# Taxonomy and Biogeography of the Cladocera from Southern Thailand, with Specific Reference to *Alona* Baird, 1843 and *Macrothrix* Baird, 1843

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**Doctor of Philosophy Thesis in Biology**

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The Graduate School, Prince of Songkla University, has approved this thesis as partial fulfillment of the requirement for the Doctor of Philosophy degree in Biology.

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| ชื่อวิทยานิพนธ์ | อนุกรมวิธานและการแพร่กระจายเชิงชีวภูมิศาสตร์ของคลาโดเซอราในแหล่งน้ำจืด เขตพื้นที่ภาคใต้ของประเทศไทย โดยเน้นศึกษาในสกุลอะโลนาและแมคโครทริค |
| ผู้เขียน | นางสาวสุปิยนิตย์ ไม้แพ |
| สาขาวิชา | ชีววิทยา |
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## บทคัดย่อ


ศึกษาอนุกรมวิธาน การแพร่กระจายเชิงนิเวศและการแพร่กระจายเชิงชีวภูมิศาสตร์ของคลาโดเซอราที่พบในตัวอย่างเชิงคุณภาพที่เก็บในฤดูฝนและฤดูร้อนระหว่างเดือนกันยายน 2542 ถึงเดือนพฤษภาคม 2543 จากแหล่งน้ำจืดในพื้นที่ภาคใต้ของประเทศไทย จากการศึกษาพบคลาโดเซอราทั้งสิ้น 6 วงศ์ 31 สกุล 72 ชนิด เป็นชนิดใหม่ของโลกหนึ่งชนิดและเป็นชนิดที่มีรายงานเป็นครั้งแรกของประเทศไทย 12 ชนิด Chydoridae เป็นวงศ์ที่มีความหลากชนิดมากที่สุด (45 ชนิด) ตามด้วย Macrothricidae (11 ชนิด) และ Daphniidae (6 ชนิด) สกุล *Alona* เป็นสกุลที่พบจำนวนชนิดมากที่สุด (13 ชนิด) ตามด้วยสกุล *Macrothrix* (9 ชนิด) และ *Chydorus* (7 ชนิด) ตามลำดับ

จากการศึกษาสัณฐานวิทยาของสกุลที่มีจำนวนชนิดมากที่สุดสองสกุลคือ *Alona* และ *Macrothrix* โดยละเอียด พบว่าตัวอย่างของแต่ละชนิดในทั้งสองสกุลมีความแปรผันของลักษณะทางสัณฐานวิทยาสูงทั้งลักษณะภายนอก เช่น ขนาดและจำนวนขนบนเปลือก ลวดลายบนเปลือก และลักษณะ head pores และลักษณะภายใน เช่น ความยาวของซีตีของรยางค์อกแต่ละคู่ เป็นต้น นอกจากนี้การศึกษาเปรียบเทียบลักษณะทางสัณฐานวิทยาของแต่ละชนิดในหลายประชากรทำให้สถานะทางอนุกรมวิธานในระดับชนิดของทั้งสองสกุลได้รับการตรวจสอบ

ในการประเมินจำนวนชนิดที่แท้จริงของคลาโดเซอราในภาคใต้พบว่า Chao 2 เป็นดัชนีที่มีความลำเอียงน้อยที่สุดในการศึกษาครั้งนี้ โดยพบว่าจำนวนชนิดทั้งหมดที่พบในการศึกษาครั้งนี้ไม่มีความแตกต่างมากนักจากจำนวนชนิดที่แท้จริงจากการประเมินโดย Chao 2 (76 ชนิด) แต่มีความแตกต่างมากกับจำนวน All Taxa Biological Inventory (ATBI) ต่อแหล่งน้ำ บ่งชี้ว่าประเทศไทยมีจำนวนชนิดของคลาโดเซอรามากเกินกว่าจะพบทั้งหมดในแหล่งน้ำเดียวได้ อีกทั้งผลจากการพิจารณาความแตกต่างขององค์ประกอบชนิดของคลาโดเซอรายืนยันการกระจายแบบ

non-cosmopolitanism ของคลาโดเซอรา ในทุกระดับของการเปรียบเทียบ โดยค่าความแตกต่างขององค์ประกอบชนิดของคลาโดเซอราที่สูงมากบ่งชี้ว่า จำนวนชนิดที่สามารถพบได้ทั่วไป (common species) มีอยู่น้อย อย่างไรก็ตามความแตกต่างของที่มาของแต่ละข้อมูลที่ใช้อาจส่งผลต่อการเปรียบเทียบได้

คลาโดเซอรายังแสดงความสัมพันธ์กับลักษณะของแหล่งน้ำอีกด้วย โดยพบว่ามีเพียงบางชนิดเท่านั้นที่พบปรากฏอยู่ทั่วไป ในขณะที่คลาโดเซอราส่วนใหญ่จะพบปรากฏเฉพาะในแหล่งน้ำบางลักษณะเท่านั้น นอกจากนี้ผลการศึกษายังแสดงให้เห็นว่าชนิดที่เป็น littoral species มีการแพร่กระจายในประเทศไทยโดดเด่นกว่าชนิดที่เป็น limnetic species อย่างไรก็ตามผลการวิเคราะห์ความสัมพันธ์ระหว่างปัจจัยทางกายภาพที่ตรวจวัดกับชนิดของคลาโดเซอราแสดงให้เห็นว่าปัจจัยที่ตรวจวัดนั้น อาจไม่ส่งผลโดยตรงต่อองค์ประกอบของชนิดคลาโดเซอราและการกระจายของคลาโดเซอราในพื้นที่ศึกษา

ท้ายที่สุดของการศึกษาได้อภิปรายเหตุการณ์ที่น่าจะเป็นไปได้ต่อการแพร่กระจายเชิงชีวภูมิศาสตร์ของคลาโดเซอราในปัจจุบัน ซึ่งหากพิจารณาอายุของคลาโดเซอราแล้ว เป็นไปได้ว่าชนิดที่พบได้ทั่วไปในปัจจุบัน (common species) น่าจะเป็นชนิดที่มีจุดเริ่มต้นของชนิดร่วมกันก่อนที่จะเกิดการแยกตัวของแพนเจีย (Pangaea) อีกทั้งร่องรอยของรอยเชื่อมต่อที่ปรากฏระหว่างภูมิภาคก็เป็นเหตุผลในการอธิบายการกระจายของคลาโดเซอราได้ดี ในทางกลับกันลักษณะทางนิเวศวิทยาของแหล่งน้ำที่แตกต่างกันในแต่ละบริเวณก็อาจเป็นตัวจำกัดการกระจายของคลาโดเซอราบางชนิดได้เช่นกัน

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**Abstract**

The taxonomy, ecological and biogeographical distribution of the Cladocera were studied based on qualitative samples collected in freshwater localities throughout southern Thailand in rainy and summer season during September 1999 to May 2000. A total of six families, 31genera and 72 species was recorded. Of which, one was new to science and 12 were new to Thailand. Chydoridae was the most diverse family (45 species) followed by Macrothricidae (11 species) and Daphniidae (6 species). *Alona* was the most dominant genus (13 species) followed by *Macrothrix* (9 species) and *Chydorus* (7 species).

Detailed morphological characters of two frequently encountered genera, *Alona* Baird, 1843 and *Macrothrix* Baird, 1843 were investigated. The great variation in differences of the morphology was found in both external characteristics such as size and number of ventral setae, ornamentation of valve, postabdomen and head pores, and internal characteristics such as detailed characters of each seta on each trunk limbs. Morphological comparisons of different populations were made so that the taxonomic status of the species level can be reviewed.

To assess actual species richness, Chao 2 was examined as the least bias nonparametric estimator for present data. The total species recorded was not far from S**max* Chao 2 (76 species) which was distinctly higher than the expected All Taxa Biological Inventory (ATBI) per locality. It was demonstrated that each part of Thailand contains more species than can be packed in any single waterbody. The complementarity results confirmed the non-cosmopolitanism concept in every scale. High complementarity value indicated that the number of species in common is low.

However, artifacts from differences in the original data used in the present study may handicap comparisons.

Cladoceran showed the association with habitat characteristics which is only few species occurs almost everywhere but mostly appears preferentially in definite kinds of aquatic environments. It is also clearly shown that littoral species are dominant in southern Thailand rather than limnetic ones. It is confirmed that the limnetic community is more uniform but poor in species richness while compared to the littoral community. However, correlations between the occurrence of particular cladocerans and environmental conditions revealed that measured factors may not be the most important ones to affect cladoceran species composition and distribution.

Finally, an attempt was made to discuss the possibility of biogeographic events that have led to the present day cladoceran distribution. Concerning the age of the cladoceran, common species overlapping over the regions can be explained by the sharing a common origin of species before Pangaea was broken up and the connections between the continents also served as dispersal routes between the continents. On the other hand, ecological processes can restrict the distribution range of some species.

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Supiyanit Maiphae

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## Abbreviations and Symbols

### Abbreviations used in figures

| | | |
|---|---|---|
| P1 | = | trunk limb 1 |
| P2 | = | trunk limb 2 |
| P3 | = | trunk limb 3 |
| P4 | = | trunk limb 4 |
| P5 | = | trunk limb 5 |
| P6 | = | trunk limb 6 |
| PEP | = | pre-epopodite |
| EP | = | epipodite |
| EX | = | exopodite |
| EN | = | endopodite |
| IE | = | internal endite |
| EE | = | external endite |
| IDL | = | inner distal lobe |
| ODL | = | outer distal lobe |
| E1 | = | endite 1 |
| E2 | = | endite 2 |
| E3 | = | endite 3 |
| GT | = | gnathobase |
| sn | = | sensillum |

### Abbreviations used in text

| | | |
|---|---|---|
| *et al.* | = | Et. Ali (Latin), and others |
| fig. | = | figure |
| figs. | = | figures |
| pl. | = | plate |
| cf. | = | confer (Latin, meaning compare with) |

## **Abbreviations and Symbols** (Continued)

| | | |
|---|---|---|
| aff. | = | affinis (Latin, meaning akin to, having an affinity but not identical) |
| μm | = | micrometer |
| mm | = | millimeter |
| cm | = | centimeter |
| ppt. | = | part per thousand |
| IP | = | Interpore distance (distance between anterior and posterior major head pores) |
| PP | = | Postpore distance (distance between posterior head pore and posterior corner of head shield) |
| DCA | = | Detrended Correspondence Analysis |
| CCA | = | Canonical Correspondence Analysis |
| TWINSPAN | = | Two-Way Indicator Species Analysis |
| ATBI | = | All Taxa Biological Inventory |

**Abbreviations of the reference collections**

| | | |
|---|---|---|
| AAK | = | Alexey A. Kotov |
| GU | = | Ghent University |
| KKU | = | Khon Kean University |
| NMK | = | Nikolai M. Korovchinsky |
| NUS | = | National University of Singapore |
| SM | = | Supiyanit Maiphae |

# CHAPTER 1: INTRODUCTION

## 1. Classification of the Cladocera

The species is the main objective unit of zoological taxonomy based on genetic, reproductive and ecological specificity (Mayr, 1963). Alternatively Dubois (1988) considers the genus as the fundamental objective unit, a genus being the collection of all species that can successfully interbreed. Therefore one of the main aims of taxonomy is to identify the list of real biological species. This is often not an easily resolved task. As in many other groups of animals, cladoceran taxonomy is complicated by the inferior quality of early work, the presence of cyclical parthenogenetic reproduction, and inter-specific hybridization (Wolf and Mort, 1988). The history of research has been divided into three periods (Dumont and Negrea, 2002): first phase (1662-1776); second phase (1776-1959) and the third phase (1959-present). During the first two phases, taxonomic and systematic studies were dominated by European researchers, working on the European fauna in the first half of the $19^{th}$ century. Some pages marked the beginning of study in North America by the end of the century, and the first studies on the tropics also appeared around that time. However, most regional monographs were produced in the third period (1959-present), increasingly addressing tropical parts of the world, but there still was no major study from Asia until the middle of the $20^{th}$ century, and this region remains fragmentarily being investigated until the present. In recent decades, the systematics of the Cladocera has been revolutionized but many challenging problems remain to be solved in every field of study in every part of the world. The total number of species known is approximately 500-600 (Dumont, 1996; Korovchinsky, 1997), but very few have been well studied. Also, we know little of the geographical distribution of many species, partly because of the wide gap between study sites, and errors in identification.

The classification of the Cladocera has been deeply revised several times. The current classification developed by Negrea *et al.* (1999), with additions by

Santos-Flores and Dodson (2003), recognizes two ctenopod and 11 anomopod families.

Phylum Arthropoda

Superclass Crustacea Lamarck, 1801

Class Branchiopoda Latreille, 1817 (sensu Calman, 1909)

Superorder Cladocera Milne-Edwards, 1840 (*sensu* Negrea et al.,1999)

Order Ctenopoda Sars, 1865

1. Family Sididae Baird, 1850 (emend. Sars, 1865)
2. Family Holopedidae Sars, 1865

Order Anomopoda Sars, 1865

1. Family Daphniidae Straus, 1820 (emend. Schoedler, 1858)
2. Family Bosminidae Baird, 1845 (emend. Sars, 1865)
3. Family Macrothricidae Norman & Brady, 1867
4. Family Eurycercidae Kurz, 1875
5. Family Ilyocryptidae Smirnov, 1876
6. Family Chydoridae Dybowsky & Grochowski, 1894 (emend. Stebbing, 1902)
7. Family Sayciidae Frey, 1967
8. Family Ophryoxidae Smirnov, 1976
9. Family Acantholeberidae Smirnov, 1976
10. Family Neothricidae Dumont & Silva-Briano, 1998
11. Family Dumontiidae Dodson & Santos-Flores, 2003

Order Onychopoda Sars, 1865

1. Family Polyphemidae Baird, 1845
2. Family Podonidae Mordukhai-Boltovskoi, 1968
3. Family Cercopagidae Mordukhai-Boltovskoi, 1968

## 2. General characteristics of the Cladocera

**Diagnosis of Superorder Cladocera Milne-Edwards, 1840 (Dumont and Negrea, 2002)**

Body short, with tagmosis obscure, terminating in a postabdomen armed with a pair of terminal claws (not in males of some Macrothricidae, and not in Neothricidae) and with a pair of sensory setae situated on a prominence. Carapace bivalved without hinge, enclosing trunk and its appendages (not in Onychopoda, where carapace reduced to dorsal brood sac). Head short. Labrum fleshy. Eye single, internal, with several lenses (not developed in cavernicolous species of *Alona*). Ocellus usually present. Antennules tubular in females. Antennae biramous, natatory, with 2-4 segments per branch. Mandibles of the grinding type (except in Onychopoda, where they are biting). Maxillae reduced or absent. Trunk limbs 4-6 pairs, with an exopodite (lost in Onychopoda: Cercopagidae only), similar in shape or modified individually to perform various functions. Food grove deep and narrow (except in Onychopoda, where no true food groove is found). Alimentary canal straight or with a loop. No postembryonic larval stages. Males with antennules often modified for clasping, and P1 ending in an apical clasper. Length ranges from 0.2 (in Anomopoda) to 12 mm (in Onychopoda). The general morphology of the Cladocera was shown in figure 1.

*Two Orders of the Cladocera have been recorded in Thailand; Order Ctenopoda and Order Anomopoda*

**Characters of Order Ctenopoda Sars, 1865 (Dumont and Negrea, 2002)**

Body short, compose of few, indistinct segments and ending in a postabdomen with an apical pair of claws, never articulated to the trunk. Carapace not calcified, bivalved, without hinge, enclosing only trunk and appendages. Head large, without head shield. Eyes single, internal, always fused in adults, with many lenses. Ocellus small or absent (*Diaphanosoma, Penilia*). Antennules tubular and movable in females, elongated and modified for clasping usually in males. Antennae biramous, natatory (uniramous only in females of *Holopedium*). Both branches of 2-3 segments, armed with between 13 and 27 natatory setae. Six pairs of trunk limbs (fig. 2), filtratory and showing much serial similarity, although the sixth pair is more reduced. Exopodites present. First trunk limb of male with distal hook, or with modified distal region. Food groove deep and narrow. Alimentary canal straight. Ovaries paired; ovarian cells originate anteriorly. Carapace not modified to an ephippium. Parthenogenetic eggs large, passed into dorsal brood space formed by carapace where they develop to miniature replicas of adults. Reproduction by gamogenesis alternates with parthenogenesis. No larval stages; young released from resting eggs are replicas of adults. Length up to 4 mm, usually 1-3 mm in females and 0.7-1.5 mm in males.

**Characters of Order Anomopoda Sars, 1865 (Dumont and Negrea, 2002)**

Body short, more or less laterally compressed, indistinctly segmented and ending in a postabdomen with an apical pair of claws (rarely absent), which sometime articulates to the trunk. Carapace not calcified, bivalved, without hinge, enclosing only the trunk and appendages, often with modifications (eg. along the ventral rim; sometimes honeycombed; rarely with growth lines). Head short or very short. Head shield usually well developed. Labrum fleshy. Eyes single, internal, always fused in adult, from small to big, usually with few lenses, secondarily absent in *Monospilus*, in the semi-terrestrial genera *Bryospilus* and *Nicsmirnovius*, and in subterranean species of *Alona*. Ocellus present except in blind cave species. Antennules tubular, of one or two segments, more or less large, occasionally reduced to small papillae (in females). Antennae biramous, natatory; exopod of 3-4 segments and endopod of 3 segments, armed with up to 9 long natatory setae and spines; sometimes a short terminal spine on both rami. Mandibles of the grinding type. Maxillules with few spines (maximum 4). Maxillae reduced to a mound or absent. Five or six pairs of trunk limbs of variable shape and size according to function, but none in postgenital position (figs. 3-8). Exopodites and epipodites (sometimes pre-epipodite) present. First and sixth pairs (if present) non-filtratory. First pair frequently used in locomotion. Others modified for grasping, scraping and guiding particles, and for sweeping or filtration according to species and position in the row of limbs. No metachronal beating rhythm. First trunk limb of males with apical clasping hook, and usually with long additional seta or extra spine. Food groove deep and narrow. Alimentary canal with various modifications; straight or convoluted, with or without a pair of anterior caeca, with or without posterior diverticulum, and with or without tubular and glandular organ.

**Characteristics of the six known families of the Cladocera in Thailand**

**1. Sididae Baird, 1850**

Head large, without head shield. Antennules movable, with nine sensory aesthetes. Swimming antennae long and massive, of two branches. Valve oblong, covering six pairs of basically similar thoracic limbs and a postabdomen. Male with long antennules and copulatory appendages (absent in the genera *Sida* and *Limnosida*).

**2. Daphniidae Straus, 1820**

Body laterally compressed. Carapace often with a caudal spine. Head with rostrum. Head capsule with a fornix, often strongly developed and ending in a spine. Female antennules small and either mobile or immobile; if mobile, fused to the underside of the head. Antennules of the male strongly developed, mobile, often with a long apical seta. Antennae long and mobile; endopodite of three articles with five (rarely four) swimming setae, exopodite of four articles with four setae. Five pairs of trunk limbs, all with a different structure. P1 and P2 more or less radopod-like, but more strongly fused and limb 5 as strongly reduced as in the most advanced macrothricids. P1 of the male with a copulation hook. Most diagnostic are the enormous filter screens of P3 and P4, which are true gnathobasic outgrowths. Ephippium typical, containing one or two winter eggs. Parthenogenetic eggs usually produced in large numbers, filling the incubator space of the valves.

**3. Bosminidae Baird, 1846**

Body more or less rounded, of small size. No demarcation between head shield and carapace. Head shield with three types of pores (one dorsal, one frontal, and two paired lateral ones). Female rostrum with an elongated conical extension on which the antennules insert; antennules elongated, more or less recurved, immobile, pluri-articulated, provided with sensory setae on their anterior border. Male antennules longer than rostral expansion, mobile. Antennae biramous, short, with endopodite composed of three articles and five setae, and exopodite of four articles and 3-4 setae. Ocellus absent. Six pairs of trunk limbs, but last pair reduced to a small, naked lobe.

**4. Ilyocryptidae Smirnov, 1992**

Head small and triangular. Carapace bearing marginal setae of a peculiar, often ramified, shape. Antennule 2-segmented (unique among anomopods), with short proximal segment, extending on ventral side of head. Antenna with an exopod of four segments, and an endopod of three segments. Segments of antennal branches short. Six pairs of thoracic limbs, but P6 reduced to a small, valve-like lobe. P1 and P2 small. P1 with ejector hooks situated medially. P2 superficially daphniid-like. P3 and P4 with an exopodite with 8 setae; the exopodite of P5 has 7 plumose setae. Exopodite of P3 elongated, with a suggestion of being bi-segmented. Exopodite of P4 and P5 with large exopods. All endopods with large gnathobases, and no filter-screens. Postabdomen wide and semi-circular, its distal part with long lateral setae and shorter marginal anal teeth; proximal part with long teeth. Setae natatoriae long, with long distal segment. End-claw long, with 2 thin basal spines. Eye and ocellus present.

**5. Chydoridae Dybowski & Grochowski, 1894**

Body globular or elliptic, sometimes laterally compressed, covered by head shield and carapace. Rostrum mostly strongly developed, often extended anteriorly and ventrally in a long tube. Rostrum as a rule shorter in males than in females. Number of principle head pores variable, most often 2-3 but sometimes one ore even none, and up to 4-5, connected or unconnected. Additional lateral head pores present or not, sometimes slit-shaped. Antennules uni-articulated, short and mobile, hidden under the rostrum to a variable degree. Antennules of the males larger than of the females. Antennae short to very short, both rami tri-articulated; exopodite with 3 setae natatoriae, endopodite with 3-5 such setae. Ocellus well developed, absent in some subterranean species. Eye sometimes of the same size as ocellus, or smaller, or absent in a number of genera. Mandibles attached a short distance away from the border of the head capsule. Five pairs of trunk limbs (exceptionally a rudiment of a sixth pair). P1 five lobed; gnathobase with one apical seta, or a spine, gnathobase absent; ejector hooks present. P1 of male modified; ODL with a copulatory hook and male seta. Labrum usually well developed, of different shapes, often keeled. Postabdomen with anal spines and end-claws with one or two basal spines. Ephippium of a 'primitive' type, containing one egg.

**6. Macrothricidae Norman & Brady, 1867**

Head large, little demarcated, with rostrum usually reduced. Antennule one segmented, attached to ventrum of head, cigar-shaped or apically widend. Antenna with exopod four-segmented, endopod three segmented. Distal segments of antennal branches elongated. Five pairs of thoracic limbs, but P5 strongly reduced in *Guernella*. P1 5-lobed, with one or two ejector hooks; gnathobase in many species reduced. Endopodite of P2 with 8 scrapers, but only 7 in *Guernella*. Exopodites of P3-P5 small to very small. Postabdomen usually rather broad, with rows of spines on the dorsum and some on the sides. End-claws present in all females, lacking in some males. Eyes and ocellus present. Intestine with or without convolutions. Ephippium not well delimited.

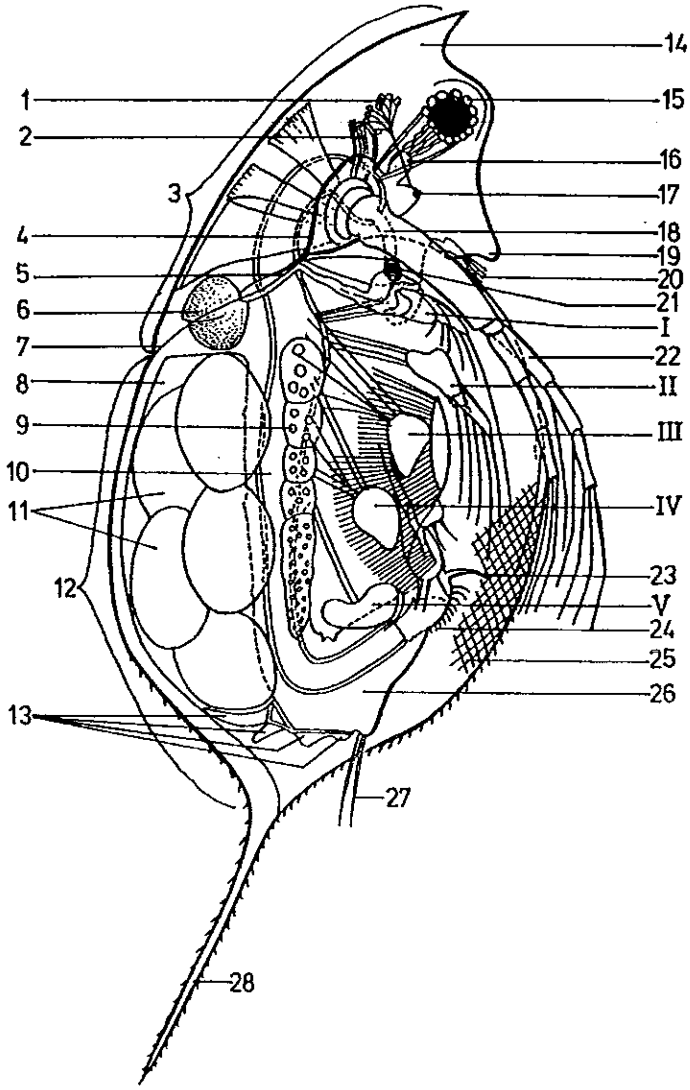
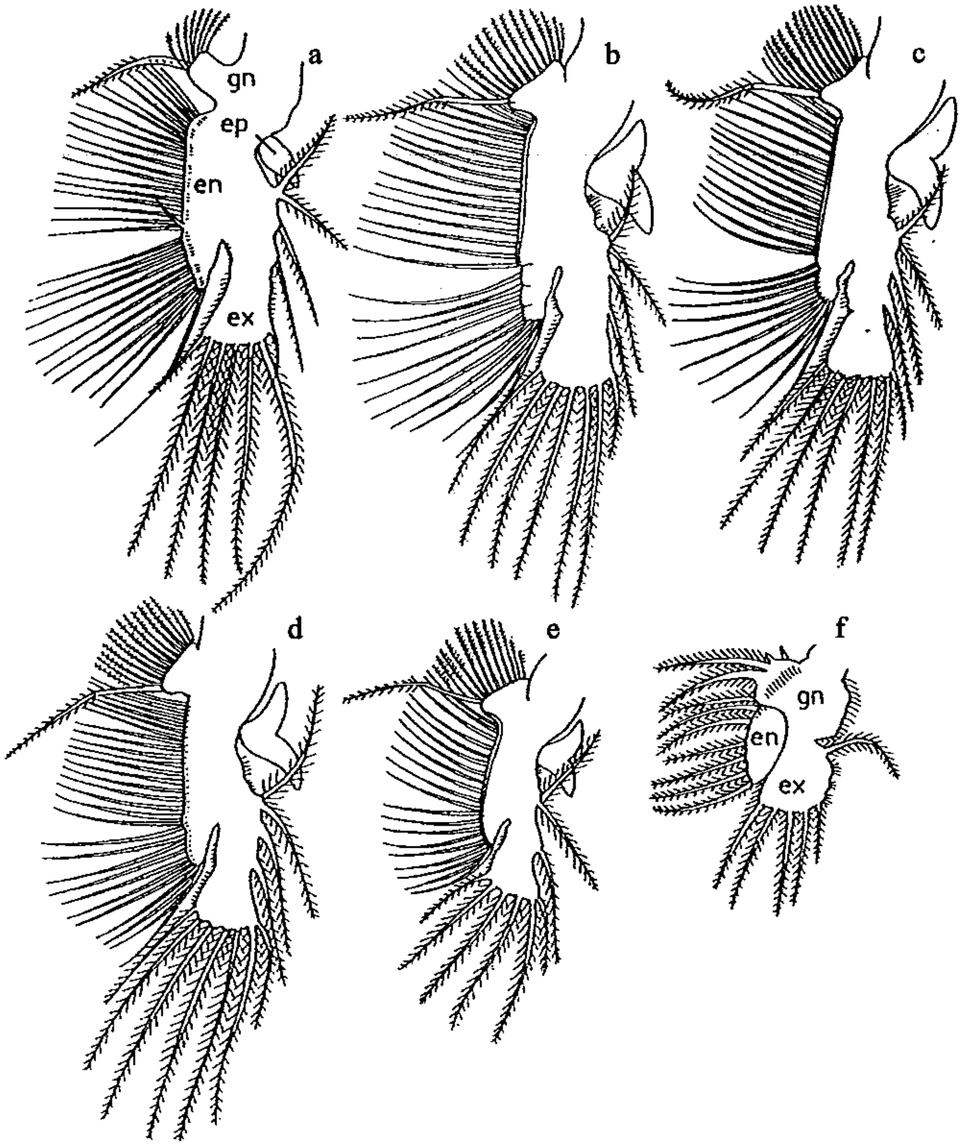



Figure 1. Morphology of the Anomopoda: parthenogenetic female of *Daphnia galeata*
1. sensory organ; 2. hepatic caecum; 3. cephalic capsule; 4. main fornix; 5. maxillary (or carapace) gland; 6. heart; 7. occipital groove (separating head shield from valves); 8. brood pouch; 9. ovary; 10. gut; 11. eggs; 12. valves; 13. abdominal processess; 14. helmet; 15. compound eye; 16. optic lobe (brain); 17. ocellus; 18. oesophagus; 19. rostrum; 20. antenna; 21. mandibula; 22. antenna; 23. end-claw of postabdomen; 24. dorsal (anal) spines of postabdomen; 25. reticulation of valves; 26. postabdomen; 27. setae natatoriae; 28. caudal spine of valves; I-V. trunk limbs 1-5. (Dumont and Negrea, 2002)




Figures 2a-f. Structure of the limbs of the Ctenopoda. *Sida crystallina* female: a. trunk limb 1; b. trunk limb 2; c. trunk limb 3; d. trunk limb 4; e. trunk limb 5; f. trunk limb 6. (Behning, 1912 referred by Dumont and Negrea, 2002)

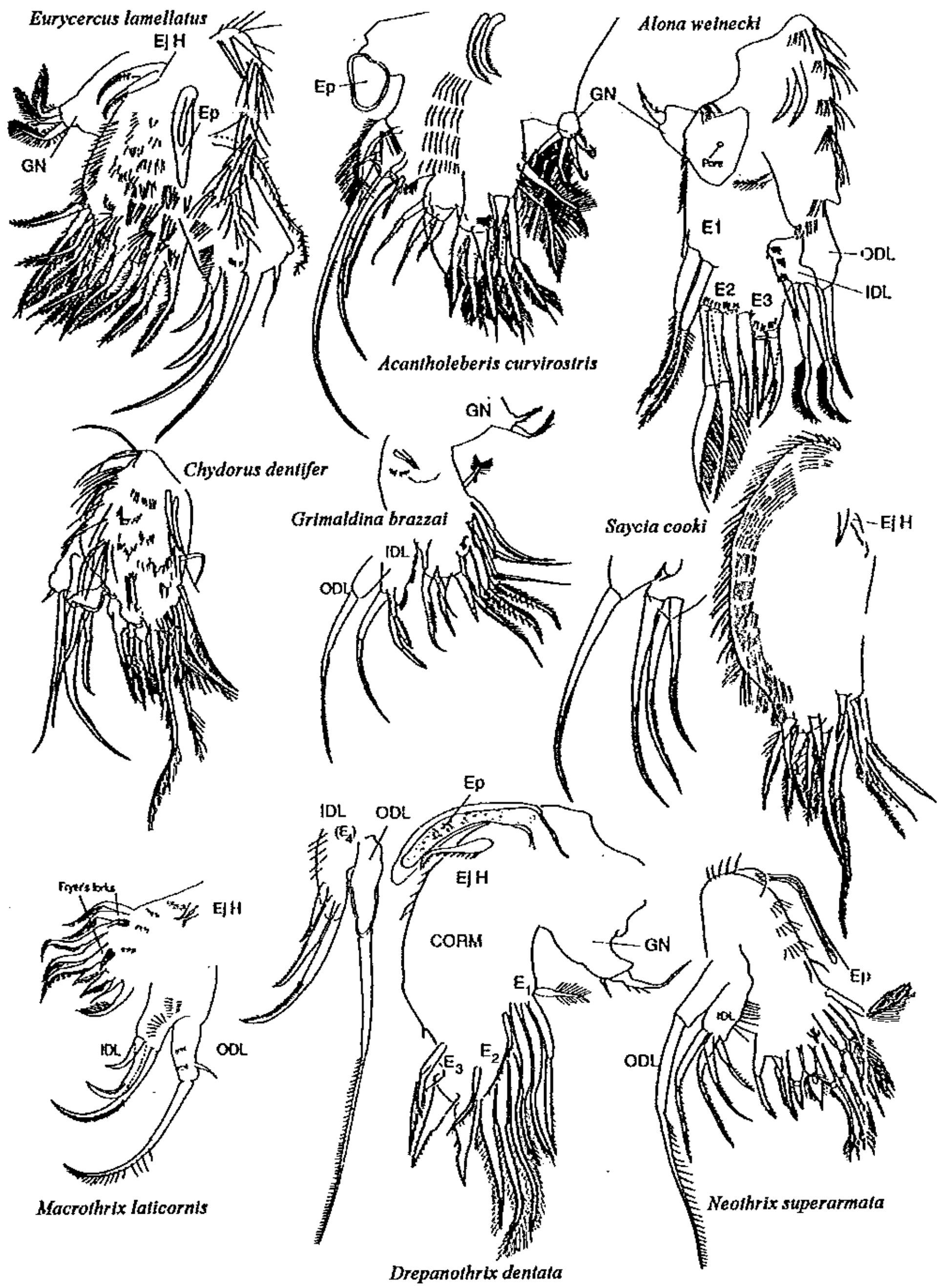



Figure 3. Trunk limb 1 in females of Radopoda. Species name are given directly on the plate. (Dumont and Negrea, 2002 after Alonso, 1996; Dumont and Silva-Briano, 1997)

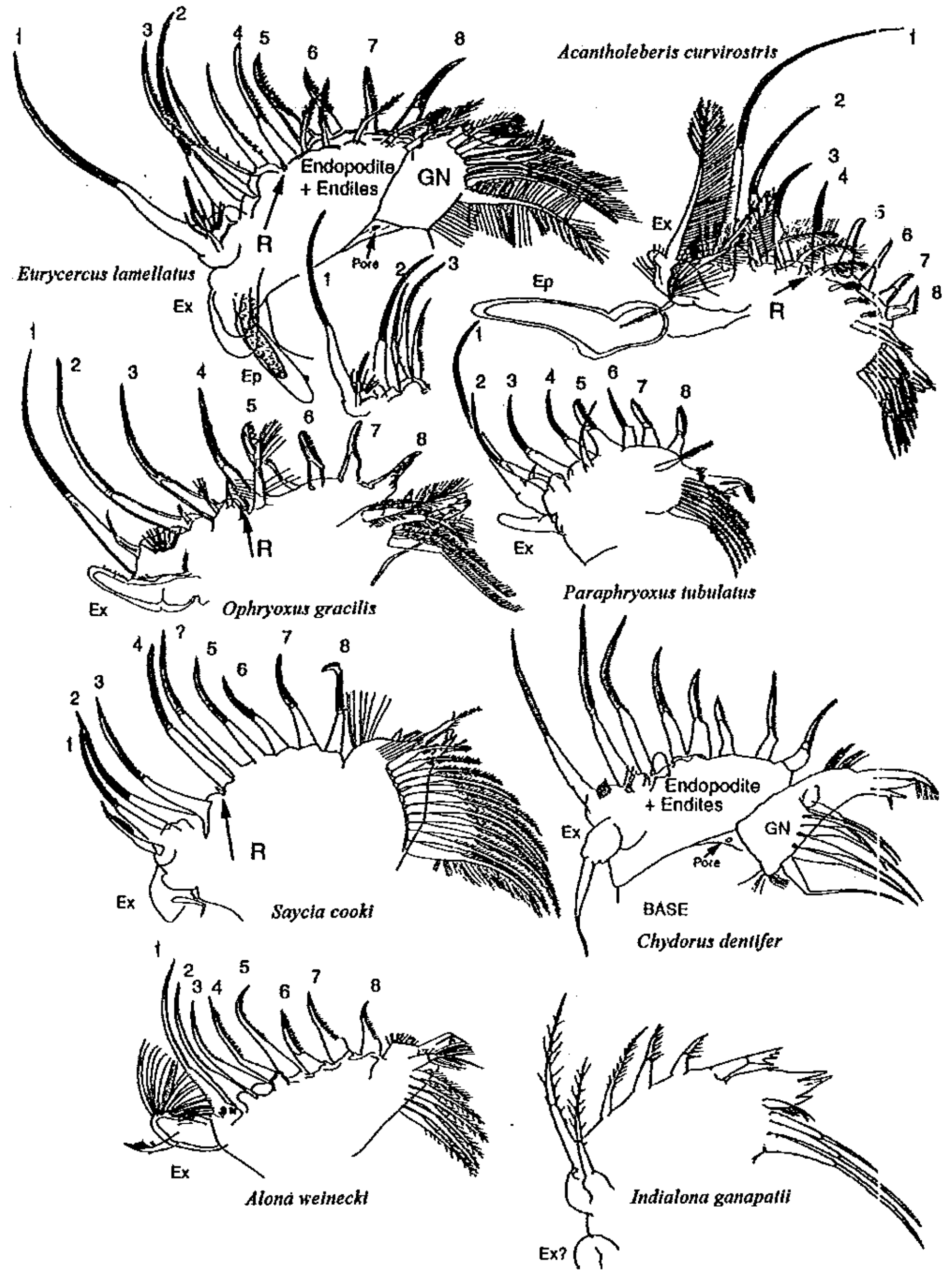



Figure 4. Trunk limb 2 in representatives of the Radopoda. R: small bottom shaped Receptor. (Dumont and Negrea, 2002 after Dumont and Martens, 1995, Dumont and Silva-Briano, 1997 and Kotov, 2000)

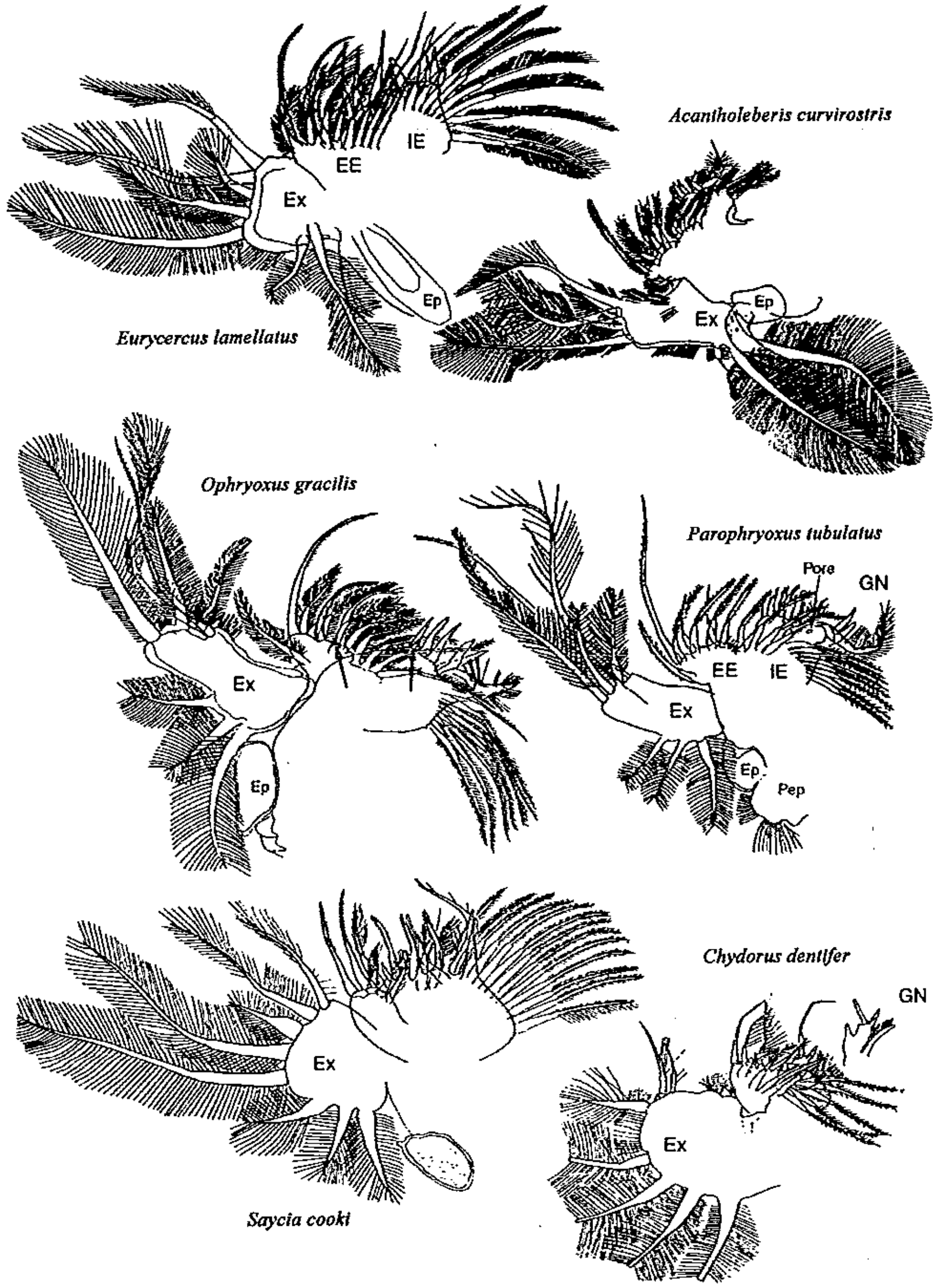



Figure 5. Trunk limb 3 in Radopoda. (Dumont and Negrea, 2002).

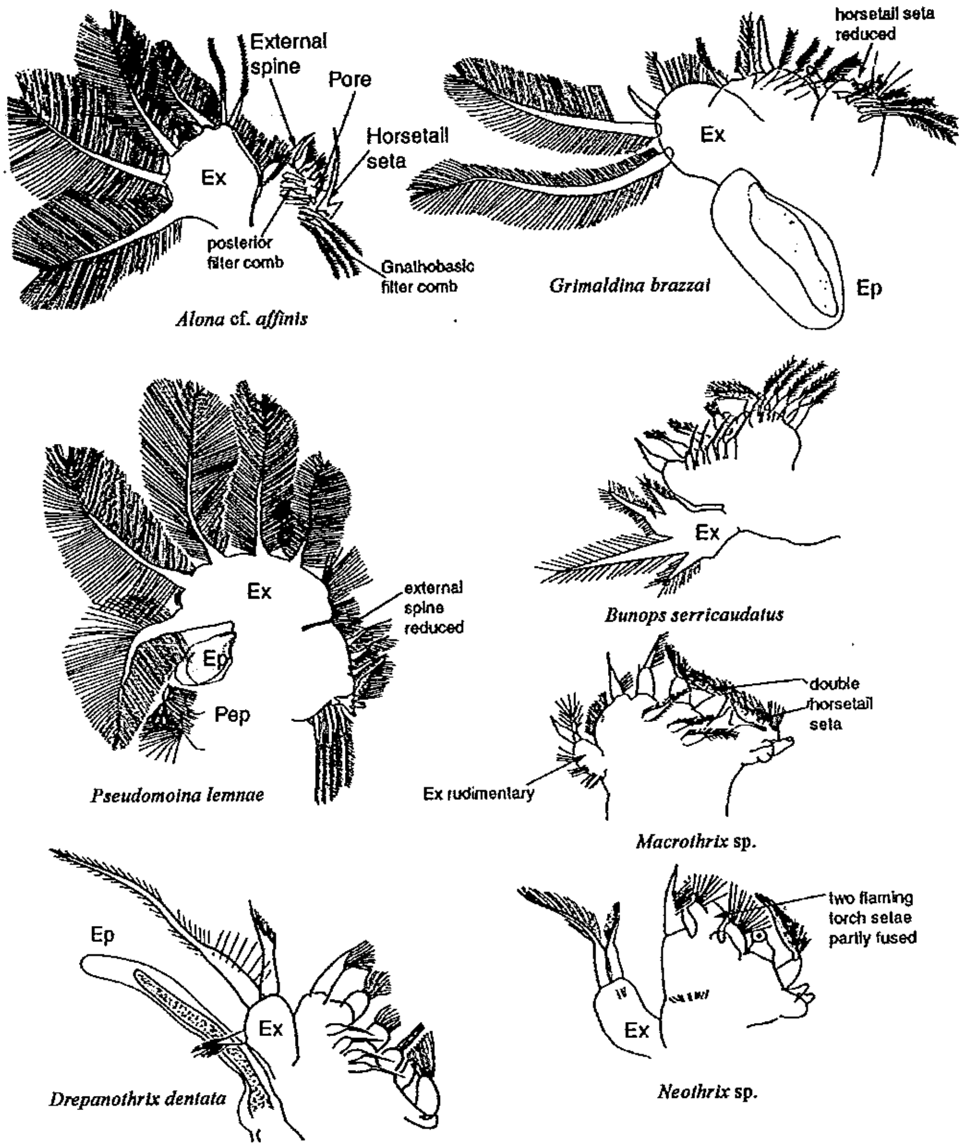



Figure 6. Trunk limb 4 in Radopoda. (Dumont and Negrea, 2002).

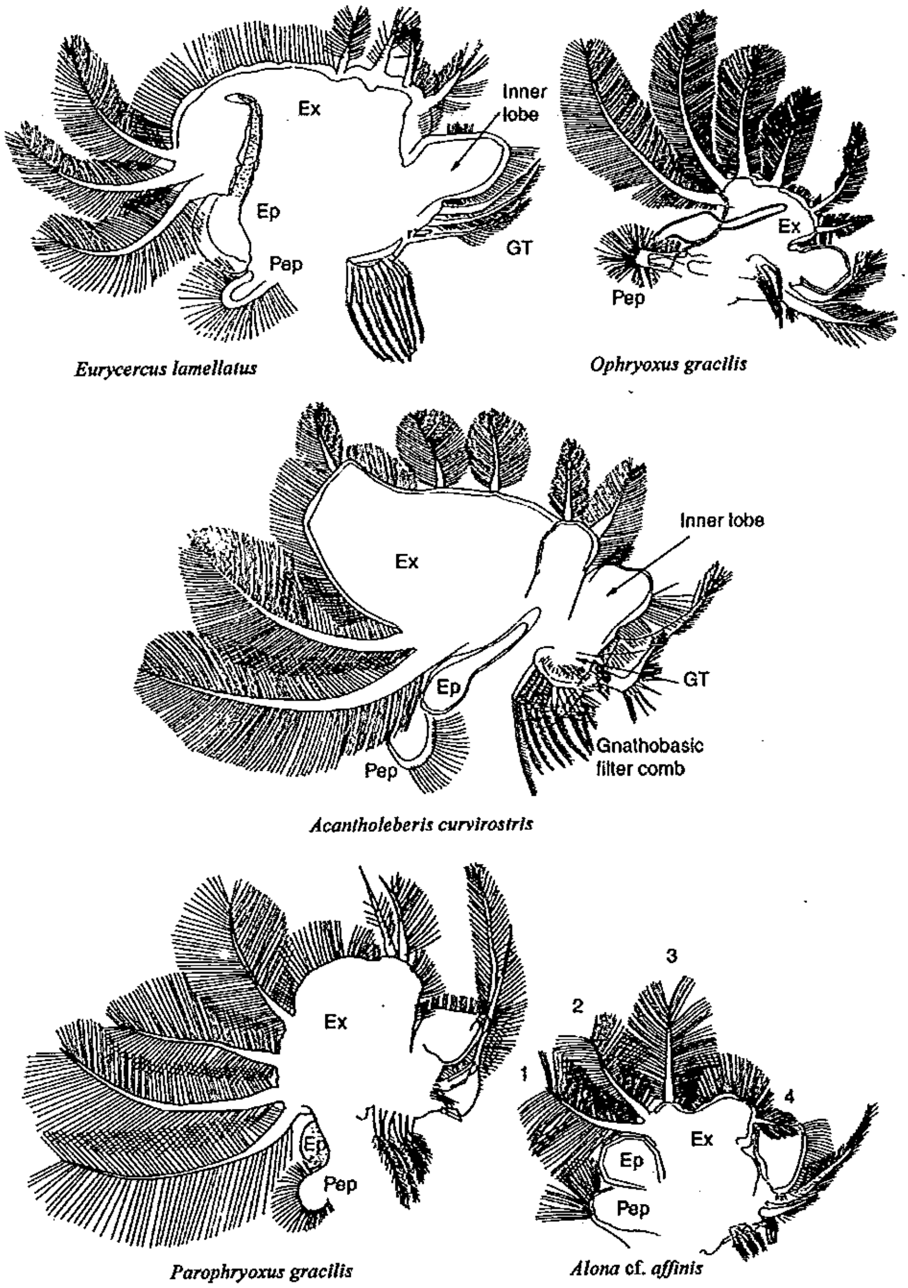



Figure 7. Trunk limb 5 in Radopoda. (Dumont and Negrea, 2002).

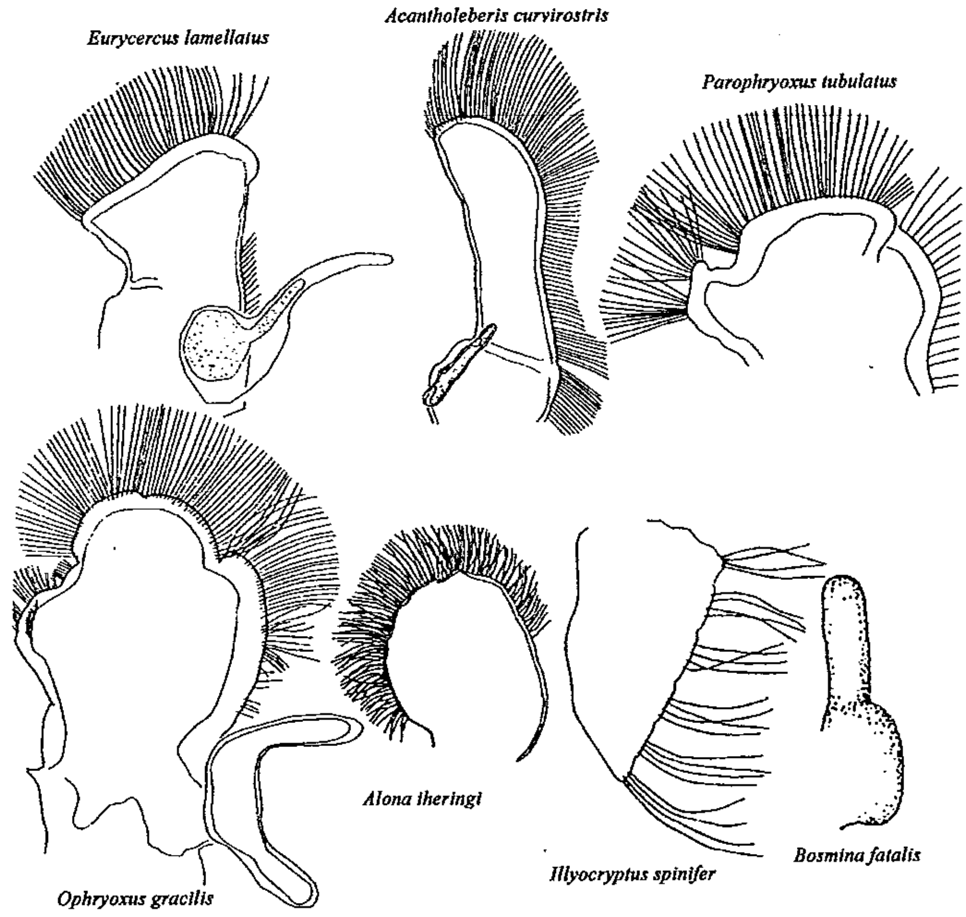



Figure 8. Trunk limb 6 in the Anomopoda. (Dumont and Negrea, 2002 after Dumont and Silva-Briano, 1997 and Kotov, 1997, 2002)

## 3. The importance of the Cladocera

Cladocera are microcrustaceans ranging in size between 2 and 60 mm. They are members of the class Branchiopoda and inhabit almost every kind of freshwater habitat, from large lake to ponds, puddles and water-filled tire ruts. They occur everywhere, from the Arctic to Antarctic, at temperate and tropical latitudes, on isolated islands, in high mountain water bodies and in permanent and temporary ponds. They penetrate ground waters and cave systems and also live in desert zones (Dumont, 1975). Cladocera have been found in moss growing on trees in rain forests several meters above the ground (Frey, 1980), but the majority of species is found in the littoral and benthic areas of lakes. There are a few estuarine species. They also have been found in saline lakes up to 19.9 g/l (Griggs, 2001) but the group as a whole is not successful in the marine environment. Some species are planktonic, living in the open water, whereas others live on or near the bottom or associated with aquatic vegetation. Cladocerans have many important functions in aquatic ecosystems. First, they play a role as primary or secondary consumers in food chains. They are an important link in the food chain of virtually every inland body of water. Cladocera convert phytoplankton, benthic plants and decaying organic matter, into a form usable by fish and larger invertebrates. Furthermore they are a major food source for many kinds of fish such as minnows and young salmon, and many aquatic insect larvae, as well as other invertebrates also feed on them (Monakov, 2002). Several genera such as *Dahphnia*, *Moina*, *Diaphanosoma* and *Pseudosida* are currently used in the aquaculture. They are high protein, have a short life cycle, and their size is appropriate as a food for many kinds of aquatic larvae. Moreover, they play an indirect role as a bioindicator of the freshwater environment. They are as sensitive to environmental conditions as diatoms, and many studies have shown that the composition of a cladoceran community depends on the physical and chemical conditions of a water body. Changes in both structural and chemical environments is detectable at species level, as each species possesses different adaptations and tolerances to different conditions. As in many other fields, cladocerans are used as a model organism for ecotoxicological testing. *Daphnia magna* is a standard test organism for quality assessment. The sequence of its full genome content is underway as well. Anomopods preserve well in sediment, of which the paleoecology and community structure has been reconstructed across hundreds and even thousand of years (Frey, 1962). Their slow evolution thus makes them useful for paleolimnological studies. In addition, cladoceran microfossil assemblages can be used in historical studies of human disturbance on lakes. Their high potential for this purpose is based on great ecological diversity, easy dispersal between lakes and short generation times. These characters enable them to closely track environmental change.

## 4. Research problems and research questions

The significance of cladocera in every subject of study, especially in taxonomical and biogeographical work, has not been fully recognized for several reasons. First of all, their microscopical size and the fact that keys are out of date, makes it hard to distinguish them. The proportion of pure morphological studies was small relative to the rapidly increasing mass of the studies on ecology, eco-morphology and genetics. The insufficient knowledge of cladoceran taxonomic diversity is caused by their often fine morphological differentiation, phenotypic variability and historical factors (Korovchinsky, 1997b).

A major confusion about their taxonomy arose from the idea of cosmopolitanism. Many taxa are often cited under the same name on different continents but have been found to represent different species level later (Frey, 1995). Although cosmopolitanism is refused by more and more observations, and some peculiar species occur in habitats such as ground waters, caves and terrestrial habitats, a base for chronic mistakes had been laid. Another problem is their great morphological variation, a classical problem in cladoceran taxonomy. On species level, the characters in single specimen seem to be quite constant while animals in one population seem to have a high morphological flexibility and variation. Instar variability between populations and cyclomorphic changes are also strong factors that complicate cladoceran systematics. The importance of characters appears to be taxon-specific. The most important taxonomical characters for each group are still unclear, so taxonomists should examine all parts of their body, to avoid the mistakes from using different criteria for their identification. Furthermore poor descriptions make taxonomy a time consuming and frustrating task. Most original descriptions of cladocerans are incomplete; lacking either a detailed clear description of useful features or good illustrations that used for comparison. Because of all mentioned above, wrong names have uncritically been applied all over the world.

The study of variation is important for each morphological comparative study, especially for work on problems about the species group. Poor morphological resolution is not only leading to confusion in systematics but also in biogeography because it is impossible to make sure where each species is distributed if we don't know what species exactly are. For the last 20 years, however, the approach has considerably evolved especially at the species level. It has become clear that many former cosmopolitan species are in fact a species-group, of morphologically related species. On the other hand, some must be treated as an infra-specific unit. So both have become an interesting and challenging topic. Most species, descriptions are out of date, incomplete and lacking many important details. The species have to be described and named because they exist in the ecosystem and fulfill have specific functions there. Part of the identification problem is due to the use of foreign keys, mostly from Europe, North America instead of using local keys. The first task in any taxonomical study is to develop a good description of the original taxon so that comparisons can be made between them and other similar taxa. However, what are the most important taxonomically significant characters? We do not know in advance which characters will become the most useful for identification.

The development of morphological studies started from the second half of the seventieth century. The researchers focused on external characters: head, head shield ornamentation, head pore, valve, body shape, first and second antennae. Also considered were postabdomen, its shape, seta natatoria, its size, anal teeth, position of anus and rows of spines, end-claw and pectens. Some also paid attention to the ephippial egg and its ornamentation. Important characters such as type of valve reticulations, similarity or dissimilarity in size of the terminal aesthetasc of the antennules, presence of an abdominal projection, reticulation on the postabdomen, length and armature of male seta on the antennule, head pores and, especially, the structure of trunk limbs were rarely used in the systematics of the cladoceran. Since 1960, researchers have begun to focus on the fine morphology of thoracic limbs structure and their functions (Smirnov, 1966, 1972; Fryer, 1968, 1974). Cladocera have 5-6 pairs of trunk limbs. These limbs are widely diverse in forms and functions. Some function in grasping, scraping, mechanically transferring food particles and filtration, or some combination of these. The first pair are used mostly in locomotion. The food groove tends to be deep and narrow. There are never any postgenital limbs and the telson or postabdomen terminates in a pair of strong terminal claws and bears a pair of dorsal sensory setae (seta natatoria). Currently, many researchers accept that these organs are important in their evolution. Only few cladocerologists (Alonso, 1996; Fryer, 1974; Paggi, 1979 and Kotov, 2000) relie mainly on only trunk limbs in their species descriptions. On the evidence of trunk limbs structure, many changes occurred in the systematics. For example Smirnov (1992b) removed the Ilyocryptidae from the Macrothricidae because of their distinctly different trunk limbs. In addition, because of the study on the details of trunk limbs, many revisions of "old" species are now underway. Detailed trunk limb morphology also resolved problems at the species-group level, which is demonstrated using several groups in *Alona* and *Macrothrix*. Some species need to be synonymised, other are shown to consist of many individual species, each with apparently restricted geographical range.

Currently the advance of the level of generic description in cladocerans must be accompanied by more detailed descriptions of old species. Although in subsequent publications, important data on the biology, their distribution were reported but no new data on morphology and variability were given and their taxonomy probably always causes lively debates among taxonomists.

## 5. History of the study on the Cladocera in Thailand

The study of cladoceran diversity in Thailand has been intermittent. Ninety six cladoceran species, in 7 families; family Chydoridae (56 species), family Daphniidae (11 species), family Macrothricidae (12 species), family Sididae (9 species), family Bosminidae (4 species), family Moinidae (3 species) and family Ilyocryptidae

(1 species), have been recorded (Boonsom, 1984; Pholpunthin, 1997; Sirimonkonthaworn, 1997; Sanoamuang, 1998; Sanoamuang and Kotethip, 2001; Phaitacum, 2001; Pipatcharoenchai, 2001; Saeng-aroon, 2001; Sa-ardrit, 2002, 2004). The first study (Boonsom, 1984) examined samples collected from habitats distributed around Thailand (no information on these localities was given). Forty eight species were recorded but only 41 species were valid (Sanoamuang, 1998). During the two subsequent decades (1984-2002) a noticeable increase in the number of taxa occurred. However, in spite of these studies the knowledge on taxonomic diversity of cladocerans, especially at species level, remained insufficient.

The largest number of presently known cladocerans in Thailand is recorded from the Northeast. They were studied in diverse habitats, covering many provinces (Sirimonkonthaworn, 1997; Sanoamuang, 1998; Phaitacum, 2001 and Saeng-aroon, 2001). A total of (1997-2001) 76 species within seven families and 29 genera was found. Forty-five species were first records in Thailand (4 species by Sirimonkonthaworn (1997), 31 species by Sanoamuang (1998) and 10 species by Saeng-aroon (2001), six species were new records for Asia (Sanoamuang, 1998).

In other parts of the country, research focused on the combined zooplankton. Sirimonkonthaworn (1997) examined zooplankton samples collected from Pathumthani Province, central part of Thailand. Fifty-three zooplankton species were recorded, including 25 cladoceran species. Pipatcharoenchai (2001) studied zooplankton samples collected from rivers, dams, reservoirs, swamps, rice fields and marshes in Kanchanaburi Province, western Thailand. The total was 141 species in three phyla and 69 genera, including 28 cladoceran species in six families and 19 genera. Among these, four species were endemic to the tropics; *Bosminopsis deitersi*, *Ceriodaphnia cornuta*, *Moina micrura* and *Diaphanosoma excisum*, and two species were endemic to Asia; *Dunhevedia crassa* and *Euryalona orientalis* and six other species were rare in the tropics; *Alona costata*, *A. rectangula*, *A. eximia* (before Van Damme *et al.*, 2003), *Grimaldina brazzai*, *Streblocerας pygmaeus* and *Leydigia acanthoceroides*.

There have been only a few studies on the Cladocera in southern Thailand. Twenty-six cladoceran species within seven families and 17 genera were found in samples collected from Thale-noi in Pattalung Provinces (Pholpunthin, 1997). Nine species were new records for Thailand: *Alona archeri*, *A. rectangula*, *Chydorus uncinatus*, *C. eurynotus*, *C. faviformis*, *C. reticulatus*, *Euryalona orientalis*, *Leydigia cillata* and *Pseudosida szalayi*, and one was the first record in Southeast Asia, *Leydigia ciliata*. However, the latest research on the Cladocera in Trang Province (Sa-ardrit, 2002) showed a noticeably higher diversity than in earlier studies. A total of 68 species (seven families and 34 genera) included six new records to Thailand: *Chydorus opacus*, *Disparalona rostrata*, *Ephemeroporus phintonicus*, *Leydigia australis*, *Notoalona freyi* and *Sarsilatona serricauda*. This brought the number of southern Thai cladoceran to 70 species, and total Thai cladoceran fauna to 96 species.

The increasing number from the latest studies should convince researchers to pay more attention to this group, but still there are very few students active. There are many reasons behind this problem. First, cladocerans are not easy to identify, due to their small size, lack of obvious differences in external morphology between species and a general perception that the taxonomic keys are out of date, difficult to follow and requiring specialist knowledge to use. Taxonomy of the Cladocera in Thailand was not described adequately whereas to perform any meaningful assessment of biological diversity, ecology or conservation status, good taxonomy is required.

The present study was originated base on the present taxonomic problems of the taxa and that of the lack of satisfied knowledge on the Thai cladoceran fauna in all aspects. Thus, the current study was undertaken to increase the level of morphological-taxonomical resolution, the biodiversity, and the biogeography of the Cladocera of Thailand, based on specimens from southern Thailand.

## 6. Objectives

To contribute to the taxonomy of the Cladoceran in Southern Thailand by performing a detailed morphological study of representatives of all taxa, but specially of the genera *Alona* Baird, 1843 and *Macrothrix* Baird, 1843

To study the biogeography of the taxa

This research consists of three parts, all were conducted to obtain knowledge on the following aspects on the cladoceran fauna:

**Part 1: Taxonomical study on the Cladocera found in southern Thailand**

An unequivocal taxonomy is a prerequisite to meaningful studies on biodiversity, ecology and biogeography, and is the basis of this study. In this study, descriptions on detailed morphological characters were firstly made for two large genera, *Alona* Baird, 1843 and *Macrothrix* Baird, 1843. The descriptions based on a type population, rather than on a single specimen, so that the degree of variability of features and range can be documented for both genders and all instars and if possible, of all available instars of parthenogenetic females, ephippial females and males. Moreover drawings including scanning electron micrograph of all parts are made to provide information on thoracic limbs to enable adequate comparison within species. In addition, the morphological characters are compared with specimens from other countries and in other regions. Finally, keys to species of the cladoceran species found in southern Thailand are proposed.

**Part 2: Diversity of the Cladoceran from southern Thailand**

The research also aimed to investigate the diversity of the Cladocera and discussion in several aspects: actual species richness and complementarity value at three different levels. Moreover, to contribute to the knowledge of ecological distribution of the Cladocera, this study will attempt to identify important environmental factors and the relationship between cladoceran fauna and their habitats.

**Part 3: Biogeographical Study**

The study on the species distribution was broken down into biogeographical regions. An attempt is made to discuss the possible biogeographic events that may have led to the present day cladoceran distribution.

# CHAPTER 2: MATERIALS AND METHODS

## 1. Study area

Thailand is a tropical country situated on the Indo-Chinese Peninsula. The country lies between latitude 97°30'E to 105°45'E, and longitude 5°45'N to 20°30'N. The weather in Thailand is hot and rather humid, with a monsoonal climate. Most of the country receives 80 percent of the total annual rainfall during the period of the southwest monsoon, from May to October. The country is geographically divided into five regions: the northern, northeastern, western, central and southern regions.

The southern part shows a remarkable and unique diversity in habitats. This part shows a predominant coastal character and specific climatologically setting, with rainfall more frequent here than in other regions. Frequent rainfall is found in coastal provinces, from Chumphon southward. It occurs during both the northeast and southwest monsoons. The rainy season can be divided into two periods: 1) under the influence of the southwest monsoon from May till September with heavy rainfall on the western part of the region and 2) the northeast monsoon from November till February with heavy rainfall on the eastern part of the region. Moreover three mountain ranges: Phuket, Nakornsrithammarat and Sankalakiri are at the origin of natural water resources. All these characteristics provide the basis for some rich ecosystems. These ecosystems can be divided into terrestrial, marine, coastal, and freshwater ecosystems (Finlayson and Moser, 1991). However, as mentioned in the previous chapter cladocerans are mostly found in freshwater habitats, and thus the present samplings were mainly restricted to freshwater habitats. The intensive survey of wetlands in southern Thailand in 1997 by Official of Environmental Policy and Planning cooperated with the Wetland International recorded about 160 freshwater habitats, including about 3,500 of rivers, streams and canals.

The fifty-nine sampling sites (fig.9) covered in this study were representative of all freshwater habitats of southern Thailand. The decision of site selection was based on the information of the latest survey (Official of Environmental Policy and Planning, 1997) and information from the Royal Irrigation Department (1997). The priority sites are all important water resources at the national or local levels. Furthermore, the decision also took into account their geographical distribution. Figure 9 shows the distribution of fifty-nine sampling sites. Different symbols on the map show each type of freshwater habitat. The identification of each type was based on the definition from these references; Finlayson and Moser, 1991; Official of Environmental Policy and Planning cooperated with the Wetland International, 2002 and http://www.twingroves.district96.k12.il.us/Wetlands.html.

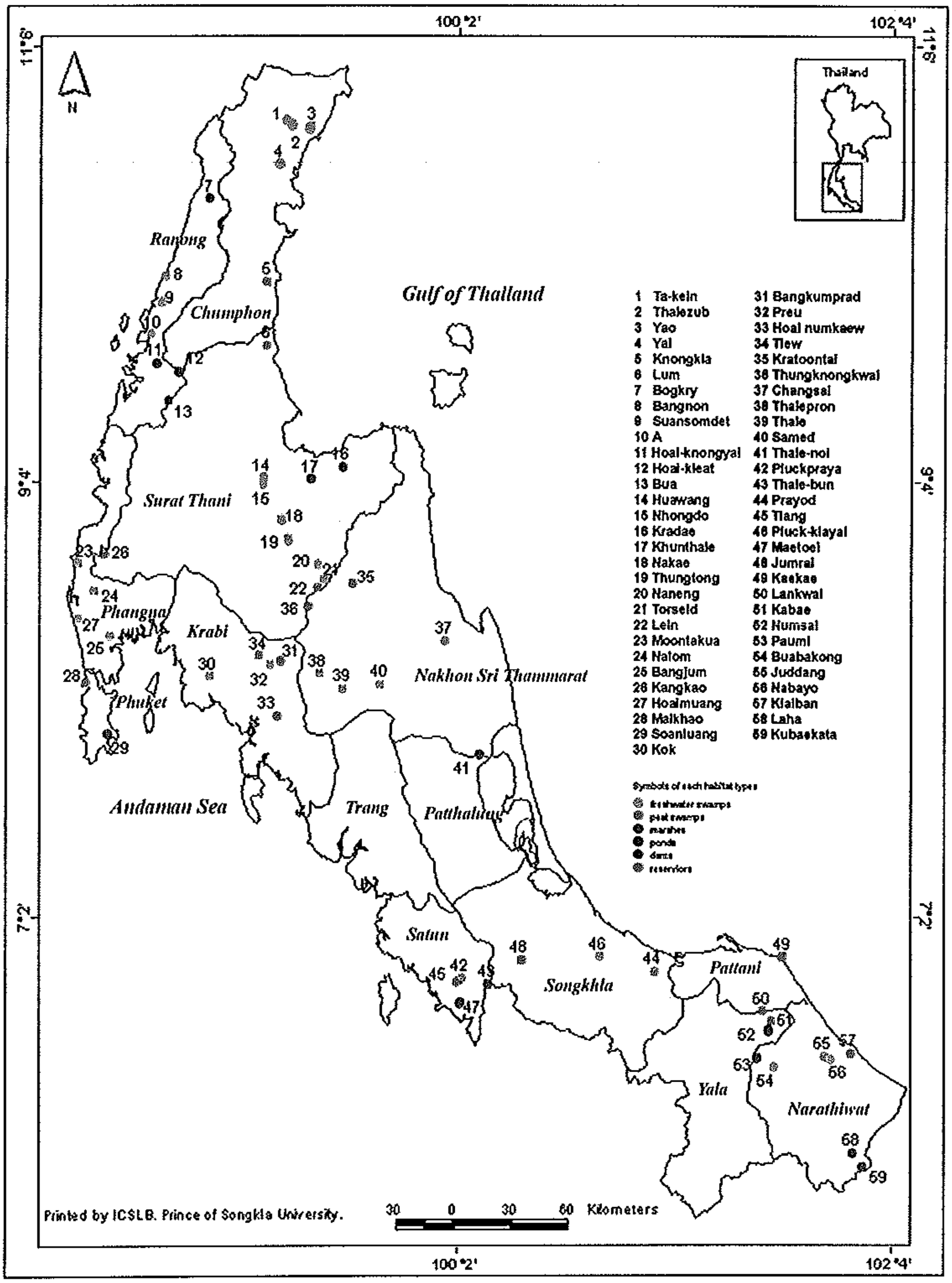



Figure 9. Sampling sites in southern Thailand

***Freshwater swamps***

A swamp is actually a small forest flooded by water. In order for a wetland to be a swamp, it needs to have about thirty percent of tree cover. Swamps generally have saturated soils or are flooded for most, if not all, of the growing season. They are often dominated by a single emergent herb species, or are forested.

