. During the Deutschen Limnological Sunda-Expedition and the Wallacea-Expedition, materials were collected on different islands of the Malay archipelago (Sumatra – mostly in lake Toba and its surroundings – Sulawesi, Java, Bali, and Flores) and the Philippines. The collections were studied mainly by V. Brehm, who published some papers in 1933-1939 (Brehm, 1933a, 1933b, 1933c, 1933d). One specifically on the Cladocera of the Deutschen Limnologischen Sunda-Expedition (Brehm, 1933a) was most extensive. It contains the descriptions of 51 species and varieties including several ones new to science (*Diaphanosoma perarmatum* Brehm*, D. paucispinosum* Brehm*, Guernella sumatrensis* Brehm*, Moina latidens* Brehm*, Alona arenaria* Brehm*, A. archeroides* Brehm*, Alonella granulata* Brehm*, Chydorus herrmanni* Brehm, *etc.*). However, in the following revisions (Smirnov, 1971, 1976, 1992, 1996; Korovchinsky, 1992; Van Damme *et al*., 2010) nearly all these taxa have been regarded invalid or vague. A few other researchers (Aurich, 1934; Rammner, 1937) also studied material from the SE Asian islands (Philippines, Java); in particular, they analyzed morphological variability in some species of the

Tab. 1. Taxa of Cladocera recorded in South-East Asia. *Good* species are in bold.

Taxa		Thailand	Malaysia and Singapore	Vietnam	Philippines	Indonesia	Cambodia
Sididae							
Sida crystallina (O.F. Müller, 1776)	s	+(6, 9)		+(3, 4, 5)			+(2)
S. crystallina ortiva **Korovchinsky, 1979**	g	+(8)					
Diaphanosoma sarsi **Richard, 1894**	g	+(1, 4, 5, 6, 7, 8, 9)	+(1, 5, 6, 7)	+(4, 5)	+(1, 2, 3, 4, 8)	+(1, 2, 3, 5, 8)	+(1)
D. sarsi var. *celebensis* Stingelin, 1900	s					+(2)	
D. celebensis **Stingelin, 1900**	g		+(8)	+(6)		+(10)	
D. sarsi var. *volzi* Stingelin, 1905	s	+(1)					
D. volzi **Stingelin, 1905**	g	+(5, 8, 9)	+(8)		+(5)	+(10)	
D. aspinosum Chiang, 1956	s		+(5, 6)				
D. cf. *volzi* Stingelin, 1905	v	+(4)					
D. excisum **Sars, 1885**	g	+(3, 4, 5, 6, 7, 8, 9, 10)	+(1, 4, 5, 6, 7)	+(2, 10)	+(3, 4, 8)	+(2, 4, 6)	+(1, 2)
D. paucispinosum Brehm, 1933	s		+(3)	+(4, 5)		+(5)	+(1)
D. leuchtenbergianum Fischer, 1850	s			+(4, 5)			
D. modigliani **Richard, 1894**	g		+(5, 6)*		+(1, 2, 3, 4)*	+(1, 5, 8, 10)	+(1)*
D. cf. *modigliani* Richard, 1894	v	+(4)					
D. perarmatum Brehm, 1933	v					+(5)	
D. dubium **Manuilova, 1964**	g	+(8, 9)	+(8)	+(6)	+(5)		
D. tropicum **Korovchinsky, 1998**	g	+(8)	+(8)	+(10)*	+(5, 8)		
D. orghidani transamurensis **Korovchinsky, 1986**	g				+(5)		
D. senegal isanensis **Korovchinsky et Sanoamuang, 2008**	g	+(8)					
D. macrophthalma **Korovchinsky et Mirabdullaev, 1995**	g	+(8)					
D. elongatum **Korovchinsky et Sanoamuang, 2008**	g	+(8)					
D. brachyurum (Lievin, 1848)	v			+(3)			
Daphnella excisa Sars, 1885	s					+(1)	
Pseudosida szalayi **Daday, 1898**	g	+(1, 8)				+(2, 10)	
P. bidentata Herrick, 1888	s	+(5, 6, 7, 9, 10)	+(5, 6, 7)	+(3, 4)	+(3, 4)	+(7)	+(2)
P. cf. *bidentata* Herrick, 1888	v	+(4)					
P. ramosa (Daday, 1904)	v	+(5, 6, 9)					
Latonopsis australis **Sars, 1888**	g	+(4, 5, 6, 7, 8, 9)	+(5, 6)	+(2, 4, 5)	+(2, 3, 4)	+(4, 5, 6, 8, 9)	+(2)
Sarsilatona serricauda (Sars, 1901)	v	+(9)					
S. papuana (Daday, 1900)	v						+(2)
S. cf. *fernandoi* Rane, 1983	v			+(6)			
Sarsilatona sp.	v	+(8)					
Latona setifera (O.F. Müller, 1776)	v			+(3)			
Daphniidae							
Daphnia lumholtzi **Sars, 1885**	g	+(4, 5, 7, 9)		+(5)			+(2)
D. similis Claus, 1876	s	+(4)	+(5, 6)			+(5)	
D. similoides **Hudeč, 1991**	g		+(9)				
D. carinata King, 1853	sc			+(5)		+(5)	
D. cephalata Schoedler, 1877	sc					+(5)	
D. rosea Sars, 1862	v			+(3)			
D. catawba Coker, 1926	v			+(3)			
D. longispina (O.F. Müller, 1776)	sc		+(1)	+(3)		+(3)	
D. cucullata Sars, 1862	v			+(5)			
D. pulex Leydig, 1860	v			+(3)			
D. magna Straus, 1820	v		+(1)				
D. triquetra Sars, 1903	v		+(1)				
Scapholeberis kingi **Sars, 1888**	g	+(1, 4, 5, 6, 7, 9, 10)	+(5, 6, 7)	+(3, 4, 5)	+(1, 3, 4)	+(2, 3, 5, 8)	+(2)
S. mucronata var. *intermedia* Daday, 1898	v					+(4)	
Simocephalus elizabethae (King, 1853)	v	+(1)		+(4, 5)		+(2)	
S. vetulus (O.F. Müller, 1776)	v	+(3, 4, 5, 9)	+(4)	+(3)	+(3, 4)	+(8)	+(1)
S. cf. *vetula* (O.F. Müller, 1776)	v				+(1)	+(5)	
S. exspinosus (Koch, 1941)	v	+(5, 9)	+(1)			+(3, 8)	
S. mesorostris Orlova-Bienkowskaja, 1995	s	+(5, 6)					
S. heilongjiangensis **Shi et Shi, 1994**	g	+(7, 9)	+(9)	+(7)	+(6)	+(11)	+(2)
S. serrulatus **(Koch, 1841)**	g	+(5, 6, 7, 9)	+(5, 6)	+(5, 7)		+(5, 6, 8)	+(2)
S. serrulatus var. *productifrons* Stingelin, 1904	s				+(1)	+(2)	
S. serrulatus var. *mixta* Grohmalicki, 1915	s					+(4)	
S. mixtus **Sars, 1903**	g			+(7)			
S. latirostris Stingelin, 1906	s	+(4)	+(2, 5, 6)		+(3, 4)		
S. acutirostratus **(King, 1853)**	g				+(3, 4)		
S. australiensis Dana, 1852	v					+(4)	
Ceriodaphnia cornuta Sars, 1885	sc	+(4, 5, 6, 7, 9, 10)	+(3, 5, 6)	+(10)	+(1, 2, 3, 4, 8)	+(2, 4, 5, 6, 8, 9)	+(2)
C. rigaudi Richard, 1894	s	+(3)	+(4)	+(1, 2, 3, 4, 5)	+(1)	+(2, 3, 5, 6, 7)	+(1)

To be continued on next page.