A large proportion of the sites were in swamps, and was comprised of 29 sampling sites: Nhong-takein, Thale-zub, Yao, Yai, Bangnon, Suan-somdet, A, Huawang, Nhongdo, Nakae, Thungtong, Naneng, Torseid, Moontakua, Nalom, Bangjum, Hoaimuang, Kok, Preu, Ban-thungkok, Thale-pron, Thale, Samed, Natam, Thale-songhong, Pluck-praya, Pluck-klayai, Buabakong and Nabayo. Representatives of these sampling sites are shown in figure 10.

***Peat swamps***

Peat swamps occur in permanently saturated areas and are sites where peat deposits are deeper than 30-40 cm (12-15 inch). They are known collectively as mires to distinguish them from other water systems which may simply accumulate some organic matter or peat. Peat is formed when decomposition fails to keep pace with the production of organic matter. This is a result of water logging, a lack of oxygen or of nutrients, high acidity or low temperatures. Such swamps receive water from precipitation and are mostly without natural surface drainage. They are also characterized by acid-loving vegetation such as horsetail (*Equisetum*).

Five sites in this study have peat swamp characteristics: Yon, Maikhao, Lan-kwai, Kabae and Juddang but a part of them, eight peat swamps, have been degenerated: Nhong-kla, Lum, Lein, Kangkao, Changsai, Prayod, Taew, Kaekae. Representatives of these sampling sites are shown in figure 11.

***Marshes***

A marsh is a freshwater area that remains wet at least half of a year. Typically a marsh does not have deep water. In the deepest marshes, floating plants with some leaves submerged, take the place of algae or duckweed. A typical marsh plant has roots that grow into the ground and underwater, and its stem rises above the water.

The most familiar plant is the cattail. Marshes are usually dominated by reeds, rushes, grasses and sedges and are sustained by water sources other than direct rainfall.

Eight marshes were sampled: Khun Tha-le, Thale-Noi, Thale-bun, Mae-tai, Numsai, Paumi, Laha and Kubaekata. The sampling sites are shown in figure 12.

***Waterfalls***

There is only one waterfall from which samples were taken for the present study, Ang-tong waterfall (fig.13a). It is the place where *Nicsmirnovious eximius* (Sa-ardrit, 2002) has been found.

***Ponds***

A pond is permanently wet around the year. Ponds usually are not large enough for winds to blow across the water and create waves that wash away any plants that may be trying to take root. This category also includes aquaculture ponds.

Four ponds that were selected for sampling: Hoai-knongyai, Hoai-kieat, Bua and Soanluang. Representative sites are shown in figure 13b.

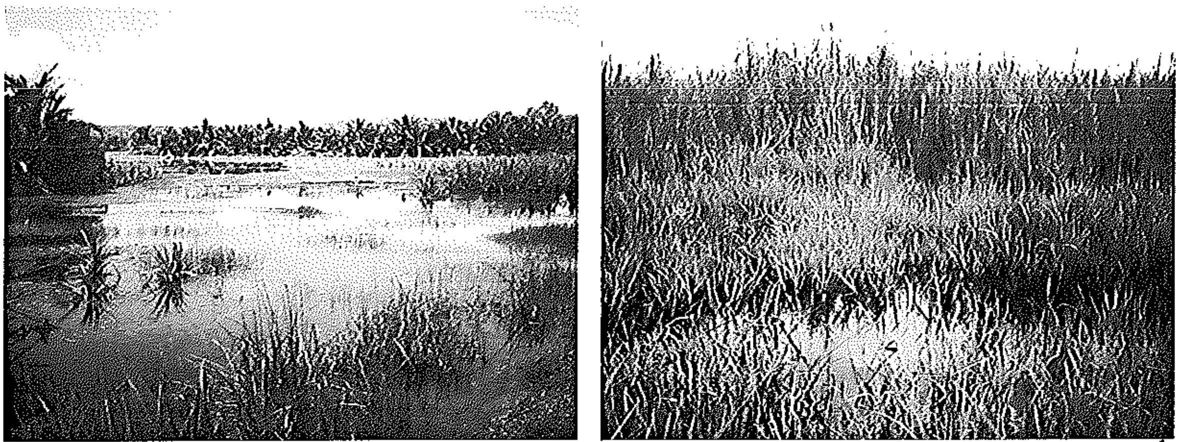
***Reservoirs***

Reservoirs are representatives of artificial water bodies. They are mostly built across rivers to store water for agriculture and electricity.

Seven reservoirs were selected for sampling: Bokgry and Kradae Bang-kumprad, Hoai numkaew, Kratoontai, Jumrai and Klaiban. Representative sampling sites are shown in figures 14-15.

a b

Figure 10. Representatives of freshwater swamp sampling sites: a. Nakae freshwater swamp, Suratthani Province; b. Tha-lezub freshwater swamp, Chumporn Province

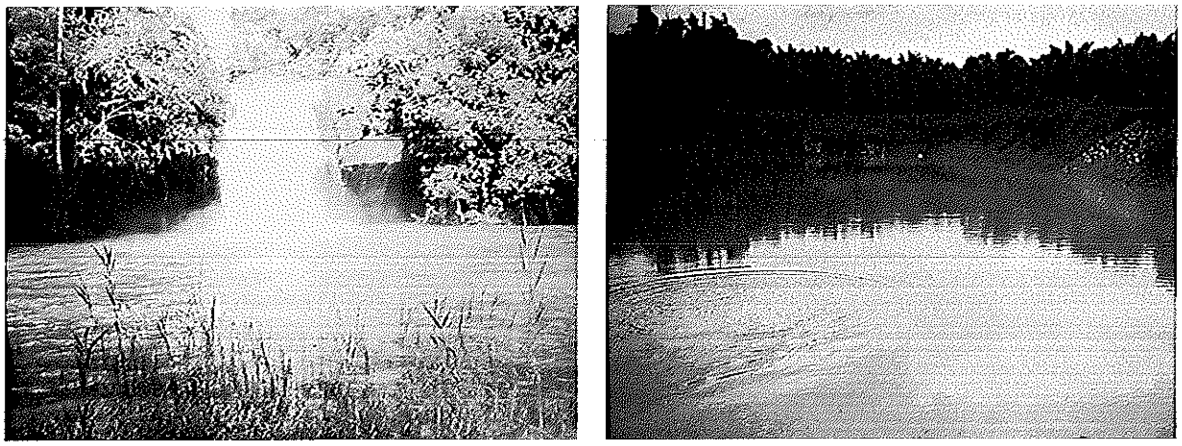


a b

Figure 11. Representatives of peat swamp sampling sites: a. Lan-kwai peat swamp, Pattani Province; b. Changsai peat swamp, Nakornsrithammarat Province

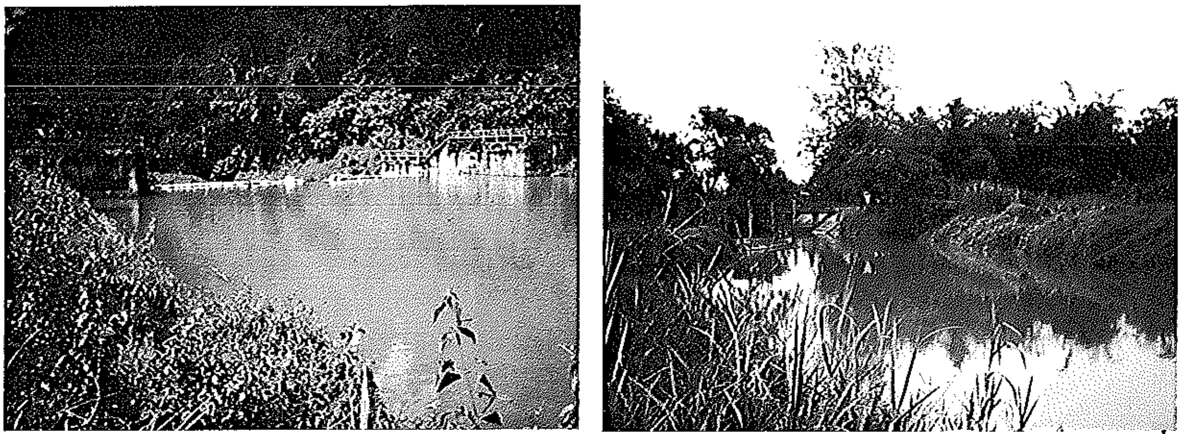
a b

Figure 12. Representatives of marsh sampling sites: a. Thungtong marsh, Suratthani Province; b. Kuntha-le marsh, Suratthani Province



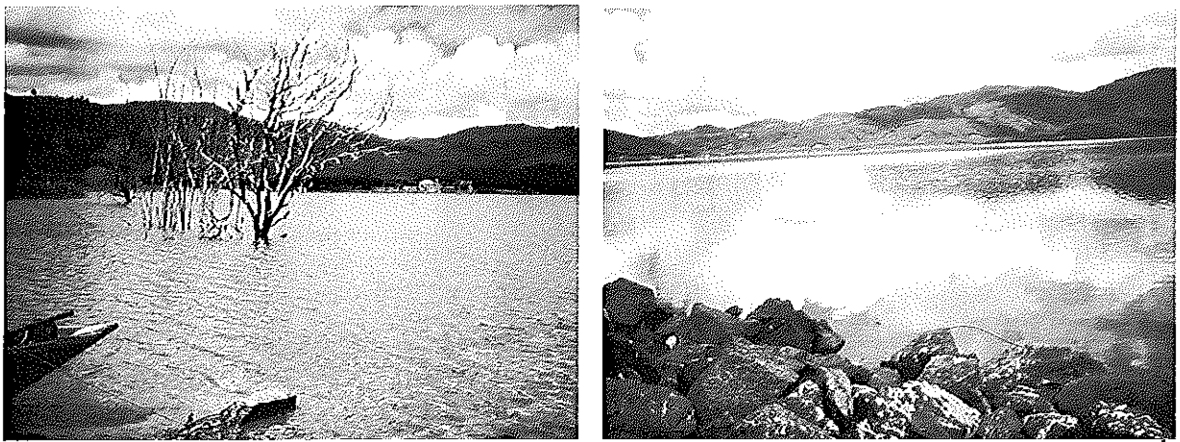
a b

Figure 13. Representatives of waterfall and pond sampling sites: a. Angtong waterfall, Trang Province; b. Bua pond, Ranong Province



a b

Figure 14. Representatives of dam sampling sites: a. Kradae dam, Suratthani Province; b. Bogkrai dam, Chumporn Province



a b

Figure 15. Representatives of reservoir sampling sites: a. Hoinumkaew reservoit, Krabi Province; b. Kratoontai reservoir, Nakornsrithammarat Province

## 2. Sampling methods

### 2.1 Cladoceran sampling

Samplings were carried out in the rainy season and summer; during September to November 1999 and April to May 2000, respectively, in fifty-nine freshwater localities throughout southern Thailand (fig.9). A total of 750 samples was qualitatively collected using standard plankton nets of mesh size 20 μm and 60 μm. The samples were immediately preserved in 4% formaldehyde.

### 2.2 Soil sampling

Soil sampling was conducted in summer when the sampling sites became dried. Crusts of mud were picked from the sides of selected habitats, some mud was scraped from the surface and was put in plastic bags. The mud can be kept in a dry, dark and preferably cold place.

### 2.3 Measurement of environmental factors

Six environmental variables: temperature, turbidity, pH, DO, conductivity and salinity were measured in each at the sampling stations, using water analysis equipment (calibrated water analysis checker) and the characteristics of each habitat such as types of habitats and percentage of vegetation cover, were recorded (Table 1).

## 3. Preparation of the specimens for investigation

### 3.1 Sorting specimens

Specimens were sorted under a stereo microscope (Olympus SZ-40), and the cladocerans were picked from the samples for identification and counting. The morphological details were examined using an Olympus CH-2 compound microscope. Completed and dissected cladocerans were prepared on permanent glass slides. The specimens were put in glycerin, mixed with few drops of formaldehyde. Glycerin helps to preserve their shape and to protect them from drying out (Haney and Hall, 1973 referred by Duigan, n.d.). Before the specimens are covered with cover slide, small pieces of clay were placed in each corner of the cover slide in order to protect them from pressure. The cover slide was then sealed with nail enamel.

### 3.2 Identification and counting

The cladocerans were identified to species level by using several keys: Idris, 1983; Korovchinsky, 1992; Smirnov, 1992, 1996; Smirnov and Timms, 1983 including up to date keys in recent publications: Dumont and Silva-Briano, 1998, 1999 and Van Damme *et al.*, 2003. The identification mostly uses the outer morphological characteristics but in most cases more detailed examination of inner and fine characteristics is needed, so the dissection method was applied.

The dissection was carried out under a stereo microscope using an insect pin to dissect each appendage. The process starts with open valves, followed by splitting the two sides of the body and then cutting each part; head, antennule, antenna, labrum, postabdomen and trunk limbs, separately. The slides were made without using the clay in the method described above.

All the specimens of each cladoceran species found in each sample were counted and the proportion of each species present was calculated.

### 3.3 Drawing

A drawing was made from completed and dissected specimens, slides were prepared as described in 3.1 and 3.2, using a camera lucida connected with a compound microscope.

### 3.4 Preparing specimens for taking Scanning Electron Micrographs

A Scanning Electron Microscope (SEM) was applied for studying the details of fine characteristics. Samples were prepared using the following method; field samples were preserved with 4% formaldehyde. After they were sorted, cleaned and identified, they were dehydrated (complete or dissected specimens) in a series of increasing alcohol concentration; 10%, 30%, 50%, 70%, 90%, 95%, 96% and 100%. Each dehydration series took 2 times and each time took 30 minutes (Duigan, 1992 referred by Korovchinsky and Smirnov, 1996). Then, the specimens were passed to the process of Critical Point Drying (CPD), mounted on 10 mm stubs and coated with gold. SEM photographs were taken using a Scanning Electron Microscope (JSM-5800LV, JEOL) to show details of anatomy of the species.

**3.5 Hatching experiment**

An aquarium was prepared for each sampling (sub) sites. The aquaria should be transparent, clean and preferably covered by a net on the top to avoid egg-laying mosquitoes. Labels according to location and the date, and hours of incubation were made.

In each of the aquaria, 1 L of cold (max. 15°C), uncontaminated rain water or aqua destillata (in any case, water with low conductivity) was poured on a small amount of dry mud (e.g.50 g). Floating ephippia sticking to the sides of aquaria were picked using a pipet. Twenty four hours of strong constant light was provided with a constant temperature (min. 25 °C). One air bubble/ 2 s of oxygen was added.

The culture was checked daily, by examining it in the dark with a fiber light or under a microscope. The exact appearance of species was noted. Algae and bacteria hatch from the first day so the animals will survive in the original stock culture without the addition of food. However, they might be removed when the density was too high.

After a particular cladoceran species was investigated, the specimens were separated to other aquaria and fed them with algae or ciliates which can be obtained by filtering pond water through a 50 μm net. The water of a separated population should be changed daily to avoid the development of toxic cyanobacteria.

**Table 1** Environmental parameters at each sampling site in southern Thailand

| | Locality | Seasons | Stations | Salinity (ppt) | Turb. | pH | Temp (oC) | Cond. uS/cm | Habitats type | Vegetation (%covered) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ta-kein | S | 1 | 0 | 230 | 7.9 | 29.9 | 0.038 | S | 0 |
| | | S | 2 | 0 | 229 | 8.45 | 30.5 | 0.036 | s | 0 |
| | | R | 1 | 0 | 231 | 8.44 | 30.3 | 0.039 | s | 0 |
| | | R | 2 | 0 | 228 | 8.43 | 30.4 | 0.037 | s | 0 |
| 2 | Thalezub | S | 1 | 0 | 23 | 6.07 | 29.0 | 0.022 | s | 50 |
| | | S | 2 | 0 | 18 | 5.29 | 27.8 | 0.013 | s | 50 |
| | | R | 1 | 0 | 29 | 5.23 | 27.1 | 0.013 | s | 50 |
| | | R | 2 | 0 | 7 | 5.35 | 28.5 | 0.013 | s | 50 |
| 3 | Yao | R | 1 | 0.01 | 11 | 7.37 | 27.5 | 0.29 | s | 65 |
| | | R | 2 | 0.01 | 10 | 7.6 | 27.6 | 0.301 | s | 65 |
| | | R | 3 | 0.01 | 10 | 7.48 | 27.6 | 0.295 | s | 65 |
| 4 | Yai | S | 1 | 0 | 34.5 | 5.57 | 33.7 | 0.0605 | s | 65 |
| | | S | 2 | 0 | 19.5 | 7.34 | 33.6 | 0.0615 | s | 65 |
| | | S | 3 | 0 | 30 | 5.38 | 33.6 | 0.061 | s | 65 |
| | | R | 1 | 0 | 45 | 3.61 | 33.3 | 0.06 | s | 65 |
| | | R | 2 | 0 | 24 | 7.53 | 34.1 | 0.061 | s | 65 |
| | | R | 3 | 0 | 15 | 7.15 | 33.1 | 0.062 | s | 65 |
| 5 | Knongkla | S | 2 | 0 | 3 | 3.53 | 31.8 | 0.3905 | ps | 0 |
| | | R | 1 | 0 | 35 | 6.36 | 28.7 | 0.284 | ps | 0 |
| | | R | 2 | 0.01 | 3 | 3.55 | 31.5 | 0.353 | ps | 0 |
| | | R | 3 | 0.01 | 3 | 3.51 | 32.1 | 0.428 | ps | 0 |
| 6 | Lum | R | 1 | 0 | 13 | 5.6 | 27 | 0.028 | ps | 0 |
| | | R | 2 | 0 | 3 | 4.29 | 26.4 | 0.027 | ps | 0 |
| | | R | 3 | 0 | 23 | 4.97 | 26 | 0.025 | ps | 0 |
| 7 | Bogkry | R | - | - | - | - | - | - | r | - |
| 8 | Bangnon | S | 3 | 0 | 11 | 6.41 | 31.6 | 0.013 | s | 25 |
| 9 | Suansomdet | S | 1 | 0 | 17 | 6.05 | 32.8 | 0.0185 | s | 50 |
| | | S | 2 | 0 | 15.5 | 6.2 | 32.55 | 0.0165 | s | 50 |
| | | S | 3 | 0 | 5.5 | 6.24 | 32.75 | 0.019 | s | 50 |
| | | R | 1 | 0 | 7 | 6.09 | 33 | 0.021 | s | 50 |
| | | R | 2 | 0 | 27 | 6.01 | 32.6 | 0.016 | s | 50 |
| | | R | 3 | 0 | 4 | 6.39 | 32.5 | 0.017 | s | 50 |
| 10 | Banna | R | 1 | 0 | 115.5 | 7.135 | 30.75 | 0.084 | p | 0 |
| | | R | 2 | 0 | 130.5 | 7.235 | 30.6 | 0.087 | p | 0 |
| 11 | Hoai-knongyai | R | 2 | 0 | 23 | 5.2 | 30.7 | 0.014 | p | 25 |
| | | R | 3 | 0 | 13 | 5.57 | 33.6 | 0.012 | p | 25 |
| 12 | Hoai-kieat | D | 1 | 0 | 35 | 7.26 | 38 | 0 | p | 0 |
| | | D | 2 | 0 | 36 | 7.99 | 36.2 | 0.011 | p | 0 |
| 13 | Bua | R | - | - | - | - | - | - | p | - |
| 14 | Huawang | R | 1 | 0 | 138 | 6.3 | 30.3 | 0.09 | s | 25 |
| | | R | 2 | 0 | 110 | 8.115 | 31.175 | 0.0805 | s | 25 |
| | | R | 3 | 0 | 104.5 | 8.11 | 31.375 | 0.0785 | s | 25 |
| 15 | Nhongdo | R | 1 | 0 | 93 | 7.97 | 31.2 | 0.078 | s | 25 |
| | | R | 2 | 0 | 123 | 8.17 | 30.9 | 0.084 | s | 25 |
| | | R | 3 | 0 | 101 | 8.15 | 31.7 | 0.076 | s | 25 |
| 16 | Kradae | S | 1 | 0 | 27 | 7.96 | 28.9 | 0.1585 | r | 0 |
| | | S | 2 | 0 | 21 | 7.555 | 28.9 | 0.1585 | r | 0 |
| | | R | 1 | 0 | 33 | 8.31 | 29.1 | 0.159 | r | 0 |
| 17 | Khunthale | S | 1 | 0 | 131 | 7.63 | 28.9 | 0.08 | m | 75 |
| | | R | 1 | 0.01 | 140 | 7.2 | 29.4 | 0.08 | m | 75 |
| 18 | Nakae | S | 1 | 0 | 19 | 4.955 | 30.1 | 0.3185 | s | 0 |
| | | R | 2 | 0 | 19 | 6.7 | 30.1 | 0.093 | s | 50 |
| | | R | 3 | 0 | 26 | 6.57 | 29.3 | 0.095 | s | 50 |

**Table 1.** (Continued)

| | Locality | Seasons | Stations | Salinity (ppt) | Turb. | pH | Temp (oC) | Cond. uS/cm | Habitats type | Vegetation (%covered) |
|---|---|---|---|---|---|---|---|---|---|---|
| 19 | Thungtong | S | 1 | 0 | 21.5 | 6.695 | 29.9 | 0.094 | s | 90 |
| | | S | 2 | 0 | 22.5 | 6.635 | 29.7 | 0.094 | s | 75 |
| | | S | 3 | 0 | 25 | 6.63 | 29.5 | 0.095 | s | 25 |
| | | R | 1 | 0 | 65.5 | 6.4225 | 30.55 | 0.393 | s | 90 |
| | | R | 2 | 0 | 7 | 6.4525 | 30.35 | 0.2725 | s | 75 |
| | | R | 3 | 0 | 7 | 6.445 | 30.6 | 0.331 | s | 25 |
| 20 | Naneng | S | 1 | 0.01 | 124 | 6.4 | 30.5 | 0.455 | s | 75 |
| | | S | 2 | 0 | 7 | 6.445 | 30.6 | 0.331 | s | 75 |
| 21 | Torseid | R | 1 | 0 | 22 | 5.74 | 28.8 | 0.015 | s | 75 |
| | | R | 2 | 0 | 38 | 5.68 | 28.2 | 0.013 | s | 75 |
| 22 | Lein | R | 2 | 0 | 6 | 6.56 | 30.6 | 0.159 | ps | 100 |
| 23 | Moontakua | S | 2 | 0 | 7 | 3.905 | 27.9 | 0.06 | s | 25 |
| | | R | 1 | 0 | 7 | 4.95 | 28.6 | 0.016 | s | 25 |
| | | R | 2 | 0 | 1 | 3.43 | 27.3 | 0.103 | s | 25 |
| | | R | 3 | 0 | 13 | 4.38 | 28.5 | 0.017 | s | 25 |
| 24 | Nalom | S | 2 | 0 | 4.5 | 5.8175 | 32.3 | 0.012 | s | 50 |
| | | S | 3 | 0 | 7.5 | 6.0725 | 33.9 | 0.004 | s | 50 |
| | | R | 1 | 0 | 9 | 6.2 | 34.7 | 0 | s | 50 |
| | | R | 2 | 0 | 3 | 5.69 | 31.5 | 0.016 | s | 50 |
| 25 | Bangjum | R | 1 | 0 | 7 | 5.91 | 28.8 | 0.05 | s | 0 |
| | | R | 2 | 0 | 13 | 5.76 | 27.6 | 0.053 | s | 0 |
| 26 | Kangkao | S | 1 | 0 | 20 | 6.9 | 30.9 | 0.0135 | ps | 0 |
| | | S | 2 | 0 | 18.5 | 6.915 | 31.45 | 0.0205 | ps | 0 |
| | | S | 3 | 0 | 19.5 | 6.885 | 31.25 | 0.016 | ps | 0 |
| | | R | 1 | 0 | 21 | 6.87 | 30.7 | 0.009 | ps | 0 |
| | | R | 2 | 0 | 19 | 6.93 | 31.1 | 0.018 | ps | 0 |
| 27 | Hoaimuang | R | - | - | - | - | - | - | p | - |
| 28 | Maikhao | R | 1 | 0.4 | 52 | 7.23 | 31.3 | 0.0749 | ps | 75 |
| | | R | 2 | 0.39 | 61 | 6.86 | 31.6 | 0.0741 | ps | 75 |
| 29 | Soanluang | R | 1 | 0 | 25.5 | 8.18 | 33.1 | 0.184 | p | 25 |
| | | R | 2 | 0 | 30.5 | 8.28 | 32.65 | 0.183 | p | 75 |
| | | R | 3 | 0 | 30 | 8.2 | 33.05 | 0.184 | p | 75 |
| | | R | 4 | 0 | 22.5 | 7.265 | 31.35 | 0.17 | p | 75 |
| 30 | Kok | S | 3 | 0 | 35 | 8.3 | 32.6 | 0.183 | s | 75 |
| 31 | Bangkumprad | R | 1 | 0 | 9 | 7.33 | 31 | 0.081 | r | 0 |
| | | R | 2 | 0 | 4 | 7.04 | 30.2 | 0.076 | r | 0 |
| | | R | 3 | 0 | 1 | 7.33 | 30.9 | 0.085 | r | 0 |
| 32 | Preu | S | 1 | 0 | 43 | 8.39 | 31.9 | 0.017 | s | 75 |
| | | R | 1 | 0 | 57 | 7.53 | 32.8 | 0.029 | s | 75 |
| | | R | 2 | 0 | 56 | 7.58 | 33.6 | 0.025 | s | 75 |
| | | R | 3 | 0 | 51 | 6.8 | 33.3 | 0.024 | s | 75 |
| 33 | Hoai numkaew | S | 3 | 0 | 14 | 8.65 | 31.8 | 0.148 | r | 0 |
| | | R | 1 | 0 | 3 | 7.34 | 29.7 | 0.144 | r | 0 |
| | | R | 3 | 0 | 3 | 7.33 | 30.1 | 0.15 | r | 0 |
| 34 | Ban thungkok | S | 1 | 0 | 15.5 | 8.365 | 31.55 | 0.1445 | s | 75 |
| | | S | 2 | 0 | 16 | 8.57 | 31.5 | 0.147 | s | 75 |
| | | S | 3 | 0 | 13.5 | 8.445 | 31.85 | 0.1455 | s | 75 |
| 35 | Kratoontai | S | 1 | 0 | 61 | 6.27 | 32.1 | 0.023 | r | 0 |
| | | S | 2 | 0 | 30 | 6.84 | 30.95 | 0.024 | r | 0 |
| | | R | 2 | 0 | 15 | 6.8 | 31.3 | 0.024 | r | 0 |
| 36 | Thungknongkwai | R | 3 | 0 | 6.25 | 7.5775 | 30.425 | 0.181 | ps | 0 |
| 37 | Changsai | R | - | - | - | - | - | - | ps | - |

**Table 1.** (Continued)

| | Locality | Seasons | Stations | Salinity (ppt) | Turb. | pH | Temp (oC) | Cond. uS/cm | Habitats type | Vegetation (%covered) |
|---|---|---|---|---|---|---|---|---|---|---|
| 38 | Thalepron | S | 1 | 0 | 7 | 7.62 | 30.35 | 0.1825 | s | 75 |
| | | S | 2 | 0 | 5.5 | 7.535 | 30.5 | 0.1795 | s | 75 |
| | | S | 3 | 0 | 2.5 | 7.915 | 30.25 | 0.179 | s | 75 |
| | | R | 1 | 0 | 4 | 8 | 30.1 | 0.182 | s | 75 |
| | | R | 2 | 0 | 10 | 7.24 | 30.6 | 0.183 | s | 75 |
| | | R | 3 | 0 | 1 | 7.83 | 30.4 | 0.176 | s | 75 |
| 39 | Thale | S | 1 | 0 | 53 | 7.72 | 32.8 | 0.043 | s | 25 |
| | | S | 2 | 0 | 30 | 8.05 | 32.3 | 0.039 | s | 50 |
| | | R | 1 | 0 | 21 | 5.33 | 30.3 | 0.029 | s | 25 |
| | | R | 2 | 0 | 10 | 5.68 | 29.7 | 0.029 | s | 50 |
| | | R | 3 | 0 | 9 | 5.4 | 29.8 | 0.028 | s | 50 |
| 40 | Samed | S | 1 | 0 | 25 | 7.535 | 30.15 | 0.187 | s | 50 |
| | | R | 1 | 0 | 32 | 7.4 | 30.3 | 0.188 | s | 50 |
| | | R | 2 | 0 | 27 | 7.64 | 30.5 | 0.216 | s | 50 |
| 41 | Thale-noi | R | 1 | 0 | 40 | 7.64 | 30.5 | 0.164 | s | 100 |
| 42 | Pluckpraya | S | 1 | 0 | 155 | 7.04 | 30.8 | 0.232 | s | 90 |
| | | S | 2 | 0 | 32 | 8.02 | 33.3 | 0.34 | s | 75 |
| | | S | 3 | 0 | 40 | 7.64 | 30.5 | 0.164 | s | 25 |
| | | R | 1 | 0 | 15 | 6.72 | 30.9 | 0.058 | s | 90 |
| | | R | 3 | 0 | 3 | 7.34 | 32.6 | 0.045 | s | 25 |
| 43 | Thalebun | S | 3 | 0 | 94.5 | 6.05 | 32.4 | 0.0355 | m | 50 |
| | | R | 2 | 0 | 46 | 6.495 | 35.7 | 0.027 | m | 90 |
| | | R | 3 | 0 | 89 | 6.56 | 34.9 | 0.037 | m | 50 |
| 44 | Prayod | S | 1 | 0 | 17.5 | 5.46 | 29.1 | 0.028 | ps | 0 |
| 45 | Taew | S | 1 | 0 | 8 | 6.245 | 29.25 | 0.01 | ps | 0 |
| | | S | 2 | 0 | 12 | 6.2 | 29.15 | 0.012 | ps | 0 |
| | | S | 3 | 0 | 13 | 6.425 | 29.3 | 0.012 | ps | 0 |
| | | R | 1 | 0 | 81.5 | 6.03 | 28.35 | 0.019 | ps | 0 |
| | | R | 2 | 0 | 35.5 | 6.055 | 30.45 | 0.01 | ps | 0 |
| | | R | 3 | 0 | 77 | 6.085 | 28.3 | 0.017 | ps | 0 |
| 46 | Pluck klayai | S | 1 | 0 | 48 | 6.43 | 32.9 | 0.0185 | s | 0 |
| | | S | 2 | 0 | 31.5 | 6.385 | 32.9 | 0.01825 | s | 0 |
| | | R | 1 | 0 | 180.5 | 8.065 | 33.1 | 0.051 | s | 0 |
| | | R | 2 | 0 | 244.75 | 7.8575 | 34.15 | 0.039 | s | 0 |
| 47 | Maetae | S | 1 | 0 | 39 | 6.235 | 27.3 | 0.0275 | m | 0 |
| | | S | 2 | 0 | 29.5 | 6.3425 | 27.35 | 0.02625 | m | 0 |
| | | R | 1 | 0 | 140 | 5.635 | 30.8 | 0.03 | m | 0 |
| | | R | 2 | 0 | 146.5 | 5.6275 | 30.45 | 0.0335 | m | 0 |
| 48 | Jumrai | S | 1 | 0 | 44.5 | 7.05 | 29.25 | 1.56 | r | 0 |
| | | S | 2 | 0 | 46.75 | 7.005 | 29.225 | 1.595 | r | 0 |
| | | R | 1 | 0 | 38 | 7.65 | 31.25 | 6.8 | r | 0 |
| | | R | 2 | 0 | 36 | 7.685 | 31.425 | 6.88 | r | 0 |
| 49 | Kaekae | S | 1 | 0.06 | 40 | 7.14 | 29.3 | 1.49 | ps | 0 |
| | | S | 2 | 0.07 | 49 | 6.96 | 29.2 | 1.63 | ps | 0 |
| | | R | 1 | 0.35 | 42 | 7.58 | 30.9 | 6.64 | ps | 0 |
| | | R | 2 | 0.37 | 34 | 7.72 | 31.6 | 6.96 | ps | 0 |
| 50 | Lankwai | S | 1 | 0 | 43 | 6.46 | 34.2 | 0.023 | ps | 50 |
| | | S | 2 | 0 | 36 | 6.75 | 34 | 0.025 | ps | 50 |
| | | S | 3 | 0 | 46 | 6.65 | 31 | 0.025 | ps | 75 |
| | | R | 1 | 0 | 39 | 5.46 | 32.5 | 0.028 | ps | 50 |
| | | R | 2 | 0 | 67 | 5.83 | 32.6 | 0.03 | ps | 50 |
| | | R | 3 | 0 | 65 | 5.98 | 33.1 | 0.014 | ps | 75 |

**Table 1.** (Continued)

| | Locality | Seasons | Stations | Salinity (ppt) | Turb. | pH | Temp (oC) | Cond. uS/cm | Habitats type | Vegetation (%covered) |
|---|---|---|---|---|---|---|---|---|---|---|
| 51 | Kabae | S | 1 | 0 | 81 | 6.52 | 32.9 | 0.019 | ps | 75 |
| | | S | 2 | 0 | 15 | 6.34 | 32.9 | 0.018 | ps | 100 |
| | | R | 1 | 0 | 52 | 8.48 | 31 | 0.075 | ps | 75 |
| | | R | 2 | 0 | 309 | 7.65 | 35.2 | 0.027 | ps | 100 |
| 52 | Numsai | S | 1 | 0 | 48 | 6.3 | 30.5 | 0.023 | m | 90 |
| | | S | 2 | 0 | 33 | 6.23 | 31.3 | 0.022 | m | 90 |
| | | S | 3 | 0 | 51 | 6.31 | 32.8 | 0.022 | m | 90 |
| | | R | 1 | 0 | 138 | 5.79 | 32 | 0.049 | m | 90 |
| | | R | 2 | 0 | 52 | 5.66 | 33.6 | 0.029 | m | 90 |
| | | R | 3 | 0 | 40 | 7.33 | 37.8 | 0.025 | m | 90 |
| 53 | Paumi | S | 1 | 0 | 58 | 6.02 | 27.2 | 0.03 | m | 90 |
| | | S | 2 | 0 | 20 | 6.45 | 27.4 | 0.025 | m | 90 |
| | | R | 1 | 0 | 127 | 5.65 | 31.5 | 0.023 | m | 90 |
| | | R | 2 | 0 | 153 | 5.62 | 30.1 | 0.037 | m | 90 |
| 54 | Buabakong | S | 1 | 0 | 4 | 6.3 | 29.1 | 0.017 | s | 90 |
| | | S | 2 | 0 | 24 | 5.88 | 29.8 | 0.017 | s | 90 |
| | | S | 3 | 0 | 5 | 6.25 | 29.9 | 0.017 | s | 90 |
| | | R | 1 | 0 | 4 | 3.63 | 34.6 | 0.022 | s | 90 |
| | | R | 2 | 0 | 4 | 5.9 | 33.2 | 0.017 | s | 90 |
| | | R | 3 | 0 | 4 | 5.53 | 32.7 | 0.019 | s | 90 |
| 55 | Juddang | S | 1 | 0 | 92 | 5.76 | 30.9 | 0.016 | ps | 75 |
| | | S | 2 | 0 | 10 | 5.3 | 26.1 | 0.017 | ps | 75 |
| | | R | 1 | 0 | 20 | 6.57 | 35 | 0.015 | ps | 75 |
| | | R | 2 | 0 | 5 | 4.76 | 29.1 | 0.022 | ps | 75 |
| 56 | Nabayo | S | 1 | 0 | 17 | 6.215 | 31.9 | 0.017 | s | 75 |
| | | S | 2 | 0 | 8 | 6.12 | 28.2 | 0.024 | s | 75 |
| | | S | 3 | 0 | 4 | 6.31 | 29 | 0.024 | s | 75 |
| | | R | 1 | 0 | 36 | 5.78 | 33.2 | 0.029 | s | 75 |
| | | R | 2 | 0 | 9 | 5.45 | 28.2 | 0.024 | s | 75 |
| | | R | 3 | 0 | 26 | 5.47 | 30 | 0.032 | s | 75 |
| 57 | Klaiban | S | 1 | 0 | 40 | 6.83 | 31.7 | 0.019 | r | 25 |
| | | S | 2 | 0 | 14 | 6.62 | 35 | 0.029 | r | 50 |
| | | S | 3 | 0 | 60 | 6.46 | 32.9 | 0.018 | r | 50 |
| | | R | 1 | 0 | 30 | 5.25 | 33 | 0.027 | r | 25 |
| | | R | 2 | 0 | 13 | 4.5 | 32.5 | 0.033 | r | 50 |
| | | R | 3 | 0 | 20 | 5.14 | 34.7 | 0.023 | r | 50 |
| 58 | Laha | S | 1 | 0 | 9 | 5.95 | 28.1 | 0.015 | m | 25 |
| | | S | 2 | 0 | 16 | 6.1 | 30.2 | 0.011 | m | 25 |
| | | S | 3 | 0 | 5 | 6.86 | 30.8 | 0.011 | m | 25 |
| | | S | 4 | 0 | 8 | 5.18 | 28.7 | 0.013 | m | 0 |
| | | R | 1 | 0 | 6 | 6.38 | 30.6 | 0.011 | m | 25 |
| | | R | 2 | 0 | 14 | 6.48 | 28.9 | 0.012 | m | 25 |
| | | R | 3 | 0 | 34 | 5.8 | 29.8 | 0.09 | m | 25 |
| 59 | Kubaekata | S | 1 | 0 | 9 | 6.47 | 29.4 | 0.01 | m | 90 |
| | | S | 2 | 0 | 7 | 6.02 | 29.1 | 0.01 | m | 90 |
| | | S | 3 | 0 | 17 | 6.38 | 29.2 | 0.014 | m | 90 |
| | | R | 1 | 0 | 123 | 6.06 | 26.2 | 0.026 | m | 90 |
| | | R | 2 | 0 | 40 | 6 | 30.5 | 0.012 | m | 90 |
| | | R | 3 | 0 | 31 | 6.11 | 30.4 | 0.008 | m | 90 |

**Note:** - = no data, S = summer, R = rainy season; s = swamp, ps = peat swamp, m = marsh, p = pond, r = reservoir; Turb. = turbidity, Cond. = conductivity

## 4. Data analysis

### 4.1 The actual cladoceran species richness

Species lists from one hundred and eighty-three qualitative samples were used to analyze the species richness. From the cladoceran species list of those samples, a species accumulation curve was constructed on which, per sample series, 50 randomizations were carried out, such that the standard deviations for each data point could be calculated. The calculation was carried out by the Estimates program version 6.0 (http://viceroy.eeb.uconn.edu/estimates).

Among eight methods of extrapolating from the species collected to establish the true species numbers (Cowell and Coddington, 1994), Chao's, a non-parametric method, was the most reliable estimator (Referred by Chao, 1987; Chao and Lee, 1992; Dumont and Segers, 1996).

### 4.2 The complementarity values

The measurement of non-similarity (complementarity) is a method used to compare species richness of the cladoceran fauna among different habitat types, within parts of Thailand and among species lists of several Asian countries. Literature sources (Idris and Fernando, 1981a, b; Rajapaksa and Fernando, 1982; Sharma and Michael, 1987; Bromley, 1993; Pholpunthin, 1997; Sirimonkonthaworn, 1997; Sanoamuang, 1998; Pipatcharoenchai, 2001 and Sa-ardrit, 2002, 2004) were used to analyze the data.

It is calculated as followed;

$$C_{j,k} = Uj,k / Sj,k$$

With $S_{j,k}$ $= S_j + S_k - Vj,k$

$S_j$ = species richness of lake j;

$S_k$ = species richness of lake k;

$S_{j,k}$ = sum of species richness of lake j and k;

$V_{j,k}$ = species number shared between lake j and k; and

$U_{j,k}$ $= S_j + S_k - sV_{j,k}$

$U_{j,k}$ = number of species unique to lake j and k

### 4.3 The species composition and its relationship with environmental factors

To analyze the spatial distribution of cladoceran species, a Detrended Correspence Analysis (DCA) was performed on the data matrix including all sites and species with their abundance. The analysis was performed for ln(n+1)-transformed data, down-weighting of rare species and detrending-by-segments as a supplement to the Two way indicator species analysis (TWINSPAN). The TWINSPAN is used to classify the habitats related to the species composition, which is the indicator by which species of each TWIN-group can be reported.

To order the species and samples in relation to environmental variables, the direct gradient analysis program of Canonical Correspence Analysis (CCA) was performed for ln(n+1)-transformed data with Monte Carlo testing to evaluate the statistical significance of the outcome.

Rare species were routinely deleted from the data sets, believing that rare species contribute little to the community analysis but add noise to the statistical solution (Cao, *et al.*, 1998). Thus, the species of which the abundance was less than 10% of the total were eliminated from the analysis so that the variance was decreased.

*The statistical analyses using PC-ORD program, version 3.2*

# CHAPTER 3: RESULTS AND DISCUSSIONS

This chapter consists of three parts. The first part deals with the taxonomical study on the Cladocera found in southern Thailand. The morphological characters on a number of specimens of the member of large two genera, *Alona* Baird, 1843 and *Macrothrix* Baird, 1843 were investigated in detail and the comparisons of the specimens from different localities were examined. In addition, keys to 72 cladoceran species found in southern Thailand are proposed. In the second part, the biodiversity of the cladoceran fauna from 59 localities in southern Thailand was analysed. The actual species richness of cladoceran fauna was assessed by exploring the observed species richness in each area and comparing the complementarity values among areas since small scale, type of habitat, to larger scale, within four parts of Thailand and between countries, based on the cladoceran species composition. Besides, species composition and its relationship with environmental factors also were analysed. Finally, the third part deals with the species distribution which was broken down into biogeographical regions. Here, the attempt is made to discuss the possible biogeographic events that may have led to the present day cladoceran distribution.

## Part 1 Taxonomical Study on the Cladocera found in southern Thailand

As stressed before, to perform any meaningful assessment of biological diversity, biogeography, ecology or conservation status, good taxonomy is indeed required. The first task in any taxonomic study is to develop a good description, and two other, difficult ones are to select in advance which characters will be the most useful or are likely to change with ontogeny, and to define the range of variation in each characteristic. Thus we have to study all the characters from a number of specimens, such that variability also can be discussed. Rapid recent progress and higher standards with systematics of the Cladocera (Chiambeng and Dumont, 1999; Dumont and Silva-Briano, 2000; Kotov, 2000; Sinev, 1998, 1999; Sinev and Kotov, 2000) leads to the discovery of small detailed characters and micro-characters.

This is the first attemp to clarify the status of species found in the country. The study mainly focuses on the taxonomical study of the two large genera, *Alona* Baird, 1843 and *Macrothrix* Baird, 1843. The results were divided into three sections 1) taxonomical study on *Alona* Baird, 1843; 2) taxonomical study on *Macrothrix* Baird, 1843 and 3) Keys to all known cladoceran species from southern Thailand.

# 1. Taxonomical study on *Alona* Baird, 1843

## Introduction

*Alona* Baird, 1843 belongs to the family Chydoridae Dybowski & Grochoski, 1894 and Subfamily Aloninae. It is clearly polyphyletic, with some species pairs (Sacherova and Hebert, 2003) representing genera in their own sight. Some *Alona* species have already been reallocated to other genera or have been considered new genera. Thus Dumont and Silva-Briano (2000) moved the *A. karua* group to a new genus, *Karualona* Dumont & Silva-Briano, 2000 (Dumont and Silva-Briano, 2000) using the characters on postabdomen, first, second and third trunk limbs and recently, Van Damme *et al.* (2003) reallocated the *A. eximia* group to the genus *Nicsmirnovius* Chiambeng & Dumont, 1999 using the characters on postabdomen, head pores, first antenna, second and fourth trunk limbs (Van Damme *et al.*, 2003). As concern above, the use of limb morphology as a taxonomic and phylogenetic tool played a major role in these detailed studies.

Both in terms of the world fauna and of Thailand, *Alona* is the largest genus of the family. A total of 18 *Alona* species has been recorded in the country (Boonsom, 1984; Pholpunthin, 1997; Sanoamuang, 1998; Saeng-aroon, 2001; Sa-ardrit, 2001; Sa-ardrit and Beamish 2004; Maiphae *et al.*, 2004 and present data): *Alona archeri, A. archeroides, A.* cf. *cambouei* Guerne & Richard, 1893; *A. cheni* (Chen & Peng, 1993); *A. intermedia, A. miller, A. affinis* (Leydig, 1860); *A. costata* Sars, 1860; *A. diaphana* Richard, 1895; *A. dentifera* Sars, 1901; *A. guttata* Sars, 1862; *A. monacantha* Stingelin, 1905; *A. macronyx* Daday, 1898; *A. pulchella* King, 1853; *A. quadrangularis* (O.F.Muller, 1875); *A.* aff. *karelica* Stenroos, 1897; *A. rectangula* Sars, 1862; *A. sarasinorum* Stingelin, 1900 and *A. verrucosa* Sars, 1901. The taxonomic status of some of these species is still controversial. Thus, an attempt to clarify their taxonomic status of them is made here.

The present chapter, dealing with the morphological study and the discussion of the taxonomic status of each *Alona* species, was based on 12 species found in the course of our study. Specimens from other places, inside and outside southern

Thailand, and information from the literatures were added to make a morphological-comparison. The study was based at the smallest unit, species-level, mainly on the following characteristics: general shape, shape and ornamentation of postabdomen, head pores and head shield, antennule, antenna, and especially of the trunk limbs.

## Materials and methods

Fixed samples in 4% formaldehyde were sorted under a stereo microscope. Complete and dissected slides were prepared for drawings and scanning electron micrographs followed the method mentioned in Chapter 2. Materials for each studied species were listed in the following details of each species.

## Results

A total of 12 *Alona* species; *Alona affinis* (Leydig, 1860), *A.* cf. *cambouei* Guerne & Richard, 1893, *A. cheni* (Chen & Peng, 1993), *A. diaphana* King, 1853, *A. guttata* Sars, 1862, *A. monacantha* Stingelin, 1905; *A. macronyx* Daday, 1898, *A. quadrangularis* (O.F.Muller, 1875); *A.* aff. *karelica* Stenroos, 1897; *A. rectangula* Sars, 1862, *A. sarasinorum* Stingelin, 1900 and *A. verrucosa* Sars, 1901 including one another species which used to be placed in genus *Alona* Baird, 1843, *Nicsmirnovius eximius* (Kiser, 1948) was studied in detailed of the morphological characters.

**Genus:** *Alona* Baird, 1843

**Synonymy:** Subgenus *Alona* Baird, 1843:92. *Alona* Smirnov, 1971:337-338. Genus *Biapertura* Smirnov, 1971: Smirnov and Timms, 1983: 39-50.

**References:** Dodson and Frey, 1991. 466-483; Smirnov and Timms, 1983: 56-64.

## 1. *Alona affinis* (Leydig, 1860)

**Synonymy:** Leydig, 1860 (*Lynceus affinis*): 223, Taf. 9: figs. 68-69. *Alona (Biapertura) affinis*-group; Smirnov, 1974: 574-579, figs. 582-590.

**References:** Alonso, 1996: 345-346, fig. 154; Sinev, 1997 (*Alona afiinis*): 47-58, figs. 1-5.

**Type locality:** Friedriechshafen und Langenargen, Germany

**Materials examined:**

*Southern Thailand:* ten parthenogenetic females, examined complete and thereafter dissected, from Thungtong swamp, Keinsa District, Suratthani Province (8° 52.66'N, 99°11.83'E), southeastern Thailand, temperature 29°C, pH 6.4, conductivity 0.39 and salinity 0 ppt., collected date 01-10-1999, collected by the author, SM.

: five parthenogenetic females, examined complete and thereafter dissected, from Knong-kla peat swamp, Chumporn Province, (9° 59.40'N, 99°07.75'E), southern Thailand, collected by the author, SM

: two parthenogenetic females, examined complete and thereafter dissected, from Sri-Trang swamp, Hatyai District, Songkhla Province, southeastern Thailand, collected by the author, SM.

*Northeast Thailand:* two parthenogenetic females, examined complete and thereafter dissected, from Lake Kud-thing, Nong Kai Province, northeastern Thailand, collected by C. Saeng-aroon, KKU.

*Malaysia:* one parthenogenetic female, examined complete and thereafter dissected, from Rantang Abang Marsh, Terrenganu, western Malaysia, collected date 2003, collected by the author, SM.

**The details of morphological study**

**Species description** (see figures 16-17)

**Parthenogenetic female**

***General shape*** (fig. 16a)*:* sub-rectangular in lateral view, maximum height at ¾ of body. Length 0.7-0.8 mm, about 1.6-1.7 times maximal height (n=10). Dorsal margin forms slight curve. Postero-dorsal and postero-ventral angles almost round or forming a small hillock. Posterior margin slightly concave, postero-ventral corner broadly rounded. Antero-ventral corner rounded. Ventral margin almost straight, anteriormost with 18-20 marginal setae followed by 56-60 slender setae, gradually decreasing in length toward posterior end. Posteriorventral corner with 4-5 groups of 4-6 setules, lengths of setules in each group equal. Valve ornamentation consisting of ridge (figs. 16a, d) but not obvious in some specimens.

***Head*** (fig.16a)*:* Relatively small. Rostrum short, pointing downward. Compound eye present, larger than ocellus, distance between eye and ocellus shorter than distance from tip of rostrum to ocellus distinctively. Posterior margin of head shield angulated, with an angle of 70-80°. Two major head pores, of same size, with a narrow connection between them (figs. 16c, d), PP about 1.5 times as distance as IP. Two small lateral head pores, located slightly close to posterior, about 0.8 IP distance from midline, level before anterior median pore.

***Labrum*** (fig.16b)*:* large, with a rounded or polygon-like anterior margin and an angulated tip (the polygon-like not obvious as in Sinev (1997)), with two clusters of setules at the posterior margin.

***Postabdomen*** (fig.16e)*:* wide, about 2.5 times as long as high, distal part about 2.5 times longer than preanal portion. Proximal portion with almost parallel dorsal and ventral margin, gradually narrowing distally. Posterodorsal corner sharp. Anal margin relatively straight, with no distinct pre-and postanal corner and bearing 4-5 rows of small denticles, each row consisting of 2-10 denticles. Lateral fascicles: 11-13 postanal groups, each consisting of 4-6 denticles. Marginal denticles: 12-15 groups of merged spinules, gradually increasing in size distally and bearing 3-5 fused denticles on inner edge. Three groups of venterolateral denticles and groups of small setules between them. Natatorial setae with long distal end, setulated.

***Terminal claw*** (figs.16a, e)*:* Equal in length to preanal portion. Basal spine as a half of the claw, 3-4 fine setules arising proximal to base of spine, 1 setule clearly arising in proximal part of basal spine, close to the base of claw (fig.16e).

***First antenna (antennule)*** (figs.16a, f)*:* short, not reaching tip of rostrum. Body compact, rod-like, about twice as long as wide, three rows of small spines on inner and outer side of body. Distal end with seven aesthetascs unequal in length, two longest as long as antennular body (fig.16a), others long as a half of antennular body. All aesthetascs projecting beyond tip of rostrum (fig.16a).

***Second antenna*** (figs.16a, g)*:* short (fig.16a), antenna formula, setae 0-0-3/1-1-3, spine 1-0-1/1-1-1. All setae bisegmented, two setae of distal segment of exopodite with a spinule at the point of articulation. Seta arising from basal segment of exopodite thin, not extending beyond tip of distal segment. Seta arising from middle segment of exopodite longer than endopodite. Spine of basal segment of exopodite as long as middle segment. Terminal spines shorter than terminal segment of exopodite.

**Trunk limb: six pairs**

***First trunk limb (P1)*** (figs.17a, b)*:* Outer distal lobe (ODL) with one seta (I') slender and bearing fine setules, hardly visible. Two spines present at the base of ODL (fig.17b). Inner distal lobe (IDL) with three setae (I-III), seta I one hook-like, relatively large, a group of small setules present at 1/3 of the seta (fig.17b), setae II and III slender, the same length as ODL seta, second segment unilaterally armed with fine setules, shorter on seta III, one small sensilla (sn) located between seta I and II. Group of spines present on IDL trunk. Endite 3 (E3) with four plumose setae (1-4) subequal in length, seta 1 and 2 armed with short setules distally, seta 3 and 4 armed with longer setules distally, seta 4 slightly slender than the others, one small sensilla (sn) located close to the base of seta 2. Endite 2 (E2) bearing two apical setae (5-6), of which seta 5 the longest, both setulated. Endite 1 (E1) with three apical setae (7-9), setae 7 and 8 as the same length, bilaterally with fine setules, followed by seta 9 located laterally, as half as setae 7 and 8, armed with long setules from base to tip. Groups of slender spinules present more radial on inner side of endite 2. Trunk with 5-6 rows of slender spines laterally. Basally two long and slender ejector hooks, of the same length, unilaterally armed with short setules. Epipodite and gnathobase not seen.

***Second trunk limb (P2)*** (fig.17c)***:*** Epipodite not seen. Exopodite (EX) round-elongated, small setules apically, a setulated seta basally, bending over the exopodite. Endopodite (EN) triangular, with eight scrapers (1-8), generally decreasing in length towards gnathobase though scraper 4 shorter than scraper 3, scrapers 1 and 2 bisegmented, similar unilaterally armed with fine setules distally, one small sensillum (sn) at base of scraper 1; scrapers 3-5 bisegmented, unilaterally armed with strong setules distally, scrapers 6-8 more robust, bisegmented, unilaterally armed with strong setules distally. Distal armature of gnathobase (GT) with two elements (I-II), element I naked, element II more robust, armed with seven denticles from base to tip. Gnathobasic filter comb with seven plumose setae (1-7), setae 1 and 2 considerably shorter, setae 3-7 similar in length.

***Third trunk limb (P3)*** (fig.17d)***:*** Epipodite not seen. Exopodite (EX) globular, bearing seven setae (1-7): seta 1 and 2 located laterally, in typical V-formation, seta 1 longer than seta 2, both bilaterally setulated, seta 3 slender and longest, about 7 times of seta 4, bilaterally setulated, setae 4 and 5 shortest, both similar in length and similar armed with bilaterally setulated, seta 6 about 1/3 of seta 3, armed with three rows of more robust setules; one row longer and slender and other two strong and shorter, seta 7 more slender, bilaterally armed with short, fine setules distally.

Endopodite (EN) divided to two rows; anterior row with eight setae (1-8), setae 1 and 2 stout, seta 2 shorter than seta 1, distally armed with short well-spaced and hardly visible setules, seta 3 more slender, bilaterally setulated distally, setae 4-7 provided with short setules distally, with a wide basal part, one sensilla rod-like, naked, between setae 6 and 7; posterior row with four setae (1'-4'), similar in length and all bilaterally setulated. Gnathobase (GT) with three elements (I-III), element I large, curved inwards, unilaterally setulated, element II and III shorter, naked, fused at the base of each other. Gnathobasic filter comb with seven (?) setae.

***Fourth trunk limb (P4)*** (fig.17e)*:* Epipodite not studied. Exopodite (EX) more round, bearing six setae (1-6) with generally gradual increasing in length anteriorly; setae 1 and 2 are of equal in length, although the first may be shorter, bilaterally setulated with long setules, setae 3 and 4 slender, bilaterally setulated with long setules, setae 5 and 6 similar in length, half as long as the first two, plumose.

Endopodite (EN) or inner portion, anteriorly bearing five setae (1-5), seta 1 rounded basally and more slender distally, unilaterally armed with fine short setules, setae 2-4 'flaming-torch' setae, distally armed with long-slender setules, counting 5-6 setules each, seta 5 rod-like receptor comparable in size to flaming-torch setae, naked; posteriorly bearing four soft setae (1'-4'), setae 1'and 2' shorter than setae 3 and 4, all bilaterally setulated. Gnathobase (GT) with three elements (I-III), element I large-slender, unilaterally setulated distally with short setules, element II and III naked fused at base to each other.

***Fifth trunk limb (P5)*** (figs.17f-h)*:* Pre-epipodite (PEP) round, radial setulated apically, elongated digitiform projection not seen. Epipodite (EP) rounded, smaller than pre-epipodite, elongated digitiform projection presents (fig.17g). Exopodite (EX) clearly bilobed, bearing four apical setae (1-4); anterior portion smaller than posterior portion, setae 1-3 on anterior portion, seta 2 longest, setae 1 and seta 3 gradually smaller, respectively, all setulated; posterior portion larger, more round, bearing one seta (seta 4), relatively short in some specimens (fig.17f) and relatively longer in some specimens (fig.17g), two denticles basally in some specimens (fig.17f).

Endopodite (EN) larger, more ovoid, setulated apically, two endopodite setae setulated distally, one as a half length of another. Gnathobasic comb of three seta (fig.17h).

***Sixth trunk limb (P6):*** not studied.

**Variability:**

Some variability was noted in these following characters: 1) the specimens can be sub-rectangular or irregularly oval 2) the lateral head pores may be situated in front or at the same level as the first medial pore 3) the labrum can be rounded or spade shaped, two rows of setules on the inner side, regular or irregular in number between group 4) size and curve of the hook-like seta on IDL is different between specimens, even in the same population 5) two spines at the base of inner distal lobe of P1 present or not present in some specimens and 6) presence of a long digitiform projection on epipodite of P5.

**Differential diagnosis:**

This species can be distinguished by its large size, which is up to 0.9 mm; it is the largest known species of *Alona* (Sars, 1901) and it has 1) two main head pores with a narrow connection between them (only *A. verrucosa* has the same number of major pores but the latter has special flower-like lateral pores); 2) a rounded or polygonal like labrum with two clusters of setules and 3) a large, wide postabdomen provided with 12-15 marginal spines with spinules at posterior margin and 11-13 broad lateral fascicles of setae. Only *A. quadrangularis* has a similarly armed postabdomen while most other species display a small number of marginal denticles, usually without spinules.

**Remarks:**

Sinev (1997) remarks that the body shape is variable and depends on the age of the specimen, it can be sub-rectangular or irregularly oval, with the posterodorsal corner variously produced. The lateral head-pores may be situated in front or at the level of the first main pore. Variability of the antenna seems to be unimportant; the shape of the labrum is highly variable, specimens with a rounded or polygonal margin as well as with an angulated or broadly rounded tip can be found in the same population; the shape of postabdomen varies even within a single population, the distal half can be narrowing distally or with parallel margins; the number of lateral fascicles setae and marginal denticles ranges from 12 to 16, with 1-2 proximalmost denticles.

However we found that Thai specimens mostly show the following differences (table 2); 1) antennule with only one lateral seta; 2) presence of a group of setules at the 1/3 of IDL hook-like seta and group of two spines and row of more robust spines at the base of IDL setae (fig.17b); 3) a sensillum on IDL and endite 3; 4) two stout setae on gnathobase 2, one armed with short setules; 5) two posteriormost gnathobasic filer comb 2 times shorter than others; 6) seta 7 on exopodite 3 2/3 shorter than seta 8; 7) endopodite 4, spines of flaming torch setae long, reaching top of 1$^{st}$ seta; and 8) postabdomen mostly gradually narrowing distally, number of marginal denticles ranges from 12 to15 groups of 3-5 merged spinules.

**Biology:**

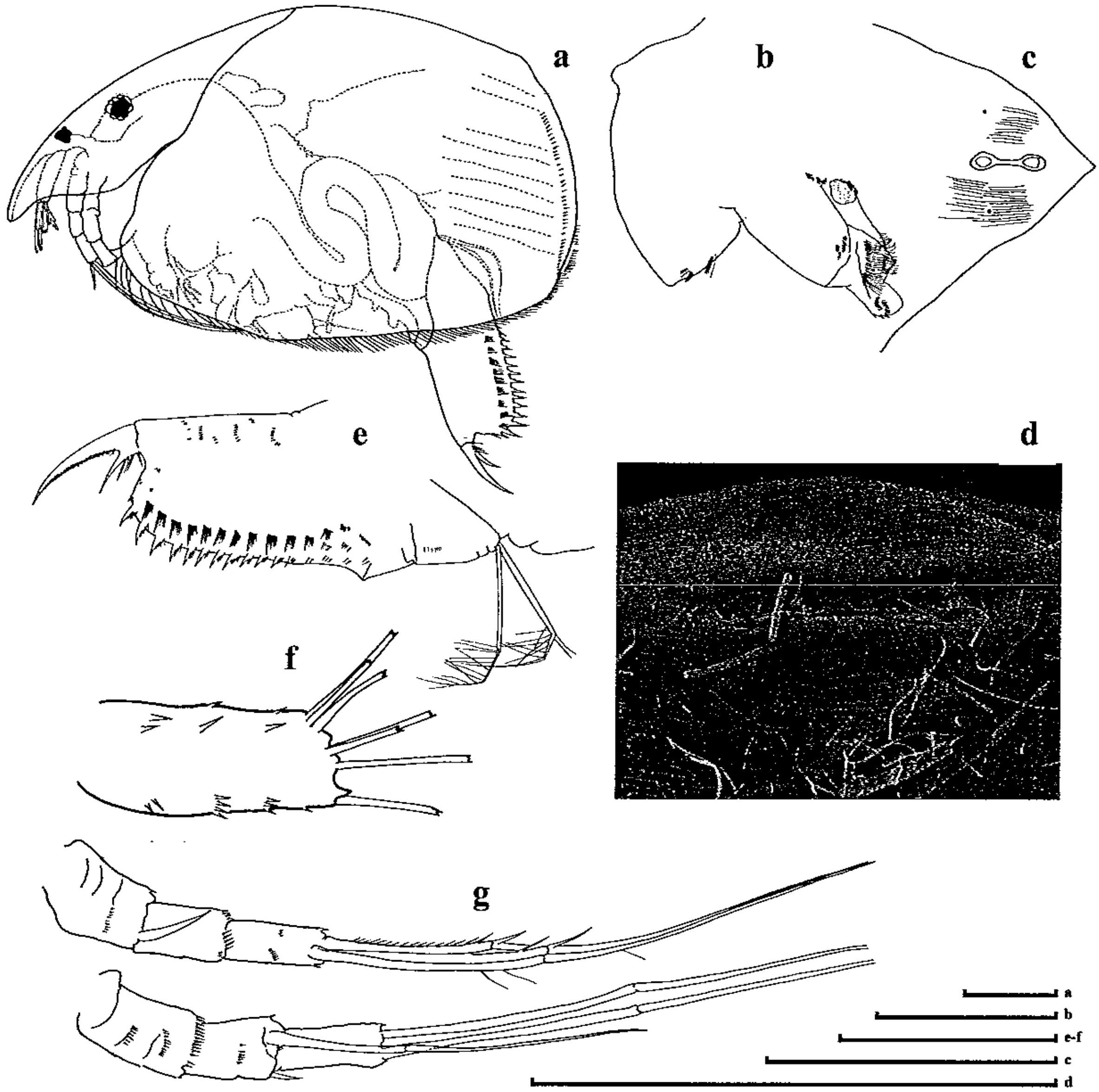
This species is mostly found among aquatic plants (Sars, 1901). In the present study it has been found in freshwater swamps, in areas dominated by *Cyperus* sp. in combination with *Nelumbo* sp. It shows higher abundance in the rainy season.

**Distribution:**

At present *Alona affinis* has been recorded on all continents but Antarctica. In Thailand it has been recorded in each study in many areas covering northern to southern Thailand, so it seems quite common in the country.

**Table 2** Morphological differences between *A. affinis* s. str. and *A. affinis* from Thailand

| characters | *A. affinis* (Sinev,1997) | *A. affinis* Thai specimens (present data) |
|---|---|---|
| **Antenna 1** | possesses one or two lateral setae | possesses one lateral seta |
| **Trunk limb 1** | | |
| IDL | hook-like seta curved, naked | hook-like seta curved and very strong in some specimens, row of short setules in the middle (fig.2b) |
| | no seta near the base | 2 seta near the base (fig. 2b) |
| seta 9 | bilaterally armed with short setules | bilaterally armed with long setules |
| sensillum (sn) | not mentioned | present on IDL and E3 |
| **Trunk limb 2** | | |
| gnathobase | 2 stout setae | 2 stout setae, one armed with strong setules |
| gnathobasic filter comb | posteriormost seta 3 times shorter | 2 posteriormost setae 2 times shorter |
| **Trunk limb 3** | | |
| exopodite | seta 7 about 1/2 shorter than seta 8 | seta 7 about 2/3 shorter than seta 8 |
| **Trunk limb 4** | | |
| endopodite | spines on flaming torch setae short, reach half of seta 1 | spines on flaming torch setae long, reach to the top of seta 1 |
| **Trunk limb 5** | | |
| endopodite | setulated distally | setulated distally, plus one row of small setules |
| gnathobase | 3 shorter setae | 3 longer setae |
| **Postabdomen** | | |
| shape | parallel margins | parallel margin, mostly gradually narrowing distally |
| marginal denticles | with 0-5 spinules | with 3-5 spinules |




Figures 16a-g. *Alona affinis* (Leydig, 1860): parthenogenetic females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figure a, adult female in lateral view; Figure b, labrum; Figures c-d, head shiled and its head pores; Figure e, postabdomen; Figure f, antenna I; Figure g, antenna II. Scale bar denotes 100 um.


Figures 17a-h. *Alona affinis* (Leydig, 1886): appendages of females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figures a-b, trunk limb 1 and its inner and outer distal lobe; Figure c, trunk limb 2; Figure d, trunk limb 3; Figure e, trunk limb 4; Figures f-h, trunk limb 5 and its gnathobasic filter comb. Scale bar denotes 100 um.

## 2. *Alona cambouei* Guerne & Richard, 1893 and *A.* cf. *cambouei* Guerne & Richard, 1893

**Synonymy:** Daday, 1910: 128-130, Taf. 6, figs. 30-35 (*pulchella*); Rey and Saint-Jean, 1968: 11, fig. 25, A-D (*pulchella*); Rajapaksa and Fernando, 1987, fig. 139 (*pulchella*); Dumont *et al.*, 1984: 166-167, fig.2, 1-2 (*pulchella*); Chen, 1993: 27, figs.1-5 (*pulchella*); Venkataraman, 1993: 382-383, figs. 34-37 (*pulchella*).

**References:** Guerne and Richard, 1893: 224-244, figs. 10-11; Richard, 1894: 371-374, figs. 5-8; Sinev, 2001: 5-18, figs. 34-58.

**Type locality:** Madagasca

**Materials examined:**

*Southern Thailand:* one parthenogenetic female, examined dissected, from Maikhao peat swamp, Phuket Province, collected by the author, SM.

*Malaysia* : one parthenogenetic female, examined complete and thereafter dissected. Collected by C. H. Fernando, Fernando collection, Raffles Museum, NUS.

*Southern Spain:* one parthenogenetic female, examined complete and thereafter dissected, from Used, Zaragoza, collected by Van Damme, K., GU.

**The details of morphological study**

**Species description** (See figures 18-19)

**Parthenogenetic female**

***General shape*** (figs.18a-b)*:* Length 0.32-0.34 mm, about 1.4 times maximal height (n= 3) while Venkataraman (1991) reported its size 0.26 mm in female and 0.33 mm in male (Venkataraman, 1995). Body in lateral view oval, largest height around the middle but body seems almost parallel. Dorsal margin generally curved, depression between head and the rest of body absent. Postero-dorsal and postero-ventral margin rounded, with small setules reaching the middle of the body. Ventral margin almost straight, ventral setae relatively long, with slender 34-40 setae which slightly differ in length, slightly decreasing towards posterior end, longer setae clearly at anterior part, end before posteroventral corner (fig.18b). Valves with longitudinal striation, some specimens rectangular-like.