Tab. 1. Continued from previous page.

Taxa		Thailand	Malaysia and Singapore	Vietnam	Philippines	Indonesia	Cambodia
C. dubia Richard, 1894	v					+(1, 5, 8)	
C. cf. *dubia* Richard, 1894	v					+(5)	
C. pulchella Sars, 1862	v	+(4)			+(3, 4)		
C. reticulata (Jurine, 1820)	sc	+(4)		+(3)			
C. megalops Sars, 1862	v			+(3)			
C. lacustris Birge, 1893	v			+(3)			
C. quadrangula (O.F. Müller, 1785)	v			+(3, 5)			
C. laticaudata P.E. Müller, 1867	v			+(5)			+(2)
Moinidae							
Moina dubia Guerne et Richard, 1892	s	+(3)	+(4)	+(4, 5)	+(1, 2)	+(5)	
M. dubia parva Jenkin, 1934?	s		+(3)			+(6)	
M. micrura Kurz, 1874	sc	+(4, 5, 6, 7, 9, 10)	+(5, 6, 7)	+(10)	+(2, 3, 4, 8)		+(2)
M. macrocopa (Straus, 1820)	v	+(4)		+(3)	+(3, 4)		
M. brachiata (Jurine, 1820)	v		+(1)	+(3)	+(3, 4)		
M. rectirostris Baird, 1850	s			+(3)			
M. macrophthalma Stingelin, 1913	s				+(1)		
M. weberi Richard, 1891	s				+(1)	+(1, 5)	
M. weismanni Ishikawa, 1896	v						+(1)
M. paradoxa Weismann, 1880	s					+(2)	
M. propinqua Sars, 1885	s					+(2, 4)	
M. latidens Brehm, 1933	s					+(5)	
Moinodaphnia macleayi (King, 1853)	g	+(1, 4, 5, 6, 9, 10)	+(5, 6)	+(3, 5)	+(3, 4)	+(3, 5)	+(2)
Macrothricidae							
Guernella raphaelis Richard, 1892	sc	+(5, 6, 7, 9, 10)	+(5, 6)		+(3, 4)		+(2)
G. sumatrensis Brehm, 1933	v					+(5, 6)	
Grimaldina brazzai Richard, 1892	v	+(9)	+(5, 6)	+(3)	+(1, 3, 4)	+(5)	+(2)
Macrothrix triserialis Brady, 1886	g	+(1, 6, 9, 10)		+(2, 4, 5)	+(3, 4)	+(2, 4, 5, 6, 7, 8, 9)	
M. cf. *triserialis* Brady, 1886	v	+(4, 5)	+(1, 5, 6)		+(1)		
M. spinosa King, 1853	g	+(1, 3, 5) 6, 7, 9, 10)	+(1, 4, 5) 6, 7)	+(5)	+(3, 4)	+(1, 2, 3, 5, 6, 8)	+(2)
M. cf. *spinosa* King, 1853	v					+(5)	
M. flabelligera Smirnov, 1992	g	+(5, 6, 7)					+(2)
M. laticornis (Fischer, 1851)	v	+(5, 7)		+(3)	+(1)		
M. cf. *laticornis* (Fischer, 1851)	v	+(9)					
M. paulensis Sars, 1900	v	+(9)					
M. cf. *paulensis* (Sars, 1900)	v	+(5, 6,					
M. pholpuntini Kotov *et al*., 2005	g	+(9, 12)					+(2)
M. hirsuticornis Norman et Brady, 1867	v	+(4)					
M. cf. *gauthieri* Smirnov, 1976	v	+(6, 9)					
M. malaysiensis Idris et Fernando, 1981	g	+(6, 9)	+(5, 6, 10)				
M. odiosa Gurney, 1907	g	+(6, 9, 12)	+(10)				
M. cf. *sioli* (Smirnov, 1982)	v	+(6)					
M. cf. *superaculeata* Smirnov, 1982	v	+(6, 9)					
M. sumatrensis Brehm, 1933	v		+(2)			+(8)	
M. capensis-monodi Gauthier, 1930	s		+(5, 6)				
M. rosea (Lievin, 1848)	v			+(3)			
M. cf. *squamosa* Sars, 1888	v				+(1)	+(7)	
M. tobaensis Johnson, 1956	v					+(8)	
M. vietnamensis Silva-Briano *et al*., 1999	g			+(7)			
Echinisca rosea (Jurine, 1820)	s				+(3, 4)		
Streblocerus pygmaeus Sars, 1901	s	+(4, 5, 6, 9)	+(5, 6)				
S. spinulatus Smirnov, 1992	g		+(8)				
Bunops cf. *tuberculatus* (Fryer et Paggi, 1972)	v						+(2)
Ophryoxidae							
Ophryoxus gracilis Sars, 1862	v			+(3)			
Ilyocryptidae							
Ilyocryptus halyi Brady, 1886	s	+(1)	+(1)	+(5)		+(2, 6, 7, 8)	
I. spinifer Herrick, 1882	sc	+(4, 6, 7, 9, 12)	+(2, 10)		+(3, 4)	+(5)	+(2)
I. cf. *spinifer* Herrick, 1882	v	+(5, 6)	+(5, 6)				
I. cf. *bhardwaji* Battish, 1981	v	+(9)					
I. cf. *raridentatus* Smirnov, 1989	v	+(9, 12)					
I. thailandensis Kotov et Sanoamuang, 2004	g	+(9, 12)		+(11)			
I. isanensis Kotov *et al*., 2005	g	+(9, 12)					

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Tab. 1. Continued from previous page.

Taxa		Thailand	Malaysia and Singapore	Vietnam	Philippines	Indonesia	Cambodia
I. longiremis Sars, 1888	s				+(1)	+(1, 3, 5, 6)	
I. verrucosus Daday, 1905	s				+(1)		
Chydoridae							
Pleuroxus laevis Sars, 1862	s	+(1, 9)	+(5, 6)	+(9)		+(5)	
P. aduncus (Jurine, 1820)	sc	+(4)		+(1)	+(3, 4)	+(5)	
P. aduncus var. *laticaudatus* Brehm, 1933	v					+(5, 8)	
P. denticulatus Birge, 1879	s	+(4)		+(3)			
P. uncinatus Baird, 1850	v	+(6, 9)					
P. hamatus hamatus Birge, 1879	s			+(4, 5)			
P. similis Vavra, 1900	v			+(5)	+(3, 4)		
P. trigonellus (O.F. Müller, 1785)	v					+(5)	
P. trigonellus var. *brevicornis* Brehm, 1933	v					+(5)	
P. australis Henry, 1922	s					+(5)	
Picripleuroxus laevis (Sars, 1862)	v	+(6, 7)					
P. quasidenticulatus Smirnov, 1996	v	+(7, 9)					
Chydorus barroisi (Richard, 1894)	s	+(1)	+(1, 3, 5, 6, 7)	+(2, 3)	+(1, 2, 3, 4)	+(2, 5, 6, 8)	
Ch. barroisi barroisi (Richard, 1894)	s			+(4, 5)			
Ch. sphaericus (O.F. Müller, 1776)	sc	+(3, 4, 9)		+(3)		+(3, 6, 8)	
C. sphaericus sphaericus (O.F. Müller, 1776)	s			+(4, 5)			
Ch. sphaericus var. *parvus* Daday, 1898	s	+(1)				+(2)	
Ch. cf. *sphaericus* (O.F. Müller, 1776)	v		+(7)		+(1)	+(5)	
Ch. leonardi King, 1853	v		+(1)			+(5)	
Ch. sphaericus cf. *leonardi* King, 1853	v					+(8)	
Ch. alexandrovi (Poggenpol, 1874)	v			+(4, 5)			
Ch. herrmanni Brehm, 1933	v				+(1)	+(5)	
Ch. eurynotus Sars, 1901	v	+(4, 5, 6, 7, 9)	+(2, 5, 6)		+(3, 4)		+(2)
Ch. eurynotus eurynotus Sars, 1901	v			+(5)			
Ch. parvus Daday, 1898	g	+(5, 6, 7, 9)	+(5, 6)		+(3, 4)		
Ch. pubescens Sars, 1901	v	+(5, 6, 9)					+(2)
Ch. cf. *pubescens* Sars, 1901	v	+(7)	+(5, 6)				
Ch. ventricosus Daday, 1898	g	+(4, 5, 6, 7, 9)	+(5, 6, 11)		+(3, 4, 7)	+(4, 13)	+(2, 3)
*Ch.*cf. *ventricosus* Daday, 1898	v					+(8)	
Ch. reticulatus Daday, 1898	g	+(5, 6, 9)	+(5, 6, 11)			+(5)	+(2)
Ch. sinensis Frey, 1987	g	+(5, 9)					
Ch. obscurirostris Frey, 1987	v	+(9)					+(2)
Ch. obscurirostris obscurirostris Frey, 1987	v	+(6)					
Ch. o. tasekberae Frey, 1987	g	+(6)	+(11)				
Ch. opacus Frey, 1987	g	+(9)					
Ch. faviformis Birge, 1893	v		+(5, 6)				
Ch. invaginatus Frey, 1982	g	+(14)					
Ch.gibbus Sars, 1891	v			+(3)			
Ch. robustus Stingelin, 1905	s					+(2, 5, 8, 9)	
Ch. robustus var. *laticornis* Brehm, 1953	s				+(1)		
Ch. globosus Baird, 1843	s					+(6)	
Ch. cf. *dentifer* Daday, 1905	v						+(2)
Chydorus sp. with honeycombed valves	v			+(1)			
Alonella karua Sars, 1888	s	+(1)	+(1)	+(2)	+(1)	+(2, 5, 7)	
A. breviceps Stingelin, 1905	g	+(1)					
A. nana (Baird, 1850)	v	+(4, 6, 9)	+(5, 6)				
A. clathratula Sars, 1896	g	+(5, 6, 9)					+(2)
A. excisa (Fischer, 1854)	v	+(5, 6, 9)	+(1, 5, 6, 7)		+(1, 3, 4)	+(2, 5, 6, 8)	+(2)
A. excisa excisa (Fischer, 1854)	v			+(5)			
A. exigua (Lilljeborg, 1853)	v						+(2)
A. hamulatus (Birge, 1910)	s		+(5, 6)				
A. sculpta Sars, 1901	s				+(1)	+(2, 5)	
A. sculpta var. *insulcata* Stingelin, 1905	s			+(2)			
A. dadayi Birge, 1910	v			+(3)			
A. kulczynskii Grohmalicki, 1915	s				+(1)	+(4)	
A. globulosa Daday, 1910	s					+(5)	
A. diaphana King, 1853	s					+(5)	
A. granulata Brehm, 1933	v					+(5)	
Disparalona hamata (Birge, 1879)	v	+(5, 6, 7, 9)					+(2)
D. caudata Smirnov, 1996	g	+(5, 6, 9)					+(2)
D. rostrata (Koch, 1841)	v	+(9)	+(5, 6)	+(5)			

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Tab. 1. Continued from previous page.