***Head:*** Moderate size, rostrum well developed, blunt. Compound eye present, size larger than ocellus; distance between eyes and ocellus same as between ocellus and tip of rostrum. Head shield wide, anterior margin with blunt apex (fig. 18f), posterior margin with three notches, the middle notch located in the midline. Three major head pores, shape not round in Thai and Malaysian specimens (figs.18e-d), but rounded in Spain specimen (fig.18g), without connection. Central pore is the same size as the anterior and posterior one. Lateral pores small, located around the middle.

***Labrum*** (fig.18c)*:* Round and relatively large. Labral tip rounded or slightly angular. Posterior edge convex.

***Postabdomen*** (figs. 18h-j)*:* gradually narrowing distally but almost straight. Anal margin almost straight (figs.18h,j) and concave in Spain specimen (fig.18i), with distinct pre-and post-anal corner, not obvious in some specimens (fig.18h), bearing about 14 small denticles. Supra-anal projection well-marked and located considerably above the middle, lower corner rectangular. Lateral fascicles about 5-7 groups, each counting 9-11 denticles. Lateral fascicles on anal margin about 9 groups, of which the denticles situated parallel to each other. Teeth-like marginal spines gradually increasing in size distally, in group of 3-4, mostly three distally, and three distal ones one each side being much larger than the others. Natatorial setae moderately, setulated distally.

***Terminal claw:*** elongated, about as long as anal margin (figs. 18h-j), very long in Malaysia specimen, compared with postanal margin. Basal spine slender, length almost half terminal claw, two additional setules or more in Spain specimen (fig.18i) situated at the base of basal spine. Denticles of pecten along the claw.

**Trunk limb: five pairs**

***First trunk limb (P1)*** (figs.19a-d)***:*** Outer distal lobe (ODL) with one seta (I'), one slender, length as long as IDL setae, bearing short, hardly visible setules distally. Inner distal lobe (IDL) with three setae (I-III), two subequal in length (I-II), their distal end unilaterally armed with sparsely spines decreasing in length distally, seta III smaller, curved-like.

Endite 3 (E3) with four plumose setae (1-4). Endite 2 (E2) with three apical setae (5-7), seta 5 smallest, seta 6 and seta 7 unequal in length; seta 7 only half of length of seta 6 in Spain specimen (fig.19a), both slender, setulated with long setules on one side and shorter setules on other side. Endite 1 (E1) with two apical setae (8-9), setulated. Groups of slender spinules present on inner side of second endite. Trunk with 6-7 rows of slender spines laterally. Basally two long and slender ejector hooks, of the same length, unilaterally armed with short setules. Epipodite and gnathobase not seen.

***Second trunk limb (P2):*** not studied.

***Third trunk limb (P3)*** (figs.19e-f)***:*** Epipodite (EP) not seen. Exopodite (EX) sub-rectangular, bearing six setae (1-6): setae 1 and 2 long, located laterally, in typical V-formation, both as the same length and setulated, seta 4 slender, setulated, seta 5 long and slender, bilaterally armed with long and fine setules distally, the last seta (6) small and slender, as half as seta 6, unilaterally armed with sparsely short setules distally.

Endopodite (EN) (fig.19f); distally with three setae (1-3), setae 1 and 2 stout, seta 2 shorter than seta 1, distally armed with well-spaced setules; posteriorly with four setae (1'-4'), gradually increasing in length towards gnathobase, all setulated. Gnathobase (GT) with two elements (I-II), element I large, curved inwards, unilaterally setulated, element II shorter, naked, fused at the base of each other. Gnathobasic filter comb with seven setae, setulated.

***Fourth trunk limb (P4)*** (figs.19g-h)***:*** Epipodite and Endopodite not seen. Exopodite (EX) round, bearing six setae (1-6); setae 1 and 2 are of equal in length, although the second may be longer, both setulated, seta 3 setulated, longest about 1.5 time of the first two, setae 4 and 5 as the same length in Thai specimen (fig.19g) and seta 5 longer in Spain specimen (fig.19h), theirs length about half that of the longest, both setulated, the last seta (6) shortest, about 1/3 of the longest (fig.19g) or as the same length of seta 4 (fig.19h). Row of setules laterally.

Endopodite (EN) or inner portion (fig.19h), anteriorly bearing five setae (1-5), seta 1 elongated, unilaterally armed with fine setules, setae 2-4 'flaming-torch' setae, distally armed with long slender setules, counting 5-6 setules each, seta 5 rod-like receptor, comparable in size of seta 4, naked; posteriorly bearing four soft setae (1'-4'). Gnathobase (GT) with two large elements (I-II), element I unilaterally setulated distally with long setules, element II naked, fused at the base of each other.

***Fifth trunk limb (P5)*** (figs.19i-j)***:*** Pre-epipodite (PEP) small, oval, setulated apically with long setules and rows of small setules basally, no elongated digitiform projection. Epipodite (EP) bilobed, elongated, no elongated digitiform projection. Exopodite (EX) bilobed, bearing four setae (1-4); anterior portion smaller than posterior portion, setae 1-3 on anterior portion, all the same length (fig.19j) or seta 3 shorter, as half of those two obviously (fig.19i), all setulated; posterior portion larger, more oval, bearing one seta (4), relatively short, about 3 times shorter than seta 3, setulated.

Endopodite (EN) larger, more oval, setulated apically, two endopodite setae setulated distally. Gnathobasic filter comb not seen.

**Differential diagnosis:**

This species can be distinguished by 1) the disconnected three main head pores; 2) the postabdomen with dorsal and ventral margins parallel, and the teeth-like marginal denticles of postabdomen occurring in groups; and 3) on trunk limb 1, ODL seta shorter than IDL setae and seta 6 about 1.5 times longer than seta 7.

**Remarks:**

The members of the *Alona pulchella*-group, *A. pulchella, A. cambouei, A. glaba* and *A. laevissima,* share characteristics such as an elongated postabdomen with parallel margins, very well developed lateral fascicles of setae and moderately developed marginal denticles. Sinev (2001) mentioned that disconnected central head pores is the main character for separating *A. cambouei* from *A. pulchella* and also uneven number of notches of posterior margin of head shield, less number of setae on ventral margin of valve (30-35 setae in *A. cambouei* and 40-45 in *A. pulchella*), preanal angle of postabdomen prominent and anal margin prominent. Thai specimens share most characters with *A. cambouei* as shown in characters 1-6 and 14-15 (table 3), and they share only three characters with *A. pulchella* (characters 9, 13 and 16). However, there are some characters different from both *A. pulchella* and *A. cambouei,* as described from Iraq, Sudan (Sinev, 2001) and southern Spain in the following characters 1) three central head pores disconnected but their shape not rounded but more elongated; 2) number of setae on ventral margin of valve range between those specified by Sinev (2001) as *A. cambouei* (30-35 setae) and *A. pulchella* (40-45 setae); 3) postanal margin as long as anal margin but in Malaysian specimen postanal margin two times longer than anal margin; 4) preanal angle prominent in Thai, Sudan and Spain specimens but not prominent in Malaysian ones; 5) anal margin of Thai and Malaysian specimens not concave; 6) long terminal claw but very long in Malaysian specimen; 7) ODL seta as long as IDL setae in Thai specimen but this seta is shorter in specimen from other places; 8) seta 6 of trunk limb 1 subequal in length of seta 7 in Thai specimen but this seta about 1.5 times longer than seta 7 in specimens from other places; 9) seta 3 of trunk limb 4 long, about 1.5 times longer than seta 2 in Thai specimen but shorter in specimens from other places and 10) setae 4-6 of trunk limb 4 show differences in length; in Thai specimen seta 4 equal in length as seta 5; and seta 6 shortest, as half of those two ; seta 6 of P4 as a half of setae 4 and 5 in Thai specimens but in Spain specimens shorter.

**Biology:**

Found in swamps and marshes; common among aquatic weeds (Nayar, 1971).

**Distributions:**

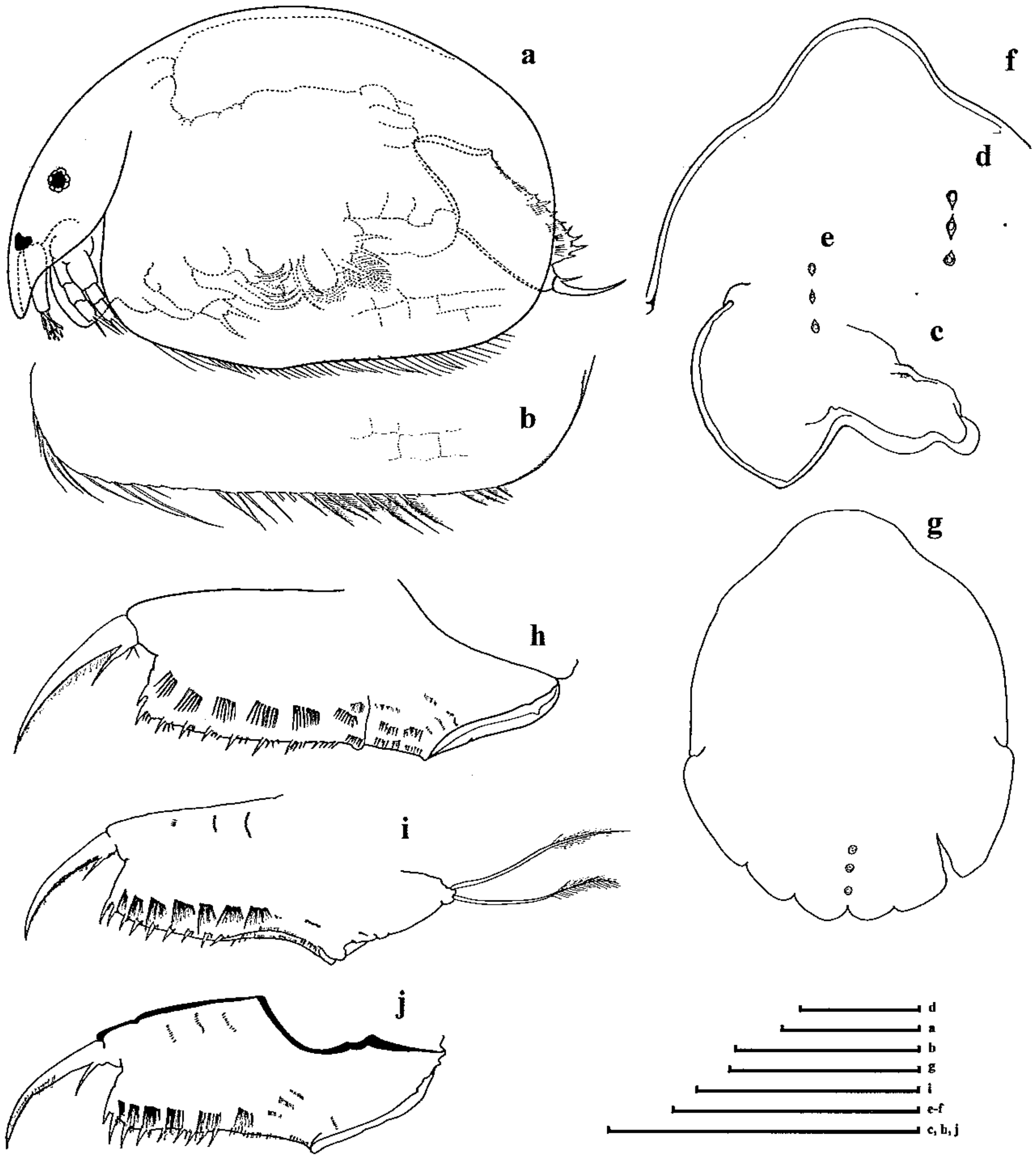
*Alona cambouei* is distributed in South America i.e. Chili, Patagonia (Richard, 1897; Jenkin, 1934), Africa (Harding, 1955; Sinev, 2001), tropical Asia i.e. India, Madagasca (Jenkin, 1934) and also, reported from Australia (Griggs, 2001).

**Table 3** Morphological comparisons among *A. pulchella* and *A. cambouei* from Iraq and Sudan (Sinev, 2001), *A. cambouei* from southern Spain and *A.* cf. *cambouei* from western Malaysia and Thailand

| **Characters** | | ***A. pulchella*** Australia (Sinev, 2001) | ***A. cambouei*** Iraq / Sudan (Sinev, 2001) | ***A. cambouei*** southern Spain (present data) | ***A.* cf. *cambouei*** western Malaysia (present data) | ***A.* cf. *cambouei*** southern Thailand (present data) |
|---|---|---|---|---|---|---|
| **Head pores** | 1) | 3 central pores rounded-shape interconnected | 3 central pores rounded-shape disconnected | 3 central pores rounded-shape disconnected | 3 central pores shape not rounded, disconnected | 3 central pores shape not rounded, disconnected |
| **Head shield** number of notches of posterior margin | 2) | even or greater; 10 or 12 | uneven; 5 or 7 | uneven; 3 | | |
| of head shield | 3) | central pair of notches located symmetrically from midline | the middle notch located in midline | the middle notch located in midline | | |
| **Number of setae on ventral margin of valve** | 4) | 40-45 setae | 30-35 setae | | | 36-41 setae |
| **Postabdomen** | 5) | postanal margin 1.5 times of anal margin | postanal margin ~ anal margin | postanal margin ~ anal margin | **postanal margin 2 times of anal margin** | postanal margin ~ anal margin |
| | 6) | preanal angle not prominent | preanal angle prominent | preanal angle prominent | preanal angle not prominent | preanal angle prominent |
| | 7) | anal margin almost straight | anal margin strongly concave | anal margin concave | anal margin almost straight | anal margin almost straight |
| | 8) | terminal claw long compare with postanal margin | terminal claw long compare with postanal margin | terminal claw long compare with postanal margin | terminal claw **very long** compare with postanal margin | terminal claw long compare with postanal margin |

**Table 3.** (Continued)

| Characters | | *A. pulchella* Australia (Sinev, 2001) | *A. cambouei* Iraq / Sudan (Sinev, 2001) | *A. cambouei* southern Spain present data | *A.* cf. *cambouei* western Malaysia present data | *A.* cf. *cambouei* southern Thailand present data |
|---|---|---|---|---|---|---|
| **Trunk limb 1** | | | | | | |
| ODL-IDL | 9) | ODL seta as long as IDL setae | ODL seta shorter than IDL setae | ODL seta shorter than IDL setae | | **ODL seta as long as IDL setae** |
| Endite 2 | 10) | seta 6 ~1.5 times longer than seta 7 | seta 6 ~1.5 times longer than seta 7 | seta 6 ~1.5 times longer than seta 7 | | **seta 6 subequal of seta 7** |
| **Trunk limb 4** | | | | | | |
| exopodite | 11) | seta 3 longest, 1.2 times longer than seta 2 | seta 3 longest, 1.2 times longer than seta 2 | seta 3 longest, 1.2 times longer than seta 2 | | seta 3 longest, 1.5 times longer than seta 2 |
| | 12) | seta 4 shorter than seta 5, | seta 4, 5, 6 as equal in length | seta 4 shorter than seta 5 | | seta 4 as equal as seta 5 |
| | 13) | seta 6 as a half of seta 5 | | seta 6 shorter than seta 5 | | seta 6 as a half seta 4,5 |
| **Trunk limb 5** | | | | | | |
| Epipodite | 14) | | | bilobed | | bilobed |
| Exopodite | 15) | bilobed, but not obviously | bilobed, but not obviously | bilobed | | bilobed |
| | 16) | seta 3 almost the same length of seta 2 | seta 3 almost the same length of seta 2 | **seta 3 half of seta 2** | | seta 3 almost the same length of seta 2 |




Figures 18a-j. *Alona* cf. *cambouei* Guerne & Richard, 1893: parthenogenetic females from Maikhao peat swamp, Phuket Province, southwestern Thailand (a-d, j), Rantang Abang marsh, Terrenganu, eastern Malaysia (e-f, h) and Zonragoza, Spain (g, i). Figure a, adult female in lateral view; Figure b, ventral margin of valve; Figure c, labrum; Figures d-e, head pores; Figure f, anterior margin of head shield; Figure g, head shield; Figures h-j, postabdomen. Scale bar denotes 100 um.


Figures 19a-j. *Alona* cf. *cambouei* Guerne & Richard, 1893: appendages of females from Maikhao peat swamp, Phuket Province, southwestern Thailand (c-e, g, j) and Zonragoza, Spain (a-b, f, h-i). Figures a-d, trunk limb 1; Figure e, exopodite of trunk limb 3; Figure f, endopodite of trunk limb 3; Figures g-h, trunk limb 4; Figures i-j, trunk limb 5. Scale bar denotes 100 um.

### 3. *Alona cheni* (Chen & Peng, 1993)

**Synonymy:** *Alona setigera* Chen & Peng, 1993: 19, figs 1-5 (not *A. setigera* Brehm, 1931)

**Reference:** Sinev, 1999 (*A. cheni*): 142-146, figs 8-10.

**Type locality:** India, Ahmedabad, Aiwa Reservoir

**Holotype:** parthenogenetic female from India, Ahmedabad, Aiwa Reservoir, 25.III.1964, slide in Canada balsam, deposited in the collection of the Zoological Museum of Moscow State University, inventory number M1-05.

**Paratype:** parthenogenetic females from the same locality, mounted on slides in glycerol, sealed with Canada balsam, also deposited in the collection of the Zoological Museum of Moscow State University, inventory number M1-06 and M1-07.

**Materials examined:**

*Southern Thailand:* 20 parthenogenetic females, examined complete and thereafter dissected, from Thungtong Swamp, Keinsa District, Suratthani Province (8° 52.66'N, 99°11.83'E), southeastern Thailand, temperature 29°C, pH 6.4, conductivity 0.39 and salinity 0 ppt., collected date 01-10-1999, collected by the author, SM.

*:* ten parthenogenetic females, examined complete and thereafter dissected, from Mai-khao peat swamp, Phuket Province (8° 07.21'N, 98°17.34'E), southwestern Thailand, temperature 31.3-31.6°C, pH 6.86-7.23, conductivity 0.07 and salinity 0.4 ppt. collected by the author, SM.

*Northeast Thailand:* two parthenogenetic females, examined complete and thereafter dissected, from Lake Kud-Thing, Bung Kan District, Nong Khai Province, collected date 28.02.1998, by C. Saeng-aroon, KKU.

*Malaysia:* one parthenogenetic female, examined complete and thereafter dissected, collected by Fernando, C. H., Fernando collection, NUS.

*Singapore:* one parthenogenetic female, examined completed and thereafter dissected, collected by Fernando, C. H., Fernando collection, NUS.

**The details of morphological study**

**Species description** (See figures 20-22)

**Parthenogenetic female**

***General shape*** (figs.20a-b, 22a-c)*:* Length 0.35-0.48 mm, about 1.5-1.6 times maximal height (n=30). Body in lateral view oval, more ovoid in some specimens (fig.22c), maximum height around the middle of body and narrowing anteriorly. Dorsal margin forms slightly curve. Postero-dorsal and postero-ventral angles round. Posterior margin slightly concave. Ventral margin almost straight, some specimens with small hillock in the middle (figs.22a-b) with 46 slender setae, slightly different in length, slightly decreasing in length posteriorly, longer setae clearly at anterior part in some specimens (fig.22b), end before posteroventral corner. Antero-ventral angle concave.

***Head*** (figs.20a-d, 22a-c)*:* Relatively small, with short rostrum, broadly rounded, pointing downward. Compound eye present, larger than ocellus, distance between eye and ocellus slightly shorter than distance from tip of rostrum to ocellus. Head shield length about 1.2 times maximum width (fig.20c), posterior margin broadly rounded. Three major head pores connected by a channel, the connection between central and posterior pore wide, that between central and anterior pore narrower (figs.20c-d), central pore smaller than anterior and posterior one, located slightly close to posterior; two lateral pores large, transversely oriented, with characteristic irregular sac-like structure, large semi-circular pockets located behind lateral pores, depth of pockets 0.5 times length of pore. Distance between posterior head pore and posterior corner of head shield (PP) about 0.8 times distance between anterior and posterior head pores

(IP). Transverse lateral pores of about 1IP length, located about 0.5IP distance from midline, at level between anterior and central pore.

***Labrum*** (figs.20e, 22d)*:* height about 2 times maximum width. Labral keel naked, bending, notch at anterior margin, rounded to blunt apex, forming an angle in some specimens (fig.22d), possessing one cluster of setules at posterior margin (fig.20e).

***Postabdomen*** (figs.20h, 22e-g)*:* Length about 2.5 maximum height, distal part about 1.5 times longer than preanal portion. Slightly narrowing distally, dorsal and ventral margin almost parallel, with clearly form an angle between distal and dorsal margins about 45°-60°. Posterodorsal corner sharp, with an angle of 90° or little less. Posterior margin with indentation. Anal margin relatively straight, with no distinct pre-and postanal corner, hard to define, bearing 3-5 rows of small denticles, each row bearing up to 11 denticles. Lateral fascicles: 7-9 postanal groups, each consisting 5-9 denticles, gradually increasing in length distally. Marginal denticles: 8-11 groups of merged spinules, gradually increasing in size distally and bearing 3-5 fused denticles on inner edge. Three or four groups of venterolateral denticles. Natatorial setae relatively short.

***Terminal claw*** (figs.20h, 22e-g)*:* Long and slender, as long as pre-anal margin, bearing a short and slender basal spine, length about 1/3 or ¼ terminal claw, situated at half its length from base of pecten, inner and outer rows of small pectens from base of basal spine to tip of claw, longer pecten on last half (figs.22e-g).

***First antenna (antennule)*** (figs.20a-b, f, and 22d)*:* short, not protruding beyond tip of rostrum but pointing downward. Body compact, about twice as long as wide. Distal end with nine aesthetascs, one distalmost aesthetasc, implanted on elongated apex, as long as antennule and about 1.5 times as long as other aesthetascs, subapical aesthetasc of same length as antennule, accompanied by antennular sensory seta, implanted at about one third of distal end. All aesthetascs projecting beyond tip of rostrum (figs.20a-b, 22d).

***Second antenna*** (figs.20a-b, g)***:*** relatively short, reach about 1/3 of body. Basal segment with conical distal spine. Antennal formula spines with three marginally spines in formula: 0-0-1/1-0-1 and with eight setae in formula: 1-1-3/0-0-3. All setae bisegmented, setulated distally. Seta arising from basal segment of endopodite not extending beyond tip; exopodite seta longer and setulated. Seta arising from middle segment of exopodite long, as half of three seta on distal segment. Terminal spines as long as their segment. Surface of segments with rows of setules. Coxa with distinct short denticle on anterior side between rami and its surface provided with clusters of longer setae on upper part, longest rows at second coxa.

**Trunk limb: six pairs**

***First trunk limb (P1)*** (figs.21a-b)***:*** Epipodite and Exopodite not seen. Outer distal lobe (ODL) with one long seta (I'), with short distal setulation. Inner distal lobe (IDL) with three setae (I-III), seta I short and slender, chitinized hook-like, with one small sensillum (sn) near base, seta II and III bisegmented, similar in length to ODL seta, with fine setules along distal part. Endite 3 (E3) with four setae (1-4), seta 1 same as seta 2, both bilaterally setulated with short setules, seta 3 more slender and longer than seta 4, both unilaterally armed with short setules, one sensillum (sn) at base of seta 3. Endite 2 (E2) with three long setae (5-7), seta 5 more slender, bilaterally setulated, setae 6 and 7 armed with stiff setules along distal segment, two radial rows of setules at base of endite. Endite 1 (E1) with two setae (8-9), both setulated and longer than setae on other endites but not protruding beyond them. Close to endite 1, a blunt projection with radiant setules. Trunk with 5-6 rows of stiff setae on ventral surface, about 6 setae on last row. Two ejector hooks, similar in size, unilaterally spinulated distally. Rows of thin setae on the base of trunk, about 4-7 setae in rows. Gnathobase not studied.

***Second trunk limb (P2)*** (fig.21c)***:*** Epipodite not seen. Exopodite (EX) round-elongated, setulated on slightly inflated apex, one short seta at about half its length. Endopodite (EN) triangular, with eight scrapers (1-8), decreasing in length towards gnathobase, though scraper 4 shorter than scraper 5; scrapers 1 and 2 equal in length, unilaterally armed with fine setules as on scraper 4; scrapers 3 and 5 unilaterally armed with strong setules; scrapers 6-8 unilaterally armed with strong setules but less than on scrapers 3 and 5. Distal armature of gnathobase (GT) with two elements (I-II), both hook-like, naked, one minute element on the hillock element I. Gnathobasic filter comb with seven setae, the posteriormost considerably shortest and the rest are the same length.

***Third trunk limb (P3)*** (fig.21d)***:*** Epipodite (EP) not seen. Exopodite (EX) subquadrangular bearing seven setae (1-7), seta 1 and seta 2 located laterally, in typical V-formation, both similar in length, seta 3 longest, densely feathered, seta 4 and seta 5 the same length, about 1/5 times as long as the longest, both plumose, seta 6 and 7 slender, seta 7 about half the longest.

Endopodite (EN) divided into two rows; anterior row with three appendages on external portion (1-3). Spines 1 and 2 stout, similar in length, both unilaterally spinulated, small sensillum (sn) located between spines 1 and 2, seta 3 more slender, bilaterally setulated distally; a posterior comb of four plumose setae (1'-4'), gradually increasing in length to gnathobase. Gnathobase (GT) with three elements (I-III), element I large, curved inwards, unilaterally setulated with long setules, element II and III shorter, naked, fused at the base. Gnathobasic filter comb with seven setae, gradually increasing in length posteriorly.

***Fourth trunk limb (P4)*** (figs.21e-f)***:*** Epipodite not seen. Exopodite (EX) quadrangular, bearing six setae (1-6), seta 1 and 2 are of the same length, though seta 2 may be shorter, both bilaterally setulated, seta 3 plumose and longest, setae 4, 5 and 6 of the same length, about a half of the longest seta (fig.21e) or unequal in length, setae 4 and 5 bilaterally armed with short setules from base to tip; setae 5 and 6 forming a forceps; seta 6 more slender, bilaterally armed with shorter setules on distal part.

Endopodite (EN); anteriorly bearing five appendages (1-5). Spine 1 stout, rounded basally and more slender distally, unilaterally armed with short denticles, setae 2-4 'flaming torch' setae, seta 2 widened, apically with a crown of about 10 stiff setae, setae 3 and 4 more slender, all armed with slender-long setules on distal end, counting 6 and 8 setules respectively, seta 5 a rod-like receptor, naked; posterior portion bearing three setae (1'-3'), setae 1' and 2' are of the same length, but seta 3 about 1.5 times longer than setae 1 and 2. Gnathobase (GT) horse-tail seta compose of three elements (I-III), element I large-slender, unilaterally setulated, element II and III short, naked fused at the base to each other. Gnathobasic filter combs five setae, equally in length.

***Fifth trunk limb (P5)*** (fig.21g)***:*** Pre-epipodite (PEP) elliptical, with long setae setulated radially, elongated digitiform projection not seen. Epipodite (EP) more ovoid, smaller than pre-epipodite. Exopodite (EX) not form bilobe, bearing four apical setae (1-4), densely setulated apically; anterior portion bearing three setae (1-3), gradually decreasing in length posteriorly, though seta 1 shorter than seta 2, all bilaterally setulated, posterior portion bearing one seta (seta 4), relatively short about 1/3 of seta 3, bilaterally setulated.

Endopodite (EN) larger than pre-epipodite and epipodite, more ovoid, setulated apically, two endopodite setae setulated distally, one as a half length of another.

***Sixth trunk limb (P6):*** ciliated lobe (Sinev, 1999).

**Variability:**

Some variability was noted in 1) the shape of the labrum and number of distal setules on its apex; 2) size of center pore and width of the channel connection; 3) length of setae 4-6 on exopodite of trunk limb 4.

**Differential diagnosis:**

The characters as the shape of the postabdomen; the structure of the head pores and trunk limbs of *A. cheni* appears to share with other member of *costata*-group, *A. costata, A. rustica, A. setigera, A. hudeci, A. bicolor, A. fabricii* and *A. muelleri*, make these species easily distinguished from the majority of other *Alona.*

*A. cheni* can be separated from *A. costata* by several clear-cut differences in head pore structure and trunk limbs: middle pore smaller than other two, wide connection between middle and posterior head pore, longer lateral pores, and semi-circular, not rounded, lateral pore pockets with depth only 0.5 length of pore proper; scrapers 1-3 on trunk limb 1 of *A. costata* longer than other scrapers obviously but in *A. cheni* all scrapers seem to be more gradually increasing in length distally; seta 4 on exopodite of trunk limb 3 same length as seta 5 but it shorter in *A. pulchella*; in addition seta 5 shorter than seta 6 but they are the same length in *A. costata*. The differences between the species and some differences in the present specimens are summarized in table 3.

**Remarks:**

At present we can recognize eight species of *Alona* as belonging to the *costata*-group: *A. costata, A. cheni, A. setigera, A. rustica, A. hudeci, A. bicolor, A. fabricii* and *A. muelleri*. This group is defined as follows (Sinev, 1999): 1) transverse lateral head pores with large to very shallow pockets behind. This character is unique in *Alona* and in the subfamily Aloninae as a whole and 2) male postabdomen with sperm ducts opening at end of a process protruding above base of postabdominal claws (Sinev, 1999). There are no other species of *Alona* with such a male postabdomen, similar to *Leydigia* Kurz, 1875.

During last two decades, the name '*Alona costata*' has been recorded in each study in Thailand. As usual, we followed the key from Malaysia (Idris, 1983) which shows sac-like lateral head pores as the main characteristic of this species. Without checking the difference of pores shape and/or depth of the pockets and other details, especially trunk limbs, we name any *Alona* with such a character *Alona costata*. However, after checking specimens from southern and northeast Thailand, Malaysia and Singapore, the records of *A. costata* all seem to belong to *A. cheni* as these specimens present semi-circular pockets of lateral pores and those characteristics of trunk limbs as mentioned in differential diagnosis.

However, there are some differences in general characters and trunk limbs between *A. cheni* described from type locality, India, and Thai specimens, not mentioned in the original paper, as following (table 4) 1) in Thai specimens, anterior margin and tip of labrum rounded, height about 2 times maximum width and two clusters of more dense setules on posterior margin, close to each other, but more it more obtusangular tip and height ~3 times maximum width in type specimen;

2) all scrapers on trunk limb 2 gradually increasing in length distally but in Thai specimens, seta 6-8 about 0.3-0.5 times shorter than seta 5 obviously; 3) spines on flaming torch seta on exopodite 4 about 1.5-2 times seta body in Thai specimens but only 1-1.2 times in type specimen; 4) exopodite of trunk limb 5 not clearly forming lobe; and 5) one short seta on posterior portion of trunk limb 5 as a quarter of seta 2 on anterior portion in Thai specimens but this seta about half of seta 2 in type specimen.

**Biology:**

This species has been found mostly in freshwater swamps and marshes with dominance of *Cyperus* sp. It shows a higher abundance in the rainy season.

**Distribution:**

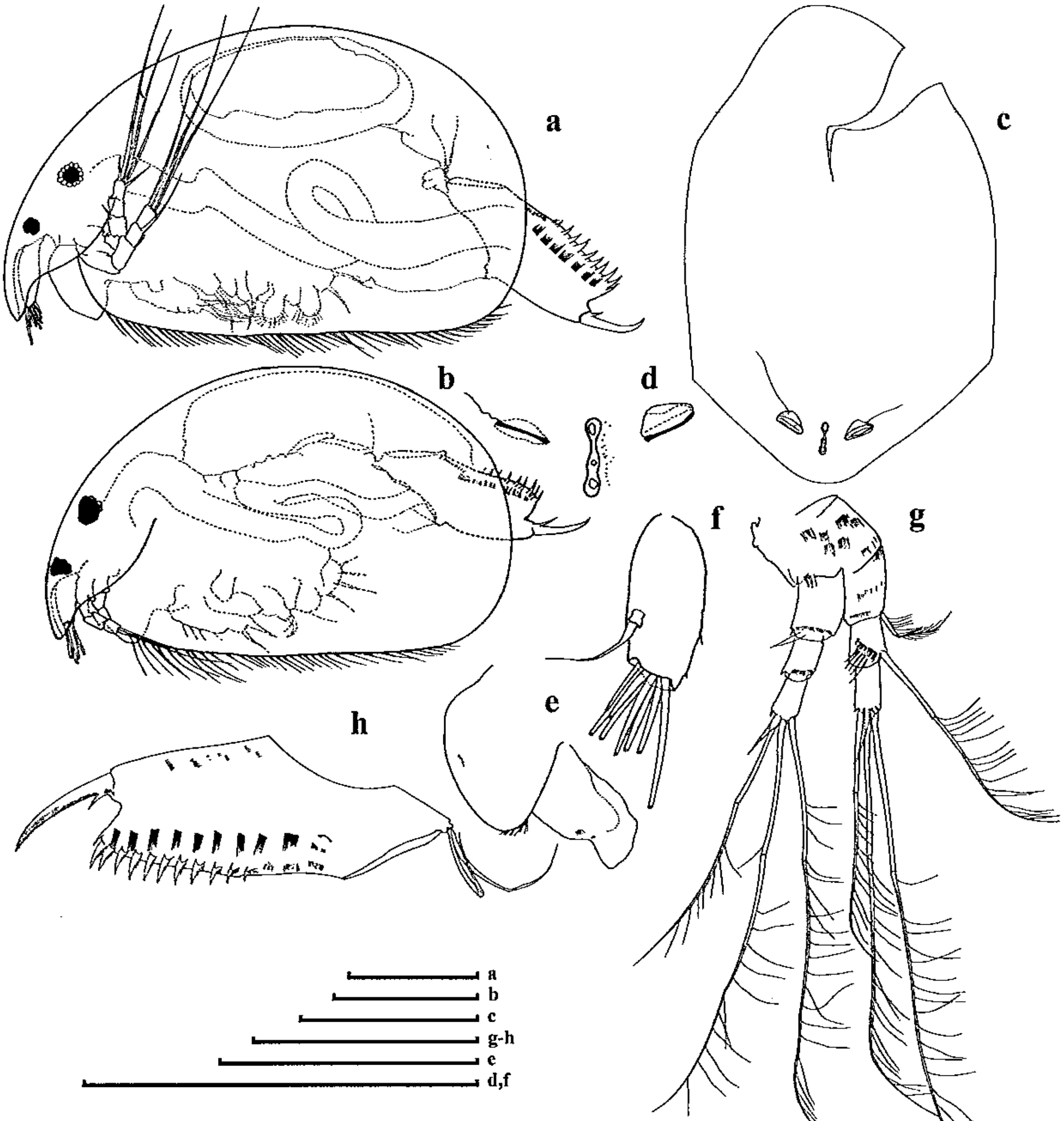
*A. costata* inhabits Europe and North Asia, reaching East Siberia and central Mongolia in the east as well as the Caucasus and northern Kazakhstan in the southeast. While A. *cheni* is currently known from three localities only, one in India, the other in China, and from Thailand, it can be presumed a common species at least in these countries, likely to have repeatedly been confused with the European A. *costata* (Sars, 1903; Chiang and Du, 1979; Sharma and Michel, 1987). The great distance between these three documented occurrences of *A. cheni* shows that its distribution is quite vast, possibly covering South and Southeast Asia.

**Table 4** Morphological comparison among *Alona costata*, *A. cheni* and *A. cheni* from Thailand

| Characters | | *A.costata* Sinev, 1999 | *A. cheni* India Sinev, 1999 | *A. cheni* Thailand Present data |
|---|---|---|---|---|
| **Head pores** | | | | |
| main head pores | 1) | 3 interconnected median head pores | 3 interconnected median head pores | 3 interconnected median head pores |
| PP/IP | 2) | 0.5-0.8 | 0.7-0.9 | 0.9 |
| lateral head pores | 3) | 2 lateral head pores transverse, length ~ 0.75IP | 2 lateral head pores transverse, length ~ 0.9-1IP | 2 lateral head pores transverse, length 1IP |
| location of lateral head pores | 4) | 0.5IP from midline | 0.7IP from midline | ~0.7IP from midline |
| pockets of lateral head pores | 5) | large rounded depth ~2 times length of pore | **semi-circular depth ~0.5 times length of pore** | **semi-circular, depth ~0.5 times length of pore** |
| **Labrum** | | | | |
| labral plate | 6) | rounded anterior & rounded tip, | **not rounded tip but obtusangular** | rounded anterior & rounded tip, |
| | 7) | height ~2 times maximum width | height ~3 times maximum width | **height ~2 times maximum width** |
| | 8) | 2 clusters of setules | 2 clusters of setules | **2 clusters of more densely setules, closer to each other** |
| **Trunk limb 2** | | | | |
| scrapers | 10) | gradually increasing in length distally **but scrapers 1-3 longer than others obviously** | gradually increasing in length distally | gradually increasing in length distally **scrapers 6-8 ~0.3-0.5 times of scrapers 1-5** |
| **Trunk limb 3** | | | | |
| Exopodite | 11) | **seta 4 shorter than seta 5** | seta 4 as same length as seta 5 | seta 4 as same length as seta 5 |

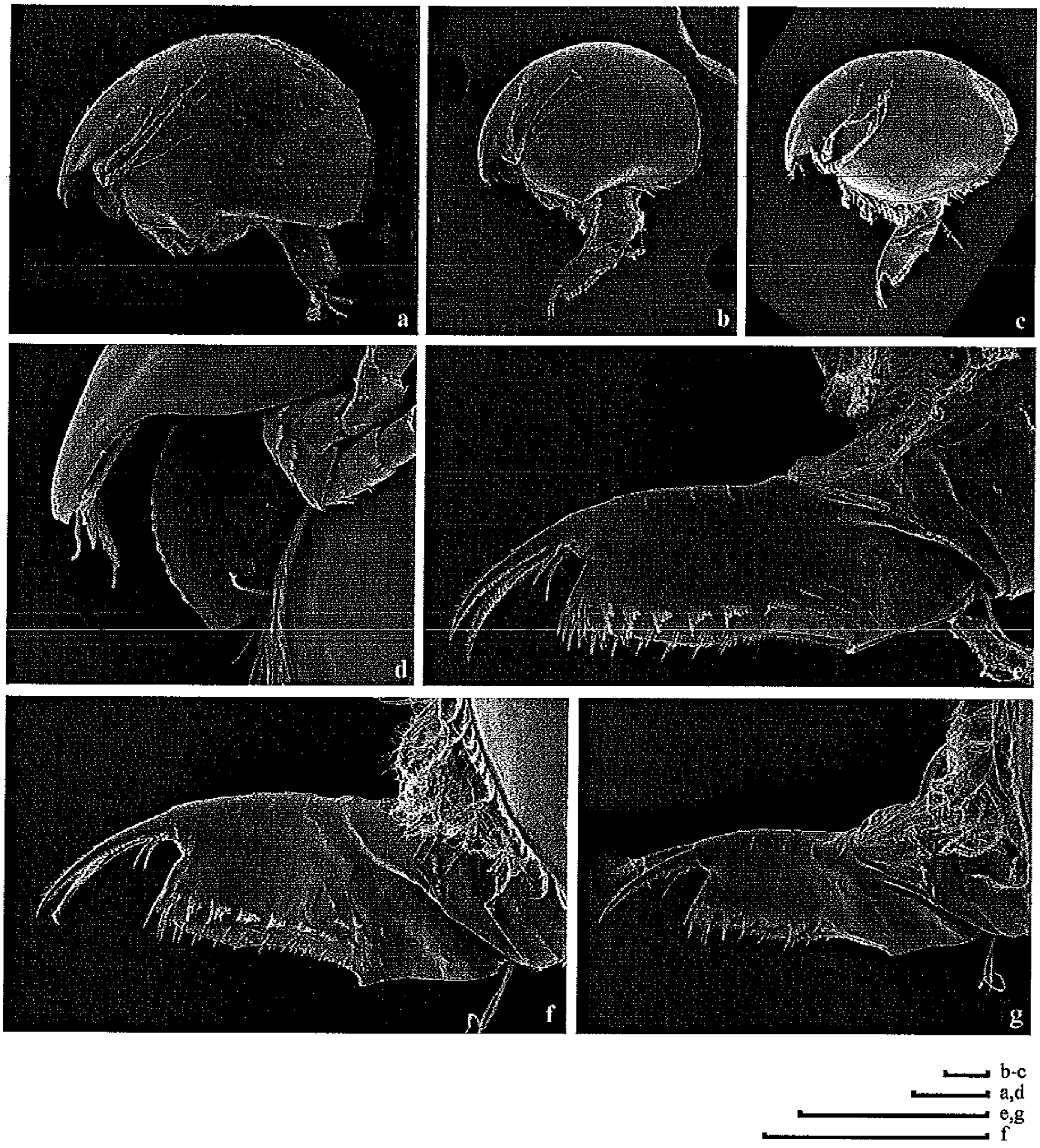
**Table 4.** (Continued)

| **Characters** | | *A. costata*<br>Sinev, 1999 | *A. cheni*<br>India<br>Sinev, 1999 | *A. cheni*<br>Thai specimens<br>Present data |
|---|---|---|---|---|
| **Trunk limb 4** | | | | |
| exopodite | 12) | **seta 5 as same length as seta 6** | seta 5 shorter than seta 6 | seta 5 shorter than seta 6 |
| endopodite | 13) | spines on flaming torch seta 1 time as long as body | spines on flaming torch seta 1-1.2 times as long as body | **spines on flaming torch seta 1.5-2 times as long as body** |
| | 14) | seta 3 on posterior portion as long as setae 1 and 2 | ? | **seta 3 on posterior portion 2 times longer than setae 1 and 2** |
| **Trunk limb 5** | | | | |
| exopodite | 15) | 2 lobes, anterior portion larger | 2 lobes, anterior portion larger | **not clearly forming lobe** |
| | 16) | one long seta on posterior portion, as 0.5 of the longest on anterior portion | one long seta on posterior portion, as half of the longest (seta 2) on anterior portion | **one short seta on posterior portion, as a quarter of the longest (seta 2) on anterior portion** |




Figures 20a-h. *Alona cheni* (Chen & Peng, 1993): parthenogenetic females from Thungtong swamp, Suratthani Province (a, c-h) and from Pak Panang Bay, Nakornsrithammarat Province (b). Figures a-b, adult female in lateral view; Figures c-d, head shield and its head pores; Figure e, labrum; Figure f, antenna I; Figure g, antenna II; Figure h, postabdomen. Scale bar denotes 100 um.


Figures 21a-i. *Alona cheni* (Chen & Peng, 1993): appendages of females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figures a-b, trunk limb 1; Figure c, trunk limb 2; Figures d-e, trunk limb 3 and its inner portion; Figures f-h, trunk limb 4 and its inner portion; Figure i, trunk limb 5. Scale bar denotes 100 um.




Figures 22a-g: *Alona cheni* (Chen & Peng, 1993): parthenogenetic females from Thungtong swamp, Suratthani Province. Figures a-c, adult females in lateral view; Figure d, labrum; Figures e-g, postabdomen. Scale bar denotes 100 um.

## 4. *Alona diaphana* King, 1853

**Synonymy:** *Alona diaphana* King, 1853: 260, pl.8, Fig.D; *Alonella diaphana* (King, 1853): Sars, 1888: 47-50, pl.5, figs.5-7; *Alona davidi* Richard, 1895: 192-195, figs. 5-8; *Alonella diaphana* (King), Syn. *Alona davidi*, Richard; Sar, 1896: 1-81, p.43; *Alona davidi* var. *iheringi* Richard, 1897: 294-296, figs. 42-43; *Alona punctata* Daday, 1898: 39-41, pl.18, figs. a-e.

**References:** King, 1853: 260, Pl. 8: fig. D.; Sars, 1888. c.,p. 47, PI. 5, figs. 5-7. Brancelj, 1900: Des.14-15, fig.3; Sars, 1901: Des. 60-61, Pl.10, fig. 3 a-b; Harding, 1955 (Percy Sladen Trust Exp.): Des. 345, figs. 65-68; Rey and Saint-Jean, 1968: 105-106, 108, fig. 22A, 22E; Infante, 1980: Des.599, fig. 6. Frey, 1991: 11-48, figs. 2-41.

**Type locality:** Sars redescribed the taxon, on the basis of three specimens raised from dried mud from a Water Hole at Cattle Station, 20 miles from Rockhampton in central coastal Queensland north of Brisbane, Australia.

**Type material:** Sars' slides and liquid samples. In the Sars collection in the Zoological Museum of the University of Oslo, Norway, there are three slides and three liquid samples of *Alona diaphana* from Australia. One of the slides and one liquid sample each contains one specimen raised from dried mud, and hence quite certainly they are from the three specimens in which Sars used to define the taxon. The other two slides are from Sydney, and the other two liquid specimens from Victoria. They obviously represent later collections that Sars never reported on. None of the preparations lists any data of collection. The material in the Sars collection is given below, with verbatim listings of the information on the labels. The two starred items are considered to derive from the three specimens in which Sars used to redescribe King's taxon in 1888. // Slides: F9649. *Alonella diaphana* King. Sydney (3 specimens); *F9650. *Alonella diaphana*, G.O Sars. udkl. of Austral. Mudder (1 specimen); F9652. *Alonella diaphaiui* (King). Centennial park (= Sydney), Whitelegge (3 specimens); Liquid samples: F4135. *Alonella diaphana* (King). Vict.

Searle, Australia, G.O. Sars (3 specimens); F4153. *Alona diaphana* G.O. Sars. Victoria A, Australia (ca. 60 specimens); *F18328. *Alonella diaphana* (King). Australia. udkl. of törret Mudder, G.O. Sars (1 specimen).

**Materials examined:**

*Southern Thailand :* 20 parthenogenetic females, examined complete and thereafter dissected, from Thungtong swamp, Keinsa District, Surattani Province (8° 52.66'N, 99°11.83'E), southeastern Thailand, temperature 29°C, pH 6.4, conductivity 0.39 and salinity 0 ppt., collected date 01-10-1999, collected by the author, SM.

: five parthenogenetic females, examined complete and thereafter dissected, from Jumrai reservoir, Songkhla Province, southern eastern Thailand, temperature 29.2°C, pH 7.05, conductivity 1.59 and salinity 0 ppt . collected by the author, SM.

: two parthenogenetic females, examined complete and thereafter dissected, from Yai swamp, Chumporn Province (10° 32.49'N, 99°12.02'E), southern Thailand, temperature 33.56°C, pH 6.09, conductivity 0.061 and salinity 0 ppt. collected by the author, SM.

*Northeast Thailand:* Two parthenogenetic females, examined completed and thereafter dissected, from Lake Gud-Thing, Nongkai Province, collected by C, Saeng_aroon, KKU.

**The detailed of morphological study**

**Species description** (See figures 23-25)

**Parthenogenetic female**

***General shape*** (figs.23a-c, 25f)*:* Body in lateral view oval to ovoid (fig.23a), maximum height around the middle of body and gradually narrowing posteriorly. Length 0.38-0.70 mm, about 1.4-1.6 times maximal height (n=20). Dorsal margin generally uniformly curved, depression between head and rest of body absent. Postero-dorsal angle not prominent, postero-ventral margin broadly rounded, with small setules reaching to middle of body (figs. 23b-c, 25f). Dorsal edge strongly arched in the middle and joins the posterior edges of valves, without any intervening angle. Ventral carapace margin forming a wide V-shape, ventral embayment before the middle. A row of numerous setae along posterior margin at some distance from one on inner side of carapace. Ventral setae relatively short, with 56-65 setae (figs.23a-c), decreasing in length posteriorly, between them series of small setules, postero-anglemost -small spines-like setules (fig.23b).

***Head*** (figs.23a, d, 25a)***:*** Moderately size, rostrum well developed, blunt. Compound eye present, size larger than ocellus; distance between eyes and ocellus same as between ocellus and tip of rostrum, although sometime shorter. Head shield round-elongated (fig.23d), length about 1.5-1.7 times maximum width. Three major head pores of same size, connected with narrow channel, PP about 1.2 times as distance as IP. Two very small lateral pores located slightly close to anterior pore, about 1.5 IP distance from midline.

***Labrum*** (figs.23a, 25a)***:*** relatively large, anterior margin rounded and rounded tip, labral keel naked.

***Postabdomen*** (figs.24g-h, 25b)***:*** Relatively broad, width about 2 times height. Dorsal margin almost straight, but in some specimens gradually curving anteriorly. Ventral margin curved, widest posteriormost. Posterodorsal corner sharp. Preanal corner present but small, situated more ventrally than postanal corner. Anal margin evenly arched, tapering distally, with no distinct postanal margin. Lateral fascicles: 7-8 postanal groups, consisting of 8-10 denticles, third or fourth distalmost group the largest of the fascicles, not reaching beyond dorsal margin of postabdomen, continuing proximally in group, more radial, of about 6-8 groups, each consisting of 8-10 smaller denticles. Marginal denticles 9-11 groups of 3-5 merged spinules, of which middle groups slightly larger than anterior and posteriormost. Two to three groups of venterolateral denticles. Natatorial setae with long distal end, setulated.

***Terminal claw*** (figs.24g-h, 25b)***:*** Long and slender, longer than preanal portion of postabdomen. Basal spine as 1/3 of claw, three fine setules as 1/3 long as basal spine arising proximal to base of spine. Row of short pectens almost reaching tip of claw, longer at basal part.

***First antenna (antennule)*** (figs.23a, e)***:*** Relatively elongated and reaching but not protruding beyond tip of rostrum. Body compact, about 2 times as long as wide, two rows of very short setules transversely on anterior face (fig.23e). Distal end with eight aesthetascs of the same length, implanted on elongated apex, as long as antennular body. Subapical aesthetasc not found. All aesthetascs projecting beyond tip of rostrum.

***Second antenna*** (figs.23a, f)***:*** Relatively short, reaching less than half of body (fig.23a). Antennal formula: setae 0-1-3/0-0-3, spines 0-0-1/1-0-1. Basal segment with conical distal spine, all segment cylindrical, basal segment longest. All setae bisegmented and setulated distally. Seta arising from middle segment of exopodite longer than endopodite. Spine arising from basal segment thicker than others, but not beyond the second segment, spines at apical segment shortest.

**Trunk limb: five pairs**

***First trunk limb (P1)*** (figs.24a, 25c)***:*** Relatively large. Outer distal lobe (ODL) with two setae (I-II), seta I shorter than seta II, both distally armed with a row well spaced setules, proximally preceded by a row of large with 5 spines on seta I and 2 spines on seta II. Inner distal lobe (IDL) bearing two setae (I'-II'), seta I' long and slender, bearing short, hardly visible setules distally, seta II' slender, length half that of seta I', bilaterally setulated distal end. Endite 3 (E3) with four setae (1-4), all similar in length though seta 2 seems longer, seta 3 more robust while seta 1,2 and 4 more slender, all bilaterally setulated on distal part. Endite (E2) bearing two apical setae (5-6), of which seta 5 longer, both unilaterally setulated at basal part and bilaterally at distal end. Groups of slender setules present radially on inner side of the endite. Endite 1 (E1) with three apical setae (7-9). Setae 7 and 8 of same length, both bilaterally setulated with fine setules on distal part, two small spines on basal part of seta 8. Seta 9 located laterally of trunk, slender, length half of previous two, naked. Trunk with four rows of stiff setae on ventral surface, 6-7 setae each. Rows of slender spinules present on trunk. Basally two ejector hooks, different in length, one half shorter than another, both unilaterally spinulated. Epipodite and gnathobase not seen.

***Second trunk limb (P2)*** (figs. 24b, 25d)*:* Epipodite not seen. Exopodite (EX) elongated, bearing small setules on the apex. Endopodite (EN) triangular, with eight scrapers (1-8), generally decreasing in length towards gnathobase though scraper 3 shorter than scraper 4 and scraper 6 shorter than scraper 7; scrapers 1-5 bisegmented, similarly unilaterally armed with fine setules distally, scrapers 6 and 8 bisegmented, similarly unilaterally armed with small denticles distally, scraper 7 more robust, armed with about 20 stronger denticles. Distal armature of gnathobase (GT) with four elements (I-IV), hillock between scraper 8 and gnathobase, apically setulated (fig.25d). Element I distinctively fish-hook like at apex, element II and III smaller, all naked and fused at the base, element IV minute. Gnathobasis filter comb with five setae, the first two of the same length and considerably shorter than the other three.

***Third trunk limb (P3)*** (figs.24c, 25e)*:* Epipodite not seen. Exopodite (EX) small, quadrangular, bearing seven setae (1-7): setae 1-3 located laterally, 2-3 in typical V-formation, seta 1 smallest, ½ of seta 2, seta 2 and seta 3 of the same length, plumose seta 4 longest, seta 5 plumose, setae 6 and 7 more slender, both similar in length and armed with short setules from base to tip. Followed by row of setules on body of exopodite.

Endopodite (EN) divided into two rows; anterior row bearing five setae (1-5), setae 1 and 2 stout, bisegmented, both are the same length, distally armed with well-spaced short setules, hardly visible, one small receptor between them, setae 3-5 more slender, seta 4 smallest, one rod-like seta located between seta 3 and seta 4; posterior row bearing four setae (1'-4'), gradually increasing in length towards gnathobase, all bilaterally setulated. Gnathobase (GT) with three elements (I-III), element I largest, curve inwards, unilaterally setulated, element II and III smaller, naked, fused at the base of each other. Gnathobasic filter comb 7 setae, subequal in length, all bilaterally setulated.

***Fourth trunk limb (P4)*** (figs.24d-e)***:*** Epipodite not seen. Exopodite (EX) more round than oval, bearing six setae (1-6), setae 1 and 2 are of the same length though seta 1 may be longer, both plumose, seta 3 about 2 times as long as seta 2, plumose, a hillock between seta 2 and seta 3 (arrow), conical-like seta 4 shortest, about 1/3 of the longest, bilaterally setulated, seta 5 longer than seta 6, both more slender, unilaterally with short setules, followed by row of long setules on body of exopodite.

Endopodite (EN) or inner portion; anteriorly bearing five setae (1'5), spine 1 naked, large spoon-like, seta 2-4 'flaming-torch' setae (fig.24e), distally armed with long slender setules, counting 6-7 setules each, followed by seta 5 round-elliptical like receptor, comparable in size to flaming torch setae, naked; posteriorly bearing three setae (1'-3'), generally increasing in length towards gnathobase, all unilaterally setulated. Gnathobase (GT) with three elements, element I large, unilaterally setulated, element II and III hook-like, smaller, naked, fused at the base of each other. Gnatobasic filter comb two setulated setae.

***Fifth trunk limb (P5)*** (figs.24f-g)***:*** Pre-epipodite (PEP) rounded, densely setulated apically, elongated digitiform projection not seen. Epipodite (EP) smaller, rounded, elongated digitiform projection not seen. Exopodite (EX) bilobed (arrow), bearing four apical setae (1-4); anterior portion as same size as posterior portion, setae 1-3 on anterior portion gradually decreasing in length posteriorly, though seta 2 may be longer in some specimens (fig.24g), all bilaterally setulated, seta 4 on posterior portion smallest, length a half of seta 3, bilaterally setulated. Row of setules between two lobes; no hillocks.

Endopodite (EN) rounded, relatively large, setulated apically, endopodite seta unilaterally setulated, slightly longer than gnathobasic seta. Gnathobasic filter comb, if any, not seen.

**Variability:**

Some variability was noted in the following characters: 1) wide range of parthenogenetic female size; 0.38 to 0.70 mm. 2) postabdomen, anal portion rounded and tapering distally obviously (figs.23g-h) or distal portion more rounded (fig.25b) 3) fork-like setules on two IDL setae, varied in number from 2-5 setules 4) scrapers

3-5 of trunk limb 2 as the same length or scraper 4 longer and 5) setae 1-3 on anterior portion of trunk limb 5 are equal in length (fig.24f) or seta 2 longer (fig.24g).

**Differential diagnosis:**

This species can be distinguished by: 1) rostrum folded over distally so that it appears truncate in lateral view; 2) the general characters of postabdomen- broad and flat, with the postanal margin longer than either the anal or pre-anal portion, tapering distally; 3) ventral of valve, row of strong setae reach to postero-angle of valve, series of smaller setules among them, and continue with small setules to postero-dorsal angle as a distinct submarginal line parallel to the margin; 4) two IDL setae and two ODL setae, the latter each provide with a row of course setae on distal segment and more robust fork-like spines later on; 5) two small spines on basal part of seta 8 of trunk limb 1; 6) large hillock with row of 14-15 apical setae between scraper 8 on trunk limb 2 and its gnathobase; 7) very long seta 3 on exopodite of trunk limb 4 and 8) the present of hillock between setae 2 and 3 of trunk limb 4.

**Remarks:**

This species was originally described by King in 1853 but the description at that time was quite poor and the illustrations are difficult to compare with the information from others. However, Sars partially redescribed the specimens later and his description came to be a standard for comparison of what is called *Alona diaphana* (Frey, 1991). Since 1888, taxa resembling Sars' redescription of *diaphana* have been reported from other continents, mostly under *Alona davidi*, which was described by Richard from Haiti. Also, in Thailand the names of *Alona diaphana* King, 1853 or/and *Alona davidi* Richard, 1895 have been listed (Boonsom, 1984; Pholpunthin, 1997; Sanoamuang, 1998; Saeng-aroon, 2001), as it is not rare in the country. It is confusing to name a species alternatively as *Alona diaphana* King, 1853 or *Alona davidi* Richard, 1895 the name being applied depending on the authors (Boonsom, 1984; Sanoamuang, 1998). This also can lead to a mistake to estimate the species richness of the country.

However, our specimens look very much similar to Frey's taxon, which is close to Sars's redescription (Frey, 1991). The differences among the populations are shown in table 5. Although these characters show quite a wide range of differences, which suggest more than one species (Sinev, *et al.*, unpublished data), the comparison of more specimens from various localities in the world is needed before concluding on their status. Since the status remains unresolved, we preferred to call *A. davidi* (Richard, 1895) as the junior synonym of *A. diaphana* King, 1853.

**Biology:**

The species has been found in several types of habitats, some materials were collected in pools of residual stagnant water and some materials can be found in slow-running water habitats as well. However, it shows highly abundance in the stagnant-vegetative habitats, where the *Nelumbo* sp. and *Nymphaea* sp. dominant.

**Distribution:**

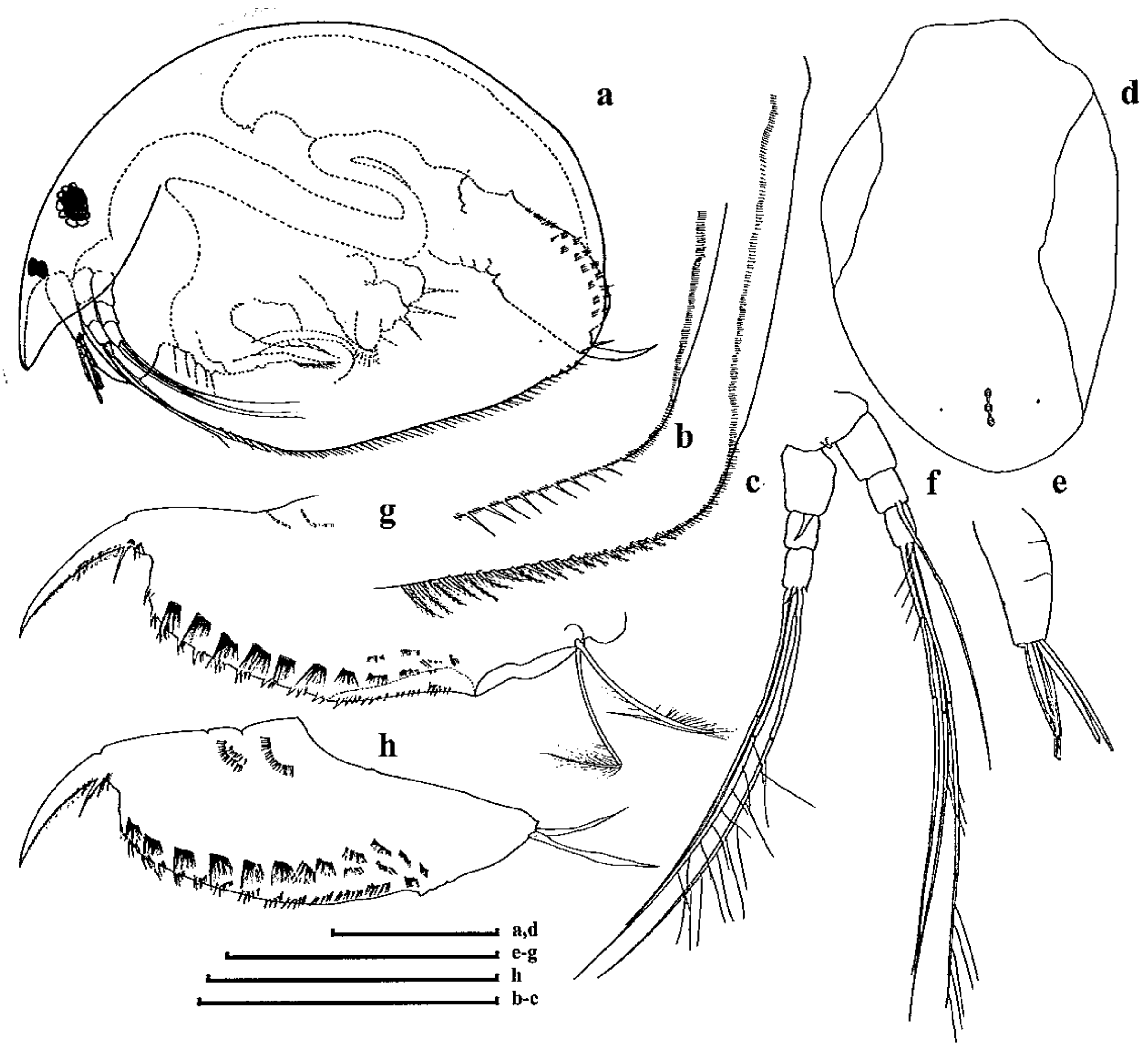
*A. diaphana* is widely distributed over the tropical and sub-tropical regions of all continents; particularly in Africa. In Europe it was recorded in some locations in Italy (Margaritora and Specchi, 1985) and in southern parts of Yugoslavia (Hrbacek *et al.,* 1978). In Thailand it is distributed from northeast to southern Thailand, so it is not rare in the country.

**Table 5** Morphological comparison among populations of *A. diaphana* from Frey, 1991; Sinev *et al.*, unpublished data and present data

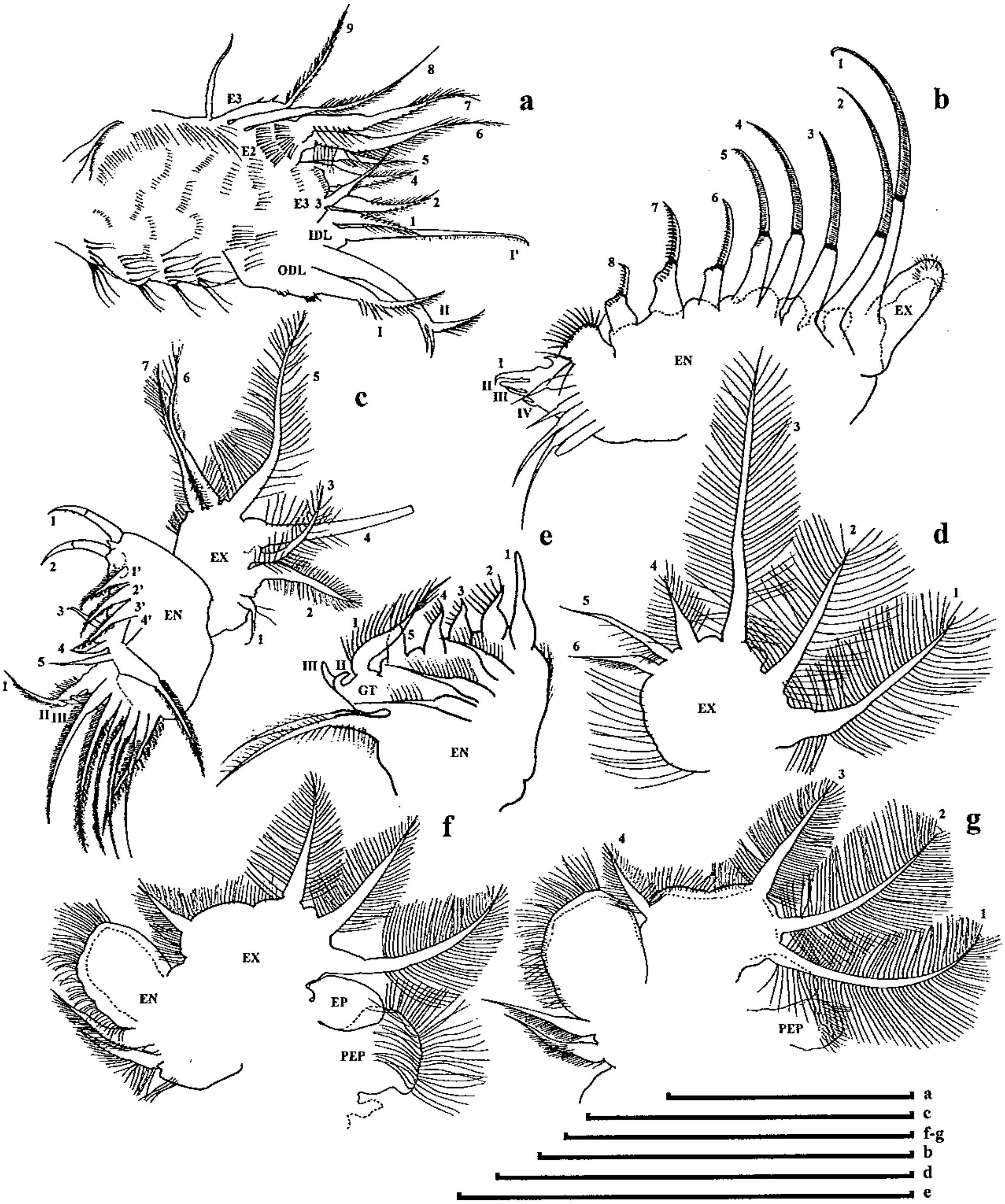
| **characters** | | ***A. diaphana*** Frey, 1991 | ***A. diaphana*** population 1 | Sinev *et al.*, unpublished data population 2 | ***A. diaphana*** Thai specimen |
|---|---|---|---|---|---|
| **Size of females** | 1) | up to 0.51 mm | up to 0.57 mm | up to 0.69 mm | |
| **Number of ventral margin setae** | 2) | 57-75 setae | 58-67 setae | 84-95 setae | 55-64 setae |
| **Head pores** location of head pores | 3) | PP < 1 IP | PP < 1 IP | PP = 1.5-2 IP | PP = 1.2 IP |
| **Labrum** anterior margin | 4) | convex | convex | wavy | convex |
| **Antenna 2** seta of basal segment of exopodite | 5) | longer than second segment | longer than second segment | shorter than second segment | shorter than second segment |
| **Trunk limb 1** accessory seta | 6) | 3 times shorter than ODL seta | 2 times shorter than ODL seta | 3 times shorter than ODL seta | 2 times shorter than ODL seta |
| **Trunk limb 3** exopodite | 7) | seta 5 longer than seta 6 | seta 5 longer than seta 6 | same length | seta 5 longer than seta 6 |
| | 8) | seta 3 long obviously | seta 3 long obviously | seta 3 long obviously | seta 3 long obviously |
| finger-like projection on epipodite | 9) | - | present | absent | absent |
| **Trunk limb 4** exopodite | 10) | - | seta 3 moderate length | seta 3 long obviously | seta 3 long obviously |
| | 11) | | seta 5 longer than seta 6 | equal | seta 5 longer than seta 6 |

**Table 5.** (Continued)

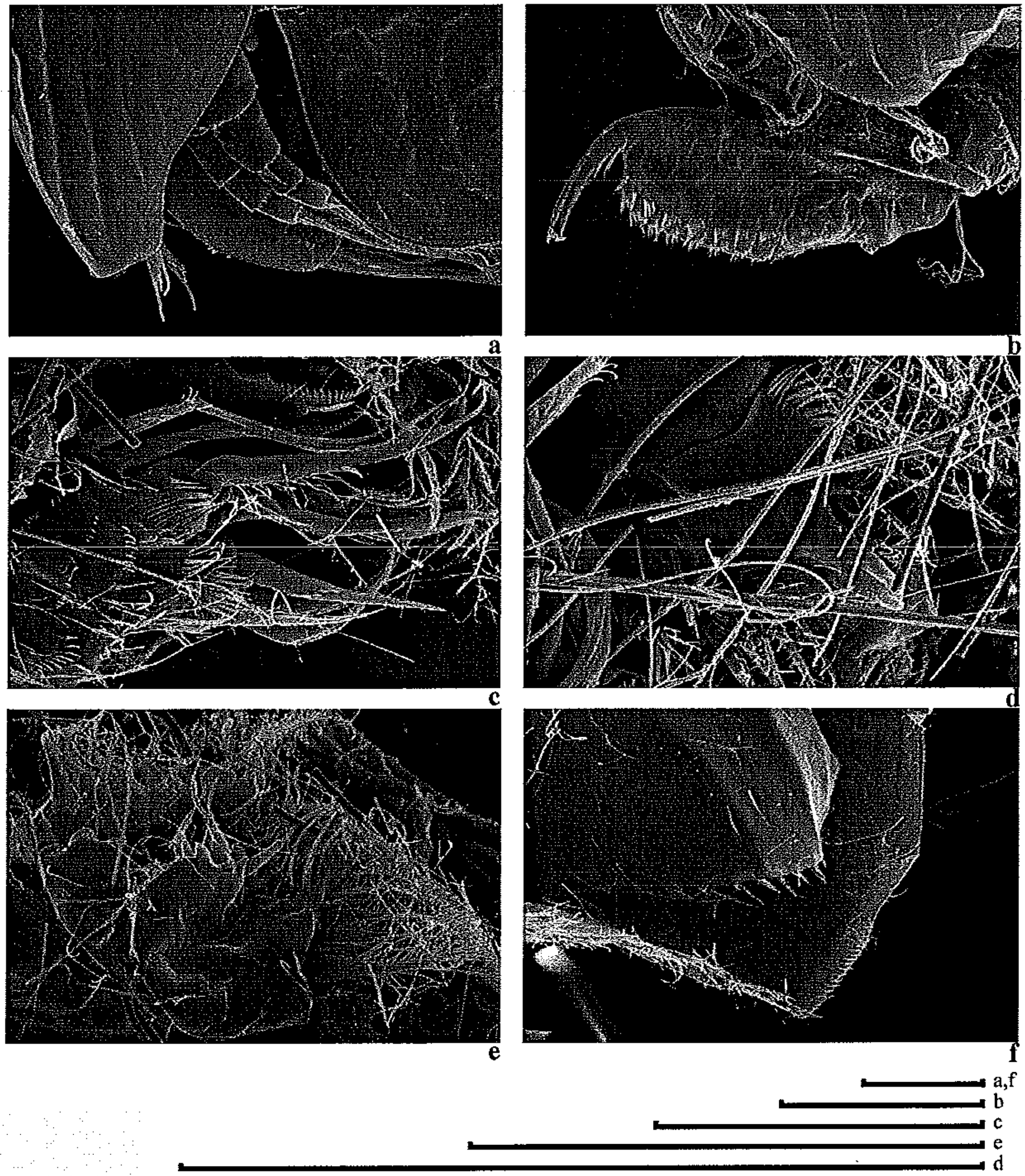
| characters | | *A. diaphana* Frey, 1991 | *A. diaphana* Sinev *et al.*, unpublished data | | *A. diaphana* Thai specimen |
|---|---|---|---|---|---|
| | | | population 1 | population 2 | |
| finger-like projection on epipodite of P3-5 | 12) | - | present | absent | absent |
| **Trunk limb 5** | | | | | |
| finger-like projection on epipodite of P3-5 | 13) | - | present | absent | absent |




Figures 23a-h. *Alona diaphana* Richard, 1895: parthenogenetic females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figure a, adult female in lateral view; Figures b-c, postero-ventral angle of valve; Figure d, head shield and its head pores; Figure e, antenna 1; Figure f, antenna 2; Figures g-h, postabdomen. Scale bar denotes 100 um.