Taxa		Thailand	Malaysia and Singapore	Vietnam	Philippines	Indonesia	Cambodia
Ephemeroporus barroisi (Richard, 1894)	sc	+(4, 5, 6, 7, 9, 10)					+(2)
E. hybridus (Daday, 1905)	v	+(6, 9)					
E. phintonicus (Margaritora, 1969)	v	+(6, 9)					
E. tridentatus (Bergamin, 1939)	v	+(6, 9)					
Dadaya macrops (Daday, 1898)	g	+(1, 4, 5, 6, 7, 9, 10)	+(1, 2, 5, 6)	+(3, 5)	+(3, 4)	+(2, 5, 9)	+(2)
Dunhevedia crassa King, 1853	g	+(1, 4, 5, 6, 7, 9)	+(5, 6)	+(4, 5)	+(1, 3, 4)	+(2, 5, 7, 9)	
D. serrata Daday, 1898	g	+(5, 6, 7) 9)	+(5, 6) 11)		+(3, 4, 7)	+(13)	+(2)
D. siedleckii Grohmalicki, 1915	v					+(4)	
Pseudochydorus globosus (Baird, 1843)	sc	+(9)	+(5)				+(2)
Alona acuticostata Sars, 1903	g					+(3)	
A, cf. *acuticostata* Sars, 1903	v						+(1)
A. acuticostata var. *tridentata* Stingelin, 1905	v	+(1)					
A. diaphana King, 1853	s	+(5, 6, 7)		+(3)			+(2)
A. guttata Sars, 1862	v	+(3, 6, 7, 9)	+(5)	+(2, 5)	+(3, 4)	+(2, 3, 5, 6)	+(2)
A. cf. *guttata* Sars, 1862	v		+(6, 7)				
A. rectangula Sars, 1862	sc	+(5, 6, 7, 9)	+(5)	+(3, 4, 5)			+(2)
A. cf. *rectangula* Sars, 1862	v		+(6)				
A. affinis (Leydig, 1860)	sc	+(4, 5, 6, 9)	+(2, 5, 6)	+(3)		+(5)	+(2)
A. cf. *affinis* (Leydig, 1860)	v				+(1)		
A. affinis var. *elegantula* Brehm, 1933	v					+(5)	
A. quadrangularis (O.F. Müller, 1875)	sc	+(6, 9)	+(5, 6)				
A. verrucosa Sars, 1901 s.l.	sc	+(4, 6, 9, 10)	+(1, 5, 6)	+(2)	+(1)	+(8)	
A. verrucosa verrucosa Sars, 1901	s	+(5)					
A. pseudoverrucosa (Smirnov, 1971)	s						+(2)
"*A. verrucosa pseudoverrucosa* Smirnov, 1974", probably *A. pseudoverrucosa verrucosa* (Sars, 1901)	s	+(5)					
A. sarasinorum Stingelin, 1900	g	+(6, 9)			+(1)	+(2, 5)	
A. cf. *sarasinorum* Stingelin, 1900	s		+(5, 6)			+(5)	
A. davidi Richard, 1895	v	+(4)	+(5, 6)	+(4, 5)	+(3, 4)	+(2, 7, 8)	
A. davidi punctata (Daday, 1898)	v						+(2)
A. karua King, 1853	s	+(4, 5)	+(5, 6)	+(3)	+(1)	+(8)	+(1)
A. cambouei Guerne et Richard, 1893	v		+(3)	+(1, 4, 5)	+(2, 3, 4)	+(5)	
A. cf. *cambouei* Guerne et Richard, 1893	v	+(5, 9, 10)				+(8)	
A. costata Sars, 1862	sc	+(5, 6)	+(5, 6)	+(3)			+(2)
A. eximia Kiser, 1948	s		+(5, 6)	+(9)			
A. cf. *eximia* Kiser, 1948	v	+(5)					
A. milleri Kiser, 1948	g	+(5, 9)					
A. monacantha Sars, 1901	sc	+(6, 9, 10)	+(5, 6)	+(3, 4, 9)			
A. monacantha tridentata Stingelin, 1905	v	+(5)					+(2)
A. pulchella King, 1853	v	+(6, 9, 10)			+(3, 4)		+(2)
A. cf. *pulchella* King, 1853	v	+(5)	+(5, 6)				
A. dentifera (Sars, 1901)	v			+(3)			
A. cf. *dentifera* (Sars, 1901)	s	+(6, 9)	+(5, 6)				
A. cf. *karelica* Stenroos, 1897	s	+(6)	+(5, 6)				
A. archeri Sars, 1888	sc	+(9)			+(1)	+(2)	
A. cf. *archeri* Sars, 1888	v					+(5)	
A. arenaria Brehm, 1933	v						
A. archeroides Brehm, 1933	v					+(5, 8)	
A. cheni Sinev, 1999	g	+(9)					
A. intermedia Sars, 1862	v	+(9)	+(5, 6)		+(1)	+(5)	+(2)
A. cf. *intermedia* Sars, 1862	v					+(8)	
A. intermedia var. *minor* Stingelin, 1905	v			+(2)			
A. globulosa Daday, 1898	s			+(3)	+(1)		
A. bukobensis Weltner, 1896	sc				+(1)		
A. pseudanodonta Brehm, 1933	v				+(1, 3, 4)	+(5)	
A. alonopsiformis Brehm, 1933	v				+(1)	+(5)	
A. circumfibriata Megard, 1967	v				+(3, 4)		
A. sarsi Richard, 1891	v					+(1)	
A. tenuicaudis Sars, 1862	s					+(3)	
A. glabra Sars, 1901	v					+(5, 8)	
A. siamensis Sinev et Sanoamuang, 2007	g	+(14)	+(12)				
A. kotovi Sinev, 2012	g			+(8)			
Pseudalona longirostris Daday, 1905	s				+(1)	+(3, 5)	+(1)

To be continued on next page.

Tab. 1. Continued from previous page.

Taxa		Thailand	Malaysia and Singapore	Vietnam	Philippines	Indonesia	Cambodia
Matralona freyi (Idris et Fernando, 1981)	g		+(5, 6)				
Armatalona macrocopa (Sars, 1894) s.l.	g	+(9, 14)					
Karualona iberica (Alonso et Pretus, 1989)	v	+(6, 9, 10)					
K. karua (King, 1853)	g	+(9, 10)					+(2)
Anthalona obtusa Van Damme *et al.*, 2011	g					+(13)	
A. harti harti Van Damme, Sinev et Dumont, 2011	g	+(14)		+(8)			+(4)
A. sanoamuangae Sinev et Kotov, 2012	g	+(14)		+(8)			
Celsinotum macronyx (Daday, 1898)	g	+(5, 6, 13)	+(5, 6, 11)		+(7)	+(5, 13)	
Kurzia longirostris (Daday, 1898)	g	+(4, 5, 6, 7, 9, 13)	+(2, 5, 6, 11)	+(4, 5)	+(3, 4, 7)	+(13)	+(2)
K. brevilabris Rajapaksa et Fernando, 1986	g	+(9, 13)	+(11)		+(7)	+(13)	
K. latissima (Kurz, 1875)	v			+(3)			
Biapertura karua (King, 1853)	s			+(4, 5)	+(3, 4)		
B. pseudoverrucosa Smirnov, 1971	s				+(3, 4)		
B. pseudoverrucosa verrucosa (Sars, 1901)	s			+(5)			
B. affinis (Leydig, 1860)	s				+(3, 4)		
B. affinis vietnamica Thanh, Bau et Mien, 1980	v			+(5)			
B. intermedia (Sars, 1862)	s			+(5)			
Euryalona orientalis (Daday, 1898)	g	+(1, 4, 5, 6, 7, 9, 13)	+(5, 6, 11)	+(5)	+(3, 4, 7)	+(2, 5, 8, 9, 13)	+(2)
E. occidentalis (Sars, 1901)	s			+(3)			
Acroperus harpae (Baird, 1834)	g	+(6, 9, 14)	+(5, 6, 7)	+(9)		+(5, 6)	
Alonopsis singalensis Daday, 1898	s			+(2)		+(2, 5)	
A. lomnicki Grohmalicki, 1915	s					+(4)	
Camptocercus australis Sars, 1896	v	+(6, 7, 9)				+(2)	
C. cf. *australis* Sars, 1896	v		+(5, 6)				
C. rectirostris Schoedler, 1862	v	+(4)	+(4)	+(3)			+(2)
C. uncinatus Smirnov, 1971	v	+(5, 9)			+(3, 4)		
C. vietnamensis Thanh, Bau et Mien, 1980	g			+(5, 8)			
Leydigia acanthocercoides (Fischer, 1854)	v	+(4, 5, 7, 9)	+(5, 6)	+(3, 4, 5)	+(3, 4)	+(5)	
L. laevis Gurney, 1927	v	+(5, 9)					
L. ciliata Gauthier, 1939	sc	+(9)					+(2)
L. australis Sars, 1885	v	+(9)					+(2)
"*L. hamulatus* Birge", probably *Pleuroxus hamulatus* Birge, 1910	v			+(3)			
"*L. striatus* Schoedler", probably *Pleuroxus striatus* Schoedler, 1858	v			+(3)			
L. propinqua Sars, 1903	s					+(3, 5)	
L. leydigi (Schoedler, 1863)	v					+(8)	
Leydigiopsis sp.	v	+(5, 6)					+(2)
Nicsmirnovius eximius (Kiser, 1948)	g	+(6, 7, 9, 14)	+(12)				+(2)
Notoalona globulosa (Daday, 1898)	g	+(5, 6, 7, 9)	+(11)		+(7)	+(13)	+(2)
N. freyi Rajapaksa et Fernando, 1987	v	+(6, 9)					
Oxyurella singalensis (Daday, 1898)	g	+(4, 5, 6, 7, 9, 10)	+(5, 6)	+(4, 5)	+(3, 4)	+(9)	+(2)
O. longicaudis (Birge, 1910)	v			+(3)			
O. tenuicaudis (Sars, 1862)	v			+(4)			+(2)
Graptoleberis testudinaria (Fischer, 1851)	sc	+(9)	+(5, 6)				
Indialona macronyx (Daday, 1898)	s	+(9)			+(3, 4)		
I. globulosa (Daday, 1898)	s		+(5, 6)		+(3, 4)	+(9)	
Leberis diaphanus (King, 1853)	g	+(9)					
Monospilus dispar Sars, 1862	v			+(5)			
<u>Bosminidae</u>							
Bosmina longirostris (O.F. Müller, 1785) s.l.	v	+(3, 4, 6, 9)	+(4)	+(3, 4, 5)	+(1, 2, 3, 4)	+(5)	+(1)
B. meridionalis Sars, 1904	v	+(5, 6, 7, 9)		+(10)		+(5)	+(2)
B. fatalis Burckhardt, 1924	v	+(9)			+(1, 3, 4, 8)	+(5)	+(2)
B. fatalis-philippinensis Aurich, 1934	v				+(1)		
B. coregoni Baird, 1857	v			+(3)			
Bosminopsis deitersi Richard, 1895	sc	+(3, 4, 5, 6, 7, 9, 10)	+(3, 4, 5, 6)	+(3, 4, 5, 10)	+(1, 2, 3, 4)		+(1, 2)
<u>Polyphemidae</u>							
Polyphemus pediculus (L.)	sc			+(3)			