Figures 24a-g. *Alona diaphana* Richard, 1895: appendages of females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figure a, trunk limb 1; Figure b, trunk limb 2; Figure c, trunk limb 3; Figures d-e, trunk limb 4 and its inner portion; Figures f-g, trunk limb 5. Scale bar denotes 100 um.




Figures 25a-f. *Alona diaphana* Richard, 1895: parthenogenetic female and its appendages from Thungtong swamp, Suratthani Province, southeastern Thailand. Figure a, head portion; Figure b, postabdomen; Figure c, trunk limb 1; Figure d, gnathobase of trunk limb 2; Figure e, trunk limb 3; Figure f, postero-ventral corner of valve. Scale bar denotes 100 um.

## 5. *Alona guttata* Sars, 1862

**References:** Sars, 1862: 287-289; Daday, 1902: Des.264, 264, no figs; Sabater, 1987: Des. 54, no fig.; Alonso, 1996: Des. 329, 331, fig. 146.

**Type locality:** Lake Ostensjovand, Norway

**Materials examined:**

*Southern Thailand:* two parthenogenetic females, examined complete and thereafter dissected, from Yai swamp, Chumporn Province, southern Thailand. Collected by the author, SM.

*Northeast Thailand:* one parthenogenetic female, completed and dissected, from Lake Gud-Thing, Nong Khai Province, collected by C. Saeng-aroon, KKU.

**The details of morphological study**

We found only a few specimens of this species so it was difficult to make a complete description. However, the partial description of general characters including first and second trunk limbs can be proposed here.

**Partial species description** (See figure 26)

**Parthenogenetic female**

***General shape:*** Body oval to ovoid in lateral view (fig.26a), maximum height around middle of body. Length 0.38-0.42 mm, about 1.6-1.7 times maximal height (n=3) (size 0.25-0.27 mm; Daday, 1902). Dorsal margin form slightly curved. Postero-dorsal and postero-ventral angles round. Posterior margin slightly concave. Antero-ventral corner almost rounded. Ventral margin almost straight, ventral setae relatively short, ending before posteroventral corner, followed by short setules posteriorly (fig.26b). Longitudinal valve striation best visible in posteroventral quarter of valve.

***Head:*** relatively small (fig.26a). Rostrum pointing downwards. Compound eyes present, larger than ocellus, distance between eyes and ocellus same as distance from ocellus to tip of rostrum, sometime shorter. Head shield not studied. Three major head pores (fig.26c), anterior and posterior one of the same size, central head pore smaller, all connected by a narrow channel. Two small lateral pores located slightly close to posterior.

***Labrum:*** large (fig.26a), with rounded anterior margin or slightly wavy laterally and blunt at apex, with row of spinules apically (fig.26d).

***Postabdomen:*** width about 1.5 times maximum height (fig.26f). Dorsal margin narrow distally, forming triangular-like distal end, with an angle of 45-50 $^{o}$. Posterodorsal corner sharp, with an angle of 60$^{0}$ or little less. Posterior margin with indentation. Anal margin relatively straight, with no distinct pre-and postanal corner, bearing 2-3 rows of setules, each row consisting of 5-10 setules. Lateral fascicles: 8-9 postanal groups, each consisting of 4-8 denticles. Marginal denticles: 10-11 groups of merged spinules, gradually increasing in size distally and bearing 3-5 fused denticles on inner edge. One group of venterolateral denticles. Natatorial setae with long distal end.

***Terminal claw:*** long and slender, about as long as anal margin. Basal spine, relatively moderate and slender, length a third of terminal claw or little less, situated at the base of the pecten with row of denticles on first half, three setules arising in proximal part of basal spine, close to base of claw.

***First antenna (antennule):*** reaching, protruding almost reach the tip of rostrum (fig.26a). Body elongated, about twice as long as wide. Distalmost aesthetasc, implanted on elongated apex, about 1.2 times as long as other aesthetascs. Subapical aesthetasc haft the length of antennule. All aesthetascs projecting beyond tip of rostrum.

***Second antenna:*** reach about half of body, antennal formula setae 0-1-3/0-0-3, spines 0-0-1/1-0-1 (fig.26e). All setae bisegmented. Spine arising from basal segment of endopodite not extending beyond the tip of second segment. Rows of 7-8 setules on second segment of exopodite, located at the base of long seta. Surface of segments with rows of setules. Coxa with distinct short denticle on anterior side between rami and its surface provided with clusters of longer setae on upper part, longest rows at second coxa. The spine on first exopod segment as long as the second.

**Trunk limb: five pairs**

***First trunk limb* (P1)** (figs.26g-h): relatively small. Outer distal lobe (ODL) with one seta (I') (fig.12h), slender and bearing short, fine setules distally, hardly visible. Inner distal lobe (IDL) with two slender setae (I-II), of the same length, and the same length as ODL seta, both unilaterally setulated distally. Groups of spinules at the base of IDL trunk. Endite 3 (E3) with four plumose setae (1-4), setae 1-3 of the same length, seta 4 longer and base wider, all armed with short setules distally. Endite 2 (E2) bearing three setae (5-7), seta 5 as long as seta 4 and similarly armed, setae 6-7 as same length, seta 6 unilaterally armed with fine setules distally and seta 7 unilaterally armed with sparsely setules distally. Endite 1 (E1) with two apical setae (8-9), seta 8 more slender, unilaterally armed with short and fine setules. One accessory seta located laterally (arrow). Rows of small spinules on trunk and two rows of slender spinules present more radial on inner side of endite 2. Trunk with 4-6 rows of thin setae on ventral surface, 5-7 setae each. Basally two long and slender ejector hooks, one smaller, unilaterally armed with short setules. Epipodite and gnathobase not seen.

***Second trunk limb* (P2)** (fig.26i)***:*** Epipodite and Exopodite not seen. Endopodite (EN) triangular, with eight scrapers (1-8), generally decreasing in length towards gnathobase though scraper 1 shorter than scraper 2, all bi-segmented, scrapers 1 and 2, similarly armed with fine setules distally, scrapers 3-4 unilaterally armed with strong setules distally, scrapers 5-6 unilaterally armed with finer setules distally but not fine as the first two, scrapers 7-8 base wider, unilaterally armed with strong setules distally. Small hillock before distal armature of gnathobase (GT), with four elements (I-III), one minute (I), element II hook-like, element IV small, all fused at the base. Gnathobasic filter comb present but number of setae unclear.

***Third trunk limb (P3):*** not studied.

***Fourth trunk limb (P4):*** not studied.

***Fifth trunk limb (P5):*** not studied.

**Variability:**

Variability can be found in the characters of 1) postabdomen, dorsal margin narrowing distally and form triangular-like distal end but varied in the angle; and 2) labrum: the presence of a row of a number of setules distally or only few.

**Differential diagnosis:**

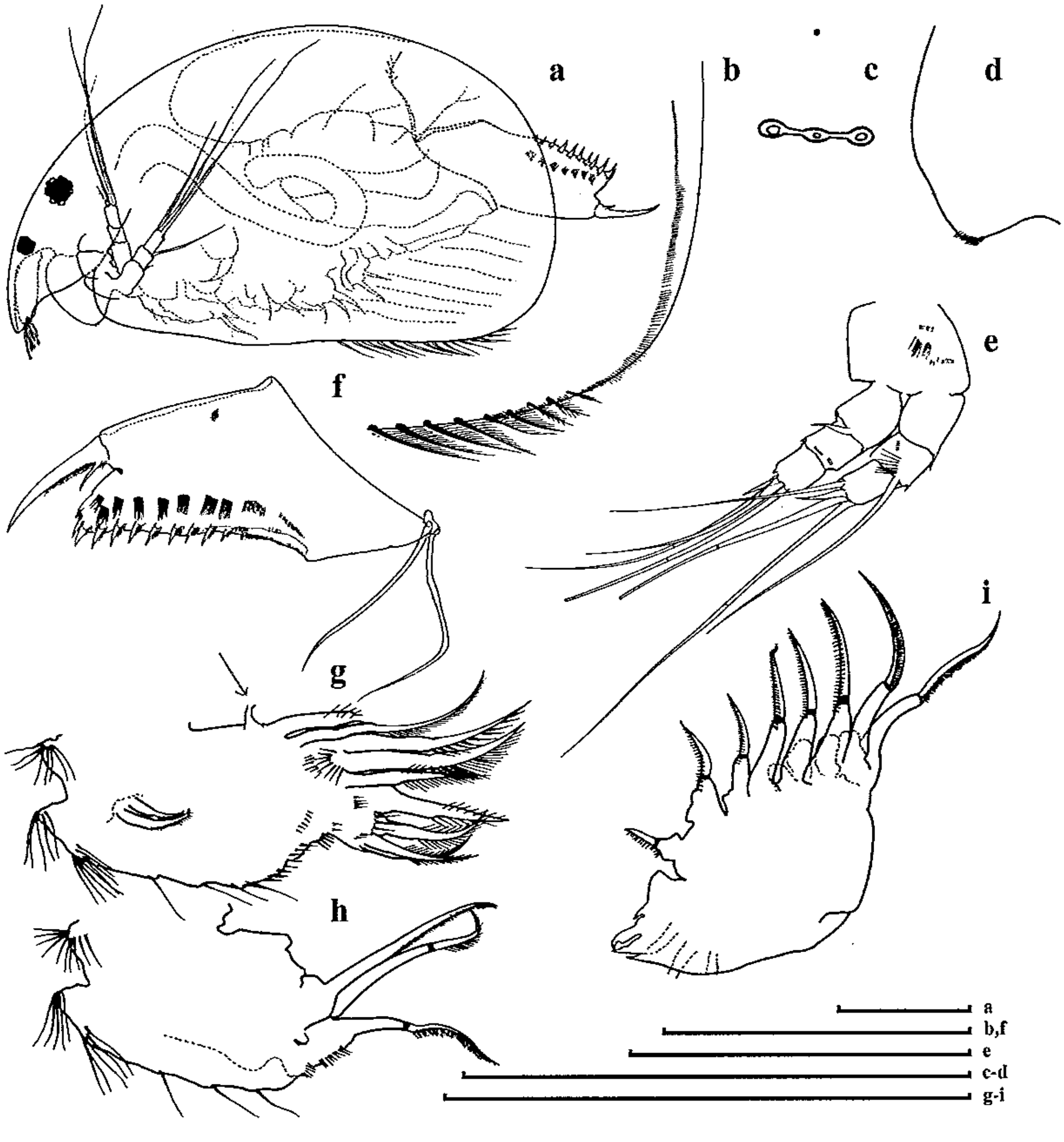
This species can be distinguished by 1) labrum: the presence of a row of setules on its tip; 2) postabdomen: dorsal margin narrow distally, triangular-like distal end, forming an angle about 45-50 $^{o}$, ventero-dorsal margin prominent; 3) second antenna: row of 6-7 long setules at the base of seta arising from middle segment of exopodite and 4) trunk limb 1: setae 6 and 7 equal in length, seta 7 armed with strong denticles.

**Biology:**

Mostly found in freshwater swamps and marshes, more abundance in shallow-stagnant habitats, with dominance of *Cyperus* sp. and *Nymphea* sp. It also can be found in the littoral of lakes and reservoirs (Armengol, 1978), it is distributed over small water bodies of the humid area (Alonso, 1985) and it was also found in the interstitial habitats Sabater (1987).

**Distribution:**

This species appears to distribute worldwide: Europe; Spain (Alonso, 1996); Africa; Cameroon (Chiambeng, 2004); Australia (Griggs, 2001), Asia; Malaysia (Idris and Fernando, 1984), Thailand (Sanoamuang, 1998).




Figures 26a-i. *Alona guttata* Sars, 1863: parthenogenetic female from Lake Kud-thing, northeastern Thailand (a), appendages of female from Yai swamp, southern Thailand (b-i). Figure a, adult female in lateral view; Figure b, postero-ventral corner of valve; Figure c, head pores; Figure d, labrum; Figure e, antenna 1; Figure f, postabdomen; Figures g-h, trunk limb 1; Figure i, trunk limb 2. Scale bar denotes 100 um.

## 6. *Alona karelica* Stenroos, 1897 and *A.* aff. *karelica* Stenroos, 1897

**References:** Stenroos, 1897: 52-53, figs 5-6.; Herbst, H.V, 1974. Des 134, Abb.6-10; Idris and Fernando, 1981: Des, 249-250, figs.62-66.; Hudec, 1986: 188-193, figs 1-9; Rey and Vasquez, 1986: 155-157, pl. IX, figs. 1-11.; Venkataraman, 1999: Des, 276, no fig.

**Type locality:** Ondajoki, Finland

**Materials examined:**

*Southern Thailand:* one parthenogenetic female, dissected parts examined, from Pluck Praya swamp, Satul Province (6°44.34' N, 100°02.75'E), southwestern Thailand, collected by the author, SM.

*Czechoslovagia:* one dissected parthenogenetic female on slide, mounted in Canada balsam, stained with lignin pink and chlorazol black, collected from Zatin-Bol on 22-September-1981 by Dr. Igor Hudec (Hudec, 1986).

**The details of morphological study**

**1. *Alona* aff. *karelica* Stenroos, 1897**

**Species description**

**Parthenogenetic female from Pluck Praya swamp, southern Thailand (see figure 27)**

One specimen has been found in the present study which was partly destroyed, possibly due to preserved in formalin for a long time. We only observed some external characters and trunk limbs.

***Postero-ventral corner of value*** (fig.27a)***:*** Postero-ventral of valve rounded. Ventral carapace margin round, ventral setae relatively short, ending before posteroventral corner, followed by short setules posteriorly.

***First antenna (antennule)*** (figs.27b-c)***:*** Body compact, about twice as long as wide. Distal end with nine aesthetascs, two of them about 1.2-1.5 times as long as other aesthetascs, others as haft the length of antennular body, accompanied by antennular sensory seta, implanted at about one third of apex. Three rows of 2-4 lateral setae on inner portion.

***Second antenna*** (fig.27d)***:*** Basal segment with rows of spines. Antennal formula, spines 0-0-1/1-0-1 setae 0-1-3/0-0-3. All setae bisegmented. Spine arising from basal segment of endopodite not extending beyond tip of second segment. Terminal spines as long as its segment. Seta arising from the second segment of exopodite long, 4 times as long as the segment. Surface of segments with rows of setules. Coxa with distinct short denticle on anterior side between rami and its surface provided with clusters of longer setae on upper part, longest rows at second coxa.

***Postabdomen*** (fig.27e)***:*** Length about 2 times height, distal part about 1.5 times longer than preanal portion. Slightly narrow distally, distal and ventral margin almost parallel, clear angle between distal and dorsal margin, about 50 $^{o}$-60$^{o}$. Postero-dorsal corner sharp. Anal margin relatively straight, pre-and postanal corner not distinct, bearing 7 rows of small denticles, each row bearing from 6 up to 11 denticles. Lateral fascicles: 7 postanal group, each consisting 4-8 denticles but the distalmost consist only 4 denticles, gradually increasing in length distally. Marginal denticles: 8 groups, each groups bearing one denticle and 2-3 spinules basally, denticles gradually increasing in size distally and largest denticle on the third group, the first very short.

***Terminal claw*** (fig.27e)***:*** Long and slender, as long as anal margin, bearing a short basal spine, length about 1/3 of terminal claw or little less, situlated at half its length from the base of the pecten, inner rows of small pectens from base of basal spine to tip of claw, gradually decreasing in length distally, hardly seen on the last half. Natatorial setae short.

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (figs.27f-g)***:*** Epipodite and gnathobase not seen. Outer distal lobe (ODL) with one long seta (I'), bisegmented, unilaterally armed with short setules distal part, hardly visible. Inner distal lobe (IDL) with three setae (I-III), seta I and seta II the same length and similarly armed with short setules on distal segment, seta 3 hook-like chitinized seta, slender, reaching one third of seta I and II. Endite 3 (E3) with four setae (1-4), seta 1 shorter than seta 2, seta 2 as the same length as seta 3, seta 4 longest, seta 3 bilaterally armed with short setules on distal part, seta 4 unilaterally setulated with short setules on distal part. Endite 2 (E2) bearing three setae (5-7), seta 5 shortest, bilaterally armed with short setules on distal part, similarly to endite 3 setae; seta 6 longest, densely setulated from base to tip, seta 7 long and slender, long fine setules sparsely setulated on distal part, one sensillium (sn) located close to seta 7; two rows of setae, about 5-7 setae each, orientated more radial on basal of endite. Endite 1 (E1) with one seta (8), probably seta 9 is broken. Trunk with six rows of thin and slender setae on ventral surface, about 2-4 setae in each row. Basally, two long and slender ejector hooks, both of the same length, unilaterally armed with short denticles.

***Second trunk limb (P2)*** (fig.27h)***:*** Epipodite not seen. Exopodite (EX) bilobed, elongated; without apical or subapical seta. Endopodite (EN) triangular, with eight scrapers (1-8), decreasing in length towards gnathobase, though scraper 2 longest; scraper 1 and scraper 2 bisegmented, densely armed with fine setae distally, scraper 3 and so on similarly armed with fine setules, but not as fine as on scrapers 1 and 2. Number of elements on distal armature of gnathobase (GT) not clear. Small hillock between seta 8 and gnathobase, setulated apically. Number of gnathobasic filter comb not clear.

***Third trunk limb (P3)*** (fig.27i)***:*** Epipodite not seen. Exopodite (EX) subquadrangular, bearing six setae (1-6), seta 1 and seta 2 located laterally, in typical V-formation, seta 2 length as a half of seta 1, bilaterally setulated, seta 4 and seta 5 as equal in length, bilaterally setulated, seta 6 more slender, length as a half of seta 5

Endopodite (EN) with anterior row of two spines and one seta on outer part (1-3), spines stout, similar in length, seta 3 more slender, unilaterally setulated distally; posterior rows with four setae (1'-4'), decreasing in length towards gnathobase, bilaterally setulated distally. Number of elements on distal armature of gnathobase (GT) and gnathobasic filter comb unclear.

***Fourth trunk limb (P4)*** (fig.27j)***:*** Pre-epipodite (PEP) and Epipodite (EP) not seen. Exopodite (EX) quadrangular, bearing six setae (1-6), setae 1 -3 of the same length, bilaterally setulated, seta 4 shorter, bilaterally setulated, seta 5 length 2 times longer than seta 6, seta 6 more slender and smallest, both bilaterally setulated. Row of setules ventrally.

Endopodite (EN) inner anterior portion bearing five appendages (1-5), spine 1 slender and longest, flaming torch setae (2-4) gradually decreasing in length towards gnathobase, plus a receptor (5); posterior portion bearing comb of three setae (1'-3'), all of the same length. Distal armature of gnathobase (GT) with horse-tail seta (I) and two support setae (II-III). One last seta in gnathobasic filter comb.

***Fifth trunk limb (P5):*** not studied.

**2.** ***Alona karelica*** **Stenroos, 1897**

**Species description**

**Parthenogenetic female from Zatin-Bol, Czechoslovakia (see figures 28-29)**

***Labrum*** (fig.28b)***:*** large, rounded almost ovoid, width as long as height. Anterior margin rounded, naked, slightly wavy from the middle to posterior margin.

***Second antenna*** (fig.28a)***:*** antenna formula: setae 0-1-3/0-0-3, spine 1-0-1/1-0-1, and additional row of 3-4 slender fine spines on the second segment of exopodite. Each segment shorter distally, though the last segment may be longer. Spine arising from basal segment (first segment) of exopodite thin and long, reaching beyond its segment, sometime reaching beyond the third segment. Spine arising from basal segment of endopodite not extending beyond tip of distal segment. Terminal spine shorter than terminal segment.

***Postabdomen*** (fig.28c)*:* Elongated, length about 2.5 times as long as height, distal part about 1.5 times longer than preanal portion. Slightly narrowed distally, distal and ventral margin almost parallel, with clear angle between distal and dorsal margin, about 60°. Postero-dorsal corner sharp. Anal margin relatively straight, pre-and postanal corner not distinct, bearing rows of small denticles, each row bearing from 3 up to 11 denticles. Lateral fascicles: 6 postanal group, each consisting 7-10 denticles but distalmost of only 3 denticles, gradually increasing in length distally. Marginal denticles: 9 groups of denticles, each groups bearing one denticles and 2-3 spinules basally, denticles gradually increasing in size distally and the largest denticle on the third group.

***Terminal claw*** (fig.28c)*:* Long and slender, length as long as anal margin, bearing short basal spine, length about 1/5 of terminal claw, situated at half its length from the base of the pecten, inner rows of small pectens from base of basal spine to tip of claw, gradually decreasing in length distally, hardly seen on the last half.

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (fig.29a)*:* Epipodite and Exopodite not seen. Outer distal lobe (ODL) with one long seta (I'). Inner distal lobe (IDL) not seen. Endite 3 (E3) with four setae (1-4), seta 1 shorter than seta 2 and seta 2 shorter than seta 3, all similarly bilaterally armed with short setules on distal part; row of small setae on base of endite. Endite 2 (E2) bearing three setae (5-7), seta 5 bilaterally armed with short setules on distal part, similarly to endite 3 setae; seta 7 long and slender, length 2 times as long as seta 5, unilaterally setulated with long fine setules on distal part; three rows of setae, about 10-12 setae each, orientated more radial on basal of endite. Endite 1 (E1) with two setae (8-9), length as equal as seta 7, both setulated. Trunk with six rows of thin and slender setae on ventral surface, about 6 setae in each row. Ejector hook and Gnathobase not seen.

***Second trunk limb (P2)*** (fig.29b)***:*** Epipodite not seen. Exopodite (EX) lobed, elongated, bearing short setules but no seta apically. Endopodite (EN) triangular, with eight scrapers (1-8), generally decreasing in length towards gnathobase; scraper 1 and scraper 2 bisegmented, densely armed with fine setae distally, scraper 3 and scraper 4 similarly armed with fine setules, but not fine as present on scraper 1 and 2, scraper 5-8 similarly armed with stronger setae distally. Distal armature of gnathobase (GT) with three elements (I-III), element I naked, slender and apically hooked, element II wider, unilaterally armed with row of five denticles, element III rod-like, naked. Small hillock between seta 8 and gnathobase, setulated apically, followed by a minute denticle located close to element I. Gnathobasic filter comb with eight setae, the first two short, the others similar in length, about 2.5 times longer than the first two.

***Third trunk limb (P3)*** (figs.29c-e)***:*** Epipodite not seen. Exopodite (EX) subquadrangular (fig.29c), number of setae unclear but the studied specimen bears five (1-5), seta 1 small and slender, seta 2 length 2.5 times of seta 1, bisegmented, plumose, seta 3 and seta 4 the same length, though seta 4 base wider, seta 4 unilaterally setulated from base to tip, seta 5 longest about 4 times as long as seta 1, bilaterally setulated.

Endopodite (EN) subdivided into two rows; anterior row with two spines and a seta on extend part (1-3) and five on inner anterior part (4-8) (fig.29d), setae 1 and 2 stout, similar in length, one small sensillium (sn) located between these setae, seta 3 more slender, unilaterally setulated distally, setae 4-7 slender, similarly in size, seta 8 large, naked, rod-like; posterior rows with four setae (1'-4') (fig.29e), all of the same length and bilarerally setulated distally. Gnathobase (GT) with three elements (I-III) (fig.29d), element I longest, apically hook-like, element II shorter fused the base with element I, element III shortest. Gnathobasic filter comb with seven setae, gradually increasing in length posteriorly.

***Fourth trunk limb (P4)*** (fig.29f)***:*** Pre-epipodite (PEP) and Epipodite (EP) rounded, wavy apically. Exopodite (EX) quadrangular, bearing six setae (1-6), setae 1 and 2 plumose, of the same length, though seta 2 may be shorter, seta 3 more slender and longest, bilaterally setulated with short setules, seta 4 half of seta 3, bilaterally setulated, seta 5 length 2 times longer than seta 6, seta 6 smallest, both bilaterally setulated. Row of setules ventrally. Endopodite (EN) not seen.

***Fifth trunk limb (P5)*** (figs.29g-h)***:*** Pre-epipodite and Epipodite not seen. Exopodite (EX) not bilobed, bearing four setae (1-4); anterior portion bearing three setae (1-3), decreasing in length posteriorly, seta 1 obviously longest, seta 2 and seta 3 bilaterally setulated; posterior portion bearing one shorter seta (4), about 1/3 of the longest, distally armed with short setules.

Endopodite (EN) large, rounded, wavy and setulated apically, two endopodite setae setulated, one seta one third of the other.

**Differential diagnosis:**

*Alona karelica* can be distinguished from other species by 1) a very short basal spine, about 6 times shorter than terminal claw; 2) an elongated postabdomen, although distal part forming angle characteristic of *A. costata* (Hudec, 1986) and *A. guttata*, but the denticulation and basal spine of these species are different; 3) labrum almost ovoid, width as equal as height, and also wavy from middle of labrum to posterior margin and 4) a row of long spines on second segment, also found in *A. guttata*, but both species are differ in many other characters.

**Remarks:**

*Alona karelica* Stenroos, 1897 was originally described from Karelia (Stenroos, 1897) and later found in Finland (Smirnov, 1971), Germany (Flossner, 1963; 1972) and Slovakia (Hudec, 1980; 1986). It appears to be a Central European species, so records from other regions are questioned i.e. the record from Malaysia (Idris and Fernando, 1981). Also, the specimen found in the present study is apparently related, but clearly distinct. The comparison shows similarity between the specimen from Czechoslovakia and southern Thailand, but some characters clearly set them apart (table 6): 1) one long spine on basal segment of exopodite, present in Thai specimen but not in Czech specimen; 2) one row of 3-4 long spines on second segment of exopodite in Czech specimen against rows of small spines present in Thai specimen; 3) the proportion between length and height of postabdomen differs between the Czech specimen and Thai specimen; 4) basal spine in Czech specimen is very short compare with Thai specimen; 5) scraper 2 of trunk limb 2 in Thai specimen is longest; and 6) scraper 3 of trunk limb 2 abruptly shortened in Thai specimen but almost the same length as scraper 2 in Czech specimen.

Although distinct, we prefer to call the species found in southern Thailand as *A.* aff. *karelica* since 1) the comparison has made only from single specimen and 2) the specimen compared were uncompleted.

**Biology:**

*Alona* aff. *karelica* was found in only one area which is characterized by shallow, muddy bottom covered with vegetation especially *Cyprus* spp. and *Nymphea* spp. in association with temperature of water 33.3 °C, conductivity 0.34 µS/cm and pH 8.02, which is less acid than in Czechoslovakia (pH 5.6-6.7) (Hudec, 1986).

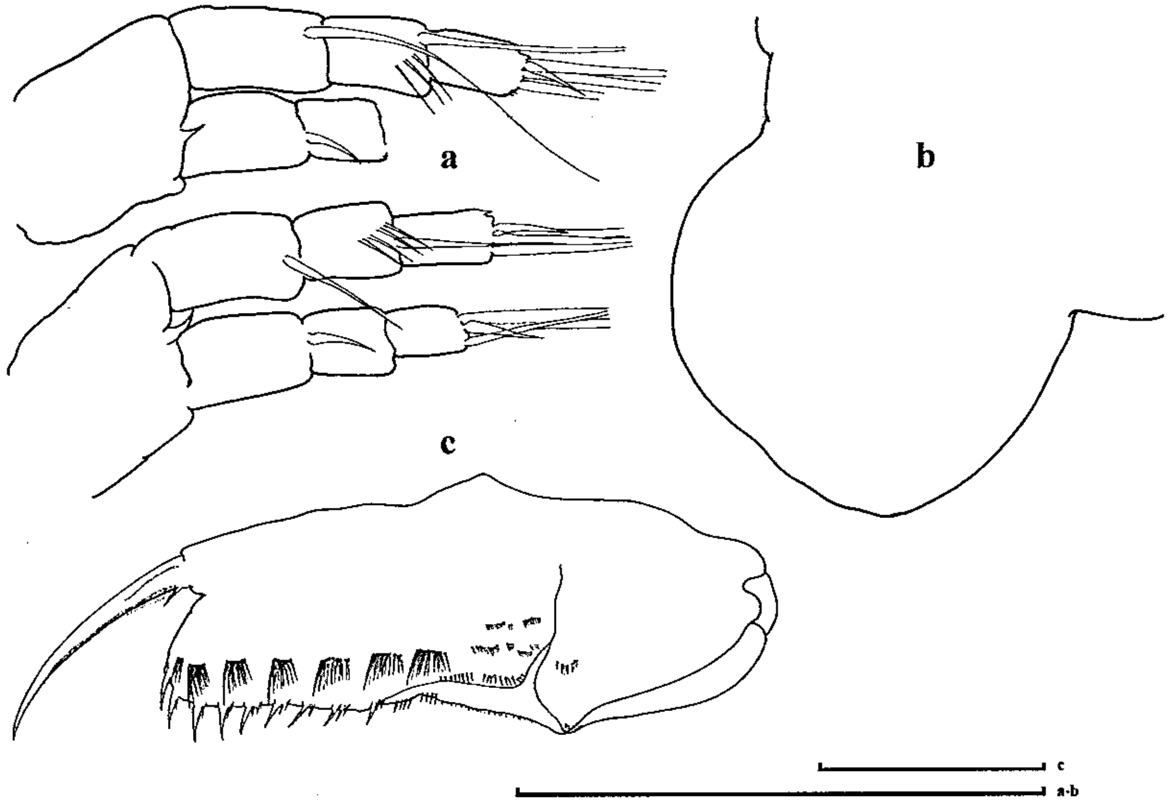
**Distribution:**

*Alona karelica* is distributed widely in Palearctic and Neotropic region and from the present studies it seems to be also distributed in Asia.

**Table 6** Different characters between *A. karelica* from Czechoslovakia and *A.* aff. *karelica* from southern Thailand

| characters | ***Alona karelica*** Zatin-Bol, Czechoslovakia | ***Alona* aff. *karelica*** Southern Thailand |
|---|---|---|
| **Antenna 2** | | |
| basal segment of exopodite | 1) no spine (fig.28a) | one long spine |
| second segment of exopodite | 2) one row of 3-4 long spines | several rows of small spines |
| **Postabdomen** | 3) length as long as 2.5 times of height | length as long as 2 times of height |
| basal spine | 4) 6 times shorter than terminal claw | 3 times shorter than terminal claw |
| **Trunk limb 2** | 5) scraper 2 shorter than scraper 1 | scraper 2 longer than scraper 1 |
| | 6) scraper 3 almost as the same length as scraper 2 | scraper 3 abruptly shorten |


Figures 27a-j. *Alona* aff. *karelica* Stenroos, 1897: parthenogenetic female from Pluck-praya swamp. Figure a, postero-ventral corner of valve; Figures b-c, antenna 1; Figure d, antenna 1; Figure e, postabdomen; Figures f-g, trunk limb 1; Figure h, trunk limb 2; Figure i, trunk limb 3; Figure j, trunk limb 4. Scale bar denotes 100 um.




Figures 28a-c. *Alona karelica* Stenroos, 1897: appendages of parthenogenetic females from Zatin-Bol, Czechoslovakia. Figure a, antenna 2; Figure b, labrum; Figure c, postabdomen. Scale bar denotes 100 um.


Figures 29a-h. *Alona karelica* Stenroos, 1897: appendages of parthenogenetic female from Zatin-Bol, Czechoslovakia. Figure a, trunk limb 1; Figure b, trunk limb 2; Figures c-e, trunk limb 3 and its inner portion; Figure f, trunk limb 4; Figures g-h, trunk limb 5. Scale bar denotes 100 um.

## 7. *Alona macronyx* Daday, 1898

**References:** Daday, 1898: 35-37, fig.15a-c.; Rajapaksa and Fernando, 1985

**Type locality:** Colombo (Beira) Lake, Sri Lanka

**Type material:** (1) Slide DX-24; II/P-631,1 labeled *Alona macronyx* Dad.: 2 specimens (remounted in glycerine jelly, 5. VII. 1965 by D. G. Frey). Lectotype on this slide (marked with a circle on the side). (2) Slide DX-25; II/P-632,1 labelled *Alona macronyx* Dad.: 2 specimens on this slide, but only one is *A. macronyx* (the other is *Kurzia longirostris*). Paralectotype. (3) Slide DX-26; II/P-633,1 labelled *Alona macronyx* Dad.: 2 specimens. Paralectotypes. (4) Slide DX-29; II/P-634,1 labelled *Alona macronyx* Dad.: 2 specimens. Paralectotypes. Catalogue numbers according to Forró and Frey 1982 (Rajapaksa and Fernando, 1985).

**Materials examined:**

*Southern Thailand:* one parthenogenetic female, examined complete and thereafter dissected, from Kabae peat swamp, Pattani Province, southeastern Thailand (6°32.15N 101°30.17E). Turbidity 81, pH 6.52, temperature 32.9 and conductivity 0.019. Collected by the author, SM.

**The details of morphological study**

**Partial species description** (See figure 30)

**Parthenogenetic female**

***General body:*** rounded to globular in lateral view (fig.30a-b), maximum height around middle of body. Length 0.26-0.38 mm, about 1.1 times maximum height (n=3). Dorsal margin generally uniformly curved, no depression between head and rest of body. Postero-dorsal angle not prominent, postero-ventral margin broadly rounded. Ventral margin convex, prominent at middle. Ventral valve setae relatively short, 18-20 setae in anterior portion, followed by 48-52 setae, decreasing in length towards posterior end, posterior ventral portion with groups of shorter setae, between them series of small setules (fig.30b).

***Head:*** moderately size, rostrum well developed, blunt (fig.30a). Compound eye present, larger than ocellus; distance between eyes and ocellus as same as distance from ocellus to tip of rostrum.

***Labrum:*** large (fig.30a), oval shaped, anterior margin rounded, minute denticle laterally located anteriormost.

***Postabdomen:*** wide (fig.30c), about 2 times as long as high, widest in postanal corner. Distal part about 2 times longer than preanal portion. Dorsal margin progressively narrowing distally from postanal corner on. Posterodorsal corner forming angle. Anal margin narrowing distally with distinct pre-and postanal corner and bearing row of small denticles, consisting of 3-5 denticles. Lateral fascicles: 10 postanal groups, each consisting of 4-8 denticles. Marginal denticles: 9 groups of spinules, bearing 1-3 grouped spinules, decreasing in number from postanal corner on, all spinules similar in size. Natatorial setae long, distal end setulated.

***Terminal claw:*** long and slender, about as long as anal margin, curved to the tip. Basal spine slender, length about a third of terminal claw, 3 fine setules arising proximal to almost base of spine. Denticles of pecten along concave edge, decreasing in length distally.

***First antenna (antennule):*** short, not reaching tip of rostrum (fig.30a). Body rod-like, high about twice as long as wide. Distal end with seven aesthetascs unequal in length, as long as antennular body. All aesthetascs projecting beyond tip of rostrum.

**Trunk limbs: five pairs**

***First trunk limb (P1):*** not studied.

***Second trunk limb (P2):*** Epipodite not seen. Exopodite (EX) sub-triangular (fig.30d), small setules apically and row of setules laterally. Endopodite (EN) triangular, with eight scrapers (1-8), decreasing in length towards gnathobase though scraper 3 longer than scraper 2, all bi-segmented; scrapers 1-3, unilaterally densely armed with fine setules distally; scrapers 4 and 5 more robust, unilaterally armed with strong denticles distally, about 15-16 denticles each; scrapers 6-7 unilaterally armed with fine setules distally but not fine as the first three, last scraper (8) unilaterally armed with stronger setules distally. Distal armature of gnathobase (GT) with three elements (I-III), elements I and II similar in size, fused at the base of each other, element III smaller, all naked. A hillock between scraper 8 and gnathobase, apically setulated. Gnathobasic filter comb present but number of setae unclear.

***Third trunk limb (P3):*** not studied.

***Fourth trunk limb (P4):*** not studied.

***Fifth trunk limb (P5):*** not studied.

**Variability:**

Unfortunately we could not study the variability of specimens from southern Thailand since the description has been written from a single specimen. However, some variability was noted with previous studies (Daday, 1898; Rajapaksa and Fernando, 1985; Sanoamuang, 1998) in the following characters 1) the size of parthenogenetic females shows a wide range; length 0.60-0.80 mm (type specimen, Daday, 1898), 0.42-0.52 (type material, Rajapaksa and Fernando, 1985), 0.42-0.49 (Sri Lanka specimens, Rajapaksa and Fernando, 1985), 0.41-0.51 (Malaysian specimens, Rajapaksa and Fernando, 1985), 0.44-0.51 (Thai specimens, Rajapaksa and Fernando, 1985). The present specimen is small comparatively with all those previous recorded, length about 0.3 mm; 2) ventral margin of labrum from rounded to truncate, however in specimen recorded from northeast Thailand (Sanoamuang, 1998) labrum more round and specimens from the south (present data) show more truncate distally; and 3) scrapers 4 and 5 on trunk limb 2 armed with strong denticles in southern Thai specimen but in the illustration of Rajapaksa and Fernando, 1985, both scrapers armed with fine setules or stronger denticles on scraper 5 but not strong as on present specimen.

**Differential diagnosis:**

This species has distinctive morphological characters, apparently different from other *Alona* especially by the present of 1) globular body shape; 2) distally narrow tapering of postabdomen; 3) groups of small marginal denticles; 4) long basal spine and 5) large denticles on scrapers 3 and 4 on trunk limb 2.

**Remarks:**

*A. macronyx* has a number of unique characters among *Alona* as the following: 1) globular body shape or high proportion of length and height, a character found in few other species i.e. *Alona diaphana*; 2) postabdomen distally tapering, marginal denticles are small and terminal claw with long basal spine; also, the details of other trunk limbs and 3) two IDL setae on trunk limb 1 which can be found in few *Alona* i.e. *A. monacantha*. We noticed that this combination of characters raises doubt whether *A. macronyx* should or should not being a separate genus. However the comparison on more details especially on trunk limbs with other member of *Alona* can be carried out when more specimens including males, ephippial females are available. Then we would be in a better position to decide on its generic status.

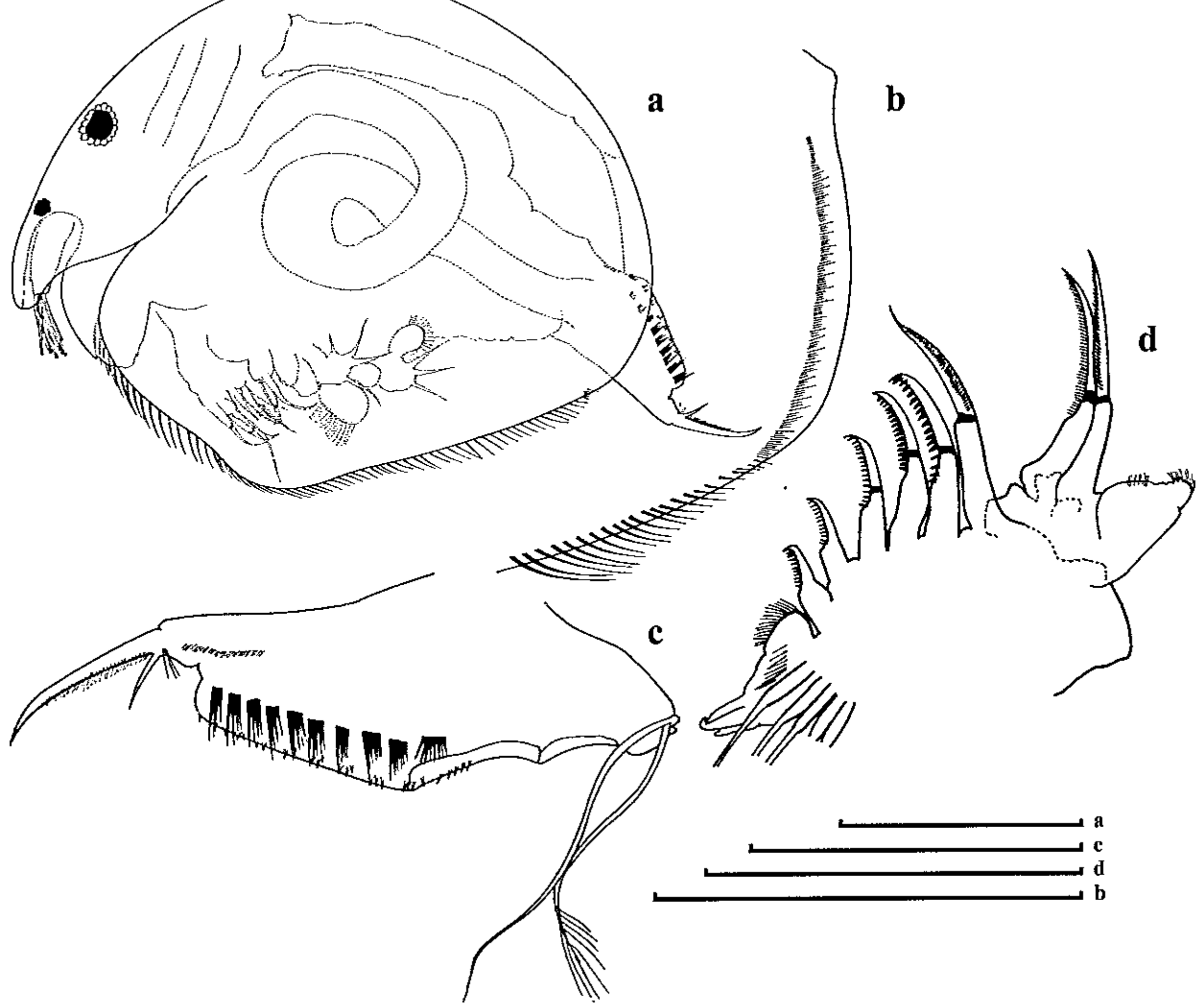
**Biology:**

This species prefers the weedy littoral region of lakes or temporary water bodies i.e. ponds, rice fields, covering a wide pH range. Examination of gut contents showed that it feeds mainly on detritus. Its detritivorous habit and rarity in zooplankton samples shows that it is probably a bottom-dwelling species (Rajapaksa and Fernando, 1985).

In present study, it was found from one locality, shallow vegetated-peat swamp with mud-bottom.

**Distribution**

This species appears to occur in the oriental region. It has been recorded from many localities i.e. Colombo (Beira), Sri Lanka (Ceylon) (Daday, 1898); Celebes (Brehm, 1938); Indonesia (Smirnov, 1974); Mindanao, Philippines (Mamaril and Fernando, 1978); Malaysia (Idris, 1979, 1983 and Idris and Fernando, 1981); Yunnan, Southern China (Shen *et al.*, 1966 and Chiang and Du, 1979); Jabalpur, India (Rane, 1983). It was recorded from several localities in northeast Thailand (Sanoamuang, 1998) but only one locality in southern Thailand (present data).




Figures 30a-d. *Alona macronyx* Daday, 1898: parthenogenetic female from Kabae peat swamp, Narathiwas Province, southeastern Thailand. Figure a, adult female in lateral view; Figure b, postero-ventral corner of valve; Figure c, postabdomen; Figure d, trunk limb 2. Scale bar denotes 100 um.

## 8. *Alona monacantha* Sars, 1901

**References:** Sars, 1901: 54-55, pl. 9: figs 5, 5a, 5b; Idris and Fernando, 1981: Des. 250, figs.67-71.

**Type locality:** "mud, partly from the neigh-boarhound of São Paulo, partly from Ipiranga", Brazil, South America

**Type material:** material from type-locality: tube GOS-F12332 & F12333

**Materials examined:**
*Southern Thailand:* two parthenogenetic females, examined complete and thereafter dissected, from Paumi marsh, Narathiwas Province, southeastern Thailand. Collected by the author, SM.

*Northeast Thailand:* one parthenogenetic female, examined complete, from Lake Kudthing, Nhongkai Province. Collected by C. Seang-aroon, KKU.

**The details of morphological study**

**Species description** (See figures 31-32)
**Parthenogenetic female:**
***General shape*** (fig.31a)*:* Body in lateral view oval, more quadrangular, maximum height around the middle of body. Length 0.25-0.31 mm, about 1.2-1.3 times maximum height in adults (n=3). Dorsal margin generally curved, depression between head and rest of body not seen. Antero-dorsal angle rounded. Postero-dorsal angle prominent. Postero-ventral margin rounded, bearing 2-3 denticles; sharp in some specimens (fig. 31a) but some more leaf-like (fig. 31b), followed by small setules along posterior margin reach to the middle of the body. Ventral margin almost straight. Ventral setae relatively short, with 26-30 setae, decreasing in length posteriorly, the posteriormost setae more robust. Ornamentation of valve stripe-like or rectangular in some specimens.

***Head:*** moderate size, rostrum well developed, pointing downwards. Compound eye present, size larger than ocellus; distance between eyes and ocellus same as between ocellus and tip of rostrum. Three major head pores, central pore the same size of anterior and posterior one, or smaller in some specimens (fig.31d) and larger in some specimens (fig. 31c), located at the middle, all connected with narrow channel.

***Labrum*** (figs.31a, e-f)*:* large, with a broadly rounded anterior margin, labral tip rounded (fig. 31e) or slightly form angle (fig. 31f). Posterior edge convex. Single minute denticle laterally, hardly visible (fig.31a).

***Postabdomen*** (fig. 31i)*:* width about 2 times height, widest at postanal corner. Dorsal margin gradually narrowing distally from postanal corner on, but almost parallel to ventral margin. Postanal margin longer than anal margin. Anal margin concave, with distinct pre-and postanal corner and bearing row of small denticles. Postanal margin slightly concave distally. Lateral fascicles: about 4 postanal groups, each consisting of 8-9 denticles; about 6 groups on anal portion, each consisting of 3-7 denticles, situated parallel to each other, row of 8-9 smaller denticles on anal margin. Marginal denticles: 6-7 groups of 2-3 spinules in group, gradually increasing in size distally, distalmost largest.

***Terminal claw*** (fig.31a)*:* about as long as postanal margin, evenly curved to tip, row of pecten from base to tip, gradually decreasing in length towards tip of claw. Basal spine slender, length about half of terminal claw, unilaterally armed with small setules along spine, 3 fine setules arising proximal to base of basal spine, length about one third of basal spine.

***First antenna (antennule)*** (figs.31a, g)*:* short, not reaching tip of rostrum. Body compact, rod-like, about twice as long as wide, three slender stules laterally. Distal end with nine aesthetascs unequal in length, one longest, as long as antennular body, length of the rest ranges from 1/2- 2/3 of antennular body. All aesthetascs projecting beyond tip of rostrum.

***Second antenna*** (figs.31a, h)***:*** reaching about half way of body (fig.31a). Antenna formula: setae 0-0-3/0-1-3, spine 0-1-1/0-0-1. Basal segment of exopodite and endopodite thicker and longer than other segments, about 2 times middle segment, middle segment shortest, terminal segment thinnest. Row of small spinules at distal edge of each segment. All setae bi-segmented, seta arising from middle segment of exopodite thin, row of three slender setules arising from base of this seta. All spines longer than their segments.

**Trunk limb: five pairs**

***First trunk limb (P1)*** (figs.32a-d)***:*** Outer distal lobe (ODL) with one seta (I') slender, as long as seta II on inner distal lobe (fig.32b) or little less (fig.32a), bearing short, hardly visible setules distally. Inner distal lobe (IDL) bearing two setae (I-II), subequal in length, their distal end unilaterally armed with long setules, counting about 5, decreasing in length distally, two basalmost obviously larger. Row of setules at base of the lobe. Endite 3 (E3) with four plumose setae (1-4), gradually increasing in length towards gnathobase though seta 2 smaller than seta 1, all plumose. Endite 2 (E2) bearing three setae (5-7), seta 5 as long as endite 3 setae, plumose, seta 6 slender and longest (fig.32d), seta 7 shorter, both unilaterally setulated with long setules distally and unilaterally armed with short and stronger setules basally, counting about 7-9 setae, two rows of small setules situated radially on inner side of endite. Endite 1 (E1) with two setae (8-9), seta 8 longer, unilaterally densely armed with fine setules distally, seta 9 shorter, unilaterally armed with shorter setules distally. Trunk with 5-6 rows of slender spines laterally, counting 4-5 spines each group, increasing in length basally. Basally two slender ejector hooks, similar in size, unilaterally armed with short setules distally. Epipodite and gnathobase not seen.

***Second trunk limb (P2)*** (fig.32e)***:*** Epipodite not seen. Exopodite (EX) elongate with naked digitiform projection. Endopodite (EN) triangular, with eight scrapers (1-8), generally decreasing in length towards gnathobase though scraper 3 shorter than scraper 4, all scrapers bi-segmented; scrapers 1 and 2 unilaterally densely armed with fine setules, scrapers 3-5 unilaterally armed with strong setules but not as strong as on scrapers 6-8, scrapers 6-8 more robust, unilaterally armed with strong denticles distally, counting 6-7 denticles. A rounded hillock between scraper 8 and gnathobase, apically setulated, followed by a minute denticle (fig.32e, arrow). Distal armature of gnathobase (GT) with three elements (I-III), element I and II of same size, rod-like, thin, naked, element III smaller, naked, located close to the base of element II, follow by a minute denticle at the base of element III. Gnathobasic filter comb present but number of setae unclear.

***Third trunk limb (P3):*** not studied.

***Fourth trunk limb (P4)*** (fig.32f)***:*** Epipodite not seen. Exopodite (EX) more round than oval, bearing six setae (1-6), seta 3 slender, plumose, a hillock between seta 2 and seta 3 (arrow), apically setulated; conical-like seta 4 shorter, about half of seta 3, seta 5 longer than seta 6, both more slender, followed by row of long setules on body of exopodite.

Endopodite (EN) or inner portion anteriorly bearing five setae (1-5). Seta 1 stout, naked, unilaterally setulated with short setules distally, hardly visible; setae 2-4 'flaming-torch' setae, gradually decreasing in size towards gnathobase, distally armed with long slender setules, counting 4-5 setules each, followed by seta 5 round-elliptical like receptor, comparable in size to seta 4, naked; posteriorly bearing three setae (1'-3'), generally increasing in length towards gnathobase, all setulated. Gnathobase (GT) with two elements (I-II), element I large, unilaterally setulated distally, element II smaller, naked, fused at the base of each other.

***Fifth trunk limb (P5)*** (fig.32g)***:*** Pre-epipodite (PEP) rounded, apically with long setules, elongated digitiform projection not seen. Epipodite (EP) rounded, similar in size of pre-epipodite, with elongated digitiform projection. Exopodite (EX) bilobed, bearing four apical setae (1-4); anterior portion bearing setae 1-3, setae 1 and 2 subequal in length, seta 3 shorter, all setae setulated; posterior portion bearing one seta (seta 4), relatively short, setulated. Row of long setules on posterior portion.

Endopodite (EN) larger, more oval, apically setulated, two endopodite setae.

**Variability:**

Some variability was noted in the following characters: 1) number of denticles at postero-ventral angle of valve which can be 2 or 3; 2) center pores vary in size, they may be smaller or larger comparatively with anterior and posterior pores; 3) labrum; tip rounded or form angle; 4) ornamental of valve striation or quadrangular; 5) ODL seta as the same length of IDL seta II or shorter; 6) basalmost spine on IDL setae large or smaller and 7) setae 6-7 on endite 2 of trunk limb 1 slender and long or shorter.

**Differential diagnosis:**

This species can be distinguished by 1) the presence of 2-3 denticles at posterior-ventral angle of valve and shape of denticles sharpen or leaf-like; 2) body shape more oval, quadrangular; 3) shape of labrum, a minute denticle at anterior margin, tip rounded or form angle; 4) row of three setules at the base of seta on middle segment of exopodite second antenna; 5) terminal claw with long basal spine; 6) ODL seta same length as IDL setae or little less and 7) IDL setae armed with long setules, basalmost setule large.

**Remarks:**

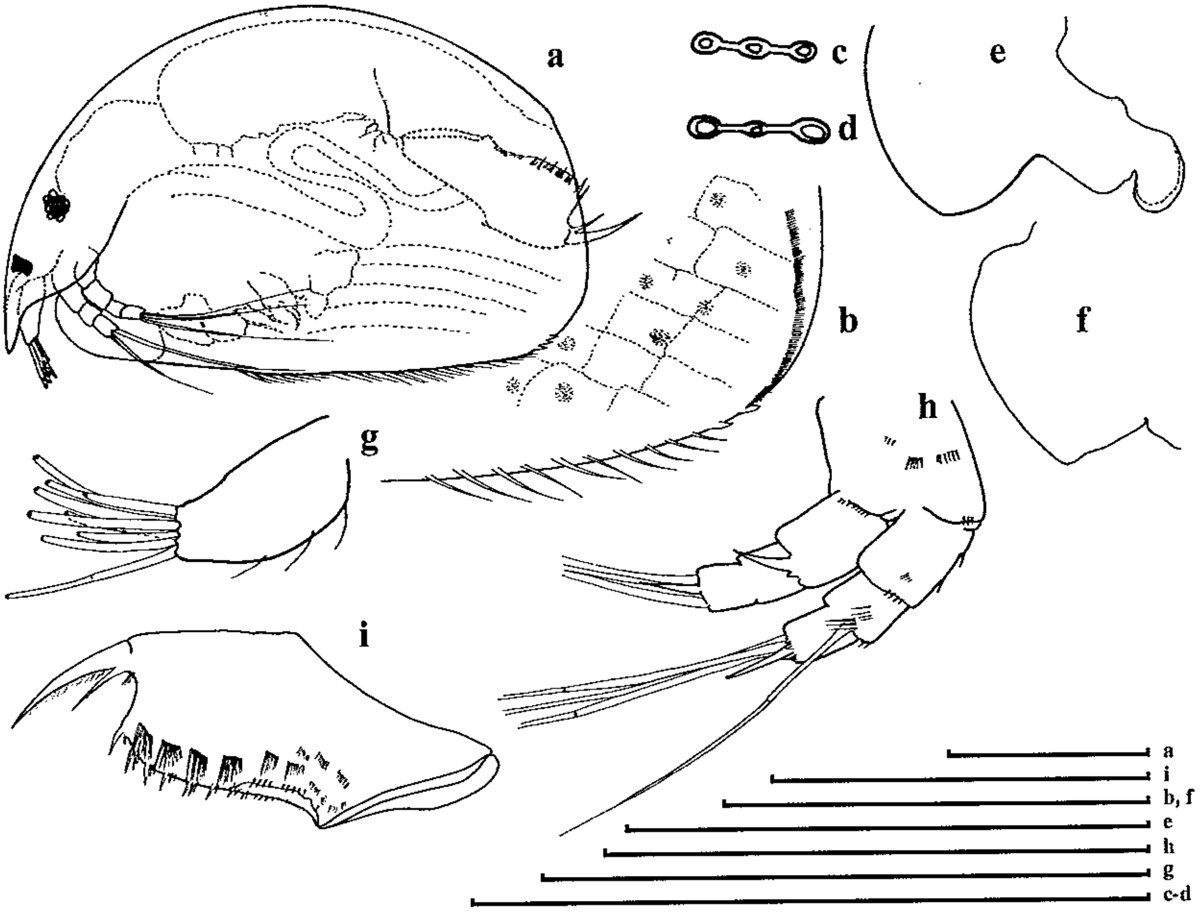
Sars (1901) described this species from Brazilian specimens with only one denticle on the postero-ventral corner of the valve. Denticle numbers later became one of the important characters for separating this species into subspecies. In 1905, Stingelin described *Alona acusticostata* var. *tridentata* from Thailand which has three denticles on each valve. In 1974 Smirnov described this species named *Alona monacantha tridentata* and it has been remarked that this subspecies, unique in the present of three denticles, was found only from Thailand. However, the number of denticles turned out to be variable since the specimens found later on show mixed numbers of denticles, even at a single locality (present data). In the Asian region, this species also show high variation: Sri Lanka specimens have only one denticle, in contrast, Malaysian specimens have a number of denticles ranging from 1-3 denticles, in different combination of both valves (Idris and Fernando, 1981), and the specimens from present study show both two and three denticles.

**Biology:**

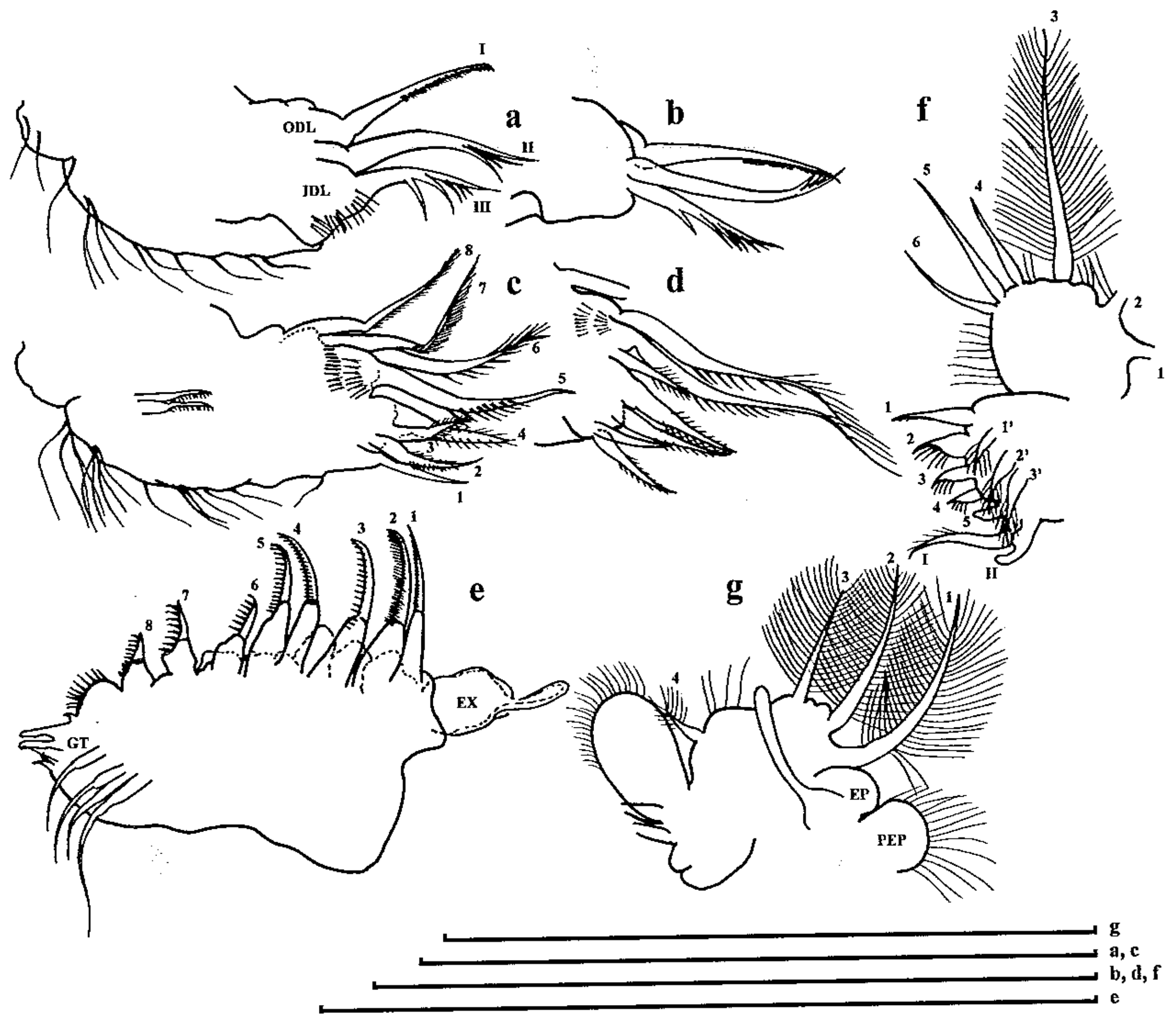
This species can be found in swamps and marshes. In present study it also can be found in open area habitats; however it reaches a high abundance in vegetated habitats.

**Distributions:**

*Alona monacantha* Sars, 1901 is distributed in Africa; Cameroon (Chiambeng, 2004), Australia (Griggs, 2001), and Asia; Malaysia (Idris and Fernando, 1981), Thailand (Stingelin, 1905; Sanoamuang, 1998; Sa-ardrit, 2001; Sa-adrit and Beamish, 2004).




Figures 31a-i. *Alona monacantha* Sars, 1901: parthenogenetic females from Paumi marsh, Narathiwas Province, southeastern Thailand. Figure a, adult female in lateral view; Figure b, postero-ventral of valve; Figures c-d, head pores; Figures e-f, labrum; Figure g, antenna 1; Figure h, antenna 2; Figure i, postabdomen. Scale bar denotes 100 um.




Figures 32a-g. *Alona monacantha* Sars, 1901: appendages of female from Paumi marsh, Narathiwas Province, southeastern Thailand. Figures a-d, trunk limb 1; Figure e, trunk limb 2; Figure f, trunk limb 4; Figure g, trunk limb 5. Scale bar denotes 100 um.

## 9. *Alona rectangula* Sars, 1862

**Synonymy:** *Coronatella rectangula* in Dubowski & Grochowski, 1894: 381

**Type locality:** Dam paa Egeberg

**Materials examined:**

*Southern Thailand:* two parthenogenetic females, examined complete and thereafter dissected, from Yao swamp, Chumporn Province (10° 42.89N, 99° 20.15E), southern Thailand. Collected by the author, SM.

*:* one parthenogenetic female, examined complete, from Kubaekata marsh, Narathivas Province (5° 51.31N, 101° 55.62E), southeastern Thailand. Collected by the author, SM.

*Northeast Thailand:* one parthenogenetic female, examined complete and thereafter dissected, from Lake Gudthing, Nhong Kai Province, collected by C. Saeng-aroon, KKU.

**The details of morphological study**

**Species description** (See figures 33-34)

**Parthenogenetic female**

***General shape*** (figs.33a-b): Body in lateral view oval to rectangular (fig.33a), maximum height at middle of body. Length 0.28-0.30 mm, about 1.5 times maximum height in adults (n=3), height 0.18-0.20 mm. Dorsal margin form curved, depression between head and rest of body not seen. Antero-ventral angle rounded. Postero-dorsal and postero-ventral angles rounded. Posterior margin convex. A row of small setules along posterior margin up to postero-dorsal margin, not organized in groups. Ventral margin slightly concave, with 29 setae of different length, shorter posterior end, series of 3-7 setules with equal length posteriad between them. Valve with longitudinal striation.

***Head*** (figs.33a, d-e)*:* relatively small. In lateral view, rostrum well developed, protruding downwards (fig.33a). Compound eyes present. Three major head pores connected by a narrow channel (fig.33d). Central pore the same size as anterior and posterior one, or little smaller (fig.33e), located at middle. Two lateral head pores located at level of middle central pore, about 1 IP distance from midline.

***Labrum*** (figs.33a, c)*:* large, with broadly rounded anterior margin and rounded tip. Labral keel rounded. Distal labral plate without setulation.

***Postabdomen*** (figs.33a, h)*:* wide about 2 times as long as high, widest at postanal corner. Dorsal margin gradually narrowing distally from postanal corner on. Preanal margin longer than anal and postanal margin. Anal margin concave, almost the same length as postanal margin, with distinct pre-and postanal corner and bearing 2 small denticles. Postanal margin slightly concave distally. Lateral fascicles: about 7-8 postanal groups, each consisting of 5-9 denticles; about 6 groups on anal margin, each consisting of 5-9 smaller denticles, situated more radial than parallel to each other. Marginal denticles: 7-9 groups of 2-3 spinules in group, gradually increasing in size distally. Natatorial setae short.

***Terminal claw*** (figs.33a, h)*:* about as long as postanal margin, evenly curved to tip. Basal spine slender, length about a third of terminal claw, 3 fine setules ariring proximal to base of basal spine, length about half of basal spine.

***First antenna (antennule)*** (figs.33a, f)*:* short, not reaching tip of rostrum. Body compact, rod-like, about twice as long as wide. Distal end with seven aesthetascs unequal in length, length about half of antennular body, aesthetascs seem to consist of two parts, - a thicker basal part and a thinner, more flexible distal part. All aesthetascs projecting beyond tip of rostrum. Accessory seta arising about 2/3 of antennular body, length as long as other aesthetascs.

***Second antenna*** (figs.33a, g)*:* short (fig.33a), reaching about 1/3 of body. Antenna formula: setae 0-0-3/0-1-3, spine 1-0-1/0-0-1. Basal segment of exopodite and endopodite longer than other segment, about 2 times middle segment, terminal segment thinner. Row of small spinules at distal edge of each segments. Seta ariring from middle segment of exopodite thin. All spines longer than theirs segment. Basal spine of endopodite as long as terminal spine of exopodite.

**Trunk limb: five pairs**

***First trunk limb (P1)*** (fig.34a)***:*** Outer distal lobe (ODL) with one seta (I'), thin and slender, length as IDL seta I, unilaterally armed with fine setules. Inner distal lobe (IDL) with two setae (I-II), seta II larger, both hook-like setae, bi-segmented, unilaterally armed with row of setae distal end, largest posteriormost seta (stout setule), three rows of small setules at base of lobe. Endite 3 (E3) with four plumose setae (1-4), similar in length, row of small setules at base of endite. Endite 2 (E2) bearing three setae (5-7), seta 5 as long as endite 3 setae, plumose, setae 6-7 slender, seta 6 longest, both unilaterally setulated with long setules distally and unilaterally armed with short and strong spines basally, counting about 6-9 setae, two rows of small setules situated radially on inner side of endite. Endite 1 (E1) with two setae (8-9), seta 8 slender, as same length as seta 7, unilaterally armed with short fine setules from base to tip, basalmost two small denticles, seta 9 not shown in figure. Trunk with 4 rows of slender spines laterally, counting 4-7 spines each group, increasing in length basally. Basally two slender ejector hooks, one longer, unilaterally armed with short setules. Epipodite and gnathobase not seen.

***Second trunk limb (P2)*** (figs.34b-c)***:*** Epipodite not seen. Exopodite (EX) round-elongated, small setules apically. Endopodite (EN) triangular, with eight scrapers (1-8), generally decreasing in length towards gnathobase though scraper 3 shorter than scraper 4 in some specimen (fig.34c), scraper 4 shorter than scraper 5 in some specimen (fig.34b) and scraper 6 shorter than scraper 7 in some specimen (fig.34b), all scrapers bisegmented; scraper 1 unilaterally densely armed with fine setules, scrapers 2-4 unilaterally armed with fine setules but not fine as scraper 1, scraper 5 unilaterally armed with strong setules distally, scrapers 6-8 more robust, unilaterally armed with strong setules distally. A rounded hillock between scraper 8 and gnathobase, apically setulated, followed by minute denticle (fig.34c, arrow). Distal armature of gnathobase (GT) with three elements (I-III), element I rod-like, thin, apically setulated, element II more robust, unilaterally armed with four strong short setules from base to tip, element III minute, naked, located close to base of element II. Gnathobasic filter comb with four slender setae, all similar in length.