g, good *species; s, synonym; v, vague species; sc, species complex.* **The species was recorded in the country but really does not occur there.*

To be continued on next page.

Tab. 1. Continued from previous page.

Note to Tab. 1

Thailand
1) Stingelin (1905)
2) Ueno (1966)
3) Mizuno and Mori (1970)
4) Boonsom (1984)
5) Sanoamuang (1998)
6) Maiphae *et al*. (2005)
7) Sa-ardrit and Beamish (2005)
8) Korovchinsky and Sanoamuang (2008a, 2008b, unpublished data)
9) Maiphae *et al*. (2008)
10) Maiphae *et al*. (2010)
11) Korovchinsky (1998, 2000b)
12) Kotov and Dumont (2000); Kotov and Sanoamuang (2004a); Kotov *et al*. (2005); Kotov and Štifter (2006)
13) Rajapaksa and Fernando (1985, 1986a, 1986b, 1987a); Hudeč (2000)
14) Van Damme *et al*. (2003); Kotov and Sanoamuang (2004b); Kotov (2006); Sinev and Sanoamuang (2007); Sinev (2009); Sinev and Kotov (2012)

Malaysia and Singapore
1) Stingelin (1905; Singapore); Spandl (1925; Sarawak)
2) Johnson (1963; Singapore)
3) Ueno (1966)
4) Mizuno and Mori (1970)
5) Idris and Fernando (1981a, 1981b)
6) Idris (1983)
7) Lim *et al.* (1984)
8) Smirnov (1992); Korovchinsky (1993, 1998, 2000b)
9) Hudeč (1991); Orlova-Bienkowskaja (1995b, 1998, 2001)
10) Kotov and Dumont (2000); Kotov *et al*. (2005)
11) Michael and Hann (1979); Frey (1982, 1987b); Rajapaksa and Fernando (1985, 1986a, 1986b, 1987a, 1987b, 1987c); Hudeč (2000)
12) Van Damme *et al*. (2003); Kotov and Sanoamuang (2004b); Sinev *et al*. (2007); Sinev and Sanoamuang (2007); Sinev and Kotov (2012)

Vietnam [North (N), South (S)]
1) Richard (1894a, N)
2) Stingelin (1905, S)
3) Shirota (1966, S)
4) Thanh and Mien (1979, S)
5) Thanh *et al*. (1980, N)
6) Korovchinsky (1989, S; 2000b, N; 2011, S)
7) Orlova-Bienkowskaja (1995a, 1995b, 1998, 2001); Silva-Briano *et al*. (1999)
8) Sinev (2011, S); Sinev and Kotov (2012, S); Sinev (2012, S)
9) Thanh and Hai (2001)
10) Zhdanova (2012)
11) Jeong *et al*. (2012)

Philippines
1) Aurich (1934); Brehm (1939, 1954)
2) Ueno (1966); Frey (1969); Lewis (1973)
3) Mamaril and Fernando (1978)
4) Mamaril (2001)
5) Korovchinsky (1995, 1998, 2000a, 2000b)
6) Orlova- Bienkowskaja (1995b, 1998, 2001)
7) Rajapaksa and Fernando (1985, 1986a, 1986b, 1987a, 1987b, 1987c); Hudeč (2000)
8) Papa *et al*. (2012)

Indonesia
1) Richard (1891; Sumatra and Celebes); Richard (1894b; Sumatra)
2) Stingelin (1900, 1905; Celebes and Sumatra)
3) Sars (1903; Sumatra)
4) Grohmalicki (1915; Java)
5) Brehm (1933a, Celebes; 1933b, Celebes; 1933c, Bali; 1933d, Sumatra, Java, Bali; 1939, Celebes, Java, Flores, Bali); Ruttner (1952, Java, Sumatra, Bali)
6) Rammner (1937; Java)
7) Brehm (1954; Kalimantan)
8) Johnson (1956; Sumatra)
9) Green *et al*. (1976; Java)
10) Frenzel (1987); Korovchinsky (1991, 1995, 1998, 2010)
11) Orlova-Bienkowskaja (1995b, 1998, 2001)
12) Kotov and Dumont (2000)
13) Rajapaksa and Fernando (1985, 1986a, 1986b, 1987a, 1987b, 1987c); Hudeč (2000); Van Damme *et al*. (2011)

Cambodia
1) Blaché (1951); Brehm (1952, 1954); Mizuno and Mori (1970)
2) Tanaka and Ohtaka (2010)
3) Rajapaksa and Fernando (1986b)
4) Sinev and Kotov (2012)

genera *Bosmina* and *Diaphanosoma*. Ruttner (1952) published an extensive ecological work on the zooplankton of large and deep lakes of Sumatra, Java, and Bali based on the material of the Sunda-Expedition. Among other things, he recorded the mass occurrence of *Daphnia carinata* King in the pelagic zone of Ranau See (Sumatra) and an astonishing occurrence of the abundant littoral species *Simocephalus serrulatus* (Koch) and *Latonopsis australis* in the pelagic zone of the lake Danau Manindjau (Sumatra). Brehm (1954) continued the investigations of the Cladocera of Borneo and then Johnson (1956) actually made the last considerable investigation of the Cladocera of Indonesian islands (lake Toba and its surroundings), presenting descriptions and important comments on 31 species, including one new to science (*Macrothrix tobaensis* Johnson of unclear taxonomic status) and others that were later recognized as new (*e.g*. *Anthalona obtusa* Van Damme, Sinev et Dumont; Van Damme *et al*., 2011). In 1950-1970s, some authors (Blachè, 1951; Brehm, 1952, 1954; Ueno, 1966; Frey, 1969; Mizuno and Mori, 1970) published only small and routine species lists (among them the first data on Cambodia by Blachè) but it is notable that during this period, cladoceran studies returned to the continent again, with inclusion of the Philippines.