***Third trunk limb (P3)*** (fig.34d)***:*** Epipodite not seen. Exopodite (EX) small, globular, bearing six setae (1-6) but first two not shown in the figure (fig.34d): seta 3 slender and longest, about 2 times of seta 4, unilaterally setulated, seta 4 setulated with long setules, setae 5 and 6 of the same length, setulated.

Endopodite (EN) divided into two rows; anterior row with eight setae (1-7), setae 1 and 2 stout, seta 2 shorter than seta 1, distally armed with 5-6 short well-spaced strong setules, one sensilla (sn) located between these setae; seta 3 more slender, setulated distally; setae 4-7 gradually increasing in length towards gnathobase, one rod-like sensilla (sn) between setae 6 and 7; posterior row with four setae (1'-4'), gradually increasing in length towards gnathobase, all setulated. Gnathobase (GT) with two elements (I-II), element I large, curved inwards, setulated, element II thin, shorter, naked, row of setules at base of this element.

***Fourth trunk limb (P4):*** not studied.

***Fifth trunk limb (P5)*** (figs.34e-f)***:*** Pre-epipodite (PEP) rounded, apically setulated with two rows of long setules, elongated digitiform projection not seen. Epipodite (EP) rounded, similar in size of pre-epipodite, elongated digitiform projection not seen. Exopodite (EX) bilobed but nor clear (arrow), bearing four apical setae (1-4); anterior portion bearing setae 1-3, seta 3 shortest in some specimen (fig.34e) but as the same length of seta 2 in some specimen (fig.34f), all setae setulated; posterior portion bearing one seta (seta 4), relatively short, widen basally (fig.34f), setulated.

Endopodite (EN) larger, more oval, apically setulated, two endopodite setae setulated distally, one as a half length of another.

**Variability:**

It was noted several times that this species shows high variability in 1) body size vary from 0.23-0.5 mm: in the original description, Sars (1901) gives the length as 0.25 mm. Lilljeborg (1901) gives the length of reproductive females as 0.36-0.50 mm, 0.25 mm height (Daday, 1903), 0.35 mm (Nayar, 1971) and 0.23-0.43 mm (Alonso, 1996), 0.4-0.43 mm width; 2) body shape; posterior margin usually sloping forward dorsally but sometimes almost vertical; 3) longitudinal striation on valve present or absent.

However, specimens from southern Thailand show more variability in details of trunk limbs: 1) length of scrapers 3-6 of trunk limb 2, scraper 3 shorter or longer than scraper 4, scraper 4 shorter or longer than scraper 5 and scraper 6 shorter or longer than scraper 7 and 2) length of seta 3 on exopodite of trunk limb 5 shortest or as equal as seta 2.

**Differential diagnosis:**

This species can be distinguished by 1) its general body shape; oval or almost quadrangular; 2) characters of postabdomen, postanal margin rounded, distal angle rounded, marginal denticles with group of spinules, basal spine reach half of terminal claw; 3) trunk limb 1 with one large ODL seta, unilaterally armed distally, basalmost setule large; three IDL setae, one of them large and armed as ODL seta and 4) one rod-like receptor between seta 6 and 7 on anterior row of endopodite trunk limb 3.

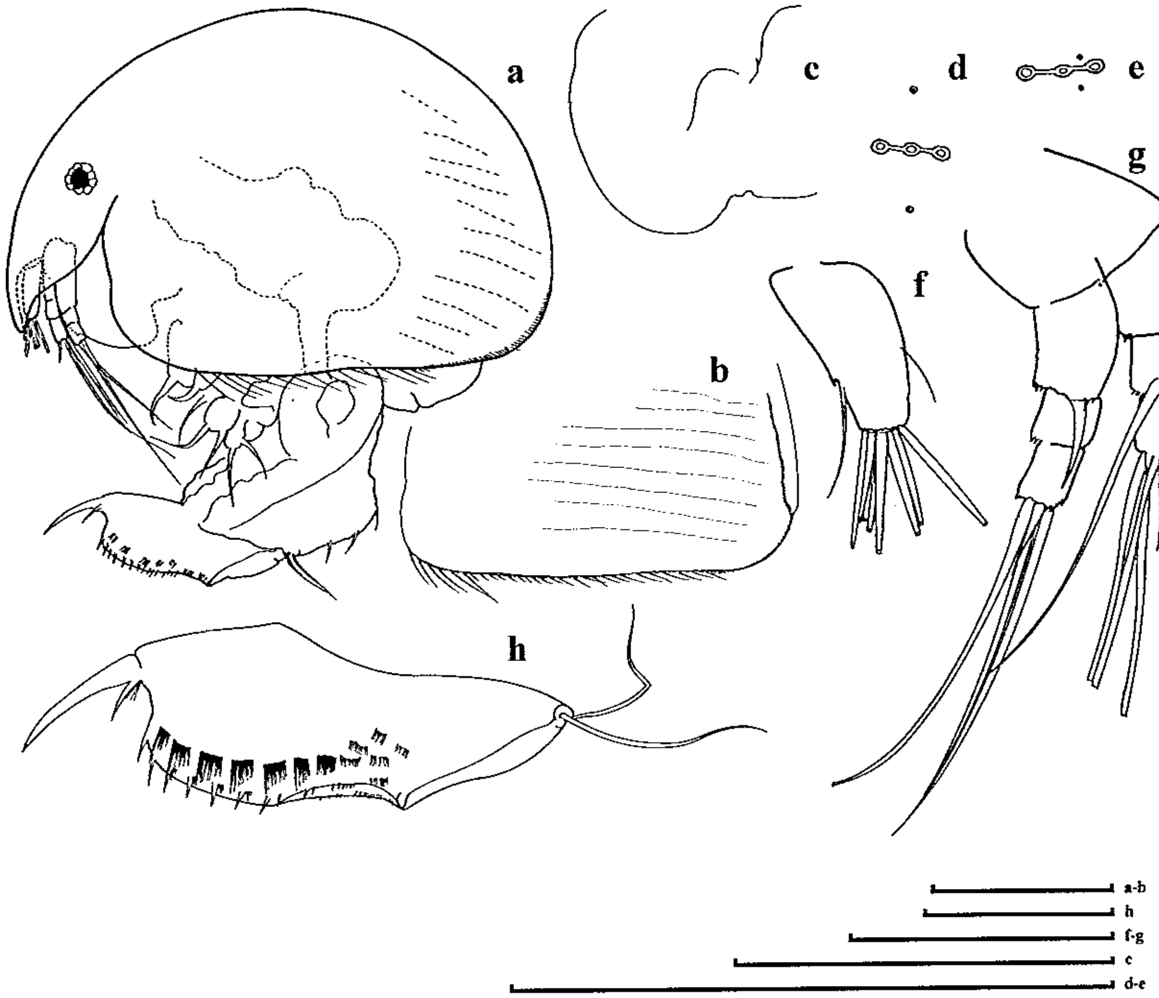
**Biology:**

This species was found to occur in vegetation and in high abundance in macrophyte places (Sars, 1901; Alonso, 1996). It is also found in interstitial habitat (Sabater, 1987) and some specimens were found in river mouth sediment (Sabater, 1986). However it has rarely been mentioned in groundwater habitats.

In our study it was found only from two localities, only in rainy season (September-October) but with a few specimens. These habitats are vegetated places, densely covered with *Nymphea* spp., *Cyprus* spp. and algae.

**Distribution:**

*Alona rectangula* is distributed in Africa; Cameroon (Chiambeng, 2004), Europe; Spain (Sabater, 1987; Alonso, 1996), Australia (Griggs, 2001) and South East Asia (Idris and Fernando, 1981; Sanoamuang, 1998; Sa-ardrit, 2001; Sa-adrit and Beamish, 2004).




Figures 33a-h. *Alona rectangula* Sars, 1862: parthenogenetic females from Yao swamp, Chumporn Province, southern Thailand. Figure a, adult female in lateral view; Figure b, ventral of valve; Figure c, labrum; Figures d-e, head pores; Figure f, antenna 1; Figure g, antenna 2; Figure h, postabdomen. Scale bar denotes 100 um.


Figures 34a-f. *Alona rectangula* Sars, 1862: appendages of female from Yao swamp, Chumporn Province, southern Thailand. Figure a, trunk limb 1; Figures b-c, trunk limb 2; Figure d, trunk limb 3; Figures e-f, trunk limb 5. Scale bar denotes 100 um.

## 10. *Alona sarasinorum* Stingelin, 1900

**References:** Stingelin, 1900: 197-198, Pl.14 figs. 4-5; Brehm, 1933: 78-79, fig.1; Smirnov, 1971, 1974: 422, fig. 388; Idris and Fernando, 1981: 247-249, figs. 57-62 and Frenzel, 1987: 498, figs. 3B-3C.

**Type locality:** Celebes (Sulawesi), Indonesia

**Holotype:** Stingelin's collection No. III/6

**Materials examined:**

*Type specimen:* one specimen on slide, Celebes, 1900

*Southern Thailand:* Twenty parthenogenetic females, examined complete and thereafter dissected, from Maikhao Peat Swamp, Phuket Province, southwestern Thailand (8°07.21′ N 98°17.34′E), pH 6.89 DO 6.9, conductivity 7.28 and salinity 0.3-0.5 ppt, collected date 27-10-01 and 07-04-02 by the author, SM.

*:* five parthenogenetic females, examined complete and thereafter dissected, from Pattani Bay, Yaring, Pattani Province, southeastern Thailand, pH 7-8, salinity 6-8 ppt. collected by S. Mulmek, SM.

*:* four parthenogenetic completed females, from Pak Panang Bay, Nakornsrithamaras Province, southeastern Thailand, collected by S. Sangkaew, SM.

**The details of morphological study**

**Partial description of type specimen (see figure 41)**

Body in lateral view rounded, gradually form curved anterior and posteriorly, maximum height around middle of body, about 1.5 time of width (fig.41a). Postero-dorsal and postero-ventral angles rounded. Ventral margin slightly concave. Head relatively small. Three major head pores of same size connected with narrow channel, central pore located at middle between anterior and posterior ones (fig.41c). Lateral head pores located at level of middle central pore. Labrum moderate size (figs.41a-b). Labral keel round with blunt apex. Distal labral plate without setulation. Anterior margin with one curl, posterior margin without any clusters of setules. Second antenna relatively short, reaching less than half of body (fig.41a). Basal segment of both exopodite and endopodite 1.5 times longer than middle and apical segments, all segments cylindrical (fig.41d). Postabdomen relatively broad since postanal angle, widest in postanal corner, around middle (figs.41a, f), with distinct pre-and postanal corner and bearing 2-3 groups of small denticles. Posterior to anal margin, 5 groups of lateral fascicles, distally decreasing in number from postanal corner on, each group counting ranges from 5-8 fascicles, not beyond to distal margin. Marginal spines in groups of 2-4, mostly 3, largest in the middle of postanal past, mostly curved and pointing in different directions. Terminal claw long and slender (fig.41e), evenly curved to tip, with a narrow row of setae along concave edge. Basal spine slender, length about half of terminal claw, two short setules arising proximal to almost the base of basal spine. Row of pectens reaching tip of claw, gradually decreasing in length distally. Inner distal lobe (IDL) of trunk limb 1 bearing three setae (fig.41g), one large, strong hook-curved like, one seta slender, unilaterally setulated basally (hardly visible), another seta thin, smallest, weakly sclerotised, curved, resembling a second hook, length about half of slender one.

**Species description of specimens from southern Thailand** (see figures 35-40)

**Parthenogenetic female**

***General shape*** (figs.35a-b, 37a-b)*:* Body in lateral view round (figs.35a, 37a), body in dorsal view wide anteriorly and elongated posteriorly (fig.37b), relatively high, maximum height at middle of body. Length 0.34-0.44 mm, about 1.3 times maximum height in adults (n=20), height 0.24-0.32 mm. Dorsal margin form curved, forming dorsal keel, depression between head and rest of body not seen. Postero-dorsal and postero-ventral angles broadly rounded. Posterior margin convex. A row of about 140 setules along posterior margin at some distance from one on inner side of carapace, these setules not organized into groups. Ventral margin slightly concave, with 86-90 setae, anterior and posterior setae equally in length, row of small setules among these setae. Antero-ventral angle rounded. Reticulation, pentagon shaped on whole valve.

***Intestine:*** with up to three convolutions

***Head*** (figs.35a, c; 37c-d)*:* relatively small. In lateral view, rostrum well developed, protruding forwards (fig.35a). Compound eyes present, size larger than ocellus; distance between eyes and ocellus greater than that between ocellus to the tip of rostrum. Three major head pores of same size connected with narrow channel, central pore located at the middle between anterior and posterior ones (figs.35c, 37c-d). Two lateral head pores located at level of middle central pore, about 1 IP distance from midline.

***Labrum:*** moderate size (figs.35a, 37e). Labral keel round with blunt apex. Distal part of labral keel as a sub-triangular, distal labral plate without setulation. Anterior margin form into one or two curls (fig.37e), posterior margin without any clusters of setules. No lateral projections on labrum and no folds surrounding its base.

***Postabdomen*** (figs.35f-g, 37g-h)*:* relatively broad since postanal angle, length about 2 or 2.5 times width (figs.35f and 35g, respectively), widest in postanal corner, around the middle. Dorsal margin gradually narrowing distally from postanal corner on. Anal margin almost straight, relatively same length as terminal claw, parallel to dorsal margin, with distinct pre-and postanal corner and bearing 3-4 groups of small denticles. Posterior to the anal margin, 5-7 groups of lateral fascicles, distally decreasing in number from postanal corner on, each group counting ranges from 9-5 fascicles, not beyond distal margin. Lateral fascicles on anal margin about 7 groups, of which the denticles (minimal 3, maximal 9) situated more radial than parallel to each other. Marginal spines 8-9 groups, 2-4 spines in group, mostly 3, largest in the middle of postanal past, mostly curved and pointing in different directions. Two-three groups of venterolateral denticles (hardly visible). Natatorial setae short.

***Terminal claw*** (figs.35f-g, 37g-h)*:* long and slender, about as long as preanal portion, evenly curved to tip, with a narrow row of setae along concave edge. Basal spine slender, length about a third of terminal claw (fig.35f) or almost a half (figs.35g, 37g-h), three short setules arising proximal to almost the base of basal spine. Row of pectens almost reaching tip of claw, gradually decreasing in length distally.

***First antenna (antennule)*** (figs.35a, d)***:*** relatively short (fig.35a), tube-like, almost reaching tip of rostrum. Body compact, about 2 times as long as wide, two rows of very short setules transversely on anterior face (fig.35d). Antennular sensory seta slender, almost as long as antennule, arising at ¾ distances from the base. Distal end with eight aesthetascs subequal in length, three longest as long as antennular body. All aesthetasces projecting beyond tip of rostrum.

***Second antenna*** (figs.35a, e; 37f)***:*** relatively short, reaching less than half of body (fig.35a). Antennal formula: setae 0-0-3/1-1-3, spine 1-0-1/0-0-1. Basal segment of both exopodite and endopodite 1.5 times longer than middle and apical segments, all segments cylindrical. All setae bisegmented. Seta arising from basal segment of exopodite thin and five times shorter than apical setae, and seta arising from middle of exopodite slender, length about one third of apical setae. Basal spine of endopodite (fig.35f) and apical spines of both exopodite and endopodite short.

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (figs.36a-b, 38a-h)***:*** Relatively large. Outer distal lobe (ODL) with one long seta (I'), bi-segmented, basally naked, setulation distally with short setules, hardly visible. Inner distal lobe (IDL) bearing three setae (I-III), seta I large, strong hook-curved like, row of 10-13 short setules along the middle portion of seta, gradually increasing in length distally; seta II slender, bi-segmented, unilaterally setulated; seta III thin, small, weakly sclerotised, curved, resembling a second hook, length half of seta II, distally armed with short setules (fig.38e). Endite 3 (E3) bearing three (?) setae (1-3), seta 1 more robust, setulated distally with long setules, seta 2 slender, setulated distally with fine short setules, seta 3 bilaterally armed with well-spaced strong short setules. Endite 2 (E2) bearing three setae (4-6), of which seta 5 longest, seta 4 one third of seta 5, bilaterally armed with shorter setules, seta 5 feathering, seta 6 more robust, unilaterally setulated; two small sensilla near the base of setae 5 and 6 (fig.38h), two rows of slender setules at base of endite. Endite 1 (E1) bearing two slender setae (7-8), both of same length, bi-segmented, seta 7 setulated distally with short setules, seta 8 setulated distal and basally. Six rows of thick setules on ventral face of limb, groups of thin setules parallel with. On anterior face, 6-8 rows of short setules radially (figs.37a; 38b). Basally, two ejector hooks, one smaller, unilaterally armed with strong setules (fig.38g).

***Second trunk limb (P2)*** (figs.36c; 39a-b)***:*** Epipodite not seen. Exopodite (EX) elliptical, bearing small setules on apex. Endopodite (EN) triangular, with eight scrapers (1-8), generally decreasing in length towards gnathobase, though their length set in groups (figs.36c, 39a); first group consist of scrapers 1 and 2, the second includes scrapers 3-5 and the last one include scrapers 6-8, which shorter in order respectively. Scrapers 1 and 2 of the same length, unilaterally densely armed with fine denticles distally; scrapers 3 and 4 unilaterally armed with small denticles distally, not as densely as in previous two; scraper 5 similar in length with scraper 4, unilaterally armed with stronger denticles but not as strong as scrapers 6-8; scrapers 6-8 more robust, similar in length, about half of scrapers 3-5, unilaterally armed with about 14-17 strong denticles. Distal armature of gnathobase (GT) with two elements (I-II) (figs. 36c; 39b), hillock between scraper 8 and gnathobase, apically setulated, followed by a minute denticle (figs.36c; 39b, arrow). Element I slender, element II hook-like at apex, fused at the base. Gnathobasic filter comb with seven setae, the first three setulated, of the same length, though the third may be longer, these setae considerably shorter than the others, seta 4-7 unilaterally setulated.

***Third trunk limb (P3)*** (figs.36d-g; 39c-g)***:*** Epipodite not seen. Exopodite (EX) small, sub-rectangular, bearing six setae (1-6) (fig.36d): setae 1-2 located laterally in typical V-formation, seta 2 shortest, about half of seta 1, both setulated; seta 3 slender and longest, about 7 times of seta 2, setulated; seta 4 slender, subequal in length to seta 3, setulated, more dense basally; seta 5 slender, as half of seta 3, setulated distally; seta 6 small, slender, setulated basally.

Endopodite (EN) divided into two rows; anterior row bearing seven setae (1-7), setae 1 and 2 stout (fig.36g), both the same length, distally armed with 2 rows of well-space strong denticles (fig.39c), counting 6-8 denticles, seta 3 more slender, setulated with long setules, one sensillum (sn) between setae 1 and 2 and another one between setae 2 and 3 (figs.36g; 39f), setae 4-6 slender, gradually increasing in length towards gnathobase (fig.36e), all unilaterally armed with short setules, seta 7 rod-like receptor, naked; posterior row bearing four setae (1'-4') alternating with one regressed seta and three small bumps (fig.39g), gradually increasing in length towards gnathobase, all setulated. Distal armature of gnathobase (GT) with three elements (I-III) (figs.36f; 39d), element I large, elongated, unilaterally setulated distally with long setules, elements II and III similar in length, setulated distally (fig.39d), fused at base of each other. Gnathobasic filter comb with seven setae, subequal in length, all setulated from base to tip.

***Fourth trunk limb (P4)*** (figs.36h-j; 40a-c)***:*** Epipodite (EP) globular, bilobe with small hillock between lobes, apically setulated with long setules, one short setules setulated. Exopodite (EX) round bearing six setae (1-6), setae 1 and 2 of the same length though seta 2 may be shorter, both setulated with long setules; seta 3 longest, about 1.5 times seta 2, plumose; a hillock between seta 3 and 4 (fig.36h, arrow) setae 4 and 5 subequal in length, seta 4 setulated with long setules; seta 5 more slender bilaterally armed with well-space short setules; seta 6 shortest, about half of seta 5, bilaterally armed with short setules. Followed by row of long setules on the body of exopodite.

Endopodite (EN) or inner portion; anteriorly bearing five setae (1-5), setae 1-4 of the same length, widened basally, seta 1 naked, with bunch of long setules at base of seta; setae 2-4 setulated distally, followed by seta 5 rod-like receptor, small, naked; posteriorly bearing three setae (1'-3'), generally increasing in length towards gnathobase, all setulated. Gnathobase (GT) with four elements (I-IV), element I large, longest, distally setulated, elements II, IV small, element III smallest, element II and III fused at base, element IV more slender, these three elements naked. Gnathobasic filter comb with five setae, similar in length, all unilaterally setulated.

***Fifth trunk limb (P5)*** (figs.36k; 40d)***:*** Pre-epipodite and epipodite not seen. Exopodite (EX) oval, subdivided into two lobes but not clear (fig.36j, arrow) bearing four setae (1-4); setae 1-3 on anterior portion gradually decreasing in length posteriorly, all setulated, small hillock between setae 2 and 3; seta 4 on posterior portion shortest, length ¼ of seta 3, unilaterally setulated. Row of long setules between two lobes.

Endopodite (EN) rounded, relatively large, setulated apically, rows of small spinules basally (fig.40d), bearing two endopodite setae, the first one shorter, the second large, widen at base, both unilaterally setulated. Gnathobasic filter comb with two setae, one rod-like seta, setulated apically, another more slender, setulated.

**Variability:**

Body size; in the original description the body ranged from 0.36-0.38 mm height and 0.46-0.52 mm width. Some variability was noted in the following characters: 1) proportion of anal margin and postanal margin of postabdomen and 2) curve of large hook-like seta on inner distal lobe.

**Differential diagnosis:**

This species can be distinguished by 1) the presence of a dorsal keel; 2) anterior margin of labrum forming one or two curls; 3) eight aesthetasc setae of first antenna, antennular seta as long as the longest aesthetasc seta and arising from a distinct tubercle; 4) the general characters of postabdomen: broad with postanal margin longer than anal and preanal portion, tapering distally, pre- and postanal angle distinct obviously, postanal angle form an angle of 45-50° degree; 5) ventral rim of valve, row of strong setules reach to postero-angle of valve, series of smaller setules among them, and continue with small setules to postero-dorsal angle; 6) three IDL setae, one large curved-hook like seta (unique character of the taxa); 7) length of eight scrapers of trunk limb 2 forming three groups; 8) the first three gnathobasic filter comb of trunk limb 2 considerably shorter than others; 9) two small sensilla (sn) between seta 1 and 2 and between seta 2 and 3 on exopodite of trunk limb 3; 10) seta 3 on exopodite of trunk limb 4 longest and 11) one seta of gnathobasic filter comb of trunk limb 5 rod-like.

**Remarks:**

*Alona sarasinorum* Stingelin, 1900 was originally described from brackish water in Celebes Island Indonesia, separated from known 'lynceids' based on shape and armature of the postabdomen, and has been recorded from athalassic saline waters throughout Asia (Brehm, 1933; Idris and Fernando, 1981 and Venkataraman, 1999). There were few specimens found in each study and no sufficient description and good illustrations available. However, previous researches show a number of unique characters: body shape, shape of the labral plate, arrangement of setules on the posterior-ventral margin of the valves, head shield, structure of the postabdomen and terminal claw and large hook-like IDL seta of trunk limb 1.

In 1977 Shirgur and Naik described *Alona taraporevalae* on specimens hatched from ephippia originating from Back Bay (India). This taxon is undoubtedly similar to *A. sarasinorum*. However their taxonomic identity has never been proven. Only once, *A. taraporevalae* was used to compare with *Celsinotum*, new genus described by Frey (1991), because of theirs similarity in gross view of characters. However, at that time the comparison stated that they are not closely related.

The results of insufficient detailed morphology as well as illustrations, their rare and narrow distribution make the taxonomical status of these two species has never been discussed. However number of specimens of *A. sarasinorum* from southern Thailand is available to write a complete description of parthenogenetic female and we also can discuss the similarity with *A. taraporevalae* and make a note on their generic status by morphological comparison with *Alona affinis*, closet species of *Alona* type species and *Celsinotum*, the genus which show high similarity in morphology.

**Details of morphological study on *Alona taraporevalae* Shirgue & Naik, 1977**

**References:** *Alona taraporevalae* Shirgur & Naik, 1977: 48-52, figs.1-3; Sharma and Michael, 1984: 35-38, figs.1a-f; Michael and Sharma, 1988: 186-188, figs.64a-f; Frey, 1991, figs.93-101.

**Materials examined:**

*Paratypes*: three specimens of *Alona taraporevalae* Shirgue & Naik, 1977 on slide mounted by D. G. Frey.

**Partial description of type specimen *Alona taraporevalae*** (see figure 42)

**Parthenogenetic females**

***General body:*** in lateral view rounded (fig.42a). Maximum height at middle of body. Length 0.40-0.44 mm, about 1.4 times maximum height in adults (n=3), height 0.27-0.32 mm. Postero-dorsal and postero-ventral angles rounded. Ventral margin slightly concave, with 46-50 setae, anterior and posterior setae equally in length, row of small setules among these setae (fig.42b).

***Head:*** relatively small.

***Labrum:*** moderate size (figs.42a, c). Labral keel round with blunt apex. Distal labral plate without setulation. Anterior margin form into one curl, posterior margin without any clusters of setules.

***Postabdomen:*** relatively broad since postanal angle, length about 2 times width (fig.42d), widest in postanal corner, around the middle. Dorsal margin gradually narrowing distally from postanal corner on. Anal margin almost parallel to dorsal margin, with distinct pre-and postanal corner and 3-4 groups of small denticles. Posterior to the anal margin, 5 groups of lateral fascicles, each group from 5-10 fascicles, not extending beyond to distal margin. Lateral fascicles on anal margin about 4 groups, of which the denticles (minimal 6, maximal 9) more radial than parallel to each other. Marginal spines about 9 groups, 2-4 spines in group, mostly 3, largest in the middle of postanal past, mostly curved and pointing in different directions. Natatorial setae short.

***Terminal claw:*** long and slender (figs.42e-f), evenly curved to tip, with narrow row of setae along concave edge. Basal spine slender, length about half of terminal claw or little less, having a single seta along anterior margin about 1/3 from base, where there is a distinct break in contour, two short setules arising proximal to almost base of basal spine (fig.42e). Row of pectens reaching tip of claw, gradually decreasing in length distally.

**Trunk limbs: five pairs**

***First trunk limb (P1):*** Outer distal lobe (ODL) of trunk limb 1 with one slender seta, longest (fig.42g). Inner distal lobe (IDL) bearing three setae, one large, strong hook-curved like; one seta slender, bi-segmented, setulated distally; another seta thin, smallest, weakly sclerotised, curved, resembling a second hook, length about half that of the slender one.

***Second trunk limb (P2):*** not studied.

***Third trunk limb (P3):*** Anterior row of endopodite of trunk limb 3 with two stout distal setae (fig.42h), both of the same length, distally armed with 2 rows of well-space strong denticles, counting 4-6 denticles.

***Fourth trunk limb (P4):*** Exopodite of trunk limb 4 round, bearing six setae (fig.42i; seta 6 difficult to draw from specimen in slide), setae 1 and 2 are of the same length, seta 1 unilaterally setulated, seta 2 setulated with long setules; seta 3 shorter, setulated; setae 4 and 5 subequal in length.

***Fifth trunk limb (P5):*** not studied.

**The relationship between *A. sarasinorum* Stingelin, 1900 and *A. taraporevalae* Shirgue & Naik, 1977**

The original description and figures of *Alona taraporevalae* is inadequate (Shirgue and Naik, 1977) although they provided both description of parthenogenetic female and male. Sharma and Michael (1984) attempted to redescribe this taxon but did not contribute new details to overall description. Frey (1991) also gave only a partial redescription from few specimens obtained from Shirgur. Here we tried to provide more details of this species but unfortunately we have only three paratypes on mounted slide to study and no male. It was difficult to see the complete setation on the trunk limbs and some other details, so that a complete description could not be attempted. Nevertheless, some more details on some parts (as above) together with the combination of previous descriptions, a morphological comparison with *A. sarasinorum* can be provided (table 7) so that the relationship between these species can be discussed.

The 29 morphological characters of *A. sarasinorum* and *A. taraporevalae* were used to compare (table 7) and state their status. They apparently showed high similarity between these two species as they have the same characteristic of 27 gross and fine characters in range of size, body shape, labrum, first and second antenna, postabdomen and details of trunk limbs 1, 3, 4 and 5 and also biological and ecological range. There are only characters of setae on exopodite of trunk limb 4 (characters 24-25) that show a difference, but only in micro-details. Unfortunately, we have no male of *A. sarasinorum* to compare with male of *A. taraporevalae* which show unique character among other Aloninae as they having lateral aesthetascs on the antennule and in having a narrow distally of postabdomen (Shirgur and Naik, 1977; Frey, 1991). However, from female characteristics we can conclude that *Alona taraporevalae* is highly likely a junior synonym of *Alona sarasinorum*.

**Noted on generic status of *Alona sarasinorum* Stingelin, 1900**

*A. sarasinorum* shows considerable differences from *Celsinotum*, a possibly related genus, in many characters of parthenogenetic females (table 7): 1) smaller size; 2) apex of labrum not strongly expand as *Celsinotum* and anterior margin not smooth but forming curls; 3) small setae present between long slender setae at postero-ventral corner of valve; 4) basal and middle setae on endopodite of second antenna; 5) postabdomen different in the relative length of three zones, with postanal zone longest; 6) three IDL setae instead of only two in *Celsinotum*; and 7) length of setae on trunk limbs 3-5. Thus, in spite of having similar general shape and postabdomen, and the taxon occurs in saline water, *A. sarasinorum* is not related to *Celsinotum*.

Moreover, it differs from the other taxa obviously by having a large and very strong hook IDL seta on trunk limb1 and characteristics of the postabdomen which are unique among the Aloninae. The completed description of parthenogenetic females raises to a higer level its information but can not lead to final conclusion. Additional details description of the ephippial females and males is indeed needed for determining its relationships to other species and its generic status.

**Biology:**

*A. sarasinorum* is found in the littoral zone of Maikhao peat swamp closed to Maikhao beach in Phuket Island, southwestern Thailand. The characteristics of the habitat are a typical peat swamp such as brownish water and cover with algae and vegetation. It appears to be more common in summer, pH ranges from 4-6, and salinity has not clearly changed during sampling year (0-4 ppt).

It also found in athalassic water in slow-running open area in southeastern Thailand, both upper and lower parts (Mulmek, S. and Sangkaew, S. pers.com.). However it has been found only in rainy season when pH ranges from 6-8 and salinity decrease to 7-8 ppt.

**Distribution:**

Until now *A. sarasinorum* has become known only from South East Asia. It is noticeably distributed along the coastal areas. As previous records, it has been found in Celebes Island, Indonesia (Stingelin, 1900 and Brehm, 1933), Rantang Abang Marsh, the place close to the western coast in Terengganu, Malaysia (Idris and Fernando, 1987) and southern Tamil Nadu, Madurai, southeastern India (Venkataraman, 1999). In the present study it also has been found only the place close to coastal area along both side of southern Thailand.

**Table 7** Morphological comparison among *A. affinis*, closet species of type species of *Alona*, *A. sarasinorum* & *A. taraporevalve* and *Celsinotum*.

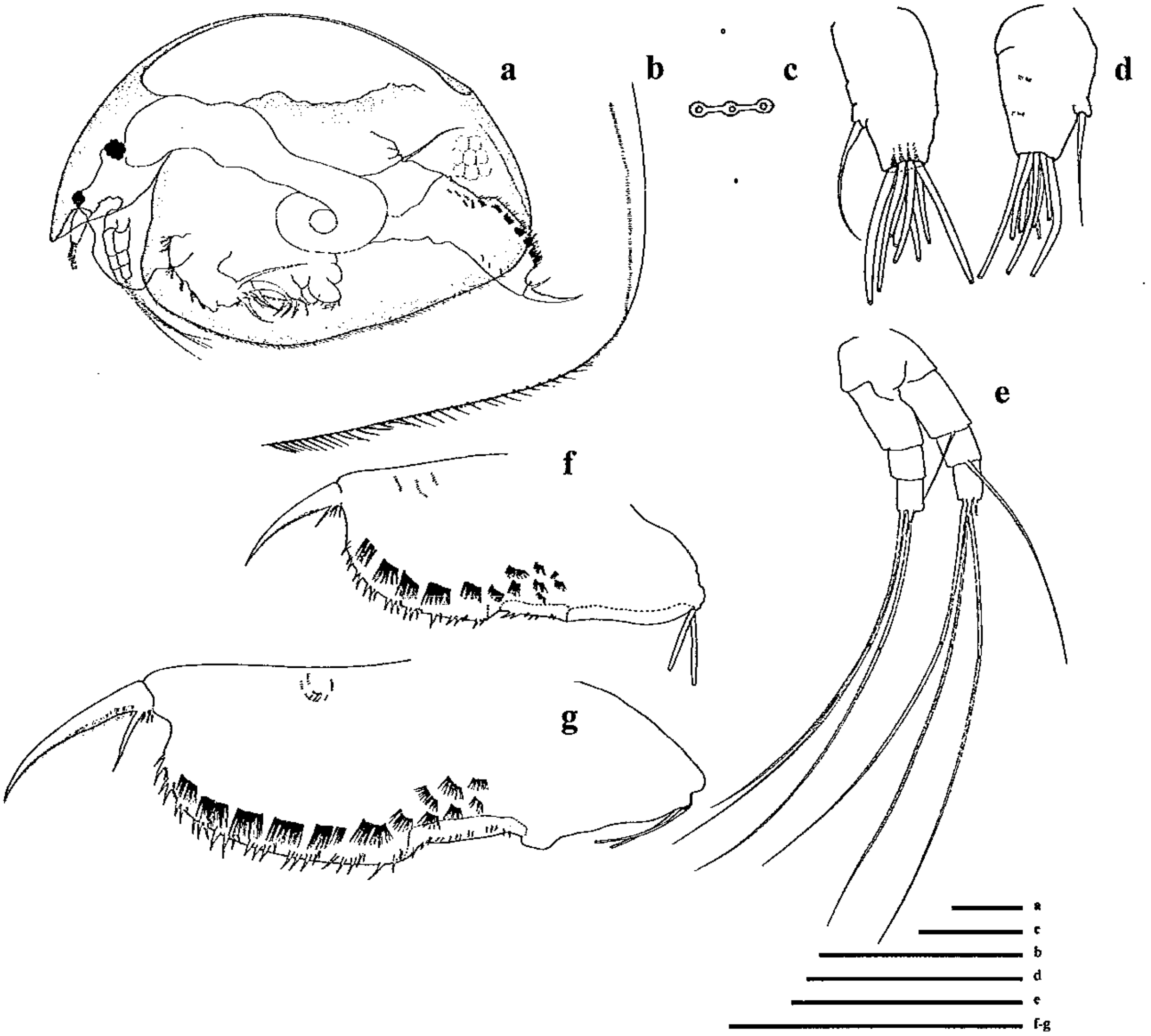
| **Characters** | | ***A. affinis*** Thai specimens (Sinev, 1999 and present data) | ***Celsinotum*** (Frey, 1991) | ***A. sarasinorum*** Type specimen & Thai specimens (present data) | ***A. taraporevalae*** Paratypes (Shirgur & Naik, 1977; Frey, 1991 & present data) |
|---|---|---|---|---|---|
| **Size** | 1) | 0.55-0.90 mm | 0.55-0.90 mm | length 0.34-0.44; height 0.24-0.32 mm | Length 0.40-0.44; Height o.27-0.32 mm |
| **L/H** | 2) | 1.7-1.9 times | >1.25 times | 1.3-1.4 times | 1.4 times |
| **Dorsal keel** | 3) | absent | present | present | present |
| **PvCv** | 4) | small setae between long-slender setae | no small setae between slender setae | shorter setae between long slender setae | shorter setae between long slender setae |
| **Labrum** | 5) | large, rounded or polygon-like | rounded, apex blunt and expand strongly anteriorly | rounded, blunt apex but not expand, | rounded, blunt apex but not expand, |
| | 6) | anterior margin angulated tip | anterior margin rounded | anterior margin form into 1-2 curls | anterior margin form into 1 curl |
| | 7) | posterior margin with two clusters of setules | no setules | no setules | no setules |
| **First antenna** | | | | | |
| lateral seta | 8) | >1 | 1 or many | 1 | 1 |
| aesthetascs | 9) | 9 | 9 | 9 | 9 |
| accessory seta | 10) | 1 or more | 1 | 1, arises from a well developed & rounded tubercle projecting from its side | 1, arises from a well developed & rounded tubercle projecting from its side |

**Table 7.** (Continued)

| **Characters** | | ***A. affinis*** Sinev, 1999 & southern Thailand specimens | ***Celsinotum*** Frey, 1991 | ***A. sarasinorum*** Type specimen & southern Thailand specimens | ***A. taraporevalae*** Shirgur & Naik, 1977; Frey, 1991 & present study (paratypes) |
|---|---|---|---|---|---|
| **Second antenna** | 11) | spines at articulation points of antennal setae | absent | absent | absent |
| | 12) | | basal & middle setae on endopodite longer | basal & middle setae on endopodite shorter than in *Celsinotum* | basal & middle setae on endopodite shorter than in *Celsinotum* |
| | 13) | | basal & terminal spines short but longer than in *A. sarasinorum* & *A. taraporevalae* | basal & terminal spines short, not visible | basal & terminal spines short, not visible |
| **Postabdomen** | 14) | | | different in the relative length of the three zones obviously, postanal longest | different in the relative length of the three zones obviously, postanal longest |
| | 15) | marginal denticles with merged spinules | 8-12 groups of marginal spines, these spines not strong as in *A. sarasinorum* & *A. taraporevalve* | 8-9 groups of marginal spines, 2-4 spines in group, these spines strong | 9 groups of marginal spines, 2-4 spines in group, these spines strong |
| | 16) | pre-postanal not distinct obviously | pre-postanal distinct but not obvious as *A. sarasinorum* & *A. taraporevalve* | pre-postanal distinct obviously | pre-postanal distinct obviously |
| | 17) | with parallel dorsal and ventral margin | dorsal margin strongly curve | dorsal margin slightly curve | dorsal margin slightly curve |

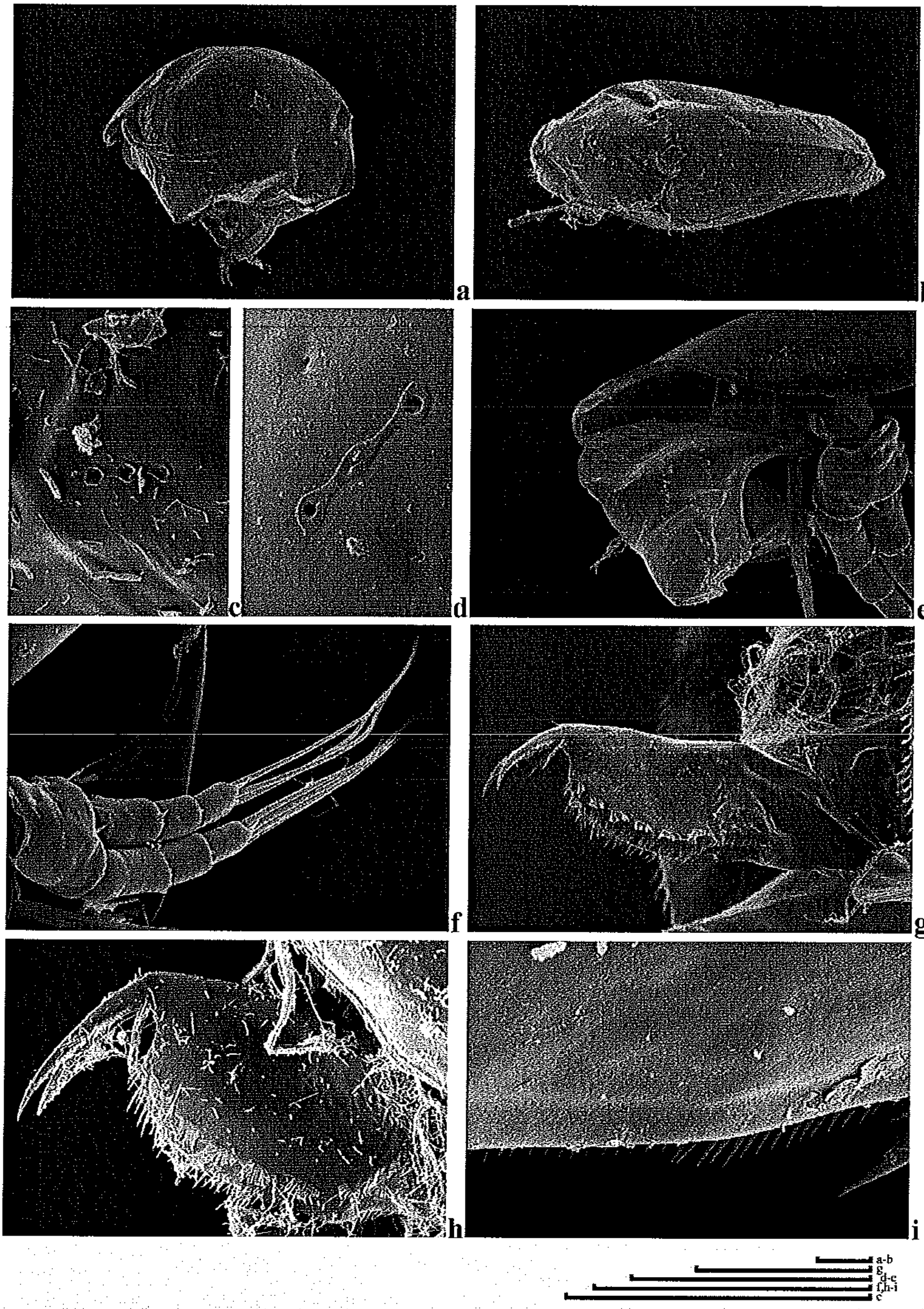
**Table 7.** (Continued)

| Characters | | *A. affinis* Sinev, 1999 & southern Thailand specimens | *Celsinotum* Frey, 1991 | *A. sarasinorum* Type specimen & southern Thailand specimens | *A. taraporevalae* Shirgur & Naik, 1977; Frey, 1991 & present study (paratypes) |
|---|---|---|---|---|---|
| **Terminal claw** | 18) | several short setules | 2-3 setules but very short & thin | 2-3 setules on base of basal spine | 2-3 setules on base of basal spine |
| **Trunk limb 1** | | | | | |
| Outer distal lobe (ODL) | 19) | 1 seta | 1 seta | 1 seta | 1 seta |
| Inner distal lobe (IDL) | 20) | 3 setae, one curved; more curved in some specimens | 2 slender setae | 3 setae, one curved-hook like seta | 3 setae, one curved-hook like seta |
| **Trunk limb 3** | | | | | |
| Exopodite | 21) | 7 setae | 6 setae | 6 setae | 6 setae |
| | 22) | seta 1=seta 2 | seta 1=seta 2 | seta 1=3 times seta 2 | seta 1=3 times seta 2 |
| | 23) | seta 3 longest, about 6 times of seta 4 | seta 3~2 times seta 4 | seta 3~seta 4 | seta 3~seta 4 |
| **Trunk limb 4** | | | | | |
| Exopodite | 24) | setae 1-3 gradually decreasing in length towards gnathobase | seta 3 longest, 2 times of seta 2 | seta 3 longest, 1.5 times of seta 2 | setae 1-3 gradually decreasing in length towards gnathobase |
| | 25) | seta 5~seta 6 | seta 5 longer than seta 6 | seta 5~2 times of seta 6 | seta 5~seta 6 |
| Endopodite | 26) | finger-like setae, unilateral setulated | | finger-like setae but more slender, bilateral setulated distally | |
| **Trunk limb 5** | 27) | bi-lobed | bi-lobed | bi-lobed | bi-lobed |
| | 28) | 1 minute seta | 1 minute seta | 1 minute seta, shorter | 1 minute seta, shorter |
| **saline** (up to 8‰ or more) | 29) | no | yes | yes | yes |

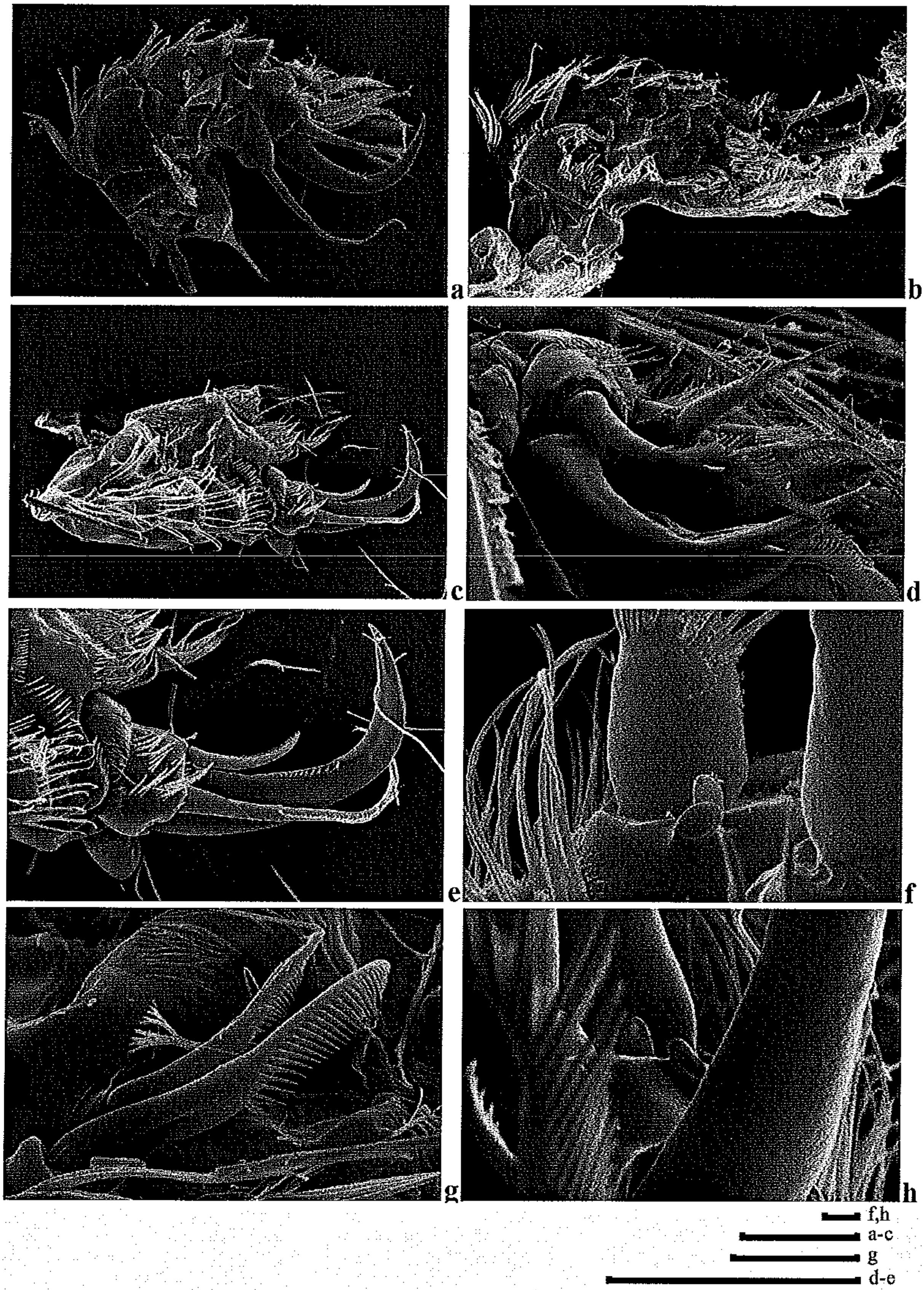



Figures 35a-g. *Alona sarasinorum* Stingelin, 1900: parthenogenetic females from Maikhao swamp, Phuket Province, southwestern Thailand. Figure a, adult female in lateral view; Figure b, postero-ventral margin of valve; Figure c, head pores; Figure d, antenna 1; Figure e, antenna 2; Figures f-g, postabdomen. Scale bar denotes 100 um.

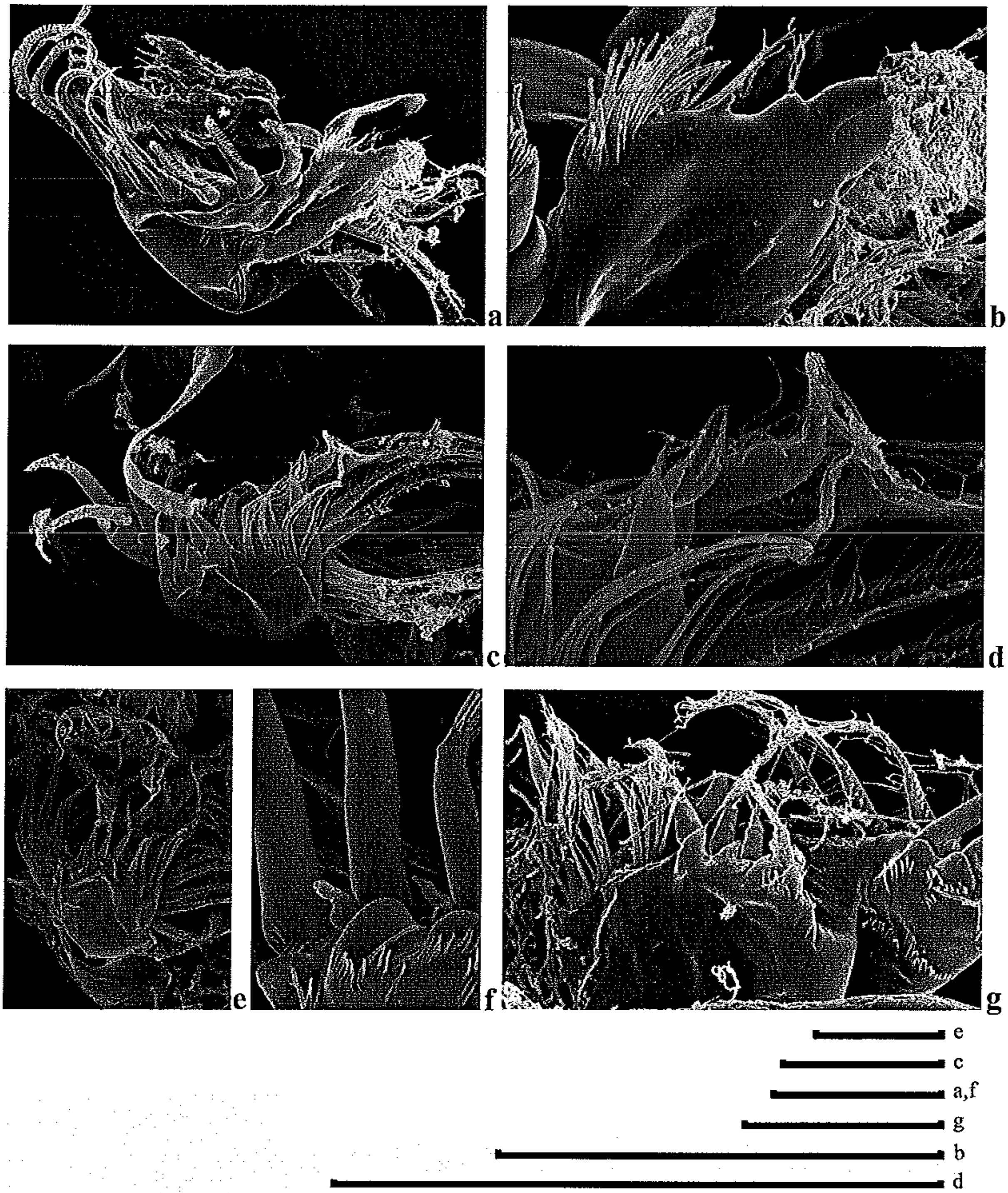

Figures 36a-k. *Alona sarasinorum* Stingelin, 1900: appendages of females from Maikhao peat swamp, Phuket Province, southwestern Thailand. Figures a-b, trunk limb 1 and its inner and outer distal lobe; Figure c, trunk limb 2; Figure d, exopodite of trunk limb 3; Figures e-f, anterior and posterior row of endopodite of trunk limb 3; Figure g, its gnathobase; Figures h-i, exopodite of trunk limb 4; Figure j, endopodite of trunk limb 4; Figure k, trunk limb 5. Scale bar denotes 100 um.



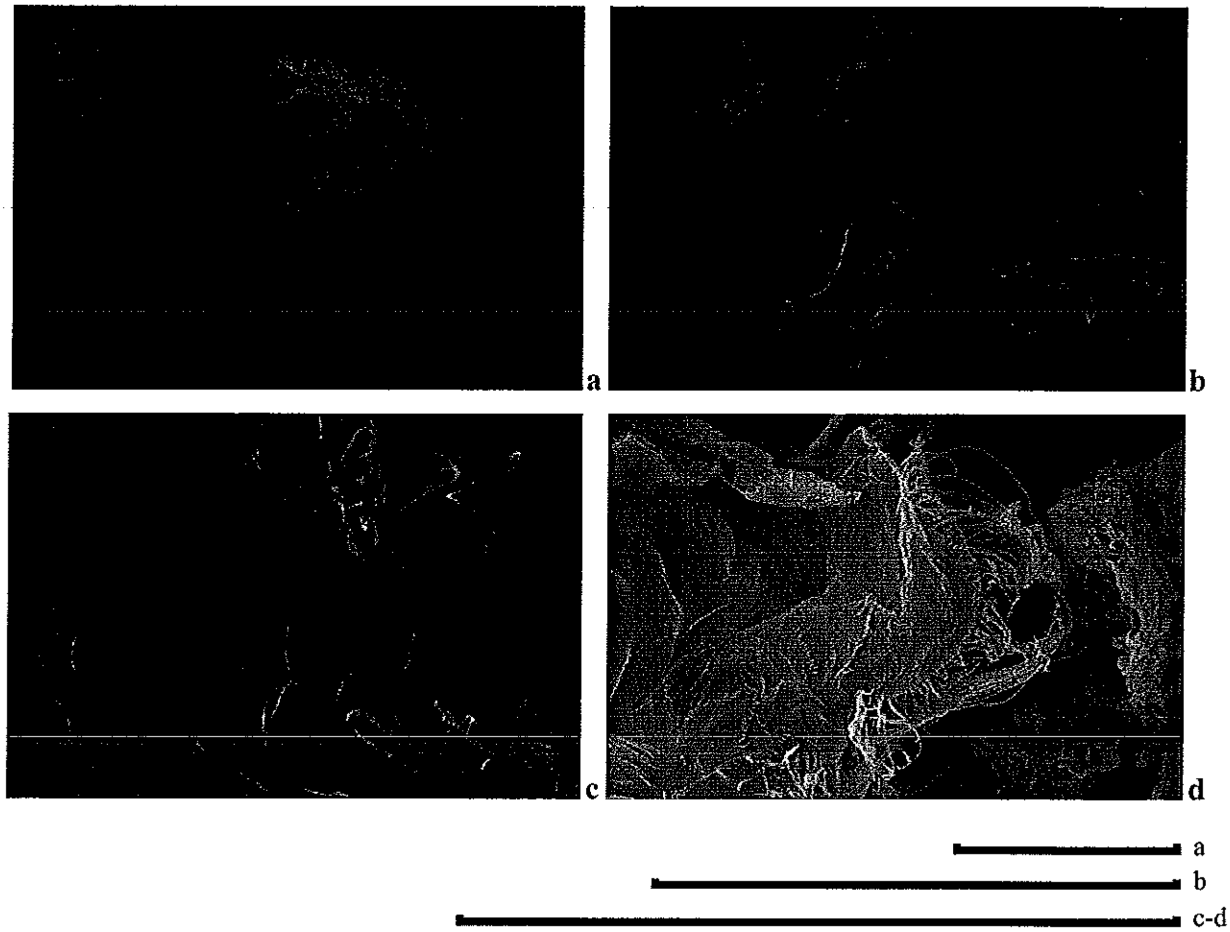

Figures 37a-i. *Alona sarasinorum* Stingelin, 1900: parthenogenetic females from Maikhao peat swamp, Phuket Province, southwestern Thailand. Figure a, adult female in lateral view; Figure b, adult female in dorsal view; Figures c-d, head pores; Figure e, labrum; Figure f, antenna 2; Figures g-h, postabdomen; Figure i, ventral of valve. Scale bar denotes 100 um.



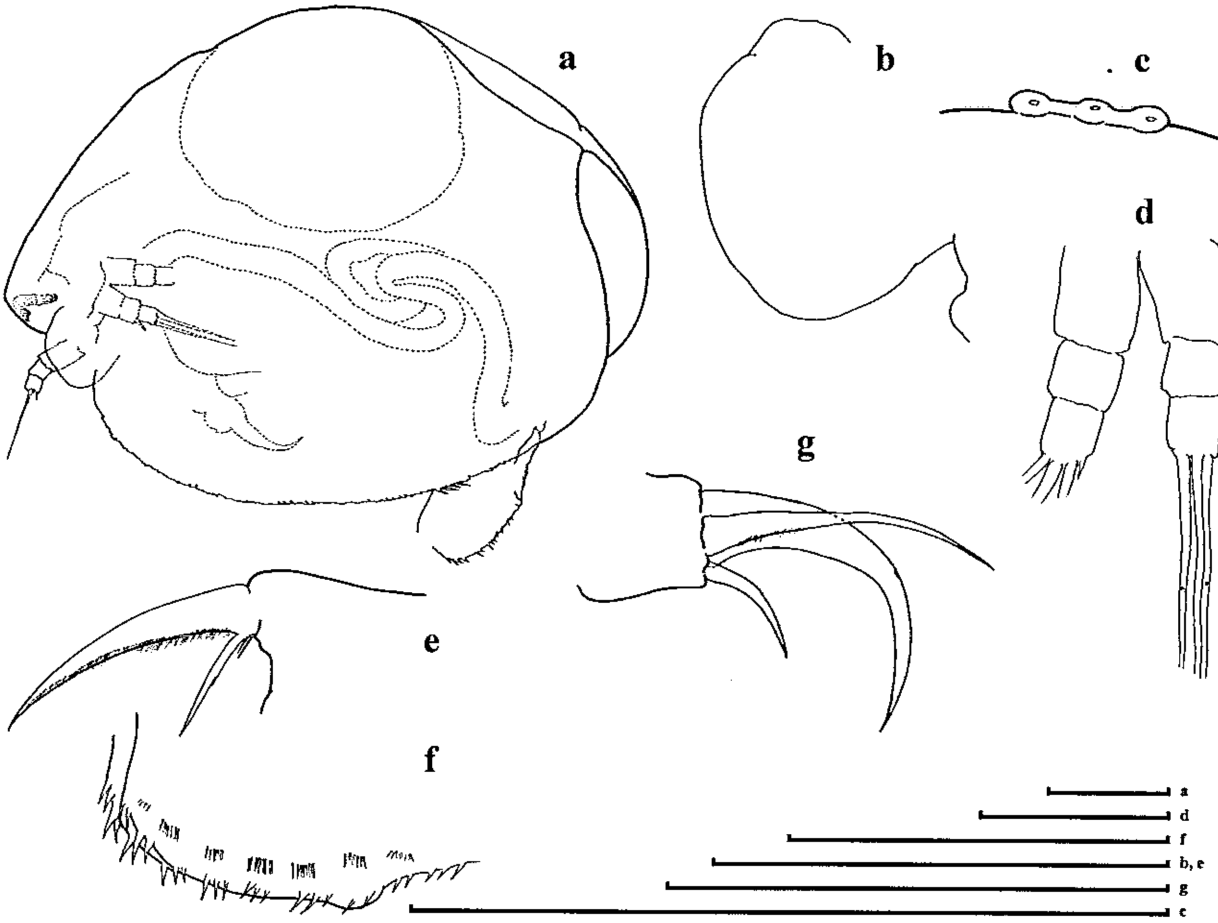

Figures 38a-h. *Alona sarasinorum* Stingelin, 1900: trunk limb 1 of parthenogenetic females from Maikhao peat swamp, Phuket Province, southwestern Thailand. Figures a-c, trunk limb 1; Figures d-e, inner and outer distal lobe; Figures f,h, sensilla; Figure g, ejector hooks. Scale bar denotes 100 um.



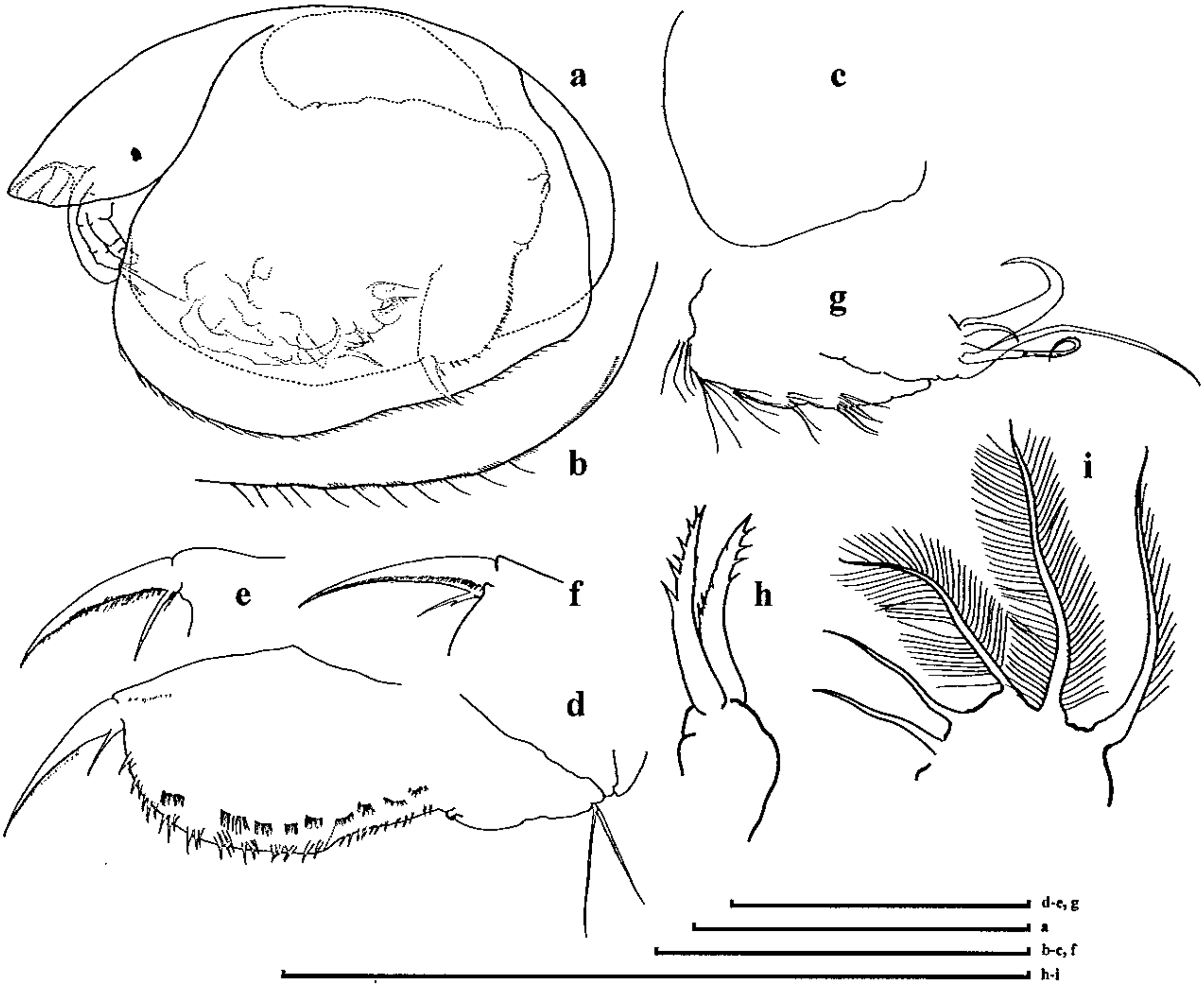

Figures 38a-g. *Alona sarasinorum* Stingelin, 1900: appendages of females from Maikhao peat swamp, Phuket Province, southwestern Thailand. Figures a-b, trunk-limb 2 and its gnathobase; Figures c-g, trunk limb 3, its gnathobase, exopodite, endopodite and sensilla on exopodite. Scale bar denotes 100 um.




Figures 40a-d. *Alona sarasinorum* Stingelin, 1900: appendages of parthenogenetic females from Maikhao peat swamp, Phuket Province, southwestern Thailand. Figure a, exopodite of trunk limb 4; Figures b-c, endopodite of trunk limb 4; Figure d, endopodite of trunk limb 5. Scale bar denotes 50 um.




Figures 41a-g. *Alona sarasinorum* Stingelin, 1900: type specimen, parthenogenetic female from Celebes, Indonesia. Figure a, adult female in lateral view; Figure b, labrum; Figure c, head pores; Figure d, antenna 2; Figure e, terminal claw; Figure f, postabdomen; Figure g, trunk limb 1. Scale bar denotes 100 um.




Figures 42a-i. *Alona taraporevalve* Shirgue & Naik, 1977: paratype, parthenogenetic females from Back Bay, Bombay, India. Figure a, adult female in lateral view; Figure b, postero-ventral corner of valve; Figure c, labrum; Figure d, postabdomen; Figures e-f, terminal claws; Figure g, trunk limb 1; Figure h, distal spines on exopodite of trunk limb 3; Figure i, exopodite of trunk limb 4. Scale bar denotes 100 um.

## 511. *Alona verrucosa* Sars, 1901

**Synonymy:** (*Biapertura verrucosa*); Smirnov, 1989:140.

**References:** Sar, 1901: Des. 56-57, Pl.9, figs. 7, 7a; Jenkin, 1934: Des. 292-295, figs. 18, 18a, 18b; Brehm, 1938: Des. 100-101, Abb. 6-7; Johnson, 1956: Des. 85-88, figs. 5-6; Rey and Saint-Jean, 1968: 111-112; Nayar, 1971: p.514, figs. 24-25; Paggi, 1975: Des. 139-144, Lam, figs. 1-22, Lam II, figs. 23-27; Smirnov, 1984: Des. P. 157, fig. 7; Venkataraman, 1995: 383, figs 41-42; Alonso, 1996 Des. 317-318, fig.141.

**Type locality:** "Gutenburg und Bleinbachmoos bei Langenhal"

**Lectotype and paralectotypes:** tubes GOS-F12338A-B, tube with paralectotypes F12337

**Materials examined:**

*Southern Thailand:* ten parthenogenetic females, examined complete and thereafter dissected, from Thungtong swamp, Suratthani Province, southeastern Thailand. Collected by the author, SM.

*:* five parthenogenetic females, examined complete and thereafter dissected, from Buabakong swamp, Narathiwas Province, southeastern Thailand. Collected by the author, SM.

*:* one parthenogenetic female, examined complete, from Yon peat swamp, Trang Province, southeastern Thailand. Collected by P. Sa-ardrit, SM.

*:* five parthenogenetic females, examined three complete and two dissected, from Pak Panang Bay, Nakornsrithammaras Province, Southeastern Thailand, collected by S. Sangkaew, SM.

*Northeast Thailand:* two parthenogenetic females, examined complete and thereafter dissected, from Lake Kudthing, Province, collected by C. Saeng-aroon, KKU.

*Brazil:* one parthenogenetic female, examine complete, from Brazil, South America, collected by Van Damme, K., GU.

**The details of morphological study**

**Species description** (See figures 43-45)

**Parthenogenetic female**

***General shape*** (figs.43a-d)*:* oval to ovoid in lateral view (figs.43a-c), largest height around the middle, or posteriormost in some specimens, length 0.26-0.32 mm. 1.4-1.7 times maximal height (n=20), height 0.17- 0.21 mm. Note that in the spotted ones, the body shows larger size and is more rounded (fig.43b), length 0.30-0.32 mm, height 0.18-0.19 mm. Dorsal margin generally curved, depression between head and rest of body absent. Postero-dorsal angle rounded, not prominent. Posteroventral corner broadly rounded. Ventral margin slightly concave, ventral embayment before the middle. Ventral setae relatively short (fig.43d), in some specimens very short (fig.43a), in some specimens short and also, densely setulated (fig.43) or relatively longer posteriorly (fig.43b), anteriormost with 8-10 marginal setae followed by 18-20 slender setae, gradually increasing in length towards posterior end. Rows of small setules from posterior ventral corner up to the middle of body. Valve with (figs.43b, 45a) or without spots (figs.43a, c).

***Head*** (figs.43a-c, e)*:* moderately size, rostrum typically long, pointing downward or ventrally (figs.43a-c). Compound eye present, larger than ocellus, distance between eyes and ocellus same as distance from ocellus to tip of rostrum. Head shield elongated (fig.43e), posteriorly 4-5 curls symmetrically. Two major head pores, same size, with a narrow connection between them (figs.43f-g). Two lateral head pores, each surrounded by internal 'flower-like' structure, located closed to anterior, about 1IP from midline, level before anterior median pore.

***Labrum:*** moderately, rounded or more ovoid (figs.43a-c). Anterior margin rounded, bearing a minute denticle, labral keel naked. A semi-circular ridge along anterior rim of keel (fig.45c).

***Postabdomen*** (figs.43j-k)***:*** width about 2 times height. Relatively broad distally, distal margin round though not obvious in some specimen (fig.43b). Dorsal margin curve. Anal margin concave bearing 19 small denticles. Postanal margin shorter than anal margin (fig.43j) but as the same length in some specimens (fig.43k), postanal corner distinct, bearing 2 groups of small denticles. Posterior to anal margin, lateral fascicles: about 10-11 postanal groups, consisting of 4-10 denticles, distally decreasing in number from postanal corner on, in contrast of theirs size, spinules of four most distal groups reaching beyond dorsal margin of postabdomen. Marginal denticles in groups: 8-10 groups, on distal margin, each group consisting of 3-5 denticles, of which middle groups slightly larger than anterior and posteriormost. Rows of venterolateral denticles (fig.43j). Natatorial setae short.

***Terminal claw*** (figs.43j-k, 45d)***:*** Long and slender, about as long as anal margin. Basal spine slender, short, length about 1/4 of terminal claw, bearing 2-3 spinules arising proximal to base of basal spine (figs.43j-k, 45d), length of these spinules as long as basal spine in some specimens (fig.43k). Denticles of pectin relatively short, both inner and outer sides (figs.43j, 45d) gradually decreasing distally, reaching tip of claw in some specimens (figs.43j, 45d).

***First antenna (antennule)*** (figs.43a-c, h)***:*** Body compact, about twice as long as wide (figs.43a, h), but about 3 times as long as wide in some specimen (figs.43b-c). Tip pointing downwards, some reaching beyond tip of rostrum (fig.43b) but most specimens not protruding beyond tip of rostrum (figs.43a, c). Four rows of small spines on inner and outer side of antennular body. Distal end with nine aesthetascs, unequal in length, implanted on elongated apex, length about 2/3 of the antennular body or shorter (fig.43b). Subapical aesthetasc of same length of normal aesthetascs, accompanied by antennular sensory seta, implanted at about one third of distal end. All aesthetascs projecting beyond tip of rostrum.

***Second antenna*** (figs.43a-c, i, 45b)***:*** relatively short (figs.43a-c). Antennal formula, setae 0-1-3/0-0-3 spines 0-1-1/1-0-1 (fig.43i). All setae bisegmented. Basal segment with conical distal spine, all segments cylindrical, basal segment longest and shorter distal end. Row of long and slender spines at joint of each segment (figs.43i, 45b). Spine arising from first segment of endopodite reaching beyond the second segment. Terminal spines longer than terminal segment. Additional lateral spines on exopodite on first and second segments.

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (figs.44a-e)***:*** Outer distal lobe (ODL) with one apical seta (I'), bi-segmented, unilaterally armed with small setules distally. Inner distal lobe (IDL) bearing two setae, seta II length as long as ODL seta, seta I shorter than seta II, both unilaterally armed with large setules (fig.44a) and larger in some specimens (figs.44b, d), these setules decreasing in length distal end. One small receptor located between these IDL setae. Groups of small serrated knobs (fig.44a) or row of slender setules at the base of the endite (figs.44b, d). Endite 3 (E3) with four plumose setae (1-4), subequal in length, setae 1 and 3 more slender and setae 2 and 4 more robust, all armed with short setules distally, row of small spinules at the base of endite. Endite 2 (E2) with three setae (5-7), seta 2 plumose, smallest, as long as seta 3, seta 6 longest (figs.44a, e) or seta 7 longest in some specimens (fig.44c), both unilaterally densely armed with long fine setules, shorter basally (figs.45a, e). Endite 1 (E1) with two setae (8-9), similar in length and similarly armed with short setules distally (figs.44a, e). Rows of small spinules on trunk, two rows of slender spinules present more radial on inner side of endite 2. Trunk with 5-6 rows of slender spines laterally. Basally two long and slender ejector hooks, one shorter, both unilaterally armed with short setules. Epipodite with long digitiform projection (fig.44d). Gnathobase not seen.

***Second trunk limb (P2)*** (figs.44f-g)***:*** Epipodite not seen. Exopodite (EX) oblong, small setules apically. Endopodite (EN) triangular, with eight scrapers (1-8), mostly decreasing in length towards gnathobase but scraper 3 shorter than scraper 4 and scraper 4 shorter than scraper 5 in some specimens (fig.44f); all bi-segmented, scrapers 1, 2 and 4 similar unilaterally armed with fine setules distally, scrapers 3 and 6 more robust, unilaterally armed with large denticles, about 6-7 denticles each, scrapers 5, 7 and 8 unilaterally armed with stronger setules distally. Distal armature of gnathobase (GT) with three elements (I-III), elements I and II hook-like tip, both fused at the base, element III smaller located at the base of the first two. Small hillock between scraper 1 and gnathobase, a minute denticle close to first element. Gnathobasic filter comb with seven setae, first seta considerably shorter, other setae generally increasing in length posteriorly.

***Third trunk limb (P3)*** (figs.44h)***:*** Epipodite not seen. Exopodite (EX) flat, sub-rectangular, relatively small, bearing six setae (1-7): setae 1 and 2 located laterally, in typical V-formation, seta 1 setulated, longer than seta 2, seta 3 longest, about 2 times longer than seta 4, setuleated, setae 4 and 5 subequal in length, seta 4 unilaterally armed with long setules from base to tip, seta 5 setulated distally, seta 6 slender and shorter than seta 5, setulated.

Endopodite (EN) divided into two rows; anterior row with three distal setae (1-3), setae 1 and 2 stout, seta 2 shorter than seta 1, distally armed with short well-spaced setules, seta 3 more slender, setulated distally; posterior row with four setae (1'-4'), generally gradually increasing in length towards gnathobase, setulated distally. Gnathobasic filter comb with five setae.

***Fourth trunk limb (P4)*** (fig.44i)***:*** Epipodite not seen. Exopodite (EX) rounded, bearing six setae (1-6), with generally decreasing in length, but seta 3 longest; setae 1 and 2 of the same length, setulated with long setules, seta 3 longest about 2 times longer than seta 4, setulated, seta 4 more robust, setulated, setae 5 and 6 more slender, similar in length, setulated with short setules.

Endopodite (EN) or inner portion, anteriorly bearing five setae (1-5), generally decreasing in length towards gnathobase; seta 1 long and slender, setae 2-4 'flaming torch' setae, seta 2 more robust, unilaterally armed with long and strong setules, setae 3 and 4 bilaterally armed with short setules distally, seta 5 rod-like receptor, relatively larger than seta 4, naked; posteriorly bearing four setae (1'-4'), generally increasing in length towards gnathobase. Gnathobase (GT) with two slender elements (I-II) both naked, fused at base of each other. Gnathobasic filter comb not seen.

***Fifth trunk limb (P5)*** (fig.44j)***:*** Pre-epipodite (PEP) small, without elongated digitiform projection. Epipodite (EP) larger than pre-epipodite, more rounded, elongated digitiform projection present. Exopodite (EX) bearing four apical setulated setae (1-4); anterior portion smaller than posterior portion, bearing three setae (1-3), seta 2 longest, setae 1 and 3 gradually smaller, respectively, all setulated; posterior portion bearing one seta (4), relatively short about a half of seta 3. Row of long setules between anterior and posterior portion.

Endopodite (EN) larger, more ovoid, setulated apically, two endopodite setae, setulated one shorter than the other, both not bending over the endite. Gnathobase (GT) relatively small, rounded.

**Variability:**

This species show high variability, noted in the following characters: 1) body shape, more ovoid (fig. 43a) or highly arched in middle of body (fig.43b); 2) presence of spots on valves (fig.43b) or absent (fig.43a); 3) different range of body size between specimens with and without spots; 4) labrum more elongated (fig.43a) or more rounded (fig.43b); 5) first antenna compact (fig.43a) or more elongated (fig.43b); 6) the proportion of anal and postanal portion, postanal longest (fig.43j) or equal as other zones (fig.43k); 7) IDL setae armed with long setules distally, posterior setule large (fig.44a), very large in some specimens (figs.44b, d); 8) elongated digitiform present or absent in trunk limb 1; and 9) two ejector hooks of the same size (fig.44c) or one shorter (figs.44a, d).

**Differential diagnosis:**

The species can be distinguished from other species by the presence of 1) two major head pores connected with narrow connection, with two flower-like lateral pores; 2) labrum, anterior margin with a minute denticle; 3) distal margin of postabdomen round and broadly widen distally; 4) row of long setules around the joint of each segment on exopodite of second antenna; 5) IDL setae of trunk limb 1 distally armed with long setules, larger posteriorly and posteriormost largest; 6) scrapers 3 and 6 of trunk limb 2 more robust and armed with strong 5-7 denticles; and 7) a sensilla (sn) located between setae 4 and 5 of exopodite 3 and two sensillae (sn) between setae 1 and 2 of endopodite 3.

**Remarks:**

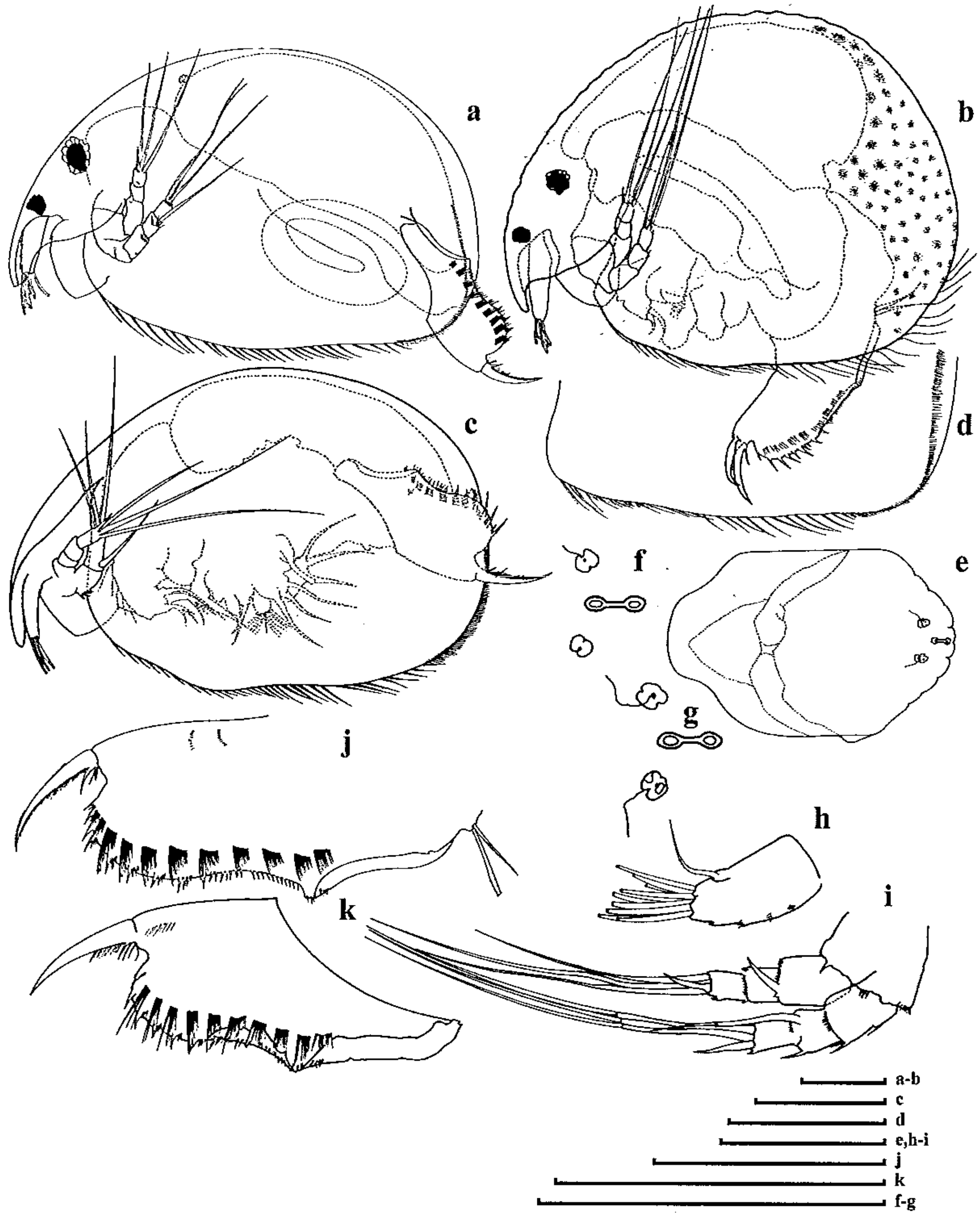
Although all specimens shared a peculiar character of 'flower-like' lateral head pores but the species shows differences between specimens both intra-and inter habitats in several characteristics as shown above. Here is apparently more than one species in this group in southern Thailand which can be roughly separated from the combination of some characters: 1) high proportion of specimens show more ovoid in shape, ventral setae relatively short, antennule compact and postanal margin of postabdomen longer than anal margin (fig.43a); and 2) few specimens show more rounded, ventral setae relatively longer posteriorly, antennule elongated and postanal margin of postabdomen as long as anal margin (fig.43b).

**Biology:**

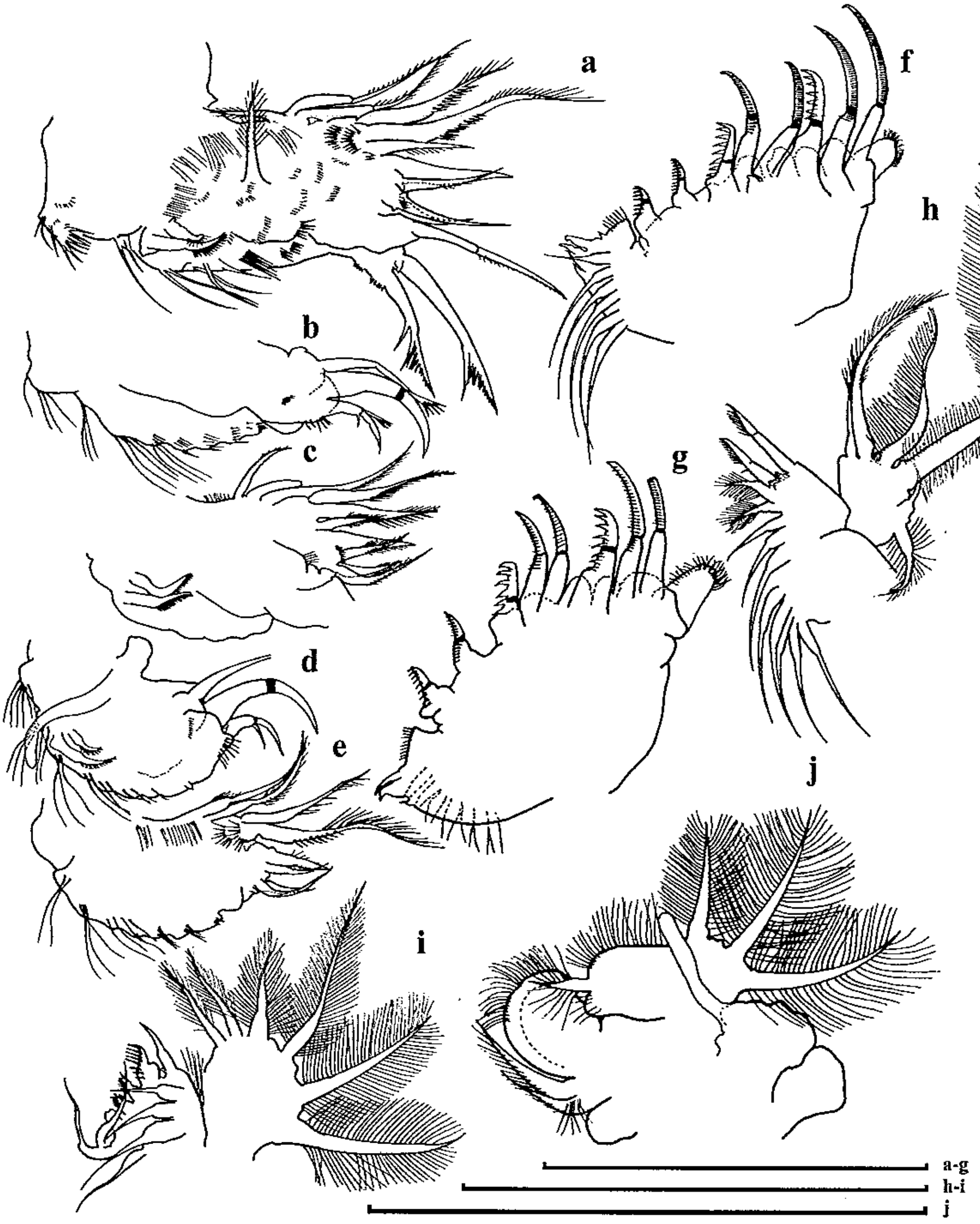
*A. verrucosa* is the most diverse species in the present sampling sites, covering Southern Thailand. It can be found in every kind of habitat, however different in number. It is high abundance in vegetated area, especially dominant of Nuphar lutea (Alonso, 1996).

**Distribution:**

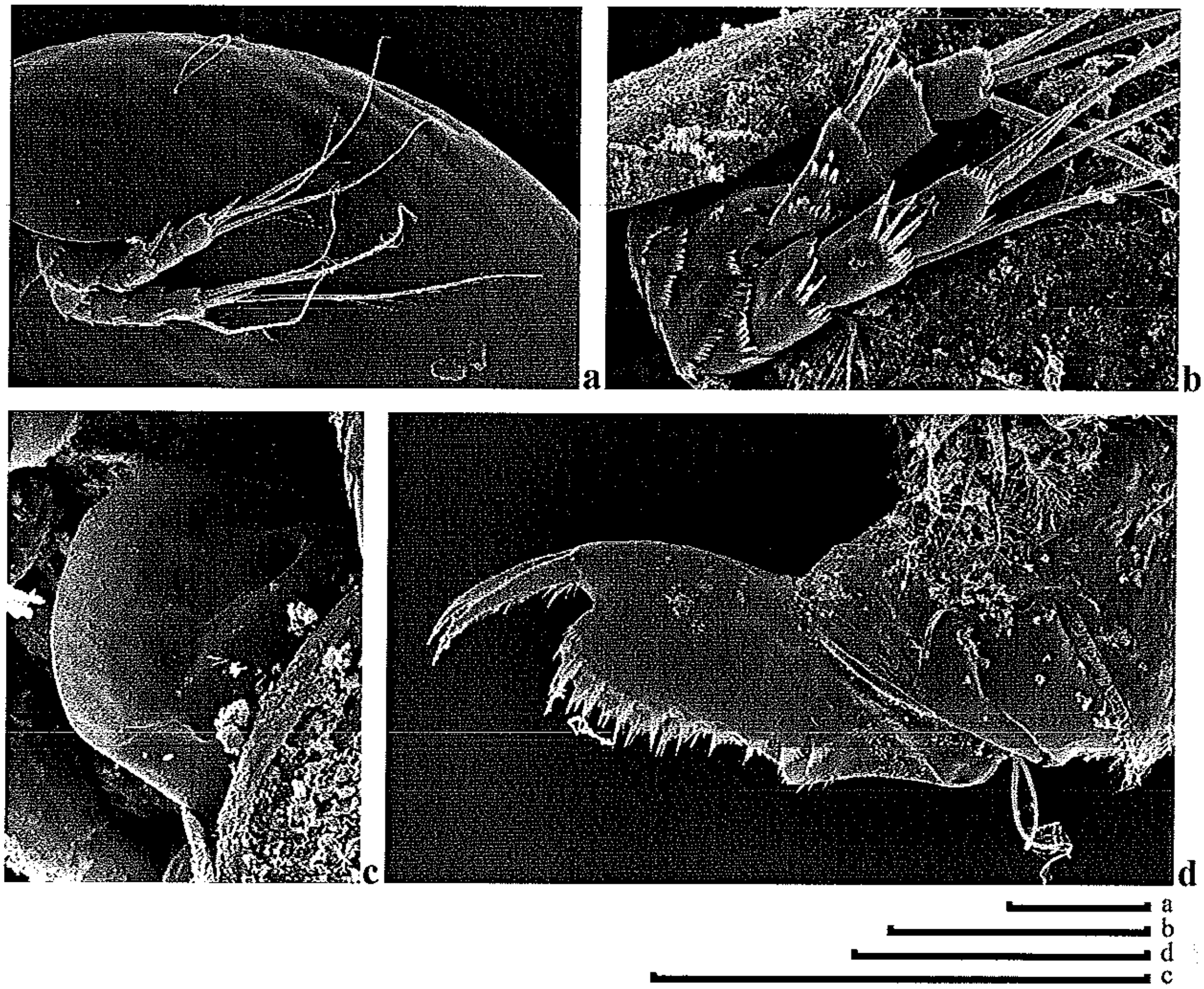
It is distributed widly in tropical zone i.e. in South America (Sao Paulo) (Jenkin, 1934); India (Nayar, 1971); Malaysia (Idris and Fernando, 1981); Thailand (Sanoamuang, 1998; Sa-adrit, 2001; Sa-adrit and Beamish, 2004).




Figures 43a-k. *Alona verrucosa* Sars, 1901: parthenogenetic females from Thungtong swamp (a, d-j), Lake Kud-thing, northeastern Thailand (k) and Brazil (c). Figures a-c, adult females in lateral view; Figure d, ventral of valve; Figure e, head shield; Figures f-g, head pores; Figure h, antenna 1; Figure i, antenna 2; Figures j-k, postabdomen. Scale bar denotes 100 um.




Figures 44a-j. *Alona verrucosa* Sars, 1901: appendages of females from Thungtong swamp, southeastern Thailand (a-c, f, h-j) and Lake Kud-thing, northeastern Thailand (d-e, g). Figures a-e, trunk limb 1; Figures f-g, trunk limb 2; Figure h, trunk limb 3; Figure i, trunk limb 4; Figure j, trunk limb 5. Scale bar denotes 100 um.




Figures 45a-d. *Alona verrucosa* Sars, 1900: parthenogenetic females from Thungtong swamp, Suratthani Province, southwestern Thailand. Figure a, head pores and its valve; Figure b, antenna 2; Figure c, labrum; Figure d, postabdomen. Scale bar denotes 100 um.

## The study on the species which used to be placed in the genus *Alona*

One additional species, *Nicsmirnovius eximius* (Kiser, 1948) which used to be placed in the genus *Alona* (*Alona eximia* Kiser, 1948) was included to study as this species was reassigned to genus *Nicsmirnovius* during my study (Van Damme *et al.*, 2003). These two genera are separated from each other by a number of important differences. The head-pores in *Nicsmirnovius* is unique among chydorids, including the partition of the aesthetascs on its antennule, with one apical, extraordinarily long, three modified internal setae of the exopodite of P3, and the squarish postabdomen. It was found that *A. eximia* shares a number of those morphological characters that separated them from *Alona* Baird, 1843 and place it with *Nicsmirnovius* Chiambeng & Dumont, 1999 (Van Damme *et al.*, 2003).

### *Nicsmirnovius eximius* (Kiser, 1948)

**Synonymy:** Kiser (1948): *Alona eximia* 315-316, figs 1-3; Smirnov, 1971: 390, fig. 467; Chiang Sieh-chin and Du Nan-shan, 1979: 218, figs A-D; Idris, 1983: 95, 97, figs.44 A-E; Sanoamuang, 1998:46; Van Damme *et. al*, 2003: *Nicsmirnovius eximius* 33-41, figs. 1-24.

**Type locality:** Pearl River, Canton, China

**Etymology:** the epitheton '*eximius*' was originally given by Kiser, meaning 'remarkable' in Latin (Van Damme *et al.*, 2003).

**Materials examined:**

*Southern Thailand*: two parthenogenetic females, dissected, from Lum peat swamp, Chumporn Province (9° 41.49' N 95° 07.67' E), collected by the author, SM.

: three parthenogenetic females, of which two completed and one dissected, from Angtong waterfall, Trang Province, Southwest Thailand (7 32.94 N 99 25.05 E), collected in August 1999 by P. Sa_ardrit, SM.

: two parthenogenetic females, completed and dissected, from Pak Panang Bay, Nakorn Sri Thammarat, Southeast Thailand, collected by S. Sangkaew, SM.

*Northeast Thailand*: one parthenogenetic female, completed, from Lake Kud-Thing, Nhong Kaii Province. Collected by C. Saeng-aroon, KKU.

**The details of morphological study**

**Species description** (See figures 46-48)

**Parthenogenetic female**

***General shape:*** Length 0.22-0.29 mm, 1.2-1.4 times maximal height (n=8). Body in lateral view oval to ovoid, largest height around the middle and narrowing posteriorly (figs.46a-c). Antero-ventral portion of valve prominent. Postero-dorsal angle not prominent, postero-ventral margin with three moderately pronounced angles. These angles are correlated with the carapace striation. Ventral carapace margin forming a wide V-shape, ventral embayment before middle (fig.46d). Ventral setae relatively short, end before posteroventral corner, marginal setae of valve longest in antero-ventral portion, Kotov and Sanoamuang (2004) provided there're the series of small setules between marginal setae. Longitudinal valve striation best visible in posteroventral quarter of valve. Granulate polygons, which are internal structures, can be easily mistaken for valve ornamentation.

***Head:*** Relatively small, rostrum typically short, truncated, pointing ventrally (figs.46a-c). Compound eyes present, about same size as ocellus, sometimes larger; distance between eyes and the latter same as between ocellus and rostral tip. Head shield not studied. Three major head pores of same size and according to Frey (1974) connected by a narrow channel, margins of pore field constricted between main pores; two lateral pores, each surrounded by internal 'flower'-shaped structure (fig.46e).

***Labrum:*** Labral keel naked, with 'lateral horns' and rounded to blunt apex (figs.46f-h, 48a-b). Shallow depression in ventral margin near short to slightly elongated apex.

***Postabdomen:*** As for the genus, broad quadrangular in terminal half, dorsal margin and ventral postanal margin parallel, posterior margin straight, at right angles with each other (figs.46k, 48d-e). Postanal margin markedly shorter than anal margin and slender terminal claw. Preanal corner present but small, situated more ventrally than postanal corner. Anal margin relatively straight, angle with postanal margin between 135° and 145°. Lateral fascicles: 7-8 postanal groups, consisting of 8-10 denticles. As Frey (1974) noted, the third or fourth distalmost is the largest within the fascicles. Spinules of four most distal groups reaching beyond dorsal margin of postabdomen, continuing proximally in groups of about 10-13 smaller denticles. Marginal denticles 9-10 groups of merged spinules, of which distalmost slightly larger than following four to six.

***Terminal claw:*** Long and slender (fig.46k). Base of terminal claw prominent, more than half of length basal spine; bearing 5 or more basal spines followed by basal spine reaching half of claw length and implanted at half its own length from claw base. Pecten short, reaching half of basal claw.

***First antenna (antennule):*** Reaching, but not protruding beyond tip of rostrum (figs.46a-c, 48c). Body compact, about twice as long as wide. Distalmost aesthetasc, implanted on elongated apex, 1.5 times as long as antennule and about 2.5 times as long as seven 'normal' aesthetascs (figs.46i, 48c). Subapical aesthetasc of same length as antennule, accompanied by antennular sensory seta, implanted at about one third of distal end.

***Second antenna:*** Basal segment with conical distal spine. Antennal formula spines 0-0-1/1-0-1 setae 0-0-3/0-1-3. Spine on first exopod segment just reaching base of apical exopodal segment, apical exopodal spine larger than endopodal apical spine.

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (figs.47a-b)***:*** Hook-like chitinized seta on IDL relatively slender, reaching half the size of largest IDL seta. Group of large spines present on IDL, close to base of hook-like seta. Two largest IDL setae subequal in length, their second segment unilaterally armed with well-spaced setules. Smallest of IDL setae – not hook like seta-, of same length as ODL seta, the latter more slender and bearing short, hardly visible setules. Third endite with four plumose setae; fourth one slightly more robust and larger than other three. Additional basal seta implanted on inner side of third endite slender, about same length as first apical seta of second endite. Second endite bearing three apical setae, of which 6 (second on the endite) the longest. First endite with two apical setae, of which the second is the longest and bent towards the gnathobase. One extra seta on inner base of second endite, bent towards same endite and slightly longer than additional seta on third endite. Groups of slender spinules present basally on inner side of second and third endites. Basally long and slender ejector hooks, unequal in size. Epipodite and gnathobase not seen.

***Second trunk limb (P2)*** (fig.47c)***:*** Exopodite elongated, bearing setules on slightly inflated apex. Endopodite with eight scrapers, similarly armed with fine denticles and generally decreasing in size towards gnathobase, but seventh scraper longer than scrapers 6 and 8. Gnathobase an elongated lobe oriented towards the scrapers and apically armed with setules, followed by a small receptor and three gnathobasic elements, the middle of which distinctively fish-hook shaped at apex (fig.47d). A pore was observed on the inner side of the gnathobase. Gnathobasic filter comb with 7 setae, of which the first three are relatively shorter than the last.

***Third trunk limb (P3)*** (figs.47e-f)***:*** Epipodite oval. Exopodite small, rectangular, with six setae: two laterally in typical V-formation, first longer than second, followed by four apical setae. Third exopodite seta curved basally, in length about twice of first exopodal seta, followed by fourth seta, about same length of second. Third and fifth exopodite setae of equal length. Distal endite with three setae, armature of first two short and hardly visible, third sparsely plumose. Basal endite with four plumose setae, equal in length. Four soft setae on inner portion, alternating with one regressed seta and three small bumps. One receptor close to gnathobase. Gnathobase with three setae, one large, setulated, curved inwards and two naked and shorter. Filter comb with 7 setae.

***Fourth trunk limb (P4)*** (fig.47h)***:*** Epipodite with globular body and with small bump, no digitiform projection. Exopodite more round than oval, bearing six setae, of which the first two are of equal length, although the first may be shorter. Third exopodite seta 1.5-2.0 times as long as second, followed by short conical fourth seta and typically modified fifth and sixth exopodite setae with blunt apex, and curved subapical aggregation of setules. Endopodite or inner portion with one finely serrulated seta and three 'flaming-torch' setae, followed by round receptor on posterior surface, comparable in size to flaming torch setae. Gnathobase not studied.

***Fifth trunk limb (P5)*** (fig.47i)***:*** Epipodite without elongated digitiform projection. Exopodite with four apical setae, three large on ventral portion. Of which first is the largest and the following two, slightly smaller, are of equal size, and one short, half as long as third seta, followed by small setulated tuft and elongated setulated lobe. Endopodite and gnathobasic seta about equal in size, not curved over elongated lobe. Gnathobase with hardly discriminative structures, among which at least one globular receptor.

**Male:** no male has been examined in the present study. However Van Damme *et al.* (2003) mentioned to one specimen (*Alona eximia*) depicted in Chiang and Du (1979:218), showing gonopore situated on posterior margin ventrally from base of terminal claw, the latter implanted subventrally. Although the depicted male postabdomen seems relatively slender in general view, accompanying drawings of the female also show an atypical postabdomen, and this is probably a result of drawing style. Also noted in the author's drawings, is the relatively more stout and robust copulatory hook on male first limb, quite remarkable compared to other chydorids, and the presence of the long aesthetasc on first antenna. Kotov and Sanoamuang (2004) described male from Mekhong River, Mukdahan, and Northern Thailand. Two characters were suggested as specific for male of *N. eximius*: expression of postanal angle of postabdomen and similar relative size of basal spine in male and female.

**Variability:**

Some variability was noted in these following characters: 1) size of main head pores; 2) shape of ventral margin of labral keel; 3) stoutness of chitinized seta on IDL of P1; 4) length of first exopodal seta of P4 and 5) spinal armature of postabdomen.

**Differential diagnosis:**

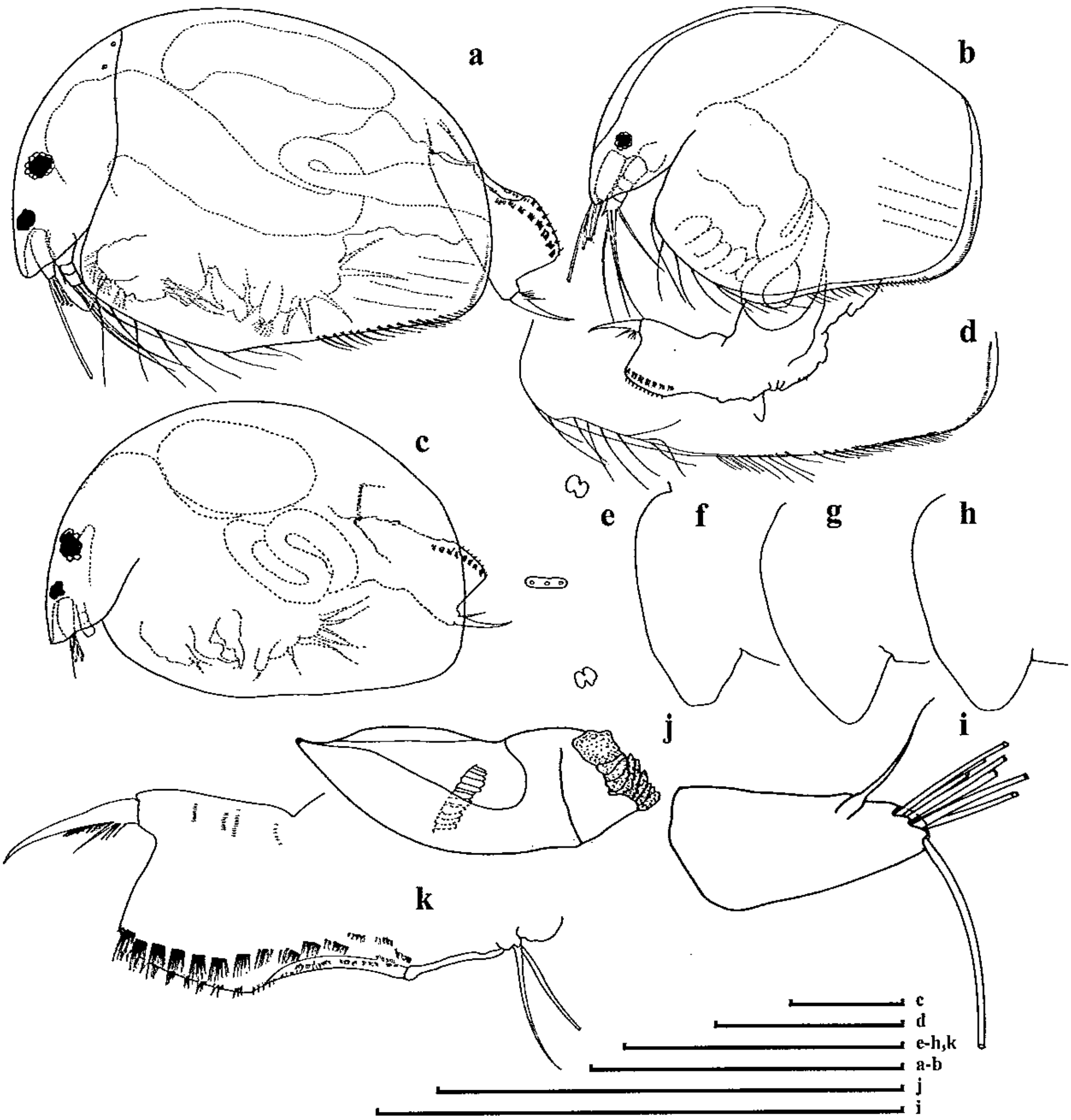
*N. eximius* can be recognized by the relatively short body of first antenna (about twice as long as wide) and the short, rounded labrum. The species closest in morphology is the African congener *N. greeni*, from which it can be distinguished mainly by the shape of the postabdomen, length of the endopodal spine on second antenna, the absence of long fingerlike-projections on epipodites of trunk limbs 4-5 and other features (see Van Damme *et al.*, 2003).

**Biology:**

*N. eximius* is normally found in littoral of clear, slow-running parts of lotic habitats such as streams or river (Frey, 1974), waterfalls, dams and canals. It has occasionally been found also in ponds (Sanoamuang, 1998), lakes or rice fields (Idris, 1983), esturine area (Sangkaew, pers. comm.) and also in our main area of study, *N. eximius* is found in peat swamp, brownish still water. However it was found only few specimens, only in rainy season.

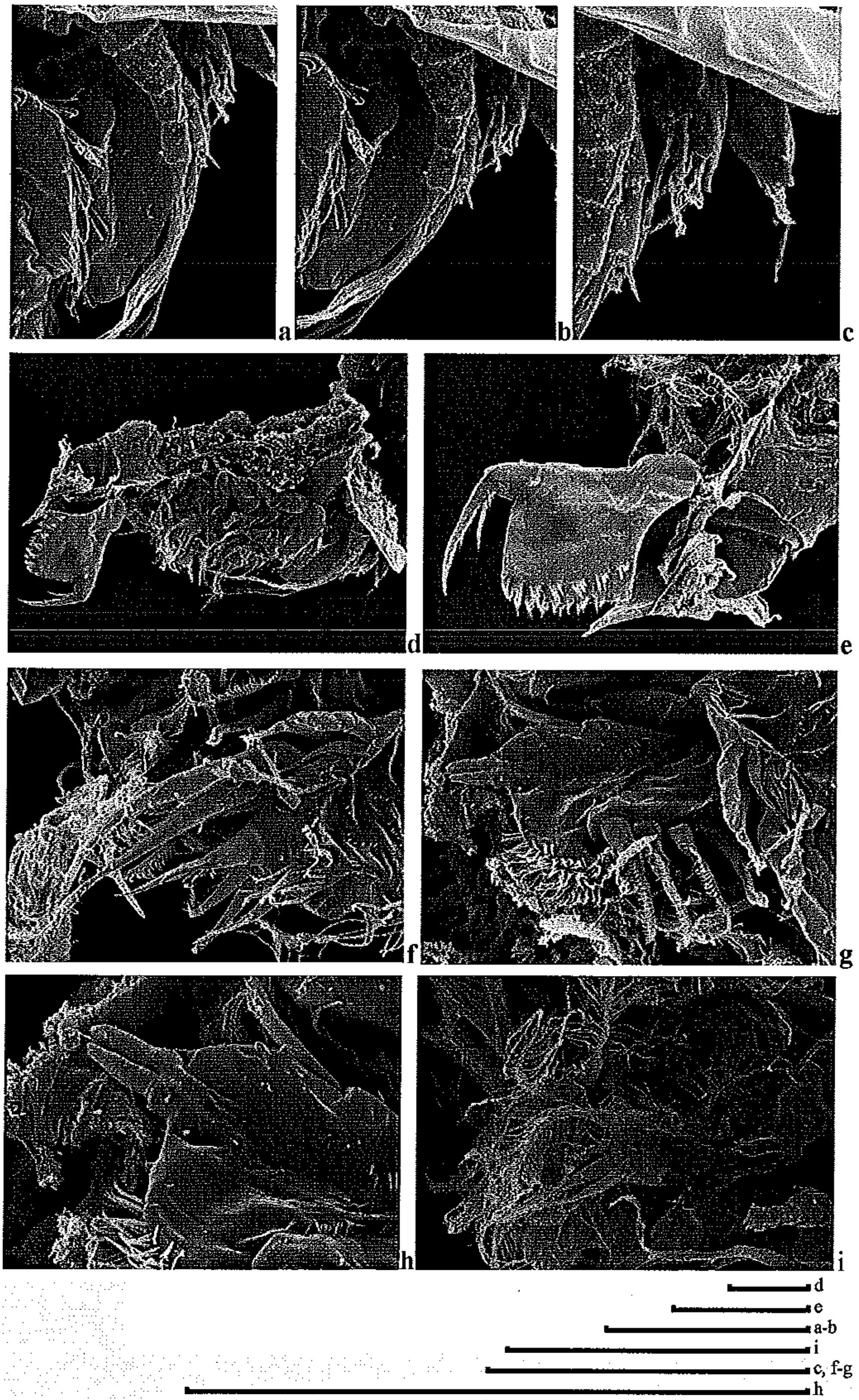
**Distributions:**

South East Asia: northeast (Sanoamuang, 1998), northern (Kotov and Sanoamuang, 2004) and southeastern Thailand (present study); Malaysia (Idris, 1983) and southern China (Kiser, 1948; Chiang and Du, 1979).




Figures 46a-k. *Nicsmirnovius eximius* (Kiser, 1948): parthenogenetic females from Angtong waterfall, Trang Province, southeastern Thailand (a, d-k), from Kla peat swamp, Chumporn Province, southwestern Thailand (b) and from Pak Panang Bay, Nakornsrithammarat Province (c). Figures a-c, adult females in lateral view; Figure d, ventral of valve; Figure e, head pores; Figures f-h, labrum; Figure i, antenna 1; Figure j, mandible; Figure k, postabdomen. Scale bar denotes 100 um.


Figures 47a-i. *Nicsmirnovius eximius* (Kiser, 1948): appendages of females from Angtong waterfall, Trang Province, southeastern Thailand. Figures a-b, trunk limb 1; Figures c-d, trunk limb 2 and its gnathobase; Figures e-f, trunk limb 3 and its gnathobase; Figures g-h, trunk limb 4; Figure i, trunk limb 5. Scale bar denotes 100 um.




Figures 48a-i. *Nicsmirnovius eximius* (Kiser, 1948):appendages of females from Angtong waterfall, Trang Province, southeastern Thailand. Figures a-c, labrum, antenna 1,2; Figure d, trunk limbs and postabdomen; Figure e, postabdomen; Figure f, trunk limb 1; Figures g-h, trunk limb 2 and its gnathobase; Figure i, trunk limb 3-5. Scale bar denotes 100 um.

## 2. Taxonomical study on *Macrothrix* Baird, 1843

### Introduction

The Genus *Macrothrix* Baird, 1843 is the type-genus of the family Macrothricidae Norman and Brady, 1867, subfamily Macrothricinae (Dumont and Silva-Briano, 1998). The name *Macrothrix* was introduced by Baird (1843), as a subgenus of *Lynceus* O. F. Müller, 1776. In 1850 Baird used *Macrothrix* as the name of a separate genus (making no comments on this change; Smirnov, 1992), containing two species, *Monoculus laticornis* Jurine and *M. roseus* Jurine. Subsequently, many authors (Daday, 1898; Vavra, 1900 and Harding, 1955 referred by Smirnov, 1992) used this generic name for species from various regions of the world. At the same time, the genus name *Echinisca* Lievin, 1848 was suggested for one species, *Monoculus roseus* Jurine. Later, Gauthier (1930) and Smirnov (1976; 1982) described several species as members of *Echinisca*. But with accumulating knowledge it became clear that the differences between the two genera are weak at all existent. Sars (1916) still recognized both *Macrothrix* and *Echinisca* as separate genera. New investigations rendered this situation untenable, the generic diagnosis being vague and incomparable.

The necessity for an elaboration of a standard set of discriminating features, including new features, is urgent. So far, the examination of available material and descriptions of *Macrothrix*-like animals has not revealed characters sufficient to specify genera or subgenera within this group but species groups have been revealed to exist. Various species have 3 or 2 setae on the exopodite of limb IV, the antennule dilating distally or rod-like, a prominence on the ventral side of the head or no prominence, long or short distal segment of setae natatoriae (or one of average size), but no correlations suggesting a generic grouping between these characters were found. Therefore, the genus *Echinisca* Lievin, 1848 was finally abandoned and considered as a junior synonym of the genus *Macrothrix* (Smirnov, 1992).

True Macrothricids posses few ancestral features, and may be useful for elucidation of phylogeny and interrelations between highly evolved groups. At the same time, the macrothricids until recently were among the most poorly studied and confused groups of the anomopods. For a long time, they were considered as poorly known morphologically, heterogonous and, probably, a non-natural group (Dumont, 1997). The reasons for the poor state of the systematic of this group are: (1) macrothricids are not common in most faunas, and (2) a geographical restriction is also apparent. Actually, the 'old' macrothricids shared only a single characteristic: the antennule jointed at the ventral side of the head, which is devoid of a rostrum (Smirnov, 1976). This is a polyphyletic character that incorrectly united such unrelated groups as the primitive Acantholeberidae and Ophryoxidae, and true Macrothricidae.

The largest genus of the macrothricidids is *Macrothrix*. It is a cosmopolitan genus, but with several endemic species in Australia (see Griggs, 2001), South America and South East Asia. Smirnov (1992) suggested that there are 34 species of *Macrothrix* in the world, but that number may be underestimated. New species have been established by recent investigations (Ciroz-Prez *et al.*, 1996; Ciroz-Prez and Elas-Gutirrez, 1997; Silva-Briano, 1998; Kotov and Brandoffi, 2004; Kotov, *et al.*, 2004). Smirnov's monograph (1992) was step in our understanding of the systematics of *Macrothrix* but the old and incomplete descriptions and dispersion of the efforts of authors, who described species from one continent without ideas on other continents, remained a problem for the systematic of *Macrothrix*. Moreover, many authors used only local material or only a specific morphotype, instead of global revisions. It is also necessary to keep in mind that a considerable number of species, which were previously regarded as cosmopolitan, holarctic or pantropical, are now known to be species-groups. In recent publications (Dumont and Silva-Briano, 1998; Dumont *et al.*, 2002 and Kotov *et al.*, 2003), authors studied the trunk limb morphology, which was helpful to demonstrate that some species should be synonymised, while other "cosmopolitan species" were focused to consist of many separate species, united in species-group. Many group-level characters were found on the trunk limb (Dumont and Silva-Briano, 1998).

In Thailand, so far ten species of *Macrothrix* have been found: *Macrothrix* cf. *hirsuticornis* Norman & Brady, 1867; *M. laticornis* (Fischer, 1851); *M.* cf. *paulensis* (Sars, 1900); *M. odiosa* Gurney, 1916; *M.* cf. *superaculeata* (Smirnov, 1982);

*M. gauthieri* Smirnov, 1976; *M. spinosa* King, 1853; *M. triserialis* Brady, 1886; *M. flabelligera* Smirnov, 1992, and one new species, *Macrothrix* sp.nov. (Kotov *et al.*, 2004). *Macrothrix* cf. *hirsuticornis* was not found in the present study. *M. laticornis* was found previously in northeastern Thailand (Sanoamuang, 1998) but there are some doubts and questions on the identity of the species which can easily be confused with *M. spinosa*, although both belong to different species-groups (*M. laticornis*-group with a receptor behind scraper 8 of trunk limb 2; *M. spinosa*-group without such a receptor). *M. odiosa* and *M.* sp. were found in Thailand for the first time. The last three species seem to be common in the country.

After decades of frustration it has become evident that a system of features is necessary for a successful resolving of the taxonomic problems, including the investigation of various materials. Such an attempt should also help to clarify the taxonomic status of the *Macrothrix* species found in southern Thailand. The present study is based, at the species-level, mainly on the following characters: general shape, shape and ornamentation of postabdomen, of its seta natatoriae, of the antennule, antenna, of the largest seta of the latter, and of the structure found on the various thoracic limbs. Thus, the present chapter deals with the morphological study and the discussion of the taxonomic status of each species of *Macrothrix*, based on specimens found in southern Thailand.

## Materials and methods

Fixed samples in 4% formaldehyde were sorted under stereo microscope, completed and dissected slides were prepared followed the method mentioned in Chapter 2. Materials for each studied species were listed in the following details of each species.

## Results

There are eight *Macrothrix* species were recorded in the present study. Three of them; *Macrothrix paulensis, M. odiosa* and *M.* sp. were placed into *Macrothrix paulensis* group. Other two; *M. triserialis* and *M.* cf. *superaculeata* were placed into *Macrothrix rosea-triserialis* group and the rest three; *M.* cf. *laticornis, M.* cf. *gauthieri* and *M. spinosa* were not put in any group.

The results are subdivided into three sections: 1) *Macrothrix paulensis*-group and 2) *Macrothrix rosea*-group and 3) Three other *Macrothrix* species

## 1. *Macrothrix paulensis*-group

There are three *paulensis*-like species; *Macrothrix paulensis* (Sars, 1900), *M. odiosa* Gurney, 1916, and *M.* sp.. A closest relative is *M. malaysiensis* Idris & Fernando, 1981 (Kotov *et al.*, 2004), but it has not yet been found in Thailand. However, it was also included in the discussion. *M. paulensis* has been recorded for a long time in South America and it was recorded twice in Thailand, once from the Northeast (Sanoamuang, 1998) and another time from Trang Province, Southern Thailand (Sa-ardrit, 2002). We found two specimens in the present study. *M. odiosa* and *M.* sp. are the first time recorded in the country.

**Basic characters of *Macrothrix paulensis*-group**

Members of *M. paulensis*-group show the following characters:

1) Labrum : large, triangular
2) First antenna : large spines at inner margin
3) Second antenna : two rows of rare, robust element (IV) in distal half of the largest lateral seta
4) P1: single ejector hook, two setae on gnathobase
5) P2 : no extra receptors, scraper 5 with enlarged subapical tooth, large additional seta on gnathobase
6) Postabdomen: sub-quadrangular

In general, the labrum in *Macrothrix* is not large, commonly sub-quadrangular (Silva-Briano, 1998; Kotov, 1999) but *M. paulensis*-group is an exception to this rule: a large, triangular labrum is a synapomorphy of this group. A subtriangular-subquadrangular shape of labrum also found in the *M. triserialis*-group but it is not so large (shorter than the ventral margin of the head, in contrast to *paulensis*-group). The presence of large spines at the inner margin of antenna I is also a synapomorphy uniting the species, highly valuable from a cladistic point of view (Kotov *et al*, 2004). These spines most probably originated as a result of an increasing in size of the marginalmost members of crossing rows of denticles, which are present on antenna I in all species in *Macrothrix*. This is a new example of oligomerization in the evolution of the Anomopoda. The largest seta of antenna II is an important structure for the systematics of genus *Macrothrix* (Smirnov, 1992; Silva-Briano, 1998). In primitive species, this seta is armed with two rows of fine spinules (Kotov, 1999). Two rows of rare, robust spinules in its distal half is one of variants of modification of this seta, which seems to be a synapomorphy of the *M. paulensis*-group. Previously the ejector hooks were not regarded as taxonomically important, and were not described in many recent articles (Silva-Briano *et al.* 1999; Dumont *et al.* 2002). As a result, we have no information on their number in closest species (i. e. *M. capensis* Sars, 1916). Dumont and Silva-Briano (1998) concluded that presence of two ejector hooks is a diagnostic trait of the order Anomopoda but there are exceptions from this rule, i.e. *M. paulensis*-group, or some ilyocryptids i.e. *Ilyocryptus acutifrons* Sars, 1862 (see Alonso, 1996). Kotov (unpublished) found a single ejector hook on limb I of *M. atahualpa* Brehm, 1936, so this character is not unique for *paulensis*-group, although, it is possible that may be the latter species is the closest relative of this group. A sub-quadrangular postabdomen is not indeed a unique trait of *paulensis*-group, because some species from *triserialis*-group also have a similar postabdomen (see Dumont *et al.* 2002, Kotov *et al.* 2003), but this character can distinguish the group from the *M. laticornis, M. spinosa* and *M. hirsuticornis*-groups.

## 1. *Macrothrix paulensis* (Sars, 1900)

**Synonymy:** Sars, 1901: Des. 31-32, no fig. (*Iheringula paulensis*); Brehm, 1938: Descr: 97-99, figs.3-4 (*Iheringular paulensis* G. O Sars); Smirnov in Brandorff *et al.*, 1982: 95, fig. 80 (*Echinisca paulensis*); Zoppi de Roa and Vasquez, 1991: Des. 55, fig. 8 (*Iheringular paulensis*); Sanoamuang, 1998: figs. 15-22.

**Type locality:** Sao Paulo (Brazil)

**Materials examined:**

*Southern Thailand*: two parthenogenetic females dissected, from Thungtong swamp, Bannaderm District, Suratthani Province, Southeastern Thailand (8° 52.66'N, 99°11.83'E), Temperature 29°C, pH 6.4, Conductivity 0.39 and salinity 0 ppt., collected date 01-10-1999 by the author, SM.

*Brazil* : one dissected parthenogenetic female from Brazil.

**The details of morphological study**

**Species description** (See figures 49-50)

**Parthenogenetic female**

***General shape*** (fig.49a) *:* Body of large adult female ovoid in lateral view, with maximum height in the middle of valve, maximal length 0.8-1.0 mm, about 1.5-1.6 times of maximum height in largest females, maximal height 0.5 mm (n=2). Dorsal margin regularly arched from tip of rostrum to posteriormost point. Low bulb between head and the rest of body. Dorsal margin of valve not elevated above dorsal margin of head, or slightly elevated, almost straight, valve margin serrate. Ventral margin concave, with serrations and setae.

***Head:*** of medium size. In lateral view, dorsal margin evenly convex, with low dome above eye (fig.49a), ventral margin without ridges and without projection at base of labrum. Compound eyes relatively large, located within a low ocular dome. Ocellus small, located closer to tip of rostrum than to eye.

*Valve* (fig.49b)*:* dorsal margin slightly convex, with serration. Ventral margin of valve arched, distinctly serrated, with marginal setae variable in length and size in different individuals, outline of alternation such as: long and large ones, protruding laterally; long and slender ones, and short ones, protruding ventrally.

***Thorax, Abdomen*:** short

***Postabdomen*** (fig.49g)*:* large, sub-rectangular in lateral view, low, with a truncated distal extremity, and a rudimentary heel. Ventral margin slightly convex, almost parallel with dorsal. Dorsal margin slightly curved. A flap on postanal part. Preanal margin long, almost straight, with short, strong setules, not clearly organised in transverse rows. In basal portion, these setules shorter than the other setules. Anal margin with rows of small setules, long hair-like setules here. In region of dorso-distal angle, rows of somewhat larger setules. Laterally to marginal rows there are series of finer setules. Small postanal margin with a group of short setules. Few groups of large anal teeth on postanal portion, with largest at ventral portion, whole dorsal side of postabdomen with numerous rows of spinules, of similar size and length, but somewhat longer in distal part.

***Postabdominal claws:*** relatively small comparative with postabdominal size (fig.49g), protruding dorso-distally, slightly and regularly bent, with pointed tip and relatively wide base in lateral view. On claw, inner dorsal row with four robust denticles.

***First antenna (antennule)*** (figs. 49c-d)*:* "rod-like" in terminology of Smirnov (1992), straight to slightly curved, with low subapical external angulation, a slender sensory seta here externally at a distance of antennular diameter from antennule joint. About 3-5 relatively large denticles at inner margin of antenna I, transverse rows of spinules on its anterior surface poorly visible under optical microscope, but were found under SEM (Kotov and Hollwedel, 2004). Distal end aslant truncated, with groups of robust spinules. Among nine terminal aesthetascs one very long, second shorter and thicker, others seven smaller and different in size, each with two minute 'claws' at the apex.

***Second antenna*** (figs. 49e-f)*:* moderately long, coxal region folded. Basal segment robust, bearing few rows of fine spinules. Distal burrowing spine as long as basal segment of exopod, naked, located on outer (anterior) surface, close to the end of basal segment. Antennal branches long, first segment of exopod shortened, segments 2-3 elongated, subequal in length, segment, fourth segment longer that each of them. Endopod with middle segment shorter than other segments, first segment longest, groups of setules around basal end of all segments of endopod and exopod.

Antenna formula, setae 0-0-1-3/1-1-3, spine 0-1-1-1/0-0-1, but additional, unjointed, bent spine on second segment of exopod. All spines shorter than half of length of their segments.

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (figs.50a-d)*:* large. Outer distal lobe (ODL) cylindrical, a long apical seta with distal segment unilaterally armed with short fine setules (fig. 50a), and a short lateral seta setulated distally. Inner distal lobe (IDL) massive, with three series of strong setules marginally, members of distal series specially strong, a single series of finer setules more redial, distally three bi-segmented setae of different size, the middle one a half as long as the longest, each unilaterally setulated in distal part. Groups of setules on their body lobe.

Endite 3 (E3) with four setae (1-4), seta 1 curved-like seta, large with fine setule unilaterally distal end and five small spines basal end, seta 2 naked and slender, more slender distally, setae 3, 4 bi-segmented, more robust basally, seta 4 longer than seta 3, bilaterally armed with two rows of robust setules. Endite 2 (E2) with three long slender bi-segmented setae (5-7) of subequal in size, bilaterally armed with two rows of setules at distal and basal parts. Endite 1 (E1) with two long bi-segmented setae (8-9) setulated in different manner, seta 8 with long setules a half of distal part but with unilaterally short setules distal end, seta 9 fully setulated with long setules along distal part and small setules between them. Forks on endite 1 and endite 2 pincer-shaped (figs. 50c-d), pincer part 1/3 as long as fork body, left side without tooth and right side with two teeth, length of left and right side equal, though right side may be shorter in some specimens. Single ejector hook large, distal segment unilaterally armed with small spines, counting about 10 spines. On limb base, a hillock with two fully setulated setae-a remainder of gnathobase I.

***Second trunk limb (P2)*** (fig.50e)***:*** At base of limb externally a hillock with bunch of robust, long setae, probably, homologous to pre-epipodites of P4-5. Exopodite (EX) a sub-quadrangular lobe with a bilaterally incurved setulated seta. Endopodite (EN) with eight scrapers, their length increasing distally, scrapers 1, 2 bi-segmented, slender, unilaterally setulated with delicate setules distally, setae 3-4 and 6-8 bi-segmented, similar in setae arrangement with fine tooth, seta 5 broad-based, bi-segmented, with strong tooth distally, counting 11-12 tooth, one large and stronger tooth near apex.

Distal armature of gnathobase (GT) with three elements (I-III): element I setulated distally, element II naked, hook-like and one element III-like seta, smaller, feathered distally, located a half way of gnathobase and filter comb. Gnathobasic filter comb with four subequal in length setae, the first seta shortest and the fourth seta broader base, all unilaterally setulated from based to tip, armature similar.

***Third trunk limb (P3)*** (figs. 50f-g)***:*** Exopodite (EX) large and flat (fig.50f), with three setae of different size distally (1-3), Outermost seta 1 longest, 2-2.5 times as long as setae 2-3, bilaterally setulated from base to tip, near this seta a row of setules, anteriormost setae 2-3 closely apposed, seta 2 with broaden base, bilaterally setulated with long setules from base to tip, smaller setules between them distally, seta 3 shorter, almost naked, few setules close to distal end. Endopodite (EN) bilobed (fig.50g). Outer lobe (External Endite = EE) with two rows of setae. Anterior row with three setae (1-3), setae 1 and 2 large, stout, unilaterally setulated distal part with short setules, seta 3 shorter, unilaterally setulated with long setules from base to tip. Posterior row with three setae (1'-3'), seta 1' long curved, naked, seta 2' curved, longest, bilaterally setulated distally with long setules, seta 3' wider base and thin distally, bilaterally setulated. Inner lobe (Internal Endite = IE) with two rows of setae. Anterior row with three setae (4-6), of similar in length, bilaterally setulated, longer setules basally. Posterior row with four setae (4'-7'), seta 4' bottle-like, naked, seta 5' long and slender, setae 6', 7' similar in length, seta 7' naked.

***Fourth trunk limb (P4)*** (fig.50h)*:* Exopodite (EX) small, with two robust feathered setae, different in length (1:2.5). Endopodite (EN) with two rows of setae. Anterior row with five setae (1-5), seta 1 with hook-like tip, setae 2-4 'flaming torch', broad at base, with distal cluster of dense setules, seta 5 bottle-shaped, naked. Posterior row with five setae (1'-5') slender, feathered distally.

Distal armature of gnathobase (GT) with three elements (I-III), element I 'horse-tail' seta like typical, element II long, rod-like and element III tri-lobed, smallest, both naked. Gnathobasic filter comb not seen.

***Fifth trunk limb (P5)*** (fig.50i)*:* Pre-epipodite (PEP) not seen. Epipodite (EP) a round big lobe. Exopodite (EX) with one long seta, bilaterally setulated. Endopodite (EN) a large flap, fringed by short setules, on inner margin one small seta.

**Variability:**

Unfortunately, we could not study variation because of the rarity of the species in the present samples.

**Differential diagnosis:**

*M. paulensis* can be distinguished from other members of the group by the following characters 1) ventral head margin without projection and 2) long hairs on anal margin of postabdomen.

**Remarks:**

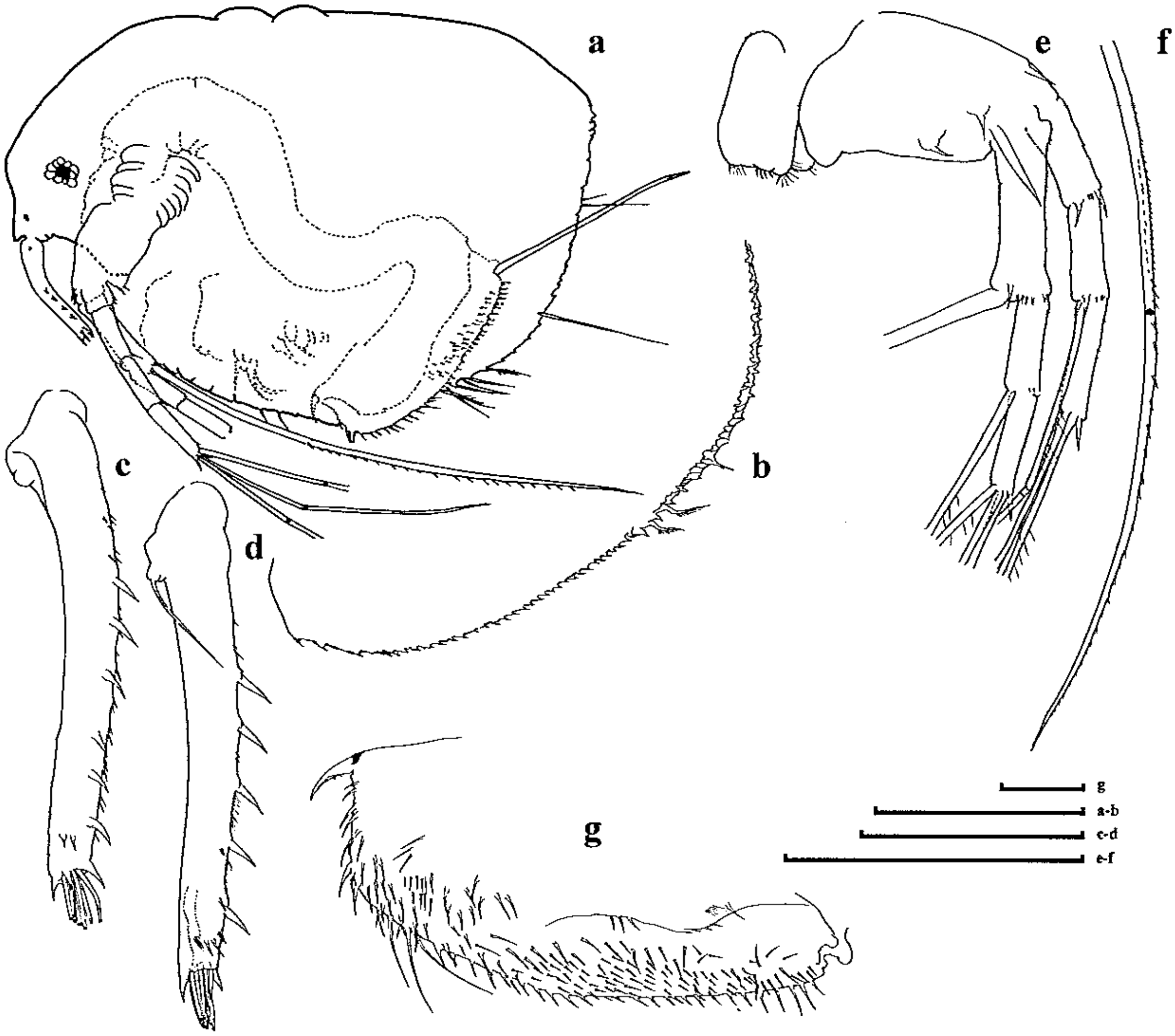
Only two specimens were found in the present study. Distinguished by having long hairs-like setules on anal margin of postabdomen (Kotov and Hollwedel, 2004); first antenna has more than five spines along its side and postabdomen quadrangular (Smirnov, 1992). The latest character differs from the specimens described from northeast Thailand, which show an oval-shaped postabdomen (Sanoamuang, 1998).

**Biology:**

Prefers shallow lakes with much vegetation. Not very active; sits mostly on plants and feeds there (Sars, 1901). In the present study, found in freshwater marsh with mud and vegetation, especially in places covered with *Nymphea* spp. Found only in dry season, when the area has less water.

**Distribution:**

*South America, Australia and Southeast Asia*: Sao Paulo, Brazil (Sars, 1901); The River Nhamunda in Brazil (Brandorff, Koste and Smirnov, 1982); Florida (Frey, 1988b); Venezuela (Zoppi de Roa and Vasquez, 1991); Australia (Sanoamuang, 1998) Northeast Thailand (Sanoamuang, 1998); Southeastern Thailand (Sa-ardrit, 2002).




Figures 49a-g. *Macrothrix paulensis* (Sars, 1900): parthenogenetic female from Thungtong swamp, Suratthani Province, southeastern Thailand. Figure a, adult female in lateral view; Figure b, ventral of valve; Figures c-d, antenna 1; Figures e-f, antenna 2 and its largest lateral seta; Figure g, postabdomen. Scale bar denotes 100 um.


Figures 50a-i. *Macrothrix paulensis* (Sars, 1900): appendages of females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figures a-b, trunk limb 1 and its inner and outer distal lobe; Figures c-d, Fryer's forks on trunk limb 1; Figure e, trunk limb 2; Figures f-g, exopodite and endopodite of trunk limb 3; Figure h, trunk limb 4; Figure i, trunk limb 5. Scale bar denotes 100 um.

## 2. *Macrothrix odiosa* Gurney, 1916

**Synonymy:** Gauthier, 1930: 95-98, fig. 2, (*M. capensis* var. *Monodi*); Brehm, 1930; 682-683, fig. 3 (*Gurneyella*); 1933: 691-693, figs. 17-20 (*Gurneyella sumatrensis, Gurneyella madagascariensis*); 1934a: 59-61, figs. 4, 5, 6, (*Gurneyella monodi*); 1938a: 26-27, Abb. 1, 2, 3 (*Macrothrix tenuicornis* var. *maxima*); 1952: 41-42, figs. 4, 5; Rammner, 1937: 44-45, figs. 6-9 (*Guerneyella sumatrensis*); Rey and Saint-Jean, 1969: 29-31, fig. 8 (*Guerneyella monodi*), Smirnov, 1976a: 118-130, figs. 94-96, 103, 109-111 (*Echnisca odiosa, Echinisca capensis monodi, Echinisca sumatrensis, Echinisca madagascariensis)*; Dumont and Van de Velde, 1977: 85-87, fig. 5 (*Macrothrix monodi*); Idris and Fernando, 1981: 238-239, figs. 11-15 (*capensis monodi*); Korinek, 1984: 51-52, pl. XXVIII.

**References:** Gurney, 1907; p.335, 25, pl.1: figs.1-2, pl.2: fig.22; Brehm, 1952; p.41-42, figs.4-5; Behning, 1938: 294, fig. 2; 1941: 225-227, fig. 97.

**Type locality:** *M. odiosa* Gurney, 1916 was first described from two localities: "Perendeniya pond" and "at Anuradhpura", in Sri Lanka. Previously this taxon was described as *M. tenuicornis* Gurney, 1907 (junior homonym of *M. tenuicornis* Kurz, 1875) from "swamp without shade; not many plants" and "large, shallow tank without shade; weeds abundant" both in Chakradharpur, Chaibassa District, Chota Nagpur, India.

**Type material:** There are no slides or tubes with "*M. tenuicornis*" Gurney, 1907 and *M. odiosa* Gurney, 1916 in Gurney's collection in the NHM; A. Cabrinovich (Kotov *et al.*, 2005), so the types are apparently lost.

**Materials examined:**
*Southern Thailand:* three parthenogenetic females, examined complete and thereafter dissected, from Thungtong swamp, Kiensa district, Surattani Province, Southeastern Thailand (8° 52.66'N, 99°11.83'E), Temperature 29°C, pH 6.4, Conductivity 0.39 and salinity 0 ‰, collected date 01-10-1999 by the author, SM.

: four parthenogenetic females, examined completed and thereafter dissected, from Tha-le songhong swamp, Yanta-khao District, Trang Province, Southeastern Thailand, collected by P. Sa-ardrit, SM.

**The details of morphological study**

**Species description** (see figures 51-53)

**Parthenogenetic female**

***General shape*** (figs.51a-g, 53a)***:*** Body of large adult female ovoid in lateral view (figs. 51a-b, 53a), with maximum height in the middle, maximal length 0.9 mm, about 1.4-1.5 times of maximum height in largest females, maximal height 0.57 mm (n=8). In anterior view (figs.51f-g), body somewhat compressed laterally, with low, but distinct dorsal keel. Dorsal margin regularly arched from tip of rostrum to posteriormost point, but interrupted by a low dome over compound eye, and a shallow depression posterior to dorsal head pore. Dorsal margin of valve not elevated above dorsal margin of head, or slightly elevated, almost straight, valve margin serrated, the dorso-posterior angle of the shell as elongated, pointed spine. Ventral margin concave, with serrations and setae.