In this period, the work by Shirota (1966), on the zooplankton of Southern Vietnam, was peculiar, due to the fact that the author recorded many temperate cladoceran species (28 of 48 species listed), among which there are four *Daphnia* species, *Ophryoxus gracilis* Sars and *Polyphemus pediculus* (L.). Judging from his publication, the author was not familiar with the Cladocera well enough and he probably also used American identification books (and possibly borrowed drawings from them), therefore his identifications often look incorrect. On the other hand, part of his samples was collected in montane water bodies, where findings of northern species could be possible [as in *Löffler islands*, see Van Damme and Eggermont (2011)]. Moreover, the above mentioned *Ophryoxus* and *Polyphemus* both have quite characteristic appearances, and are not likely to be misidentified. Nevertheless, all records by Shirota remain questionable and require further reinvestigation.

A more extensive, though rather routine, investigation was made on the Cladocera of the Philippines, with 49 species recorded by Mamaril and Fernando (1978). This survey was the last for these islands (for cladocerans). The species list published later (Mamaril, 2001), fully repeated the list from the previous publication. Other studies concerned only individual water bodies (Papa *et al.,* 2011, 2012).

Publications on South and North Vietnam contained records on 30 and 45 species respectively, including new ones (Thanh and Mien, 1979; Thanh *et al*., 1980). The following summary on the Vietnamese crustaceans (Thanh and Hai, 2001) added five species only. Also a first short list of the Laotian cladocerans (7 species) was presented (Heckman, 1974).

In the 1980s, the first extensive studies were made in Malaysia (Idris and Fernando, 1981a, 1981b; Idris, 1983) and Thailand (Boonsom, 1984). While the latter one resulted only in a list of 47 species, the former authors provided a more detailed work: 62 species, including two new ones (*Macrothrix malaysiensis* Idris et Fernando, *Alona freyi* Idris et Fernando), were either described or commented. It is remarkable that just at this time Prof. C.H. Fernando and his collaborators provided the great program on taxonomic revisions of a number of South Asian cladoceran species of the genera *Alona, Chydorus, Euryalona, Dunhevedia, Kurzia, Dadaya* and described a new genus *Notoalona* (Rajapaksa and Fernando, 1982, 1985, 1986a, 1986b, 1987a, 1987b, 1987c). Among other material, these researches were based on collections from many countries in SE Asia. Some other researchers followed in this respect: Frey (1987a) revised the honeycombed *Chydorus* species, Frenzel (1987) reevaluated the data of T. Stingelin's collection, and Korovchinsky (1989, 1991, 1993, 1995, 1998, 2000a, 2000b) started the revision of SE Asian *Diaphanosoma* species.

Since the 1990s, the taxonomic and faunistic studies of the Cladocera, had concentrated in Thailand, mainly thanks to the enthusiastic efforts by Professor Dr. L. Sanoamuang and her students. Due to these efforts, many regions of the country were surveyed and additional taxa have been revised or described as new to science (Sanoamuang, 1998; Kotov and Sanoamuang, 2004a, 2004b; Kotov *et al*., 2005; Maiphae *et al*., 2005, 2008; Sinev and Sanoamuang, 2007; Korovchinsky and Sanoamuang, 2008a, 2008b; *etc.*). Recently, a new species of Chydoridae was named in honor of Prof. Sanoamuang (Sinev and Kotov, 2012).

Professor L. Sanoamuang and her collaborators also made extensive collections in Laos and Cambodia. Very recently, the first extensive annotated list of 60 species of the Cambodian Cladocera has appeared (Tanaka and Ohtaka, 2010), but most results of these surveys remain unpublished and are under study. Some of the data have been processed during the submission of this paper (on Laos, Kotov *et al.*, 2013), therefore these new results could not be included in time in the current analysis. The same is true for the other newest updates the SE Asia Cladocera, that were made during the course of this investigation and of which the results could not be included, yet which contain most important updates on faunistics, new insights in important habitats and the description of new species (on Vietnam and South Thailand, Sinev and Korovchinsky, 2013; Van Damme *et al*., 2013; Van Damme and Sinev, 2013).

RESULTS

In total, 298 cladoceran taxa of species rank have been recorded in SE Asia for the whole period of its investigation (Tab. 1). Comparatively few (67 taxa or 22.5%) can be regarded as *good* species (27 of them were originally described from SE Asia), while others either are synonyms (68; 22.8%) or taxa of uncertain taxonomic status, including those definitely representing poorly investigated species groups (163; 54.7%).

The largest number of *good* species is observed in the Sididae (14 or 42% of all taxa of the family) and the Chydoridae (35 or 20.7%, mostly in the Aloninae (22; 22.2%), then in Chydorinae (13; 18.6%), while in Daphniidae and Macrothricidae their number is low (7 and 8 respectively) constituting 20% and 28% of all locally known taxa of these families. The worst situation is in the Moinidae and the Bosminidae, having no recently revised species (only *Moinodaphnia macleayi* (King) could be tentatively regarded *good* species because it was originally described from the neighboring Australia having many taxa in common with tropical Asia). It is unfortunate that the species composition of some genera, dominating in the planktonic communities of SE Asia (*Moina, Ceriodaphnia, Bosmina, Bosminopsis*), remain taxonomically unexplored.

Most number of taxa and *good* species are known in Thailand (155 and 54, respectively). Malaysia (+Singapore), Indonesia, Philippines, Vietnam, and Cambodia follow it in this respect (70-119 taxa and 23-33 valid species respectively). Laos, Burma (Myanmar), and Brunei remain practically unexplored (but see new update by Kotov *et al*., 2013 on Laos, which was not ready by the time this study was conducted).

Only *good* species might be used for zoogeographic analysis. Of them, a quarter (17; 25%) is known only in SE Asia (Tab. 2) but larger portion of species (25; 37.3%) is distributed in tropical/subtropical/temperate Asia and Australia. Other species were recorded in tropics/subtropics of Eastern hemisphere (12; 17.6%) or also in Western hemisphere thus found in tropics/subtropics worldwide (8; 11.8%). A small fraction of species (*Sida crystallina ortiva* Korovchinsky, *Simocephalus serrulatus* Koch, *S. mixtus* Sars*, Acroperus harpae* (Baird)) has even wider distribution, either worldwide or in northern latitudes.