***Head:*** of medium size, head length from tip of rostrum to border with valves makes up to 0.2-0.29 times of body length. In lateral view (figs.51a-b), dorsal margin evenly convex, with a low dome above eye, ventral margin with rounded projection with a tendency to be doubled (symmetrical to vertical body axis), without ridges and without projection at base of labrum. Rostrum not well developed, a fold from tip of rostrum to mandibular joint a fornix. Compound eyes relatively large, located within low ocular dome. Ocellus small, located slightly closer to tip of rostrum than to eye. In anterior view, rostrum compressed laterally, with small split-like frontal head pore close to frontal edge. Dorsal 'head pore' relatively small, ovoid, with thin ring around it, located on posterior part of head shield.

***Labrum:*** wide, spade-shaped in ventral view. In lateral view (figs.51a-b), subtriangular, with somewhat prominent postero-ventral angle and setulated distal plate.

***Valve:*** dorsal margin slightly convex, lacking serration. Ventral margin of valve arched (figs.51a-e, 53b-c), serrated, with numerous marginal setae, variable in length and size individuals: long and large one alternatively, protruding laterally; long and slender ones, and short ones, protruding ventrally, as in *M. paulensis* and other congeners (Kotov and Hollwedel, 2004).

***Thorax, Abdomen:*** short

***Postabdomen*** (figs.51k-l, 53h)*:* large, sub-rectangular in lateral view low, with truncated distal extremity, and rudimentary heel. Ventral margin slightly convex, almost parallel with dorsal, sometimes with bunch of strong setules, dorsal margin slightly bi-lobed, due to shallow depression near basal boundary of anus, but in some specimens not obvious. A flap on postanal part. Preanal margin long, almost straight, with short, strong setules, not clearly organised in transverse rows, in basal portion, these setules shorter than the other setules. Anal margin with rows of small setules, no hair-like setules here. At sides of anus, relatively large, sub-triangular anal flaps of unknown function, reported by Gurney (1907, 1916) and Kotov *et al.* (2004) as main diagnostic trait of this species. In region of dorso-distal angle, rows of somewhat larger setules. Laterally to marginal rows, series of finer setules. Small postanal margin with group of short setules. Few groups of large anal teeth on postanal portion, largest at ventral portion, whole dorsal side of postabdomen with numerous rows of spinules, of similar size and length, but somewhat longer in distal part. Seta natatoria with short segment bearing long setules (fig.51m). Obscure sculpture as longitudinal lines on sides of postabdomen visible under SEM (fig. 53h).

***Postabdominal claws:*** relatively small comparative with postabdominal size (figs.51k-l), protruding dorso-distally, slightly and regularly bent, with pointed tip and relatively wide base in lateral view. On claw (figs.51n-o), outer dorsal row of numerous delicate denticles; medial ventral row of about 5-7 fine denticles, and inner dorsal row with numerous denticles, two of them very robust. (two pectens of denticles in each claw: short fine setules on outer dorsal side (about 7-9 denticles), and the series of 15-23 denticles on ventral side, these more robust than the former).

Postabdominal seta as long as postabdomen (fig.51m), stiff, with short distal segment, supplied with rare long setules, lost in many individuals. No setules on basal segment.

***First antenna (antennule)*** (figs.51h-j)***:*** "rod-like" in terminology of Smirnov (1992), straight to slightly curved (figs.51h-i), with low subapical external angulation, a slender sensory seta here externally at a distance of antennular diameter from antennule joint. About 3-5 spines at inner margin of antenna 1. Distal end truncated (fig.51j), with groups of robust spinules. Among nine terminal aesthetascs one long, second shorter and thicker, other seven smaller and different in size, each with two minute 'claws' at the apex.

***Second antenna:*** moderately long (figs.51a, 52a, 53b, d), coxal region folded, concertina-like, with two small sensory setae. Basal segment robust, bearing transverse rows of fine spinules, bisegmented distal sensory seta at inner (posterior) margin, this seta reaching third exopod segment. Distal burrowing spine as long as basal segment of exopod, naked, located on outer (anterior) surface, close to the end of basal segment. Antennal branches long, first segment of exopod shortened, segments 2-3 elongated, subequal in length, segment, fourth segment longer that each of them. Endopod with middle segment shorter than other segments, length of endopod segments slightly increase from basal to distal one, groups of setules around basal end of all segments of endopod and exopod.

Antenna formula, setae 0-0-1-3/1-1-3, spine 0-1-0-1/0-0-1; an additional, unjointed, bent spine on second segment of exopod. All spines shorter than half of length of their segments, true spine pointed with slightly curved. Length of apical swimming setae subequal, approximately equal to length of basal segment plus length of branch, lateral seta on third segment of exopod shorter than apical seta, lateral seta on second segment of endopod similar to apical setae, lateral seta on first endopod segment remarkably larger than any other setae (figs.52b-c), protruding significantly behind them, armed with a row of robust, sparse spinules along dorsal margin (fine setules between these spinules), and other row of shorter spinules along external side. Apical spines short, straight. A single true spine on second segment of exopod, shorter than 1/3 the length of this segment; series of additional spines on first exopod segment, large additional spine on second and third exopod segment, plus big additional spine on first endopod segment.

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (figs.52d, 53e-f)***:*** large. Accessory seta absent, outer distal lobe (ODL) cylindrical, a long apical seta with distal segment unilaterally armed with short fine setules, and a short lateral seta setulated distally. Inner distal lobe (IDL) massive with four setae in different series; strong setules marginally; distal series specially strong and single series of finer setules more medially, distally three bi-segmented setae of different size, each unilaterally setulated in distal part; the smallest un-segmented, naked.

Endite 3 (E3) with four setae (1-4). Seta 1 large, elongated (but not as long as in *M. paulensis*) and curved, with fine setule unilaterally and the rest three relatively short bi-segmented setae, seta 2 smallest and slender, unilaterally armed with fine setules basal and distally, setae 3, 4 bi-segmented, bilaterally armed with two rows of robust setules. Endite 2 (E2) with three long slender bi-segmented setae of subequal size (5-7) with dense setulated at its distal section and quite distance in basal section. Endite 1 (E1) with two bi-segmented setae (8-9) setulated in different manner, seta 8 slender with unilateral setulation at its distal segment, seta 9 slender, setulated distal and basally, 2 basalmost longest. Forks on endites 2 and 3 pincer-shaped (figs. 52d, 53f), pincer part as long as basal, left side with one tooth, right side without tooth, left pincer length as long as right side. Single ejector hook with distal segment unilaterally setulated. On limb base, a hillock with two fully setulated setae-a remainder of gnathobase P1.

***Second trunk limb (P2)*** (figs.52e-h, 53g)***:*** at base of limb externally a hillock with bunch of robust, long setae, probably homologous to pre-epipodites of P3-P5.

Exopodite (EX) a sub-quadrangular lobe with two bunches of setules along outer margin, and a short, setulated seta. Endopodite (EN) with eight robust scrapers with length increasing distally, scrapers 1 longest, bi-segmented, sparsely setulated distally, scraper 2 more curved, bi-segmented, with relatively delicate feathering, scrapers 3-4 bi-segmented, with short-fine setules distally, scraper 5 bi-segmented, longer than scraper 4, with specially robust denticles, about 10 tooth and one strong tooth distalmost, scrapers 6-8 bi-segmented, with similar in tooth arrangement, counting 9, 6, 6 tooth respectively, decreasing in length distally. No sensillium between scraper 8 and gnathobase (GT).

Distal armature of gnathobase (GT) with four elements (I-IV) (figs.52e, h): element I a conical-structure, naked, more robust; element II feathered distally; element III (internalmost) well developed, seta sloped, naked, base fused with element II. An additional large fourth seta-like element (IV), located a half way to filter comb. Gnathobasic filter comb with four setae of similar in length, base wider posteriorly, setulated from base to tip.

***Third trunk limb (P3)*** (fig.52i)***:*** Exopodite (EX) large and flat, with four setae (1-4). Outermost seta 1 setulated from base to tip. Seta 2 longest about 2-2.5 times of other seta, setulated, between seta 1 and 2 about four bunches of setules. Anteriormost setae 3-4 closely apposed, with shorter distal setules, especially seta 4. Endopodite (EN) bilobed. Outer lobe (External Endite = EE) with two rows of setae. Anterior row with three setae (1-3), seta 1 short, armed with short setules distally, seta 2 longer, with unilateral well-space distal setulation. Seta 3 long. Posterior row of three setae (1'-3'), setulated. Inner lobe (Internal Endite = IE) with two rows of setae. Anterior row with four setae (4-7), seta 4 slender, curved-like seta, a small sensillium (sn) near seta 4, setae 5-7 similar in length and shape, all setulated from base to tip. Posterior row with three bi-segmented more slender setae (4'-6'), unilaterally setulated.

Gnathobase (GT) elongated, with four elements (I-IV), element I bottle-shape, element II-IV hook-like, setulated distally. Gnathobasic filter comb absent.

***Fourth trunk limb (P4)*** (fig.52j)***:*** Exopodite (EX) rectangular, small, with two plumose setae of different size, seta 1 slender and longer then seta 2 2.5 times.

Endopodite (EN) with two rows of setae. Anterior row with four setae (1-4), seta 1 slender, unilaterally setulated basally, armed with small setules distally (hardly visible), seta 2-4 'flaming torch' setules, followed by an elliptical naked seta (5). Posterior row with filter comb of five setae (1'-5'), increasing in length distally, setulated distally.

Distal armature of gnathobase (GT) with three elements (I-III), element I a back turned 'furry' seta ('horse-tail' seta), unilaterally setulated, element II rod-like, thin and long as a half of element I, element (III) leaf-like, both element II, III naked. Gnathobasic filter comb absent.

***Fifth trunk limb (P5)*** (fig.52k)**:** Large. Pre-epipodite (PEP) three rounded-lobed, with fine radial setules. Epipodite (EP) small, globular. Exopodite (EX) a small projection with a single seta. Endopodite (EN) large flap, fringed by short setules. Inner margin with three setae with size significantly increasing distally, setulated projection at limb base, remainder of gnathobase.

**Variability:**

Variation can occur in 1) size range from 0.40 -1.03 mm: parthenogenetic females from southern Thailand 0.57-0.9 mm (n=5), according to Kotov *et al.* (2004) parthenogenetic females from Lake Kud-thing, northeast Thailand 0.52-0.85 mm (n=20), ephippial female 0.63 mm (n=1); parthenogenetic female from Bhiloga Tank, India 0.62-1.03 mm (n=10). According to Gurney (1907), maximum size is 0.95 mm; according to Smirnov (1992), minimum size is 0.40 mm.; 2) number of spines on antennular body range from 3-5 spines and 3) variation occurs between juvenile and parthenogenetic female in these following characters (Kotov *et al*, 2004); in juvenile body shorter and more sub-quadrangular because dorsum of valves almost straight; border between head and valves expressed or not, smooth postero-dorsal angle located at level of dorsum. Second antenna armed analogously to that in adult.

**Differential diagnosis:**

*M. odiosa* can be distinguished from other species by: 1) the postero-dorsal angle is not shaped as a spine; 2) no serration on dorsum but presence on ventral valve margin and 3) the presence of anal flaps on postabdomen (as in *M. malaysiensis* and *M.* sp.)

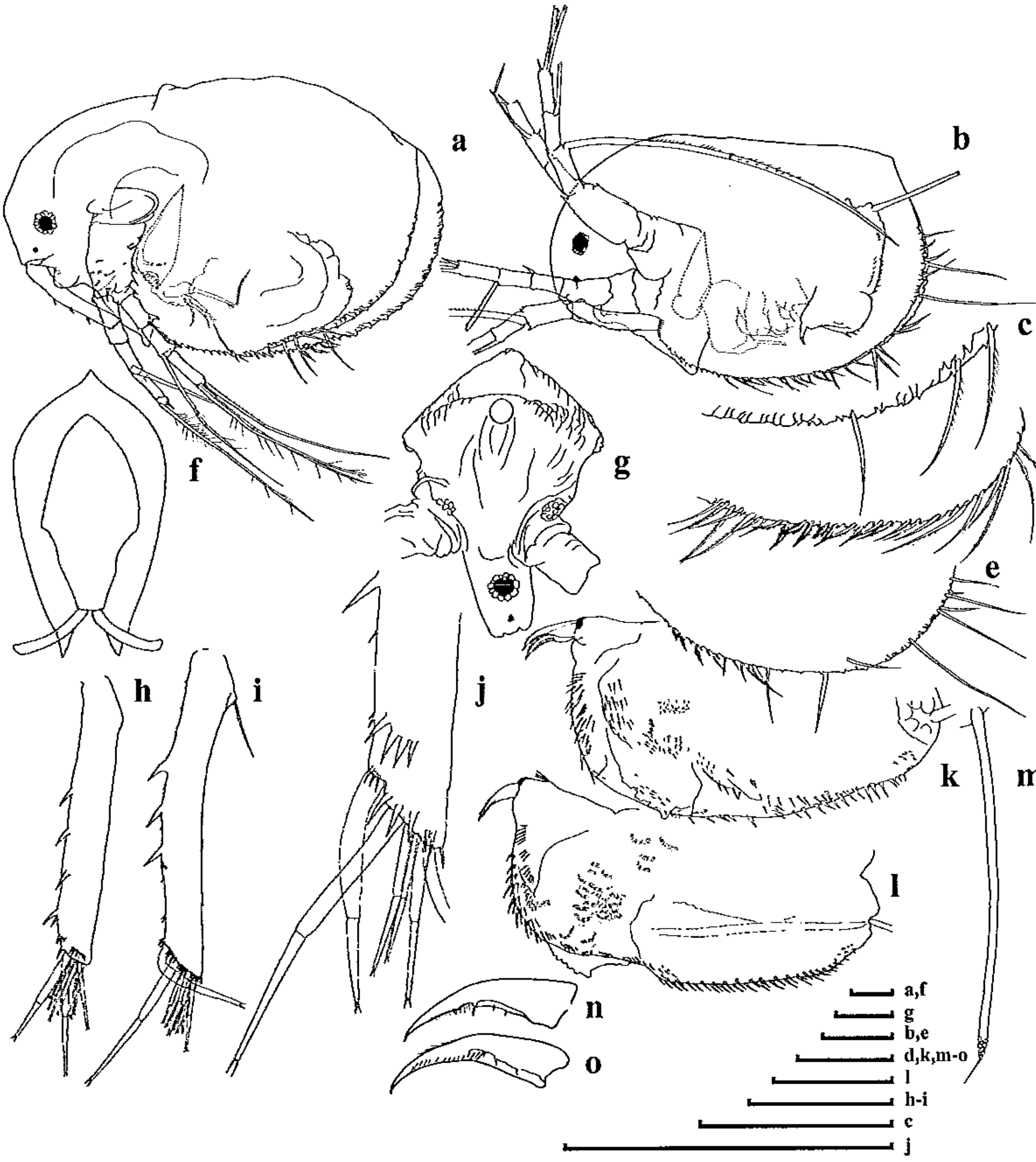
**Biology:**

Predominantly found in the littoral zone with vegetation but found in small numbers in the present study. Gurney (1916) noted that it was more abundant in samples taken at night than during the day.

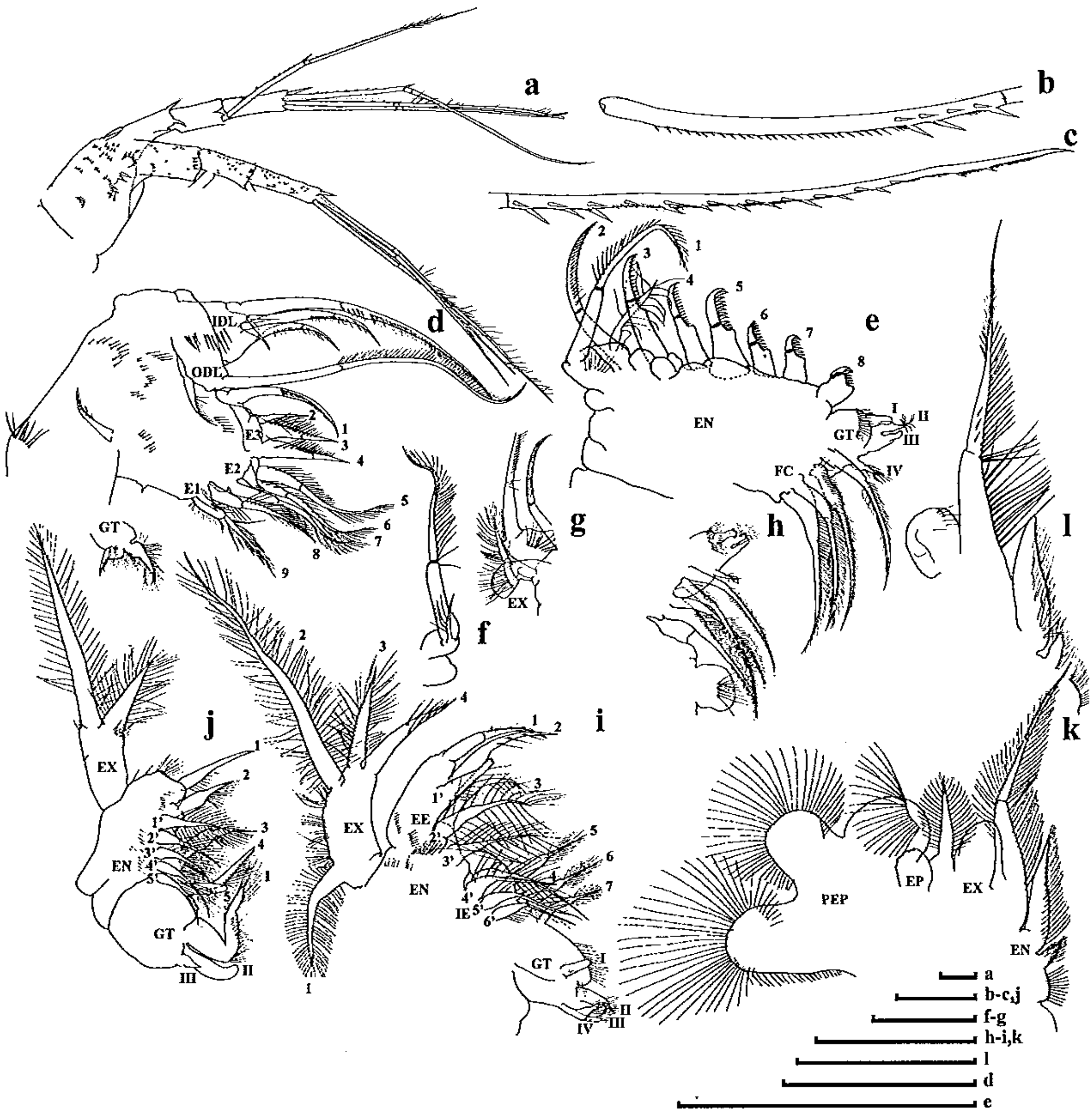
**Distribution:**

*M. odiosa* is known from many countries of subtropical and tropical Asia, i.e. Armenia, Uzbekistan and Tajikistan (Behning, 1941; Smirnov, 1976), Sri Lanka, India and Malaysia (Smirnov, 1992), Thailand (our data) and islands between Asia and Australia, i.e. Sumatra (Brehm, 1930) and Java (Rammnar, 1937), but it has never found in Australia (Shiel and Dickson, 1995; Smirnov, 1995). Also populations of this species, or its congeners, were found in a series of African countries, i.e. Mali and Burkinia Faco (Smirnov, 1992), Niger (Dumont and Van De Velde, 1977), Zambia (Korinek, 1984), Madakascar (Brehm, 1952), Republic of South Africa (Smirnov, 1976).

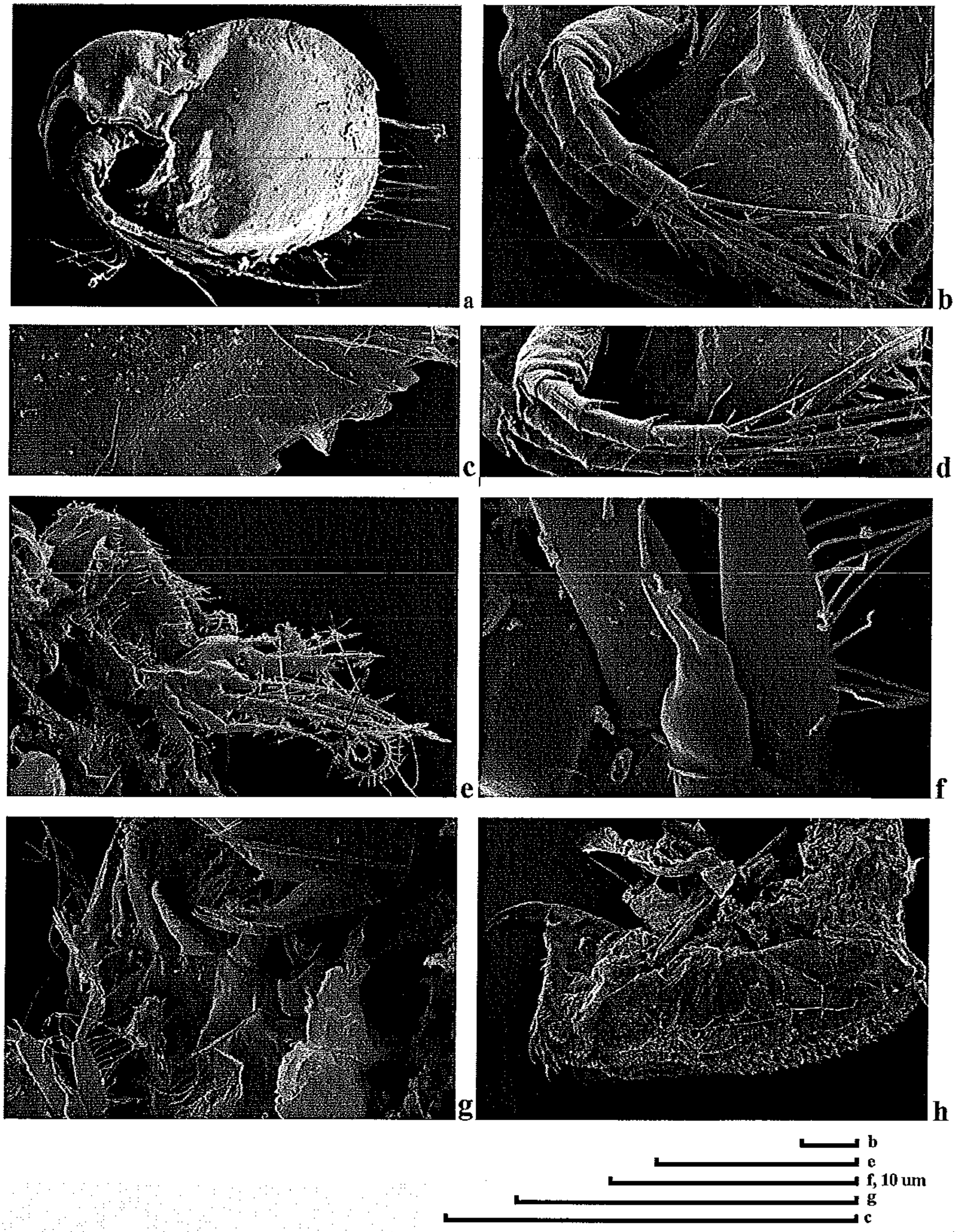
This species is not rare, but not so common in Asia and Africa like *M. spinosa* and members of *M. triserialis*-group. In present study we found only a few specimens from three localities.




Figures 51a-o. *Macrothrix odiosa* Gurney, 1916: parthenogenetic females from Juddeng peat swamp, Narathiwas Province, southern Thailand (a-c, g, k, m-o) and Bhiloga Tank on Damoh Road, Jablpur District, Madhya Pradesh, India (f, h-j, l). Figures a-b, adult females in lateral view; Figures c-e, postero-ventral portion of valve; Figures f-g, adult female in anterior view; Figures h-j, antenna 1 and its distal portion; Figures k-l, postabdomen; Figure m, its natatorial seta; Figures n-o, postabdominal claw. Scale bar denotes 100 um.




Figures 52a-i. *Macrothrix odiosa* Gurney, 1916: appendages of females from Juddeng peat swamp, Narathiwas Province, southern Thailand (a-j, l) and Bhiloga Tank on Damoh Road, India (k). Figure a, antenna 1; Figures b-c, distal and basal portion of largest seta in adults; Figure d, trunk limb 1; Figures e-h, trunk limb 2 in posterior view, its distal lobe in anterior view and gnathobase in anterior view; Figure i, trunk limb 3; Figure j, trunk limb 4; Figures k-l, trunk limb 5 and its inner portion. Scale bar denotes 100 um.




Figures 53a-h. *Macrothrix odiosa* Gurney, 1916: parthenogenetic females from Juddeng peat swamp, Narathiwas Province, southern Thailand. Figure a, adult in lateral view; Figures b, d, antenna 2; Figure c, postero-ventral portion of valve; Figures e-f, trunk limb 1 and its forks; Figure g, trunk limb 2; Figure h, postabdomen. Scale bar denotes 100 um.

## 3. *Macrothrix* sp.

**Synonymy:** *Macrothrix sioli* (Smirnov, 1982) in Saeng-aroon, 2001: 36, fig. 20; Saeng-aroon and Sanoamuang, 2002: 16, fig. 9; Sa-ardrit, 2002: *Macrothrix malaysiensis* Idris & Fernando, 1981 in Kotov and Hollwedel, 2004.

**Type locality:** Lake Kud-Thing, a shallow, natural lake, situated in the Mekong floodplain between 23° 13′ - 25° 7′ N and 59° 47′- 62° 29′ E in Bung Kan District, Nong Khai Province, NE Thailand. It has an area of 4.80 km$^2$ and a maximum depth of 7 m. Margins of this shallow lake is covered with dense macrophytes, predominantly *Ceratophyllum demersum* Linn. and *Ottelia alismoides* Pers.

**Materials examined:**
*Southern Thailand:* three parthenogenetic females from Yon peat swamp, Trang Province, collected in 08.1999 by P. Sa-ardrit, SM.

**The details of morphological study**

**Species description:** (see figures 54-56)
**Parthenogenetic female:**
***General shape*** (figs.54a-d, 56a)***:*** Body of adult sub-rhomboid to sub-ovoid in lateral view (figs. 54a-b, 56a), with maximum height at middle of valve or posteriorly, maximal length up to 1.0 mm, about 1.5-1.6 times of maximum height (n=3). Dorsal margin regularly arched from tip of rostrum to posteriormost point, but interrupted by a "step" posterior to dorsal head pore, because dorsal margin of valves elevated above dorsal margin of head. Body compressed laterally. Dorsum with high, sharp medial keel and serration (figs.54a-d), postero-dorsal angle from protruding triangle to pointed, sharp spine, approximately at level of longitudinal body axis. Ventral margin concave, possess serrations and setae. Fine reticulation on valves.

***Head*** (figs. 54a-b)***:*** In lateral view, dorsal margin evenly convex, with a low dome above eye, head ventral margin with deep depression posteriorly to joint of antenna I, then regularly convex, with fine ridges on it. Rostrum not well developed. Compound eyes relatively large, located within a low ocular dome, ocellus small, located slightly closer to tip of rostrum than to eye. Dorsal "head pore" relatively large, ovoid, not projected under level of head (fig.54e).

***Labrum*** (figs. 54a-b)***:*** large, wide, sub-triangular, with somewhat prominent postero-ventral angle and system of setae at ventral margin.

***Postabdomen*** (figs.54m-n)***:*** large, sub-rectangular, low, with truncated distal extremity, and a rudimentary heel. Ventral margin parallel with dorsal, dorsal margin seems slightly bi-lobed, due to shallow depression near basal boundary of anus, but in some specimens not obvious. A flap on postanal part. Preanal margin long, almost straight, with short, stiff setules (fig.54n), not clearly organised in transverse rows, in basal portion, these setules shorter than the other setules. Anal margin with rows of small setules, no hair-like setules. Sub-triangular anal flaps at sides of anus (figs. 54m-n), reported by Kotov *et al.* (2004) as main diagnostic trait of this species. In region of dorso-distal angle, rows of somewhat larger setules. Laterally to marginal rows there are series of finer setules. Small postanal margin with group of setules. Large teeth on postanal portion, with largest at ventral portion, whole dorsal side of postabdomen with numerous rows of spinules, of similar size and length, but somewhat longer in distal part. Obscure sculpture as longitudinal lines on sides of postabdomen.

***Postabdominal claw*** (figs. 54m-q)***:*** relatively small comparative with postabdominal size (figs. 54m-n), protruding dorso-distally, slightly and regularly bent, with pointed tip and relatively wide base in lateral, no setules on basal segment. Postabdominal claw small, outer dorsal row of numerous delicate denticles somewhat increasing in size distally (figs.54o-p); medial ventral row of about 6-9 fine denticles, and inner dorsal row with numerous fine setules, and two robust denticles (figs.54m-n). Postabdominal seta with short distal segment bearing long setules (fig.54q).

***First antenna (antennule)*** (figs.54g-i)*:* "rod-like", straight to slightly curved with low subapical external angulation, a slender sensory seta here externally at a distance of antennular disameter from antennule joint. About 3-5 relatively large denticles at its inner margin, numerous series of small denticles at all surface, and series of robust spinules at antennular end, nine terminal aesthetascs of different size.

***Second antenna*** (figs. 54a-b, j-l)*:* relatively long, large, coxa folded. Basal segment robust, bearing transverse rows of fine spinules, Distal burrowing spine approximately as long as basal segment of exopod, distal sensory seta not reaching end of second exopod and first endopod segments (fig.54j). Antennal branches long, first segment of exopod shortest, segment 2-3 elongated, subequal in length, fourth segment longer than each of them. Endopod with second segment shorter than other segments, length of endopod segments slightly increase from basal to distal one, groups of setules around basal end of all segments of endopod and exopod.

Antenna formula, setaes 0-0-1-3/1-1-3, spines 0-1-0-1/0-0-1, but an additional, unjointed, bent spine on second segment of exopod. All spines shorter than half of length of their segments. Lateral seta on first endopod segment remarkably larger than the rest (figs.54k-l), armed with a row of robust, sparse spinules along dorsal margin (fine setules between spinules), and other row of shorter spinules along external side. A single true spine on second segment of exopod, this spine shorter than the third length of this segment, a series of additional spines on first exopod segment, a large additional spine on second and third exopod segment, plus big additional spine on first endopod segment.

**Trunk limb: five pairs**

***First trunk limb (P1)*** (figs.55a-b, 56b-d)*:* largest, outer distal lobe (ODL) large and elongated (fig. 55a), supplied with a long apical seta with distal segment unilaterally armed with short fine setules, and a small lateral seta setulated distally. Inner distal lobe (IDL) with three setae, different size, the longest unsegmented, unilaterally setulated, the middle bi-segmented, finely, its distal segment unilaterally setulated, the smallest bi-segmented, unilaterally setulated with longer setules. Four series of strong setules marginally, and three series of finer setules medially, Endite 3 (E3) (fig.55b, 56c) with four setae (1-4), seta 1 elongated, large, curved, with fine setule unilaterally, four spine basally, seta 2 slender, unilaterally armed with 3-4 long setules basally, setae 3, 4 relatively shorter bi-segmented, bilaterally armed with two rows robust setules, seta 4 longer than seta 3, Endite 2 (E2) with three longer slender bi-segmented setae (5-7) of subequal in size, seta 5 bilaterally armed with finer setules, shorter setules in right side of its proximal portion, setae 6,7 of similar in length and setules pattern. Endite 1 (E1) with two slender bi-segmented setae (8-9) setulated densely distal portion. Forks on endite 2, 3 ( figs. 55b, 56d) pincer-shaped, the pincer as a half as the fork body, left side with two tooth, right side without tooth, both sides as the same length. Single ejector hook (figs. 55b, 56b) with distal segment bilaterally setulated with strong-small denticles. On limb base, a hillock with two setae a remainder of gnathobase I.

***Second trunk limb (P2)*** (figs. 55c, 56e)***:*** At base of limb externally a hillock with bunch of robust, long setae, probably homologous to pre-epipodites of P4, P5. Exopodite (EX) with bunches of setules along outer margin, and a large, incurved, plumose seta. Endopodite (EN) with eight scrapers, length decreasing inwardly, scrapers 1-2 bi-segmented, armed with fine setules distally, scrapers 3-4 and 6-7 bi-segmented, armed with stronger setules, scrapers 5, 8 with numerous strong tooth, counting about 15 and 7 tooth respectively.

Distal armature of Gnathobase (GT) with four elements (I-IV): all naked, elements II and III fused at the base. A fourth seta-like element (IV) half way to filter comb-group character. Gnathobasic filter comb with four setae with size increasing basally, first seta setulated distally, second and third seta setulated with similar pattern, fourth seta broad at its base, with fine, long setules, unilaterally at basal portion and bilaterally distal end.

***Third trunk limb (P3)*** (figs.55e-d, 56f)***:*** Exopodite (EX) with four setae (I-IV), setae 1 and 2 with long setules bilaterally, seta 2 as three times as long as seta 3, anteriormost seta 3 and seta 4 closely apposed, of same length, seta 3 with long bilaterally setulated, seta 4 armed with 7-9 strong spinules distally. One tufts of setule between setae 1 and 2. Outer lobe (External Endite = EE) with two rows of setae.

Anterior row with three seta (1-3), seta 1 with sparse setules on its distal part, seta 2 longer, naked, seta 3 short with unilaterally setulated distallly. Posterior row with four setae (1'-4'), seta 1' curved, unilaterally setulated, seta 2' longest with long setules bilaterally along seta, seta 3' short a half as long as seta 2, armed with short setules, seta 4' shortest, armed with fine spinules. Inner lobe (Internal Endite = IE) with two rows of setae. Anterior row with four setae (4-7), seta 4 a small, bottle-shaped like seta, setae 5-7 stiff setae, bi-segmented, setulated. Posterior row with three setae (5'-7'), bilaterally setulated from base to tip.

Distal armature of Gnathobase (GT) with four elements (I-IV), element I a bottle-shape sensilium, element II more curve, bilaterally setulated distally, elements III and IV fused at the base, seta III with small setae distally. Gnathobasic filter comb absent.

***Fourth trunk limb (P4)*** (figs.55f-g)*:* Exopodite (EX) relatively small, with two feathered setae of greatly different size (1:3). Endopodite (EN) with two rows of setae. Anterior row with five setae (1-5), seta 1 stout, setulated basally, setae 2-4 'flaming torches' with inflated base and slender distal part, setae 2, 3 with long setulated distally, seta 4 largest with shorter setules distally. Rod-like seta 5 naked, located close to base of this row. Posterior row with five (1'-5') slender, plumose setae.

Distal armature of gnathobase (GT) with three elements (I-III), element I large a horse-tail seta typical, element II rod-like and element III smallest, both naked. Gnathobasic filter comb absent.

***Fifth trunk limb (P5)*** (fig.55h)*:* Large. Pre-epipodite (PEP) three rounded-lobes, central lobe largest, all with fine long radiant setules distally. Epipodite (EP) large, curved, elongate, naked. Exopodite (EX) a small projection with single seta. Endopodite (EN) small flap, on inner margin three setae, distalmost specially large, second relatively short.

**Differential diagnosis:**

Among all members in *paulensis*-group, only four species have a spine at postero-dorsal angle: *M. malaysiensis, M. sioli, M. brandorffi* and *M.* sp. Among them, only *M. sioli* and *M.* sp. have dorsal margin of valves remarkably elevated under dorsal margin of head. However *M.* sp. can be separated from other by the presence of these characters:

1) Postabdomen: lateral flaps near the anus (main discriminative feature from the closest species, *M. sioli*); more numerous spinules on preanal margin of postabdomen
2) Antenna 1: deeper depression on head ventral margin posteriorly to joint of antenna 1
3) Antenna 2: shorter distal sensory seta on basal segment of antenna 2
4) Trunk limb 1: different armature of soft setae on endite 2
5) Trunk limb 2: distalmost seta of filter plate 2 with "normal" setules [see description of Kotov and Hollwedel (2004) for comparison]
6) Trunk limb 3: seta 2 on exopodite three times as long as seta 3

**Taxonomic comments:**

This taxon was first found by Saeng-aroon, 2001; Saeng-aroon and Sanoamuang, 2002 and Sa-ardrit, 2002, and determined as *M. sioli.* Then Kotov and Hollwedel (2004) found differences with true Brazilian *M. sioli,* and determined the former as *M. malaysiensis.* Kotov and Hollwedel (2004) decided that Idris and Fernando (1981b) saw only juveniles of *M. malaysiensis,* while specimens of "*M. sioli*" sensu Saeng-aroon, 2001 are "older" females. Juveniles of the latter are similar with the former. But now, after our study of paratypes of *M. malaysiensis,* Kotov *et al.* (2004) concluded that they are two separate species.

**Variability:**

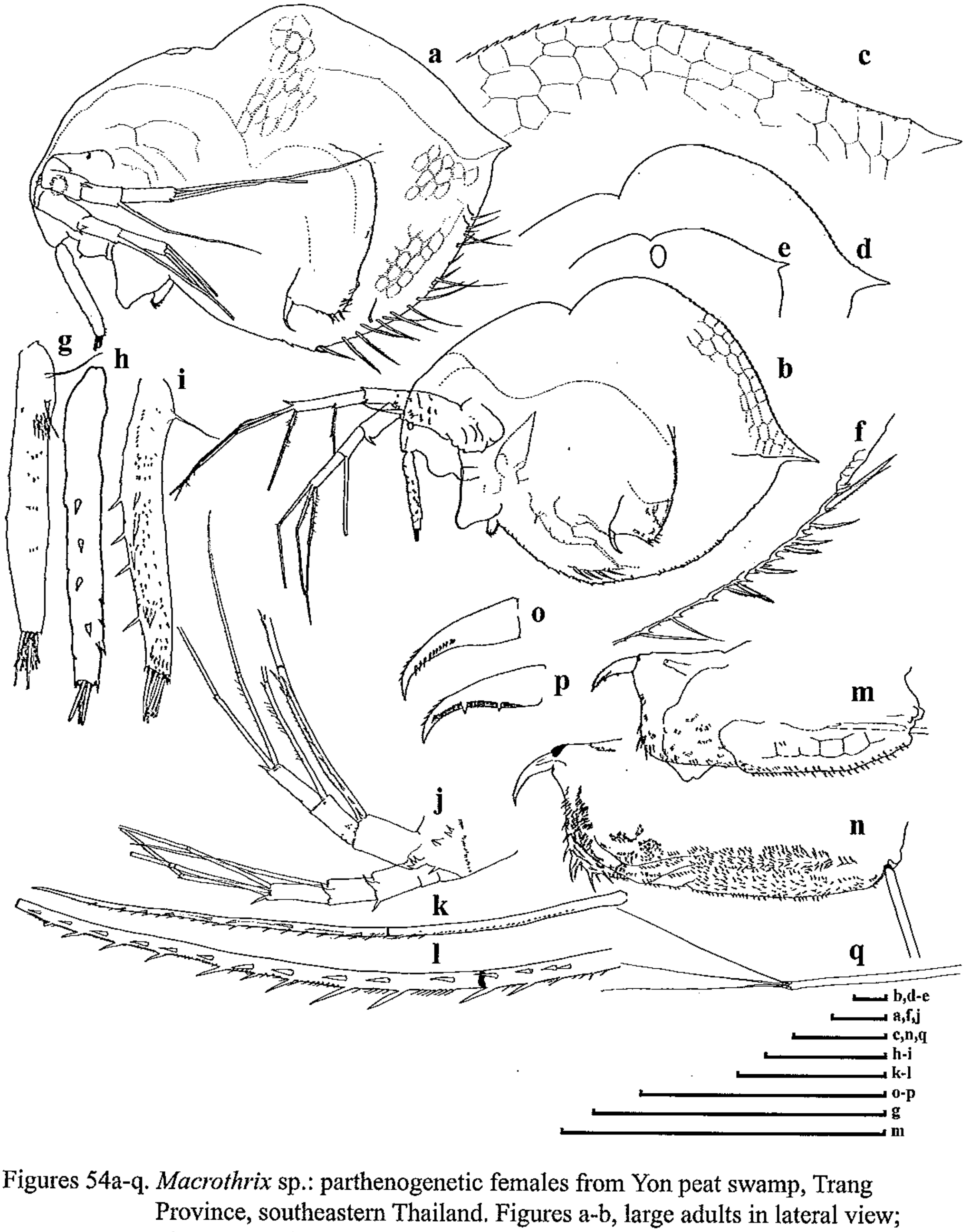
Some variability was noted in the: 1) strength of the dorsal arch (figs. 54a-d); 2) serration on dorsal and ventral valve margin (figs.54c-e) and 3) depression between head and rest of body (figs.54a-b, e-d, 56a).

**Biology:**

*M.* sp. is normally found in the littoral zone of water bodies. In our area it is found in peat swamp (Yon peat swamp) and freshwater swamp (Lake Kud-Thing, northeastern Thailand), covered with dense vegetation.

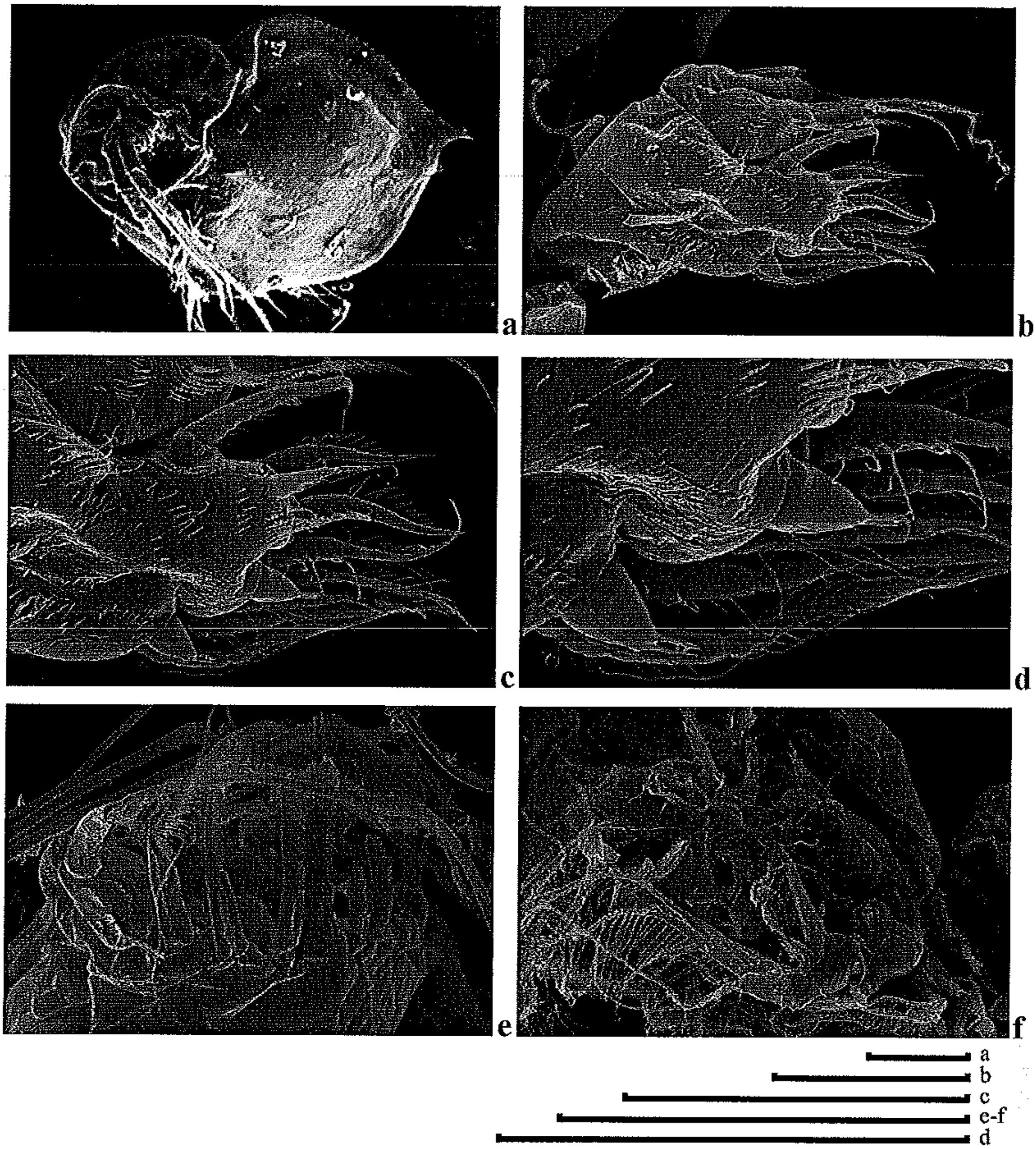
**Distribution:**

*M.* sp. is known only from Thailand (the Northeast and the South), where it is not too rare.




Figures 54a-q. *Macrothrix* sp.: parthenogenetic females from Yon peat swamp, Trang Province, southeastern Thailand. Figures a-b, large adults in lateral view; Figures c-e, dorsal of valve; Figure f, postero-ventral portion of valve; Figures g-i, antenna 1 and its distal portion; Figure j, antenna 2; Figures k-l, distal and basal portion of largest lateral seta in adults; Figures m-n, postabdomen; Figures o-p, postabdominal claw; Figure q, its natatorial seta. Scale bar denotes 100 um.


Figures 55a-i. *Macrothrix* sp.: appendages of females from Yon peat swamp, Trang Province, southeastern Thailand. Figures a-b, trunk limb 1 and its inner and outer distal lobes; Figure c, trunk limb 2; Figures d-e, trunk limb 3; Figure f, inner portion of trunk limb 4; Figure g, exopodite of trunk limb 4; Figures h-i, trunk limb 5. Scale bar denotes 100 um.




Figures 56a-f. *Macrothrix* sp.: parthenogenetic females from Yon peat swamp, Trang Province, southeastern Thailand. Figure a, adult female in lateral view; Figures b-d, trunk limb 1 and its Fryer's forks; Figure e, trunk limb 2; Figure f, trunk limb 3. Scale bar denotes 100 um.

## 2. *Macrothrix rosea* –group

Dumont and Silva-Briano (2002) showed a clear conclusion of the differential diagnosis characters among several species within *M. rosea-triserialis* subgroup: *M. rosea, M. elegans, M. triserialis*. The morphological comparison of the latter one among populations indicated that the inter-specific difference has occurred, although in micro-characters. However, it is a complicated group which awaits further studies.

Three *triserialis*-like species, *M. triserialis* Brady, 1886 and *M. superaculeata* (Smirnov, 1982), including *M. flabelligera* Smirnov, 1992, the close species of *M. triserialis*, which have been found in Thailand are studied here, with an attempt to make a detail descriptions and investigation the variations of these species.

**Basic characters of this group**

1) Postabdomen; setae natatoriae of PA are implanted on a prominence, the 'heel'
2) P1: Fryer' forks are adorned with one , two or three big teeth
3) P2: exopodite seta typical 'ibis-beak'; scrapers form a row of 8 without any doublings; possibly, scraper 5 and 4 to a lesser degree has an enlarged subapical teeth, a minute seta on gnathobase (larger in *paulensis*-group)
4) P3: seta 3 on external endite robust with 5-6 spines on one side
5) P4: 2 seta on exopodite, one large additional seta on gnathobase
6) P5: pre-epipodite 3 elongated lobes, epipodite very small, exopodite reduced to a single seta
7) Male: postabdomen without true end-claws, or with a rudiment of an end-claw (Silva-Briano *et al.*, 2002)

## 1. *Macrothrix triserialis* Brady, 1886

**References:** Brady, 1886: 295, Pl. 37, figs. 16-20; Daday, 1898a: Des. pp. 50-52, figs 24a-d.; Gurney, 1907a (India): Des. 25, fig. 21, 21a; Brehm, 1933: Des. 694-695, fig.21; Harding, 1955 (Percy Sladen Trust Exp.): Des: 338-339, figs. 34-36; Johnson, 1956: Des. 80-81, No figures; Rey and Saint-Jean, 1968: 93-94, figs. 11 A à 11 C; Thomas, 1961a (Uganda): Des. 118-119, fig. 3; Orghidan and Negrea, 1973: Des. 107-109, fig. 3; Dumont and Van de Velde, 1977: 84-85, fig. 4; Infante, 1980: Des: 597-598, fig. 4; Idris and Fernando, 1981a: Des: 239-240, figs. 16-21; Venkataraman, 1991: Des: 45-46, No figures; Ciros Pérez and Elías-Gutiérrez, 1996: Des: 298, figs. 1-2.

**Type locality:** *M. triserialis* was originally described from the Island of Sri Lanka (Brady, 1886), but subsequently cited from most of the tropics

**Materials examined:**

*Southern Thailand*: twenty parthenogenetic females, completed and dissected, from Thungtong swamp, Suratthani Province, southeastern Thailand, collected by the author, SM.

*:* two parthenogenetic females, completed and dissected, from Laha marsh, Narathiwas Province, southeastern Thailand, collected by the author, SM.

*Northeast Thailand:* one parthenogenetic female, examined complete and thereafter dissected, from Lake Kud-Thing, Nong Kai Province, collected by C. Saeng-Aroon, KKU.

*Malaysia, East coast:* twenty parthenogenetic females, examined complete and thereafter dissected, from Rantang Abang Marsh, Terengganu, collected date 16-05-2003 by the author, SM.

**The details of morphological study**

**Species description** (see figures 57-61)

**Parthenogenetic female**

***General shape*** (figs.57a-g, 60a-b)*:* Body of adult in lateral view ovoid-oblong (figs.57a-b, 60a-b), with maximum height in the middle, maximal length 0.3-0.6 mm, about 1.45-1.7 times maximum height, maximal height 0.2-0.6 mm (n = 20), ventral view elongated-oval (fig.57d) and dorsal view more elongated (fig.57c). Dorsal margin slightly curved, margin serrated dorsally (figs.57a-b, e, 60a-b), however it is hardly seen in some individuals, the dorso-posterior angle of the shell pointed, and some individuals very distinct (fig. 60b). Ventral margin concave, possess serrations and setae (figs. 57f-g).

***Head:*** Of medium size, head length from tip of rostrum to border with valves/body length = 2.5 times. In lateral view (figs. 57a-b), head triangular, slightly bulb anteriorly, dorsal margin generally regularly convex. Rostrum well develops. Compound eye small but larger than ocellus, the ocellus located closer to tip of rostrum than to eye.

***Labrum:*** Moderately size (figs. 57a-b), in lateral view approximately triangular, blunt edge, labral ridge cracked.

***Valve:*** Surface with fine stripe reticulation (figs.57b, 60a-b). Ventral margin of valve serrated posteriorly, setulated marginal setae including the large long and the short ones, protruding ventrally (figs. 57a-b, f-g).

***Thorax, Abdomen:*** short

***Postabdomen*** (figs. 57h-i, 61a)*:* Medium size, more ovoid than quadrangular in lateral view, bilobed dorsally (figs.57h-i). Ventral margin slightly convex. Large anal teeth on postanal portion (fig.61a), with largest at dorso-distal angle and ventero-postanal angle, whole body of postabdomen with numerous rows of spinules, of similar size and length, but somewhat longer in pre-anal part. Postabdominal seta (fig. 57h) has a very short distal segment bearing long setules.

***Postabdominal claw:*** small size, composing 3 segmented, the tip slightly bent, directed somewhat dorsally, with pointed tip and wide base in lateral view (figs.57h-i).

***First Antenna (antennule)*** (figs.58a-d, 60c-d)*:* "rod-like' in term of Smirnov (1992), relatively long, rod-like. Sensory seta external, located at a distance of antennular diameter. Body of appendage with about 4 rows of big spines (about 4-5 spines in disorder of each rows) on internal margin, an additional row of smaller spines sometimes present close to the tip of antennular body, numerous small setules on whole surface of antennule. At tip of antennule, a bunch of seven relatively short terminal esthetascs, slightly different in length. Around the bunch of the aesthetascs, a row of spinules of unequal size.

***Second Antenna*** (figs. 57a, 58e-k, 60e-f)*:* moderately long, about a half of body lengths (fig.57a). Coxal region folded. Basal segment bearing transverse rows of spinules. Antennal branches long, with elongated segments, length of endopod segments slightly increases from basal to distal one, groups of setules around basal ends of all segment of endopod and add one row of bigger setules on distal end of second segmented of exopod (figs.58f-i, 60e), not so strong and not obvious in some individuals (fig.58g).

Antenna formula, setae 0-0-1-3/1-1-3, spine 0-0-0-1/0-0-1 (fig.61e). All spines are about half the length of theirs segments. Largest lateral seta on first endopod segment (figs. 58j-k, 60f) 2-segmented, with 2-3 robust spines ventrally, the size is similar. A row of 8-15 smaller robust setules on dorsal side of this seta, with size gradually decreasing distally. One seta at the joint of the setae on first and second endopod segment (figs. 58 l-m).

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (figs. 59a-b)***:*** Outer distal lobe (ODL) with a long apical seta, unilaterally armed with fine setules on its distal part (fig. 59a). Inner distal lobe (IDL) with three single-segmented setae of different size (fig. 59b), the first seta longest, unilaterally setulated distally, the second seta curved, setules on the middle protion, third seta smallest armed with longer setules distally, series of strong setules basally.

Endite 3 (E3) (fig. 59b) with four setae (1-4), seta 1 curved, unilaterally armed with fine setules distally, seta 2 smallest, slender, setulated, seta 3-4 bi-segmented, more robust setae armed with row of robust setules. Endite 2 (E2) with three slender bisegmented setae (5-7) of approximately the same length, seta 5 fully setulated at distal and basal part, seta 6-7 densely setulated distally but 4-6 setules basally. Endite 1 (E1) with two bisegmented setae (8-9), subequal in length, seta 8 unilaterally setulated distal and basal parts, seta 9 bilaterally setulated distally. Forks on endite 1 and 2 pincer-shaped, pincer part a half as long as fork body, left side with three tooth, right side without tooth, left pincer portion longer than right side. Two ejector hooks large, unilaterally armed with short setules distally. On limb base, a hillock with two fully setulated setae-a remainder of gnathobase I.

***Second trunk limb (P2)*** (figs.59c-e, 61b, d)***:*** Exopodite (EX) an elongated lobe with a long, bilaterally setulated seta 'ibis-beak' typical (fig.59d). Endopodite (EN) with eight scrapers, increasing in length distally, scraper 1 longest, unilaterally setulated, scrapers 2-8 bi-segmented, scraper 2 bi-segmented, unilaterally armed with short-fine setules, scraper 3 with short tooth, counting 9 tooth, one small sensilium between scraper 2 and 3 (fig. 59d), scrapers 4-5 with strong tooth, counting 7 and 6 tooth respectively, distalmost largest (figs. 59c, 61b), scrapers 6-8 with strong tooth, similar in arrangement, counting 6 tooth each.

Distal armature of gnathobase (GT) (figs. 59e, 61d) with three elements (I-III): element I hook-like, bilateral feathered distally, element II densely setulated distally, element III unilaterally armed with 3-5 setules, element IV-like seta very small-different from *paulensis*-group. Gnathobasic filter comb with five setae, first seta small, bilaterally setulated distally, second seta slender bilaterally setulated with long setules, third and fourth setae unilaterally setulated, fifth seta broaden base, unilaterally setulated.

***Third trunk limb (P3)*** (figs. 59f-g, 61d)*:* Exopodite (EX) sub-quadrangular, with four setae (1-4), setae 1 and 2 similar in length, setulated, seta 3 longest, setulated with shorter setules, seta 4 about a half as long as seta 3, unilaterally armed with long setules. Endopodite (EN) bilobes. Outer lobe (External Endite = EE) with two rows of setae. Anterior row with three setae (1-3), setae 1 and 2 large, unilaterally armed with short, sparse setules distally, seta 3 robust, with 6 strong spines on one side. Posterior row with three setae (1'-3'), setae 1' and 2' slender unilaterally setulated with long setules, seta 3' shorter, setulated. Inner lobe (Internal Endite = IE) with two rows of setae. Anterior row with four setae (4-7), seta 4 naked, seta 5 and seta 6 setulated distally, seta 7 armed with short setules distally. Posterior row with three setae (4'-6') similar in length.

Gnathobase (GT) clearly demarcated from internal endite, distal armature with four elements (I-III), element I an elongated, naked, elliptical, element II densely setulated with long setules, element III more robust, naked and element IV fused the base with element III, short setules distally. One small hill setulated distally between element I and element II.

***Fourth trunk limb (P4)*** (fig.59h)*:* Exopodite (EX) small, with two bilaterally feathered setae, similarly in size. Endopodite (EN) with two rows of setae. Anterior row with five setae (1-5), seta 1 hook-like distally, unilaterally setulated basally, seta 2-4 'flaming torch' seta 2 and 4 unilaterally setulated distally with long setules, seta 3 shortest unilaterally armed with short setules distally, one rod-like seta 5 naked. Posterior row with five setae (1'-5'), similar in length.

Distal armature of gnathobase (GT) with three elements (I-III), element I largest 'horse-tail' seta typical, feathered distally, element II rod-like, long, element III minute, both II and III element naked. One long seta close to the base of gnathobase.

***Fifth trunk limb (P5)*** (fig. 59i)*:* Pre-epipodite (PEP) three lobes, elongated, third lobe largest, setulated distally. Epipodite (EP) small lobe, rounded, setulated more radial distally. Exopodite (EX) a small projection with single seta. Endopodite (EN) small flap, on inner margin three setae, distalmost specially large, second and third relatively short.

**Variability:**

Some variability was noted in these following characters (figs. 57a-b, 58a-d, 58f-i, respectively, table 8: 1) general shape; ovoid or sub-quadrangular; 2) pattern of spines on antennular body; spines continue in row or not continue and number of rows range from 4-6; 3) setae on second and third segment of antenna; single seta or accompanied of the large and smaller pectens presented on second and third segment or second segment only; 4) postabdomen; ovoid or sub-quadrangular shape and 5) forks on first trunk limb; two or three tooth on right side which is Silva-Briano *et al.* (2002) found 1-2 tooth.

**Differential diagnosis:**

*M. triserialis* can be distinguished from other species by the presence of these characters: 1) ibis-like seta on exopodite of trunk limb 2; 2) enlarged subapical teeth on scraper 5 of trunk limb 2 and 3) seta 3 on external endite of trunk limb 3 robust and armed with sparsely strong denticles, number ranges from 5-6 denticles in Thai and Malaysia population; 8 denticles in Sri Lanka population (Silva-Briano *et al*, 2002) and 5 denticles in Kerala population (Silva-Briano *et al*, 2002)

**Remarks:**

Comparing *M. triserialis* with the three Asian, one African and one American population, it appears that each population shows variation in different characters. The African and American populations show the same variation on scraper 5 of trunk limb 2, which is without enlarged subapical teeth. The East-Asian population show small variations from each other at the length of seta 3 of exopodite, trunk limb 3 and seta 4 of filter comb, trunk limb 2 of Keralan population not enlarged. However, it seems Thai populations, the study includes the samples from several populations in southern Thailand and the samples from northeastern, shows higher variations both gross and fine details: 1) body shows both ovoid and oblong shape, also the shape of postabdomen, occurs both ovoid and sub-quadrangular shape; 2) spines on first antenna in rows or not in rows; 3) setae 6-7 of the first trunk limb setulated as other populations but more sparse at basal part; 4) 2-3 tooth on one side of pincer portion of forks, which is range from 1-2 in other populations; 5) the additional seta on gnathobase of the second trunk limb is very small; 6) ibis-beak like seta on exopodite trunk limb 2 more slender but curved over scraper 3; and 7) seta 3 on external endite of the third trunk limb robust with 5-6 strong spines, as can be found in Keralan population but other population shows more number of spines on this seta. Although these fine characters need to be re-examined more in details under SEM, however, we can conclude that Thai population shows both intra- and inter population variation. Further, the numbers of samples from various localities need to be studied in order to clarify those characters stability.

**Taxonomic comments on *M. triserialis* Brady, 1886 and *M. flabelligera* Smirnov, 1992**

The present identification followed the key of Smirnov (1992). He defined *M. flabelligera* on the basis of differences found in detailed studies of various population of the former *M. triserialis* senso lato from its represent in the specializations of the antenna armature within this group. In the closely related *M. triserialis* the spine on the second segment of 4-segmented antennal branch is not accompanied by pectens of additional spines, and in *M. superaculeata* additional spines present on the second and third segments are single. Silva-Briano (1998) and Silva-Briano *et al.* (2002) revised this group without mention to this pattern of the spines and his drawings show the combination of the spine pattern on the second segment (see Silva-Briano, 1998: 274-302); some show a single spine (the first character separate these two species in Smirnov (1992)); some show the row of small or larger spine (the main character defined as *M. flabelligera*). Since this character shows high variations it seems this is not a good character to distinguish the member of the group. However, since the status of all member of this species-group has not proved yet we preferred to put the name of all variety as *M. triserialis* Brady, 1886 and mentioned those different characters as theirs variations.

**Biology:**

It can be found in all kinds of habitats; swamp, peat swamp, marsh, dam, reservoir and pond, ranging from freshwater to brackish. However, it is high abundant in freshwater habitats with high abundant of vegetations.

**Distribution:**

*Macrothrix triserialis*-like animals distributed worldwide in the tropical and subtropical belts of four continents, Asia, South America, Africa and Australia i.e. The Rio Nhamunda, Brazil (Smirnov, 1982); Northeast Thailand (Sanoamuang, 1998); Cameroon, Africa (Chiambeng, 2004).