As for latitudinal distribution of the SE Asian Cladocera, large part of their species (29; 42.6%) is known only in SE Asia (Tab. 2). In southern tropical/subtropical China (up to 30-34°N), 17 species (25%) were recorded while other species (10 or 15.0%) go far north, to the subtropical/temperate Eastern China and South Korea (up to 40°N). Only comparatively few species (7) occur up to the Amur river basin (44-54°N) and fewer others (4) in even more northern latitudes (up to 65-70° N). On the other hand, a conspicuous number of *good* species known in SE Asia (20) (Tab. 2) also occur in Australia, sometimes reaching the south-eastern portion of the country [*e.g.*, *Daphnia lumholtzi* Sars, *Simocephalus acutirostratus* (King)*, Dunhevedia crassa* (King)*, Alona pulchella* King), and even in New Zealand (*Armatalona macrocopa* (Sars)], thus demonstrating very wide latitudinal distribution in southern direction as well.

Rare species, known only from one-three localities, constitute a considerable fraction among the SE Asian species (18; 26.5%). Of them, for example, *Diaphanosoma modigliani* Richard is known only from two ancient lakes, lake Toba (in Sumatra) and lake Tempe (in Sulawesi) (Korovchinsky, 1998). *D. elongatum* Korovchinsky et Sanoamuang has been recorded only from two localities in Thailand (Korovchinsky and Sanoamuang, 2008a, 2008b and *unpublished data*), and *Matralona freyi* (Idris et Fernando) was found just from one locality in Western Malaysia (Idris and Fernando, 1981b; Sinev and Kotov, 2012).

DISCUSSION

The above described species evaluation and the selection of *good* species required certain assumptions. This is because, for example, not all taxa, which were formally revised and included in the recently published identification books (*e.g*., Korovchinsky, 1992; Smirnov, 1992, 1996), have been studied comprehensively. For this reason, the estimation of such taxa (22 of 67; 32.8%) as *good* species would be only tentatively realistic, as they require an accurate confirmation. Furthermore, a wide geographical distribution of some *good* taxa of species rank may testify to some uncertainty of their taxonomic status as well. For example, according to recent revision, *Euryalona orientalis* (Daday) has been suggested as pantropical (Rajapaksa and Fernando, 1987a) while more often paleotropical species were found to be different from their neotropical congeners (Rajapaksa and Fernando, 1987b, 1987c; Frey, 1987a). Also, in few taxa, there have been subtle but stable differences recorded between specimens from SE Asia and neighboring regions. In *Chydorus obscurirostris* Frey, specimens from Malaysia and Australia were attributed to different subspecies (Frey, 1987a), some intercontinental morphological differences were also reported for *Armatalona macrocopa, Leydigia ciliata* Gauthier, 1939 (Sinev *et al*., 2007; Sinev and Sanoamuang, 2011), *Alona archeri* Sars (Maiphae *et al*., 2008) and *Pseudosida szalayi* Daday (Korovchinsky, 2010) but they have not yet been evaluated taxonomically. Thus, the real number of *good* species could be considerably less than it has been formally accepted.

The next assumption concerns the identifications of taxa by non-taxonomists, specialising on particular groups. In such cases, when the interspecies morphological differences have been proven to be more subtle than thought before and many taxa remain undescribed, the probability of misidentifications increases. Also the data of older monographs on regional faunas may be often inadequate. For example, in the context of the present study, the monograph on the Chinese Cladocera (Chiang and Du, 1979), containing information on the northern distribution of many SE Asian species, is informative, though often there is no confidence about its adequateness. In such situation, the recently published comprehensive works on the cladoceran faunas of the Amur river basin (Kotov *et al*., 2011a, 2011b; Kotov and Sinev, 2011) and South Korea (Kotov *et al.*, 2012) are more informative, containing more reliable data on species composition and distribution in Eastern Asia.

Based on all the available data, the distribution of SE Asian Cladocera in the eastern part of Asia may be summarized as follows. About a quarter of the species are known

Tab. 2. Longitudinal and latitudinal distribution of *good* cladoceran species and subspecies known in SE Asia.

Longitudinal distribution (number of species)	Latitudinal distribution in Northern hemisphere				
	SE Asia	SE Asia - Southern China (up to 30° N)	SE Asia - Eastern China and S. Korea (up to 32 - 40° N)	SE Asia - Amur river basin	SE Asia - northern boreal regions (up to 70° N)
SE Asia (19)	Diaphanosoma modigliani D. elongatum D. senegal isanensis Macrothrix pholpuntini M. malaysiensis M. vietnamensis Streblocerus spinulatus Ilyocryptus thailandensis I. isanensis Chydorus obscurirostris tasekberae Alona acuticostata A. sarasinorum A. siamensis A. kotovi Matralona freyi Anthalona obtusa A. sanuamuangae		Camptocercus vietnamensis		Sida crystallina ortiva
Tropics-subtropics of Asia and Australia (25)	Diaphanosoma celebensis Macrothrix flabelligera* Chydorus reticulatus Ch. invaginatus Ch. opacus* Disparalona caudata* Armatalona macrocopa*	Diaphanosoma tropicum Simocephalus acutirostratus* Chydorus ventricosus Ch. sinensis Alonella breviceps Alona milleri Notoalona globulosa Celsinotum macronyx	A. cheni Karualona karua* Kurzia brevilabris Leberis diaphanus	Diaphanosoma dubium D. orghidani transamurensis D. macrophthalma Pseudosida szalayi* Daphnia similoides Nicsmirnovius eximius	
Tropics-subtropics of Eastern hemisphere (12)	Macrothrix odiosa Chydorus parvus Alonella clathratula* Dunhevedia serrata Anthalona harti harti	Diaphanosoma sarsi* D. excisum* D. volzi* Daphnia lumholtzi*	Scapholeberis kingi* Oxyurella singalensis	Simocephalus heilongiangensis	
Pantropics-pansubtropics (8)		Macrothrix spinosa*	Latonopsis australis* Moinodaphnia macleayi* Macrothrix triserialis Dadaya macrops* Dunhevedia crassa* Kurzia longirostris Euryalona orientalis		
Wide distribution (3)					Simocephalus serrulatus* S. mixtus Acroperus harpae
Total	29	13	14	7	4

*Species recorded from Australia.

only in SE Asia, but considerably more species (25) are known as distributed wider, either in the whole of Southern Asia or also in Australia. With the latter continent, SE Asia shares seven species, two of them (*Simocephalus acutirostratus, Armatalona macrocopa*) occur up to the south-eastern part of Australia, and New Zealand. Fewer species (12) have also been recorded in Africa, others (8) in the Western hemisphere, thus being pantropical/pansubtropical. All the intercontinental records of taxa of species rank should be checked carefully because many of them, especially the latter ones, undoubtedly represent different species (documented by numerous recent revisions; Frey, 1982, 1987b; Korovchinsky, 1996; *etc.*). To all appearance, there are no species common between SE Asia and America, excluding those resulted from the possible or real human-mediated invasions (Shirota, 1966; Fernando, 1980; Segers, 2001).

Most species (46; 67.6%) are known to occur mostly south of 30°N (of them, only five species [*Dadaya macrops* (Daday)*, Euryalona orientalis, Alona cheni* Sinev*, Kurzia brevilabris* Rajapaksa et Fernando*, Notoalona globulosa* (Daday)] were recorded slightly further to the north, reaching 32-34°N thus considered predominantly tropical taxa; 21 other species have been accepted as to be penetrating further north. Of them, 10 reach approximately 35-40°N (Central and Eastern China, South Korea, Japan) and 7 others are found in the Amur river basin (*Simocephalus heilongjiangensis* Shi et Shi*, Daphnia similoides* Hudeč*, Nicsmirnovius eximius* (Kiser)*, Pseudosida szalayi* Daday*, Diaphanosoma dubium* Manuilova*, D. orghidani transamurensis* Korovchinsky*, D. macrophthalma* Korovchinsky et Mirabdullaev). Though the distribution of some of the species is poorly known, most of them are known also to be predominantly tropical. Only the three latter species dominate subtropical and southern temperate latitudes (Korovchinsky, 2004) penetrating the tropics comparatively deeply and abundantly (*D. dubium*), or scarcely (*D. o. transamurensis, D. macrophthalma*) (Korovchisky, 2000b, 2004; Korovchinsky and Sanoamuang, 2008b, unpublished data). Four species (*Sida crystallina ortiva, Simocephalus serrulatus, S. mixtus, Acroperus harpae*) recorded in SE Asia are widely distributed in the Northern Eurasia up to 65-70°N and thus should be considered of northern origin.

It is interesting to note that some species of SE Asia in the western part of their range have a different distributional pattern, extending more deeply to the north. *Diaphanosoma sarsi* Richard and *D. excisum* Sars reach North India and Uzbekistan (~41°N) (Korovchunsky, 2004), *Daphnia lumholtzi* – delta of the Volga river (~46°N) (Behning, 1941), and *Anthalona harti harti* Van Damme *et al*. has been recorded in Abkhazia (~43°N) (Van Damme *et al*., 2011). At the same time, in Eastern Eurasia, these common and widely distributed species either are limited in their distribution by the territory of SE Asia or reach the latitudes 25-28°N in Southern China. This difference may originate both from poor knowledge of species distributions and different biological properties – including possible different taxonomic attitudes as it was noted for *Daphnia lumholtzi* by Behning (1941) – of eastern and western populations of species under consideration.

Thus, tropical species (not surprisingly) constitute the primary part of the cladoceran fauna of SE Asia, which can penetrate the neighboring subtropical and even southern temperate zones to a different degree. Only a small fraction of the species (7; 10.4%) here are of more or less northern origin dominating in the subtropical/southern temperate or in northern boreal latitudes. In general, much more tropical species tend to occupy subtropical/ temperate zones than subtropical/temperate species penetrate the tropics. The same tendency was observed in the cladoceran fauna in the south-east of the Korean Peninsula (Kotov *et al*., 2012).

At the same time, the northern faunal component may be more strong in SE Asia than it is known now; *i.e*., it is evident from the above discussed data by Shirota (1966) as well as from even earlier records by Spandl (1925) and Brehm (1933a), which listed respectively the North Eurasian *D. longispina, D. magna* Straus*, D. triquetra* Sars*,* and *Diaphanosoma perarmatum* Brehm (the latter is not well studied taxon of the *D. brachyurum* species group). Though some of these records are in fact results of misidentification or could be human introduction (Fernando, 1980) as it was also noted for rotifers (Segers, 2001), others probably represent real records that need to be investigated. In particular, Cladocera of montaneous areas which occupy considerable territories both in Mainland and Insular SE Asia, have been studied quite poorly.

Few species (*S. crystallina ortiva*, *D. macrophthalma*), likely arrived from the north to the south up to southernmost Vietnam using the Mekong river and its tributaries as a migration route. In Thailand, these species were found only in the north-eastern part of the country which is under the strong influence of the Mekong river, but they were absent in its northern part which is more elevated and comparatively isolated from large river basins (Korovchinsky and Sanoamuang, 2008b, unpublished data).

Previous authors published different numbers of the cladoceran species in different countries of SE Asia, from 45 to 62 (Shirota, 1966; Thanh *et al*., 1980; Idris, 1983), which clearly indicates an underestimation of species richnesses. Recently Maiphae *et al*. (2008) recorded 99 species (+10 unidentified forms) in Thailand, which is comparable with species numbers for the whole Oriental zone (107 species). The latter value, however, is the lowest when compared to other zoogeographical zones (Forró *et al*., 2008), which again is proof of an underestimation of the parameter.

To estimate, at least roughly, the real species richness of the Cladocera in SE Asia, we need to evaluate the number of potential *good* species, which are hidden under the names of vague taxa, clearly representing specific but not revised taxonomic units requiring further investigations: *Diaphanosoma perarmatum, Leydigiopsis* sp., *Guernella raphaelis* Richard*, Pseudochydorus globosus* (Baird)*, Alonella nana* (Baird)*, Graptoleberis testudinaria* (Fischer)*, Bosminopsis deitersi* Richard*, Bosmina meridionalis* Sars *etc.* The analysis of such taxa, based on data of Tab. 1, leads to the number of approximately 90-100 extra taxa of species rank which may be validated in the course of future taxonomic work. This result approaches a potential species richness of Cladocera in SE Asia to approximately 200 species, almost three times more than it is accepted now for the region and comparable with the estimation of a potential diversity of the global fauna (Forró *et al*., 2008). The largest portion of such taxa is represented by members of the (most speciose) family Chydoridae. Daphniidae and Macrothricidae follow them in this respect.

At present, only Thailand, more strictly, North-East Thailand and South Thailand, as well as Vietnam (small area in its south) are in the focus of the most extensive and detailed taxonomic and faunistic studies of the Cladocera (Sanoamuang, 1998; Maiphae *et al*., 2005, 2008; Korovchinsky and Sanoamuang, 2008a, 2008b; Sinev, 2011; Sinev and Sanoamuang, 2011; Korovchinsky, 2011; Sinev and Korovchinsky, 2013; Van Damme *et al*., 2013). In all other countries such studies either are at the initial stage of samples' collection and identification (*e.g*., Cambodia) or surveys and faunistics are absent completely.

CONCLUSIONS

The cladoceran species richness of SE Asia is still poorly known. From the modern point of view, only a small fraction of the species in this region has been described properly. Many of these species are known only from a single locality or very few localities, range boundaries can be tentatively outlined in some cases only. Most of the SE Asian countries are not included in the cladoceran studies. These huge gaps in knowledge, prevent a proper zoogeographic analysis. Further extensive and detailed taxonomic studies are especially needed to improve the situation.

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