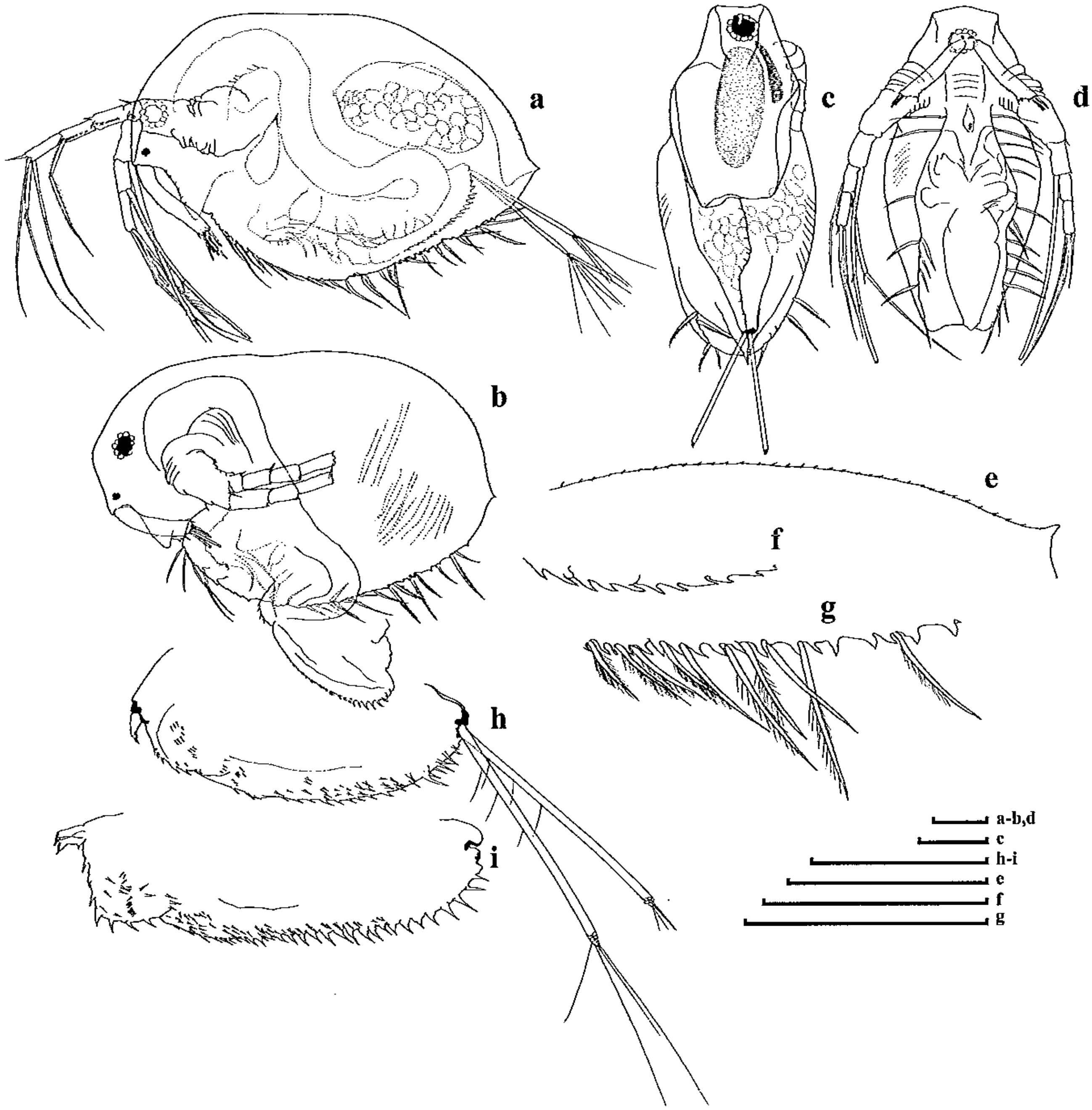
**Table 8** Morphological comparison of *Macrothrix triserialis* among localities

| Characters | | *M. triserialis* Sri Lanka -Asia- (Silva-Briano, 2002) | *M. triserialis* Kerala, India -Asia- (Silva-Briano, 2002) | *M.* cf. *triserialis* Kenya -Africa- (Silva-Briano, 2002) | *M.* cf. *triserialis* Mexico -America- (Silva-Briano, 2002) | *M. triserialis* Thailand -Asia- (present data) |
|---|---|---|---|---|---|---|
| **Body shape** | 1) | more oblong | more oblong | more ovoid | more ovoid | **ovoid or oblong** |
| **A1** | 2) | spines not in rows | spines not in rows | | spines not in rows | **spines in rows or not in row** |
| **A2, longest seta** | 3) | 3 strong spines in middle section | | **numerous short spines along distal section** | 3 strong spines in middle section | 3 strong spines in middle section |
| **Trunk limb 1** | | | | | | |
| Seta 2 | 4) | with long setules | with long setules | **with short setules** | with long setules | with long setules |
| Seta 5 | 5) | as long as seta 6 | as long as seta 6 | as long as seta 6 | as long as seta 6 | as long as seta 6 |
| Setae 6-7 | 6) | setulated | setulated | setulated | setulated | **setulated but sparse basally** |
| Epipodite | 7) | sinuous, elongated | sinuous, elongated | sinuous, elongated | rounded | ? |
| Forks | 8) | 1-2 tooth on one pincer side | 1-2 tooth on one pincer side | 1-2 tooth on one pincer side | 1-2 tooth on one pincer side | **2-3 tooth on one pincer side** |
| **Trunk limb 2** | | | | | | |
| *Seta of exopodite | 9) | ibis-beak like, small curved over scraper 2 | ibis-beak like, small curved over scraper 2 | ibis-beak like, not too curve but curved over scraper 2 | ibis-beak like, small, point downward or curved over scraper 2 | **ibis-beak like, small but curved over scraper 2 or scraper 3** |
| ***Scraper 5** | 10) | enlarged subapical tooth | enlarged subapical tooth | **normal subapical tooth** | **normal subapical tooth** | enlarged subapical tooth |
| Seta 4 of filter comb | 11) | enlarged | **normal** | enlarged | enlarged | enlarged |
| additional seta on gnathobase | 12) | relatively large | relatively large | relatively large | relatively large | **very small** |
| Scraper doubling | 13) | no | no | no | no | no |

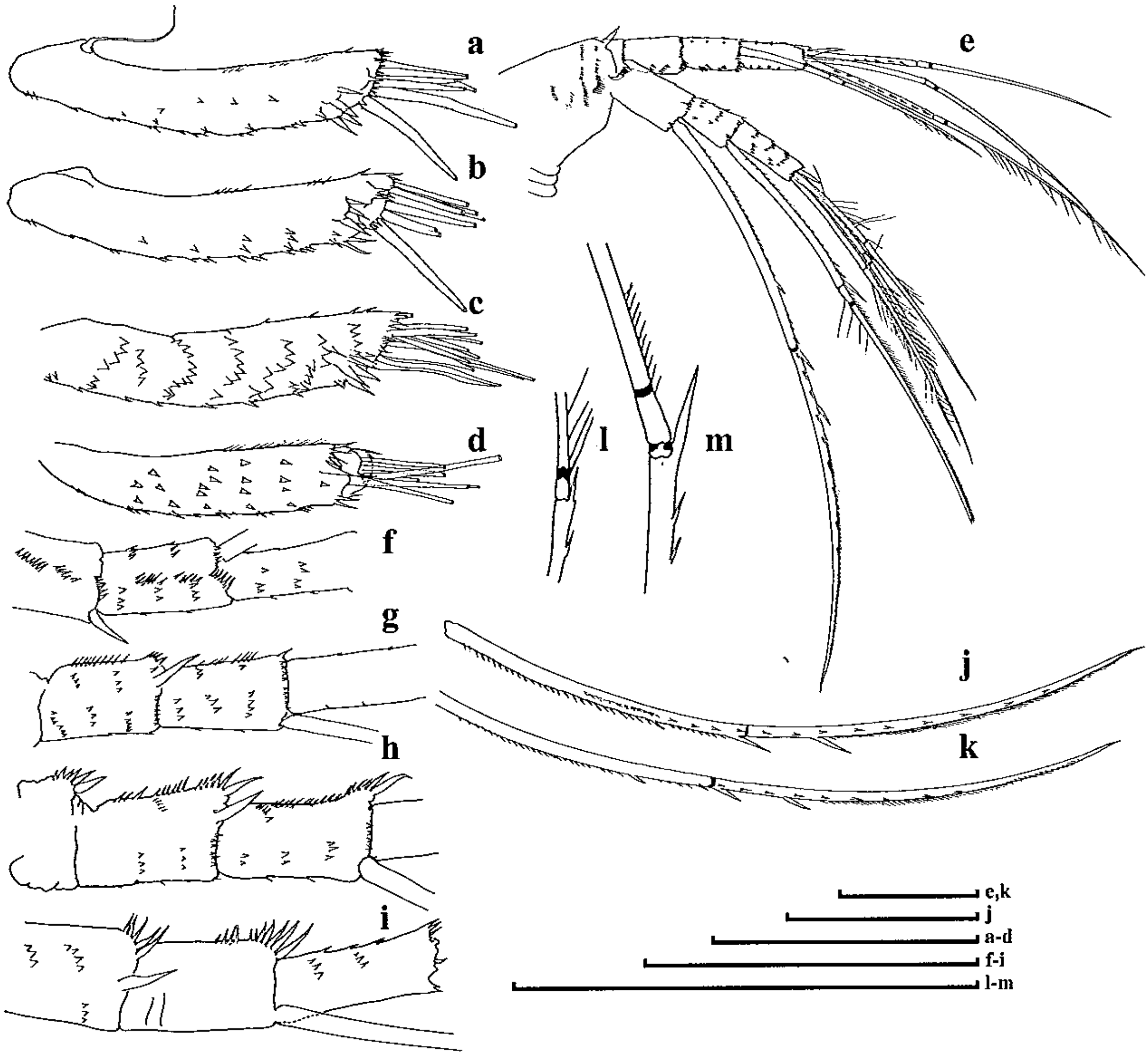
**Table 8.** (Continued)

| **Characters** | | *M. triserialis* **Sri Lanka -Asia-** (Silva-Briano, 2002) | *M. triserialis* **Kerala, India -Asia-** (Silva-Briano, 2002) | *M.* cf. *triserialis* **Kenya -Africa-** (Silva-Briano, 2002) | *M.* cf. *triserialis* **Mexico -America-** (Silva-Briano, 2002) | *M. triserialis* **Thailand -Asia-** (present data) |
|---|---|---|---|---|---|---|
| **Trunk limb 3** | | | | | | |
| seta 3 of exopodite | 14) | 2 times longer than seta 2 | **a little bit longer than seta 2** | 2 times longer than seta 2 | **2.5 times longer than seta 2** | 2 times longer than seta 2 |
| ***Seta 3 on external endite** | 15) | robust with 8 strong spines | robust with 5 strong spines | robust with ~10 strong spines | robust with ~7 strong spines | **robust with 5-6 strong spines** |
| **Trunk limb 4** | | | | | | |
| Setae of exopodite | 16) | of equal length | of equal length | one long, one short | of equal length | of equal length |
| **Trunk limb 5** | | | | | | |
| Pre-epipodite | 17) | 3 lobes | 3 lobes, elongated | 3 lobes, elongated | 3 lobes, elongated | 3 lobes, elongated |
| Epipodite | 18) | elongate | elongate | elongate | **globular** | elongate |
| Exopodite seta | 19) | glabrous | | plumose, round | short | short setulated |
| **Postabdomen** | | | | | | |
| Shape | 20) | sub-quadrangular | sub-quadrangular | sub-quadrangular | sub-quadrangular | **ovoid or sub-quadrangular** |

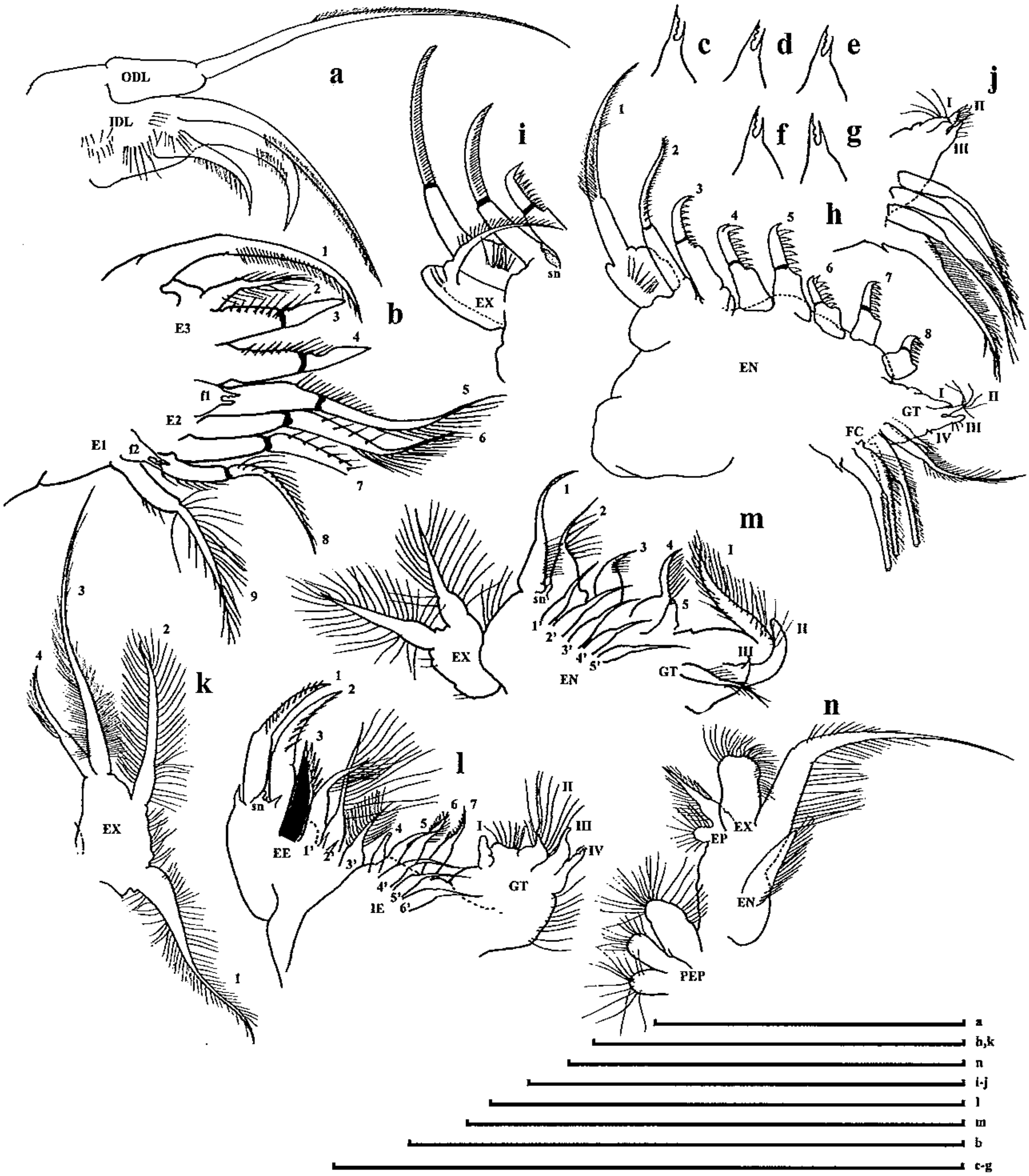
* The diagnostic characters of *M. triserialis*



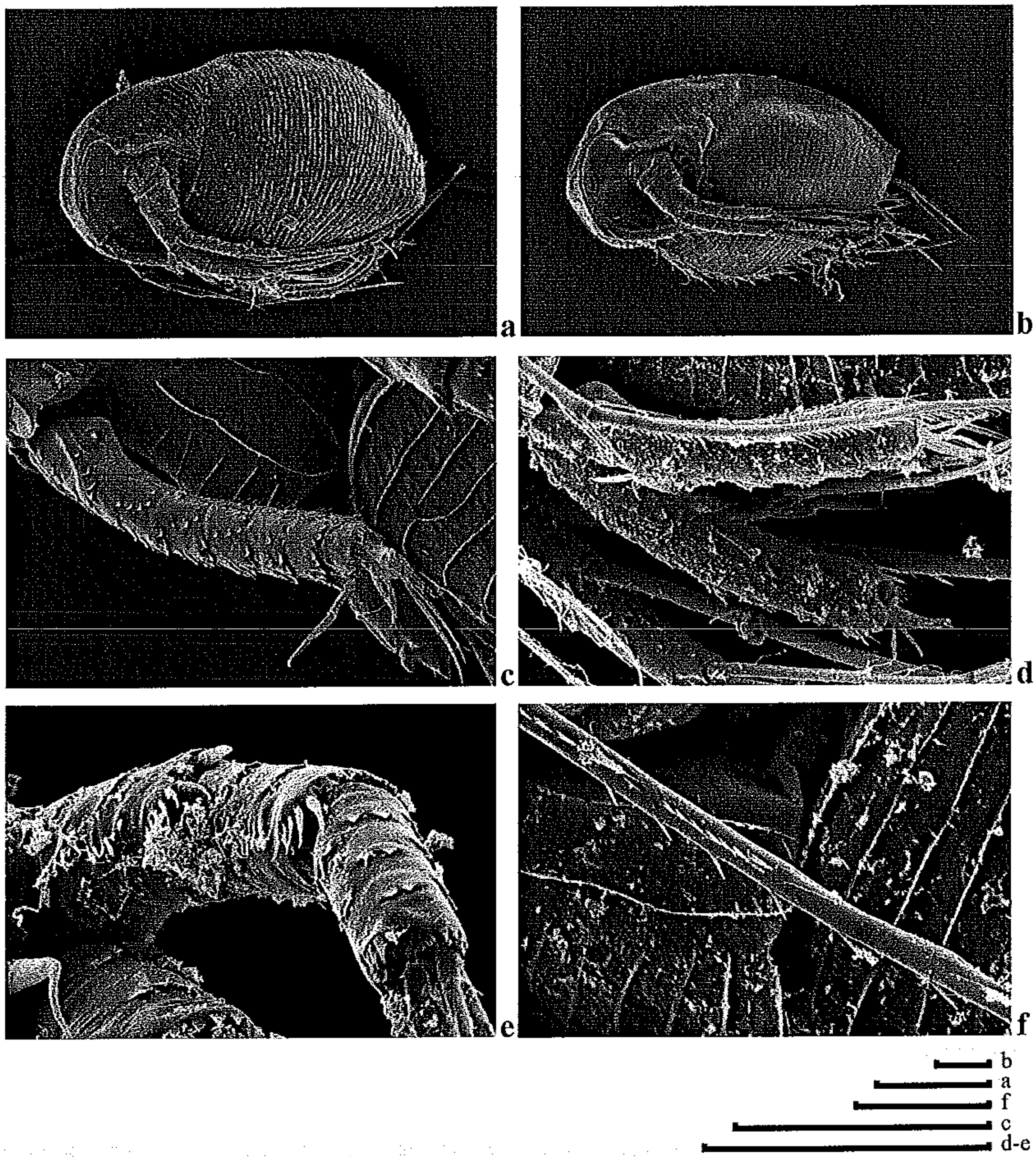

Figures 57a-i. *Macrothrix triserialis* Brady, 1886: parthenogenetic females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figures a-b, adults in lateral view; Figure c, its anterior view; Figure d, its posterior view; Figure e, postero-dorsal portion of valves; Figures f-g, postero-ventral portion of valve; Figures h-i, postabdomen. Scale bar denotes 100 um.



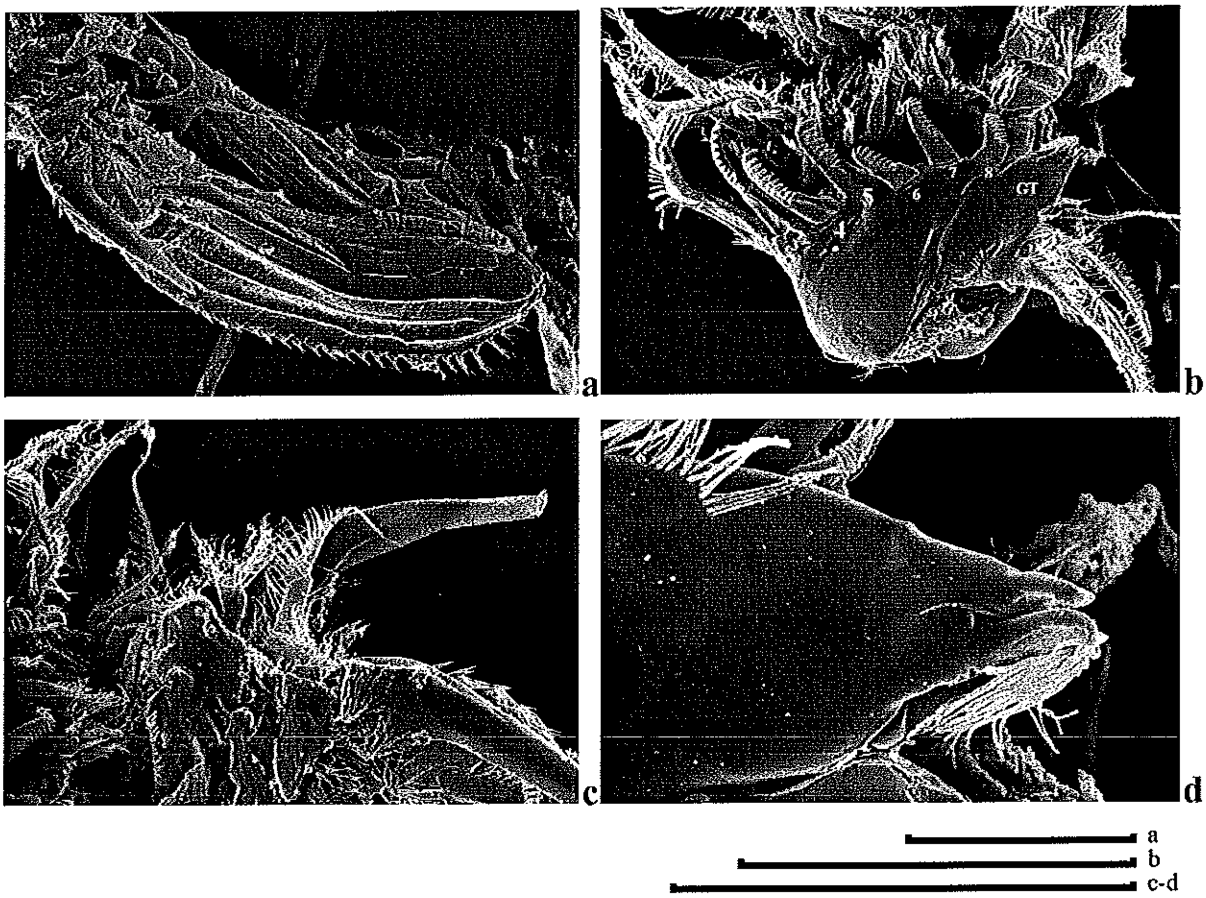

Figures 58a-k. *Macrothrix triserialis* Brady, 1886: appendages of females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figures a-d, antenna 1 and its distal portion; Figure e, antenna 2; Figures f-i, second and third segment of antenna 2; Figures j-k, distal portion of largest seta of antenna 2; Figures l-m, joints of distal setae of antenna 2. Scale bar denotes 100 um.



Figures 59a-n. *Macrothrix triserialis* Brady, 1886: appendages of females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figure a, inner and outer distal lobe of trunk limb 1; Figure b, trunk - limb 1; Figures c-g, Fryer's forks on trunk limb 1; Figures h-j, trunk - limb 2, its exopodite and its gnathobase; Figures k-l, exopodite and endopodite of trunk limb 3; Figure m, trunk limb 4; Figure n, trunk - limb 5. Scale bar denotes 100 um.




Figures 60a-f. *Macrothrix triserialis* Brady, 1886: parthenogenetic females from Thungtong swamp, Suratthani Province, southeastern Thailand (a, c-f) and from Lake Kud-thing, Nongkai, northeastern Thailand (b). Figures a-b, adults in lateral view; Fugures c-d, antenna 1 and its inner portion; Figures e-f, second and third segments of antenna 2 and distal portion of largest seta. Scale bar denotes 100 um.




Figures 61a-d. *Macrothrix triserialis* Brady, 1886: appendages of parthenogenetic females from Thungtong swamp, Suratthani Province, southeastern Thailand. Figure a, postabdomen; Figures b, d, trunk limb 2 and its gnathobase; Figure c, trunk limb 3. Scale bar denotes 100 um.

**Distribution:**

Kotov *et al.* (2003) mentioned that this species is limited to the Amazon basin and there are probably *superaculeata*-like animals at Santa Fe (Smirnov, 1992). However, from the present studies it seems to be also distributed in Asia.

## 3. Two other *Macrothrix* species found in southern Thailand

## 1. *Macrothrix spinosa* King, 1853

**References:** Sars, 1888: pl.3; Brehm, 1933d (Sunda-Exp.): Des. 695-698, figs. 22-24; Johnson, 1956: Des. 81, no fig.; Petkovski, 1973: Des. 179-182, figs. 34-43, 61; Venkataraman, 1991: Des. 45, no fig.; Sanoamuang, 1998: figs 61-66.

**Type locality:** A pond between Sydney and Liverpool, now destroyed by urbanization.

**Materials examined:**

*Southern Thailand*: five parthenogenetic females, examined complete and dissected, from several localities in southern Thailand, collected by the author, SM.

*Singapore:* one parthenogenetic female from sample no.255, examined complete and dissected, collected by C. H. Fernando, Fernando collection, Raffles Museum, National University of Singapore, SM.

*Burma:* one parthenogenetic female from sample no. 27, completed and dissected, collected by C. H. Fernando, Fernando collection, Raffles Museum, National University of Singapore, SM.

**The details of morphological study**

**Species description** (see figures 62-63)

**Parthenogenetic female**

***General shape*** (figs.62a,c)***:*** Body of adult in lateral view ovoid, with maximum height in the middle, length about 0.3-0.40 mm, about 0.2 times maximum height (n = 20). Dorsal margin slightly curved, margin serrated posteriorly. Dorso-posterior angle of the shell round. Ventral margin concave, possess serrations and setae (fig.62c).

***Head:*** of medium size, head length from tip of rostrum to border with valves is about 1/3 of body length. In lateral view, head round (fig.62a), dorsal margin generally regularly convex. Rostrum well develops. Dorsal 'head pore' moderately, located on posterior part of head. Compound eye large. Ocellus smaller than compound eye, located close to tip of rostrum.

***Labrum:*** in lateral view approximately triangular (fig.62a), blunt edge, labral ridge cracked.

***Valve:*** surface with scale-like ornamentation. Postero-dorsal of value serrated, but hardly seen (fig.62a).

***Thorax, Abdomen:*** short

***Postabdomen*** (figs.62e-f)***:*** relatively small, more ovoid in ventral view (fig.62e), sub-quadrangular in lateral view, not bilobed (fig.62f). Transverses rows of setules on preanal margin, postanal margin small. Ventral margin slightly convex anal teeth on postanal portion, with longest at postanal portion, numerous rows of spinules ventrally, of similar size and length, but somewhat longer in pre-anal part. Seta natatoria has a very short distal segment.

***Postabdominal claw:*** small size, armed with rows of 7-10 denticles along dorsal and ventral margins (figs.62e-f).

***First Antenna (antennule)*** (fig.62b)**:** relatively short, widen distally. Body of appendage with about 7 rows of small setules on internal margin. At tip of antennule, a bunch of eight (?) relatively short terminal esthetascs, slightly different in length. Around the bunch of the esthetascs, 2-3 additional rows of longer spines, unequal size, present rounded the tip of antennular body.

***Second Antenna*** (fig.62d)**:** moderately long, about two third of body lengths. Coxal region folded. Basal segment bearing transverse rows of spinules. Antennal branches long, with elongated segments, length of endopod segments slightly increases from basal to distal one, groups of setules around basal ends of all segment of endopod and add one row of bigger setules on distal end of second segmented of exopod..

Antenna formula, setae 0-0-1-3/1-1-3, spine 0-0-0-1/1-0-1 (0-1-0-1/0-0-1; Silva-Briano, 1998). All spines are about half the length of theirs segments, but the spine on first segment of endopod almost reach the segment. Largest lateral setae (on first endopod segment) 2-segmented, unilaterally setulated with small spines, the size is similar.

**Trunk limbs: five pairs**

***First trunk limb (P1)*** (figs. 63a-g)**:** Epipodite elongated. Outer distal lobe (ODL) with two setae (fig.63c), one long apical seta, unilaterally armed with long sparse setules on its distal part, counting 15 setules decreasing in length distally, second seta smaller ¼ times as long as the first, bilaterally setulated. Inner distal lobe (IDL) with three setae of different length (fig.63b), first seta longest, bi-segmented, unilaterally setulated, second seta shorter, bi-segmented, unilaterally setulated, third seta shortest, unsegmented, armed with short setules distally.

Endite 3 (E3) with four relatively short bi-segmented setae (1-4) (fig.63a), seta 1 plumose, bilaterally armed with long setules on right side and short setules on another, seta 2 slender, smallest, unilaterally armed with three well-space long setule basally, seta 3-4 more robust, bi-segmented, unilaterally setulated with one row of short setules. Endite 2 (E2) with three setae (5-7), slender, bi-segmented, similarly in length, unilaterally armed basally and bilaterally armed with longer setules distally. Endite 1 (E1) with two bi-segmented setae (8-9), subequal in length and with fully setulated distal and basal parts. Forks on endite 1 and endite 3 (figs.63d-g), pincer-shaped, pincer part about 0.7-0.8 times as long as fork body, left side with two tooth, right side without tooth, right pincer portion shorter than left side. Two ejector hooks in basal are equal in length, unilaterally armed with short setules distally. On limb base, a hillock with two fully setulated setae-a remainder of gnathobase I.

***Second trunk limb (P2)*** (fig.63h)***:*** Exopodite (EX) small, round-elongated lobe with short setules on distal part. Endopodite (EN) with eight scrapers, increasing in length distally. Scrapers 1, 2 of same length, longer than the rest about 2.5-3 times, bi-segmented, unilaterally setulated, compare with Silva-Briano (1998) the second scraping spine here relatively longer, scrapers 3-5 bi-segmented, with similar distal armed with strong tooth, counting 6 tooth each, near the apex longest teeth, scrapers 6-8 bi-segmented, with strong tooth distally, counting 5, 7, 5 tooth respectively.

Distal armature of gnathobase (GT) with three elements (I-III): element I naked, element II hook-like, bilateral feathered distally, element III naked, fused base with element II.

***Third trunk limb (P3)*** (fig.63i)***:*** Exopodite (EX) sub-quadrangular with four setae (1-4), seta 1-2 similar in length, seta 1 densely bilaterally setulated, seta 2 sparsely bilaterally setulated, row of long setules between these seta, seta 3-4 with similar armed, unilaterally setulated with sparse-stronger sharp spines, seta 3 two times as long as seta 4. Endopodite (EN) bilobed. Outer lobe (External Endite = EE) with two rows of setae. Anterior row with three setae (1-3), seta 1 long, slender, naked, seta 2 long with sparse setules distally, seta 3 unclear in figure. Posterior row with three setae (1'-3'), seta 1' long with sparse setules distally, seta 2', 3' longer, similar in length. Inner lobe (Internal Endite = IE) with two rows of setae. Anterior row with four setae (4-7), seta 4 small, seta 5-7 bottle-shaped with hook-like at apex, armed with 3-4 small spines distally. Posterior row with four setae (4'-7'), similar in length.

Gnathobase (GT) clearly demarcated from basal endite, number of elements on distal armature unclear.

***Fourth trunk limb (P4)*** (fig.63j)*:* Exopodite (EX) small, with three feathered setae, similarly in size. Endopodite (EN) with two rows of setae. Anterior row with five setae (1-5), seta 1 small, unilaterally setulated basally, seta 2-3, 5 'flaming torch', one rod-like seta 4, naked. Posterior row with five setae (1'-5') unilaterally setulated distally. Gnathobase (GT) with two elements, element I horse-tail seta, element II rod-like, naked.

***Fifth trunk limb (P5):*** not studied.

**Differential diagnosis:**

The species can be distinguished from others by the dilating distally of first antenna. It possesses serrulations along the dorsal margin of its head and value, contrary to *M. laticornis*, which its serrations only along the dorsal margin of values (Smirnov, 1992). According to Venkataraman (1991) together with the study in the present samples, this species suffices to point out the important distinguishing features of the species as found in Malaysia. These are:

1) body: small size
2) dorsal margin of carapace crossed by parallel transverse ridges and the characteristic carapace sculpture which is an irregular reticulation, and which, at least in the centre of the carapace valves, appears squamous, is only moderately well developed, but may be scarcely visible in mounted specimens though always distinctive in the living animal
3) A1: distinctly broaden towards the tip
4) the comparatively small ocellus
5) the form of the short blunt rostrum
6) Trunk limb 1: forks on endite 1, 3 with left side = 2 tooth, right side = 0,
7) Trunk limb 2: no sensillium seta behind scraper 8; no additional seta on gnathobase and seta on exopodite not seen
8) Trunk limb 3: seta 2 on exopodite as long as seta 3
9) Postabdomen: the form and armature of the more or less distinctly bi-lobed
10) Natatorial seta has a very short distal segment

**Biology:**

It is a species which appears to be confined to small water-bodies (Johnson, 1956). They often co-occurred with *M. flabelligera* and *M. laticornis* (Sanoamuang, 1998) in northeastern samples. In regard to habits, Sars (1888) mentioned that this species closely resembles the European *M. laticornis*, Jurine. Thus, for example, it is generally found near the bottom, only seldom approaching the surface of the water. In the present study, it was found in vegetated habitats; freshwater swamps, peat swamps, marshes ranging from freshwater to brackish.

**Distribution:**

A circumtropical and circumsubtropical species. Brehm (1933) remarked in the discussion of the distribution of this species that it appears to have a more restricted range than *M. triserialis.* Whilst this may be so it seems more probable that it has been commonly overlooked, and is itself of small size, so that it could easily escape observation. However, it is quite common in the present samples (occurred frequently in high number).

## 2. *Macrothrix* cf. *laticornis* (Fischer, 1851)

**References:** Norman and Brady, 1867: Des. 9-10, Pl. XXIII, figs. 4-5; Kurz, 1875: Des. 25, no figure; Brehm, 1934: Des. 58, no figure; Richard, 1894: Des. 371-372, no figure; Richard, 1897: Des. 286-287, no figure; Harding, 1955: Des. 339, figs. 40-44; Brehm, 1959: Des.82, no figure; Dumont and Van de Velde, 1977:82; Alonso, 1996: Des. 238-239, fig.106 (*Monoculus laticornis* Jurine, 1820); Sanoamuang, 1998: figs. 54-57.

**Remarks:**

This species was recorded from several localities in northeast Thailand (Sanoamuang, 1998). This is the first time it was found in the south. In both records, it was characterized by having the dorsal outline of values serrated, which are obvious serrated as in typical *M. laticornis* according to Smirnov (1992). However, an accurate checked can only be done with more characteristics. The species has so far been found from the Holarctic region (Smirnov, 1992) and the difference between 'serrated' and 'squamose' dorsal outline of the valve, the main distinctive trait in all old and recent keys-is quite subjective, and is not supported by any morphological data for these condition. This confusion accounts for many of the misidentifications from different regions of the world. Real difference between *laticornis* and *spinosa* group concern the thoracic limbs (table 9). Actually, the tropical records require re-identification and need to be proved. Unfortunately, it exists in few specimens each time it is found (there is only one specimen found in more than 300 samples in the present study), then we can not make a description of each part of the species to compare. Thus the status of the species in this region still needs to be confirmed when specimens are available.

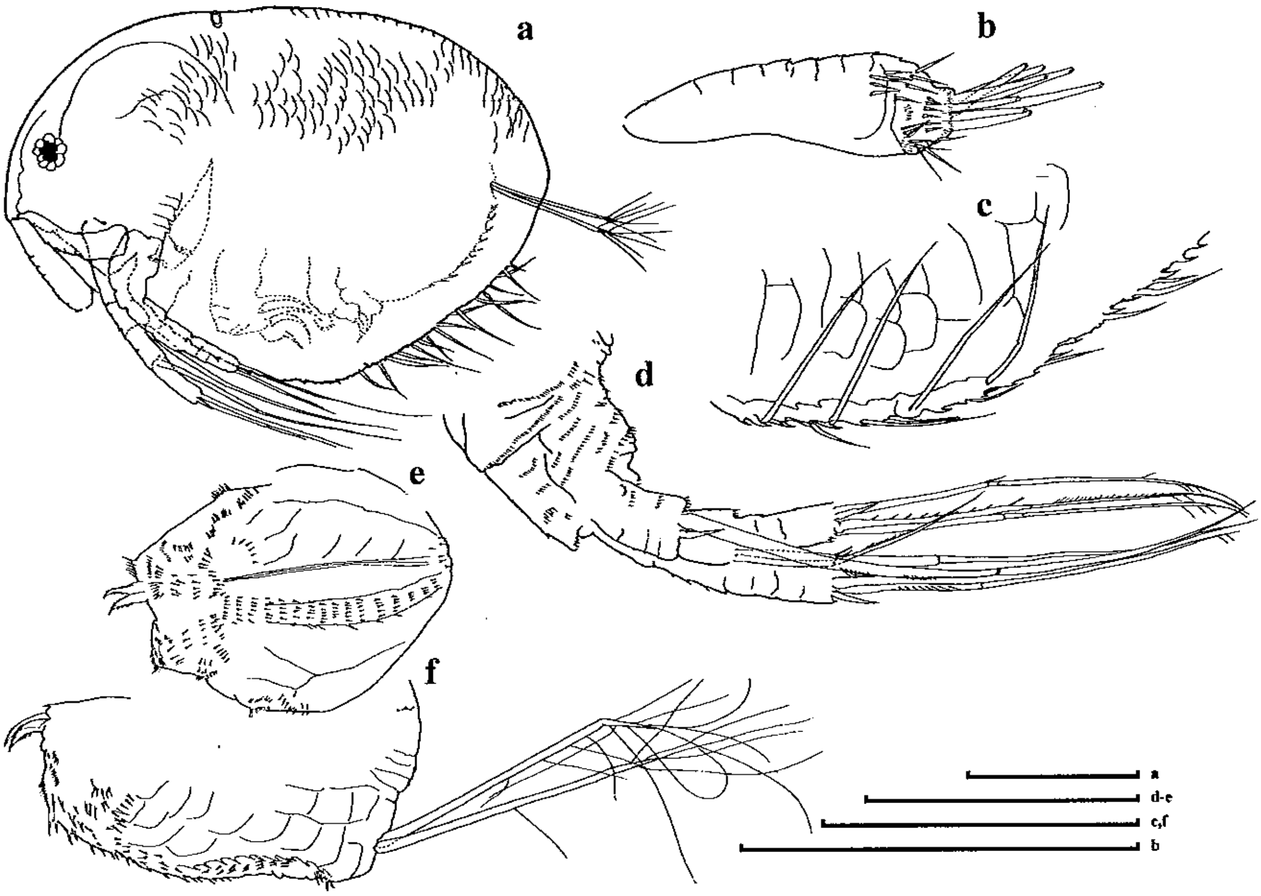
**Distribution:**

A Holarctic species and there is doubt that it occurs in South East Asia. Specimens were found on several occasions in one of the ponds on the Capachica Peninsula. The species is widely distributed in Europe and North America (Harding, 1955). Found near London, by Dr. Baird; at Belfast, by the late Mr. W. Thompson; at

Fardingslake, and in the Glebe Engine Pond, Sunderland, Country of Durham; in the East Lake, at Belsay, Northumberland, and North Shaws Loch, Selkirkshire, by G. S. B. Its range is known to extend in Europe from the neighbourhood of Geneva in the south, to Norway and Sweden in the north, and Russia in the east (Norman and Brady, 1867).

**Table 9** Morphological differences between *M. laticornis* and *M. spinosa*.

| **characters** | ***M. laticornis* s.str.** (Silva-Briano *et al.* 1999) | ***M. spinosa*** Thai specimens (present data) |
|---|---|---|
| **Head pores** | small, oval | small, oval |
| **A1** | dorsal margin without spines or ornamentation | rows of small spinules around the antennular body |
| **P1:** forks | left side=2 tooth, right side=1teeth | left side=2 tooth, right side=0 teeth |
| **P2:** scraper 4 on P2 | large subapical tooth | **very large subapical teeth** |
| scraper 5 on P2 | very large subapical tooth | **very large subapical teeth** |
| a bottle shape receptor behind scraper 8 | present | **absent** |
| **P3:** exopodite setae 3 | with short distal setules unilaterally | with short distal setules unilaterally |
| exopodite setae 4 | with short distal setules unilaterally | **with relatively long distal setules unilaterally** |
| **Postabdomen** | anal margin with groups of stout spinules, 3-4 big spines on each side | **anal margin with groups of more fine spinules** |




Figures 62a-f. *Macrothrix spinosa* King, 1853: parthenogenetic female from Thale-zub swamp, Chumporn Province, southeastern Thailand. Figure a, adult female in lateral view; Figure b, antenna 1; Figure c, ventral of valve; Figure d, antenna 2; Figure e, postabdomen in ventral view; Figure f, postabdomen in lateral view. Scale bar denotes 100 um.


Figures 63a-j. *Macrothrix spinosa* King, 1853: appendages of females from Thale-zub swamp, Chumporn Province, southern Thailand. Figure a, trunk limb 1; Figures b-c, its inner and outer distal lobe; Figures d-g, Fryer's forks of trunk limb 1; Figure h, trunk limb 2; Figure i, trunk limb 3; Figure j, trunk limb 4. Scale bar denotes 100 um.

## 3. Keys to all known cladoceran species from southern Thailand

One problem that cause to many misidentify the cladoceran species in our region is that we have no local key. Previously, our identification followed the foreign keys which described species from other continents i.e. Europe, South America. These are not adequate to apply to our local species. Here, we suggest the first local key to the present record of southern Thai cladocerans together with a drawings of characters used in each key so that the confusion in their identification can be decreased. We aimed to make practical keys rather than a phylogenetic key, so the selected characters are the easiest and the clearest that can save to separate the taxa, and not the characters that show the phylogenetic relationship. Nevertheless, for part of these keys we had no full descriptions to show all details, which create a risk to make a misidentification. Thus, besides *Alona* Baird, 1843 and *Macrothrix* Baird, 1843 for which we provided full descriptions in previous part, it is better to check other species in details against descriptions by Smirnov, 1971; Dumont and Silva-Briano, 2000; Van Damme *et al*, 2003; Kotov and Sanoamuang, 2004; Kotov *et.al.*, 2004.

# Keys to 72 cladoceran species from southern Thailand

## 1. Family Bosminidae Sars, 1865

There are only two genera of this family were found, *Bosmina* Baird, 1845 and *Bosminopsis* Richard, 1895. Both of them are more common and widely distributed especially in temperate and northern regions. There are only three species, two in genus *Bosmina* and one in genus *Bosminopsis*, have been recorded in southern Thailand.

**Key to two genera**

1 a. rostrum not fused at the base, almost parallel to each other (fig.66a); postabdomen not narrow distally and lacks large thorns near the claws.........................................................................***Bosmina*** **Baird, 1845**

*There are two Bosmina species have been found in the present study, Bosmina longirostris (O.F. Müller, 1785) and B. meridionalis Sars, 1904. The identification followed Korovchinsky and Smirnov (1995) and Sanoamuang (1998). B. meridionalis was separated from the former by having the lateral head pore situated above the mandibular articulation (Sanoamuang, 1998 referred from Korinek, 1971).*

*The specimen was named as B. longirostris as the combination of the characters of postabdomen, first antenna and the presence of seta at ventral shell spine. However, as its rarity so we can not study to describe more details.*

b. rostrum fused at the base at about ¼ of its length and strongly diverging at their apex (fig.66b); postabdomen narrow distally, with large thorns near the claws...........................................................***Bosminopsis*** **Richard, 1895**

*Only one species has been recorded in Thailand,* ***Bosminopsis deteri Richard, 1895.***

## 2. Family Chydoridae Stebbing, 1902

Key to 19 genera which have been found in southern Thailand; *Alona* Baird, 1843; *Alonella* Sars, 1862; *Acroperus* Baird, 1843; *Camptocercus* Baird, 1843; *Chydorus* Leach, 1816; *Dadaya* Sars, 1901; *Disparalona* Fryer, 1968; *Dunhevedia* King, 1853; *Ephemeroporus* Frey, 1982, *Euryalona* Sars, 1901; *Karualona* Dumont & Silva-Briano, 2000; *Kurzia* Dybowski & Grochowski, 1894; *Leydigia* Kurz, 1875; *Leydigiopsis* Sars, 1901; *Nicsmirnovius* Chiambeng & Dumont, 1999; *Notoalona* Rajapaksa & Fernando, 1987; *Oxyurella* Dybowski & Grochowski, 1894; *Picripleuroxus* Frey, 1993 and *Pleuroxus* Baird, 1843 are proposed.

**Key to 19 genera found in southern Thailand**

1 a. body oval (fig.64a), wide is about 1.5-1.7 times height..................................2
b. body global (fig.64b), wide is about 1-1.2 times height..................................18

2 a. postanal portion of postabdomen long and narrow......................................3
b. postanal portion of postabdomen not long and narrow....................................8

3 a. two or three distal anal teeth of postabdomen especially long..........................................**1. *Oxyurella* Dybowski & Grochowski, 1894**

*One species has been found in Thailand,* ***Oxyurella singalensis (Daday, 1898).***

b. distal anal teeth of postabdomen similar in size ........................................4

4 a. postabdomen tapering distally...........................................................5
b. postabdomen not tapering distally.......................................................7

5 a. rostrum long, point (fig.66c)............. **2. *Kurzia* Dybowski & Grochowski, 1894**

*One species has been found in Thailand,* ***Kurzia longirostris (Daday, 1898).***

b. rostrum blunt (fig.66d)...................................................................6

6 a. postabdominal claw with a long basal spine.............**3. *Camptocercus* Baird, 1843**

*One species has been found in Thailand,* ***Camptocercus australis Sars, 1896.***

b. postabdominal claw with a short basal spine.................**4. *Euryalona* Sars, 1901**

*One species has been found in Thailand,* ***Euryalona orientalis (Daday, 1898).***

7 a. rostrum long, point downward....................**5. *Disparalona* Fryer, 1968 (see 2.1)**

b. rostrum blunt (fig.66d)......................................**6. *Acroperus* Baird, 1843**

*One species has been found in Thailand,* ***Acroperus harpae Baird, 1843.***

8 a. postabdomen rounded, wide, enlarged, postanal portion leaf-like, with numerous well developed anal denticles; rostrum elongated, directed ventrally, reach lower than ventral portion..........................................................................................9

b. postabdomen various shaped.........................................................................10

9 a. postabdomen with long lateral setae and small anal teeth (hardly noticeable); 3 interconnected major head pores, closely spaced..................**7. *Leydigia* Kurz, 1875**

*One specimen has found in the present study which show the combination of these characters, however the specimen is not complete enough to be identified to species level. Thus, we put Leydigia sp.*

b. postabdomen with small lateral setae and large anal teeth; long rostrum; 2 major head pores with wide connection between them...............**8. *Leydigiopsis* Sars, 1901**

*One specimen has found in the present study which shown the combination of these characters, however the specimen is not complete enough to be identified to species level. It can be noted that the specimen look very much similar to Leydigiopsis* sp. *which has ever been recorded from the Northeast, Thailand (Sanoamuang, 1997).*

10 a. posterior edge of valves less than or equal half the total height of the shell..............................................................................................................11

b. posterior edge of valves greater than half the total height of the shell..............................................................................................................14

11 a. postanal portion of postabdomen oval; postabdomen wide and almost parallel; setae on the posterior half of ventral margin of the valves inserted on its inner surface............................................**9. *Dunhevedia* King, 1853 (see 2.2)**

b. postanal portion of postabdomen elongate; all ventral setae of valves inserts on its edge ..........................................................................................12

12 a. posterior edge of valves equal the half the total height of the valve..........................................................**10. *Alonella* Sars, 1862 (see 2.3)**

b. posterior edge of valves less than half the total height of the valve..........................................................................................13

13 a. body more elongated; postabdomen relatively long, elongated and slightly bent, postanal slightly concave; antennule without a peg at its base........................................................**11. *Picripleuroxus* Frey, 1993**

*One species of this genus has been recorded in southern Thailand, **Picripleuroxus laevis** (Sars, 1862). The differential diagnosis as the following; body elongated; postabdomen elongated and slightly bent, distal anal teeth of postabdomen larger than others and postero-ventral of valve rounded with small 1-2 denticles.*

b. body more oval; postabdomen relatively short............**12. *Pleuroxus* Baird, 1843**

*One species has been recorded in southern Thailand, **Pleuroxus uncinatus Baird, 1850.** It differs from others by its hooked rostrum and denticles at the postero-vental angle of valves.*

14 a. midline of head shield with no major pores, only two minor pores.......................................**13. *Notoalona* Rajapaksa & Fernando, 1987 (see 2.4)**

b. midline of head shield with 2-3 major pores, minor pores laterally...............15

15 a. valve with small denticles at the postero-ventral angle of valve; two interconnected major head pores.........**14. *Karualona* Dumont & Silva-Briano, 2000**

*One species has been recorded in Thailand, **Karualona iberica Dumont & Silva-Briano, 2000.** However, since Karualona group is widely distribute it is* *believed that there are more than one species of this genus exist in the waterbodies of Thailand.*

b. valve without denticles at the postero-ventral angle of valve.........  ............16

16 a. *5*-shaped postabdomen (fig.69b); fifth and sixth exopodite setae on fourth trunk limb with blunt spoon-like apex.....................**15. *Nicsmirnovius* Chiambeng & Dumont, 1999** (see Van Damme *et al.*, 2003)

*In Thailand we found one species of this genus, Nicsmirnovius eximius (Kiser, 1948).*

b. postabdomen various shaped........................**16. *Alona* Baird, 1843 (see 2.5)**

17 a. eye and ocellus large; labrum elongated and narrow (peculiar structure, fig.67a); first antenna attached near tip of rostrum and protruding beyond tip of rostrum...........................................................**17. *Dadaya* Sars, 1901**

*Only one species found in Thailand,* ***Dadaya macrops (Daday, 1898).***

b. eye and ocellus comparatively small..................................................18

18 a. labrum serrated with 1-4 teeth (fig.67b); proximal denticles on postanal margin of postabdomen longer than distal denticles...........**18. *Ephemeroporus* Frey, 1982 (see 2.6)**

b. labrum not serrated; proximal denticles on postanal margin of postabdomen same size or smaller than distal denticles...........**19. *Chydorus* Leach, 1816 (see 2.7)**

**2.1 Key to two species of *Disparalona* Fryer, 1968**

1 a. elongated body, height is about 1.2-1.4 times of width, long postabdomen, preanal angle of postabdomen prominent.........**1. *Disparalona hamata* (Birge, 1879)**

b. more elongated body, height is about 1.5-1.7 times of width, rather long postabdomen, pre-anal angle of postabdomen not prominent.................**2. *D. caudata* Smirnov, 1996**

**2.2 Key to two species of *Dunhevedia* King, 1853**

1 a. labral plate smooth.....................................**1. *Dunhevedia crassa* King, 1853**

b. labral plate serrated (fig.67b) .................................**2. *D. serrata* Daday, 1898**

**2.3 Key to three species of *Alonella* Sars, 1862**

1 a. body larger, length is about 1.5-1.7 times of height; quadrangular shape or oblong, rostrum point downwards, shell with polygonal-like ornamentation, postero-ventral angle of valve with denticle......................................................2

b. body relatively small, length is about 1.2-1.4 times of height; ovoid shape, rostrum curve inwards, shell with longitudinal striation from anterior to posterior, postero-ventral angle of valve with sharp denticle.......**1. *Alonella nana* (Baird, 1850)**

*It has been recorded as the Holarctic species, but it was recorded from Malaysia (Idris, 1983) and it is not rare in southern Thailand.*

2 a. body quadrangular (fig.64c), length is about 1.5 times of height, postero-ventral angle with blunt denticle ......................................**2. *A. excisa* (Fischer, 1854)**

b. body more oblong (fig.64d), length is about 1.7-1.8 times of height, postero-ventral angle with sharp denticle................................**3. *A. clathratula* Sars, 1896**

*These two species look very much similar. Only those characters, sometimes, not clear enough to make a decision what species it is. Thus, intensive study in details of a number of specimens of both species is necessary.*

**2.4 Key to two species of *Notoalona* Rajapaksa & Fernando, 1987**

1 a. postero-ventral of valve rounded with short setae and smaller ones in between; postabdomen relatively long; labrum not smooth...........**1. *Notoalona globulosa* (Daday, 1898)**

b. postero-ventral of valve rounded with obviously long ventral setae; postabdomen short and rounded distally; ..........................**2. *N. freyi* Idris & Fernando, 1980**

**2.5 Key to 11 species of *Alona* Baird, 1843**

1 a. body oval (fig.64a), length about 1.3-1.7 times of height............................2
b. body globular (fig.64b), length about as long as height..............................11

2 a. postabdomen slender, distally round, anal margin deep (s-shape, fig.69a)..........3
b. postabdomen more elongated, distally form an angle, anal margin shallow or almost straight ........................................................................................7

3 a. body with dorsal keel, postabdomen slender, postanal margin longer than anal margin.......................................................................................................4
b. body without dorsal keel, postanal margin as long as anal margin....................5

4 a. distinct pre-and post-anal angle of postabdomen; 3 IDL setae with one large hook-like seta; accessory seta of antennule arising from distinct tubercule..........................................**1. *A. sarasinorum* Stingelin, 1900** (figs. 35-41)
b. pre-and post-anal angle of postabdomen not distinct; 2 IDL setae, slender.............................................**2. *A. diaphana* Richard, 1895** (figs. 23-25)

5 a. antenna with a row of 3-4 setules at the joint of second segment; postabdomen with long basal spine about 1/2-1/3 of terminal claw; three main head pore ..........................................................................................................6
b. antenna with row of setules around the joint of each segment; postabdomen with short basal spine about ¼ of terminal claw; two main head pores with two 'flower-like' lateral pores (fig.68c).............................**3. *A. verrucosa* Sars, 1901** (figs. 43-45)

6 a. labrum with denticle; postero-ventral corner of valve with 2-3 denticles...................................**4. *A. monacantha* Stingelin, 1905** (figs. 31-32)

b. labrum without denticle; postero-ventral corner of valve smooth..........................................**5.** ***A. rectangula*** **Sars, 1862** (figs.33-34)

7 a. three main head pores; size relatively smaller........................................8

b. two main head pores; large animal, size up to 0.9 mm...............................................**6.** ***A. affinis*** **Leydig, 1860** (figs. 16-17)

8 a. three main head pores with connection; distal angle of postabdomen sharp, form 45-60°.......................................................................................9

b. three main head pores without connection; distal angle of postabdomen more blunt, form 80-90° ...........**7.** ***A.*** **cf.** ***cambouei*** **Guerne & Richard, 1893** (figs.18-19)

9 a. two small lateral pores; postabdomen form sharp distal end.........................10

b. two semi-circular 'sac-like' lateral pores (fig.68a)..................**8.** ***A. cheni*** **Chen & Peng, 1993** (figs.20-22)

10 a. labrum rounded, smooth; 3 IDL setae on trunk limb 1; distal portion of postabdomen form an angle of 50-60°........**9.** ***A.*** **aff.** ***karelica*** **Stenroos, 1897** (fig.27)

b. labrum with a cluster of setules at the apex; 2 IDL setae on trunk limb 1; distal portion of postabdomen form an angle of 45°............**10.** ***A. guttata*** **Sars, 1862** (fig.26)

11. a. postabdomen tapering distally 'saw-like' (fig.69c), peculiar character............................................**11.** ***A. macronyx*** **Daday, 1898** (fig.30)

b. postabdomen with other shape..........................................................2

**2.6 Key to four species of *Ephemeroporus* Frey, 1982**

1 a. no denticles at postero-ventral corner of valve..........................................2

b. denticle present at postero-ventral corner of valve.....................................3

2 a. 2-3 spine-like setae at postero-ventral corner of valve; 3-4 teeth on labral plate, labral tip point.........................**1.** ***Ephemeroporus tridentatus*** **(Bergamin, 1939)**

b. no denticle or spine-like setae at postero-ventral corner of valve; 3-4 teeth on labral plate, labral tip blunt......................**2.** ***E. phintonicus*** **(Margaritora, 1969)**

3 a. labral plate with single tooth...........................**3.** ***E. hybridus*** **(Daday, 1905)**

b. labral plate with 3-4 teeth; a denticle at postero-ventral corner of valve small to large size...............................................**4.** ***E. barroisi*** **(Richard, 1894)**

**2.7 Key to seven species of *Chydorus* Leach, 1816**

1 a. 'honey-comb' like exterior shell (fig.65c)..........................................2

b. shell smooth or with small setules...................................................3

2 a. postabdomen with point anal teeth; one hook-like IDL seta on trunk limb 1 subequal in length of another IDL seta.........**1.** ***Chydorus obscurirostris obscurirostris*** **(Frey, 1987)**

b. postabdomen with curved anal teeth; one hook-like IDL seta on trunk limb 1 longer than another IDL seta................**2.** ***C. obscurirostris tasekberae*** **(Frey, 1987)**

3 a. exterior of shell smooth...................................................................4

b. exterior of shell not smooth.............................................................6

4 a. anterior ventral of valve smooth; valve smooth......................................5

b.1-3 knobs present at anterior ventral of valve; polygons on valve with wavy or straight boundaries...............................................**3.** ***C. parvus*** **Daday, 1898**

5 a. body globular; labrum widely round, depress near the apex, apex pointed.........................................................................**4.** ***C. eurynotus*** **Sars, 1901**

b. body sub-globular; labrum more oval, rounded apex......**5.** ***C. ventricosus*** **Daday, 1898**

6 a. valve polygons (fig.65b), wavy boundaries; setules on valves, densely around the boundaries..................................................**6. *C. pubescens* Sars, 1901**

b. valve reticulated with hexagonal patterns (fig.65a); wavy or straight boundaries; boundaries build low vertical wall..................................**7. *C. reticulatus* Daday, 1898**

## 3. Family Daphniidae Straus, 1820

There are five genera of this family have been recorded in southern Thailand; *Moina* Baird, 1850; *Moinodaphnia* Herrick, 1887; *Scapholeberis* Schoedler, 1858; *Ceriodaphnia* Dana, 1853 and *Simocephalus* Schoedler, 1858.

**Key to five genera found in southern Thailand**

1 a. antennule one segmented, mobile and mostly long, attached to the posterior lower side of the head..............................................................................2

b. antennule comparatively small, one segmented, immovable fused with the head, ..............................................................................3

2 a. ocellus rarely present, three setae on the exopod of second antenna..............................................................................**1. *Moina* Baird, 1850**

*Only one species has been found in southern Thailand, **M. micrura Kurz, 1874**. This species has a large head, with well developed supraocular depression and a large eye. There are no hairs on either the head or shell. Postabdominal claw lacks strong pectin but has a row of thin setae. It is often found in permanent lakes (Goulden, 1968), distributes throughout tropical and subtropical regions.*

b. ocellus present, four setae on the exopod of the second antenna, well developed fold on the postabdomen that serves to close off the brood pouch..................................................**2. *Moinodaphnia* Herrick, 1887**

*Only one species has been found in Thailand, **M. macleayi King, 1853**. This species has long cigar-shaped of the first antenna, four distal setae on terminal segments of second antenna exopod. It distributes covering circumtropical region.*

3 a. ventral valve margin straight, forming a posterior spine............**3. *Scapholeberis* Schoedler, 1858**

*Only one species has been found in Thailand, **S. kingi Sars, 1903**. This species has a broadly rounded body, maximum height after the middle of the body. Head relatively small, rostrum rounded. Posterior margin straight vertically with distinct posterior dorsal, ventral margin straight horizontally.*

b. ventral valve margin rounded, a posterior spine present or maybe not..............................................................................................4

4 a. head comparatively low, without rostrum..............**4. *Ceriodaphnia* Dana, 1853**

*Only one species in this genus has been found in Thailand, **C. cornuta Sars, 1885**. This species has a broadly rounded or oval body. Head small, anterior margin rounded and sometimes with a horn-like process. First antenna short and broad, with a long lateral setae and group of sensory setae on the apex. Ocellus absent. Postero-dorsal corner of valve projected, forming sharply pointed processes. It is one of very common species in tropical freshwaters.*

b. head comparatively high, with rostrum..................**5. *Simocephalus* Schoedler, 1858 (see 3.1)**

**3.1 Key to species of *Simocephalus* Schoedler, 1858**

1 a. dorso-posterior valve prominence rounded, depression of head shield shallow...............................................***S. heilongjiangensis* Shi & Shi, 1994**

***S. mesorostris Orlova-Bienkowskaja, 1995**, species which has been recorded from Thailand in every study, is a junior synonym of S. heilongjiangensis.*

b. dorso-posterior valve prominence large, separate from the rest of valves by deep embayment. Its length exceeds the diameter of the circle inscribed in its contour ....................................................................................***S. serrulatus* (Koch, 1841)**

## 4. Family Macrothricidae Norman & Brady, 1976

There are three genera have been found in southern Thailand; *Guernella* Richard, 1892; *Strebloceras* Sars, 1862 and *Macrothrix* Baird, 1843.

**Key to three genera of Macrothricid which have been found in southern Thailand**

1 a. anal teeth on postabdomen present; antennule vary in size and setules ornamentation; ...............................................................................2

b. no anal teeth on postabdomen; antennule thick, wide in the middle with peculiar transverse rows of setules; postabdomen wide.................**1. *Guernella* Richard, 1892**

*It is one circumtropical species, **Guernella raphaelis Richard, 1892**.*

2 a. antennule curved, with 4-5 strong long setules distally; postabdomen rounded, clearly bi-lobed, strong teeth on anal margin.....................**2. *Strebloceras* Sars, 1862**

*There are four species in this genus (S. serricaudatus, S. inexpectatus, S. spinulatus and S. pygmaeus) but only one species has been found in Thailand, **S. pygmaeus Sars, 1901**. It is rare in the present samples.*

b. antennule rod-like or dilating distally; postabdomen rounded or quadrangular, setules or teeth on anal margin..........................**3. *Macrothrix* Baird, 1843 (see 4.1)**

### 4.1 Key to nine species of *Macrothrix* Baird, 1843 including two closet species of *Macrothrix* sp. nov.

1 a. dorsal outline of value smooth or minute serrations or with a tooth......................2

b. dorsal outline of valve serrated obviously.......**1. *M.* cf. *laticornis* (Fischer, 1851)**

2 a. antennule rod-like (fig.70a).........................................................................3

b. antennule dilating distally (fig.70b).........**2. *M. spinosa* King, 1853** (figs. 62-63)

3 a. two ejector hooks on trunk limb 1...............................**3. *M. triserialis*-group (4)**

b. single ejector hook on trunk limb 1...................................................5

4 a. setules on basal segment of postabdominal seta.......................**4. *M. superaculeata* (Smirnov, 1982)**

b. no setules on basal segment of postabdominal seta...........**5. *M. triserialis* Brady, 1886** (figs. 57-61)

5 a. labrum relatively small, rounded..............**6. *M. malaysiensis* Idris & Fernando, 1981**

b. labrum large, sub-triangular..................................**7. *M. paulensis*-group (6)**

6 a. hair-like setules near anus, ventral head margin without projection..........................................**8. *M. paulensis* (Sars, 1900)** (figs. 49-50)

b. no hair-like setules near anus, ventral head margin with projection...............7

7 a. postero-dorsal angle smooth, low projection, dorsal margin of valves not prominent above head...............................**9. *M. odiosa* Gurney, 1916** (figs. 51-53)

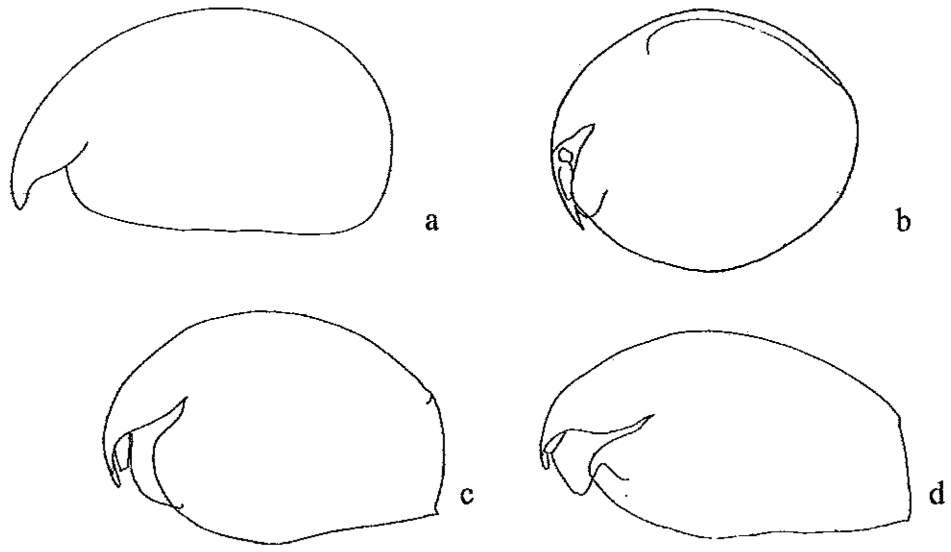
b. postero-dorsal angle with prominent spine, dorsal margin of values prominent above head.......................................................................................8

8 a. no anal flaps on postabdomen.............**10. *M. sioli* (Smirnov, 1982) (see Kotov and Hollwedel, 2004)**

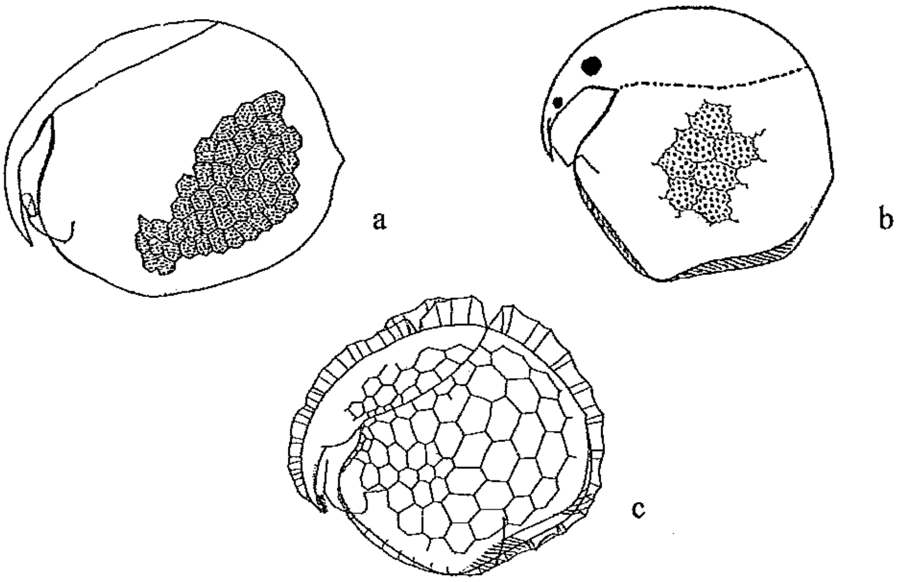
b. anal flaps on postabdomen...........................**11. *Macrothrix* sp.** (figs. 54-56)

### 5. Family Ilyocryptidae

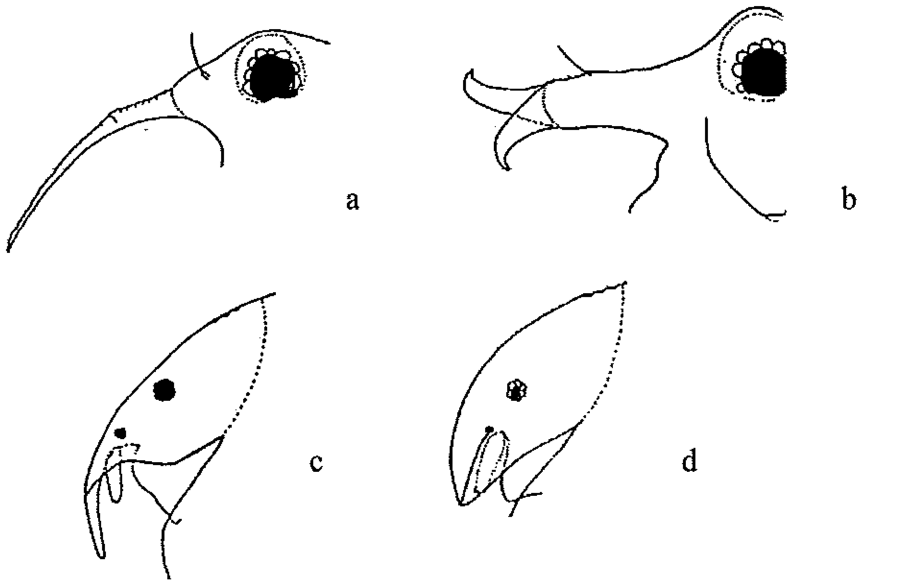
Only one species has been recorded in southern Thailand, ***Ilyocryptus spinifer* Herrick, 1882**. However, there are four other species were recorded from northeast Thailand, *I. thailandensis* Kotov & Sanoamuang, 2004; *I.* cf. *raridentatus* Smirnov, 1989; *I.* cf. *bhardwaji* Battish, 1981 (Kotov and Sanoamuang, 2004) and *I.* sp. nov. (Kotov and Sanoamuang, 2004).



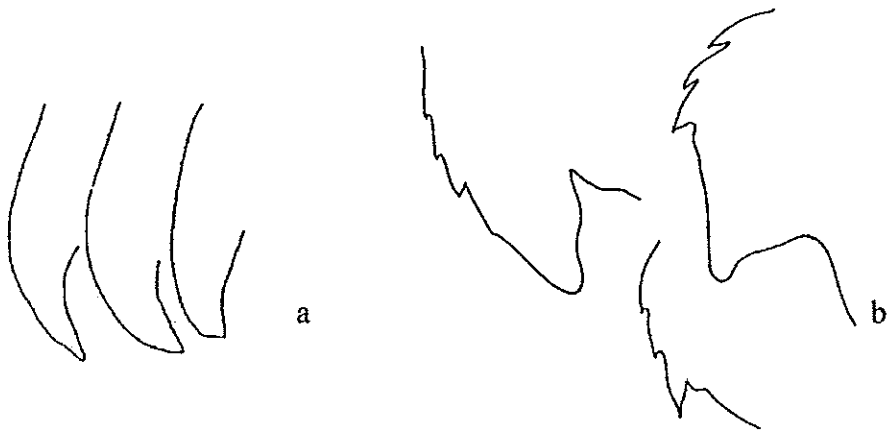
Figures 64a-d. Body shape: a. oval shape; b. globular shape; c. quadragular shape; d. oblong/elongated shape



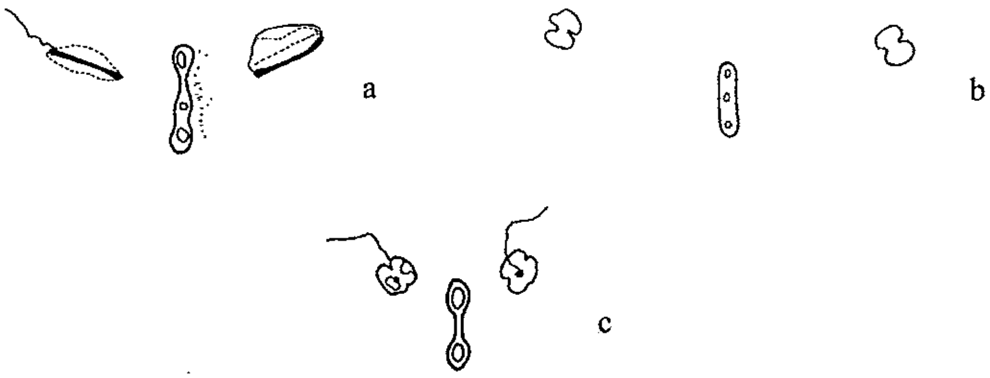
Figures 65a-c. Ornamentation of valves: a. reticulated; b. polygonal; c. honey-comb like



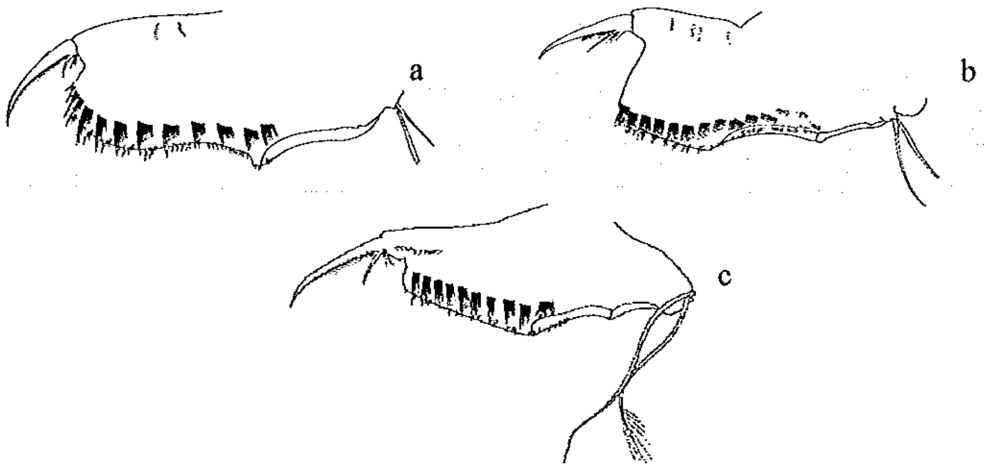
Figures 66a-d. Rostrum: a. fused at the base; b. separated at the base; c. pointed; d. blunt



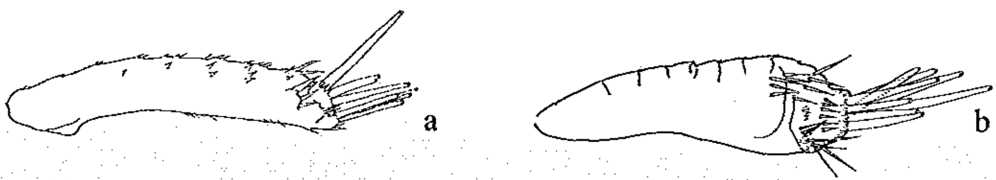
Figures 67a-b. Labrum: a. elongated and narrow (peculiar structure in *Dadaya*); b. serrated with 1-4 tooth




Figures 68a-c. Head pores: a. semicircular-like lateral pores; b. *Cosmarium*-like lateral pores; c. flower-like lateral pores




Figures 69a-c. Postabdomen, anal portion: a. *s*-shaped; b. *5*-shaped; c. saw-like shaped




Figures 70a-b. First antenna (antennule): a. rod-like; b. dilating distally

# Part 2: Diversity of the Cladocera from southern Thailand

## 1. Introduction

The latest estimation of the number of cladocerans (Korovchinsky, 1996) added up to 602 species, comprising of 12 families; Chydoridae (274 species), Daphniidae (134 species), Macrothricidae (56 species), Sididae (40 species), Moinidae (26 species), Bosminidae (18 species), Ilyocryptidae (18 species), Holopediidae (2 species), Podonidae (17 species), Cercopagidae (14 species), Polyphemidae (2 species) and Leptodoridae (1 species). Only 129 species (17% of all known species) were considered as sufficiently well described (valid species) and 146 species as rather well described (fair species) but needing further study using modern methods of investigation. The status of all other species is vague. A number of new species has since been reported in recent publications (Dumont and Silva-Briano, 1999; Kotov, 2002; Kotov *et al.*, 2003 and Van Damme *et al.*, 2003).

The Cladocera have not received much taxonomic attention in any area of the world where studies have been conducted. As a result no up to date species list for any part of the world, and there is no complete identification key for this group. This is the beginning of the confusion in their systems and leads to a difficulty for further study of other topics like ecology. The knowledge is fragmentary, especially in the tropical zone.

Since the first period, studies on the Cladocera in tropical and subtropical regions were few. The available literature usually deals with the diversity, systematics and life histories of a few species. For Asia, there are the classical works in Philippines (Mamaril and Fernando, 1977), Nepal (Dumont and Van De Valde, 1977), Sri Lanka (Fernando, 1980) and Malaysia (Idris and Fernando, 1983). However, knowledge on the Cladocera from Thailand progressed strongly during the last two decades (Boonsom, 1984; Pholpunthin, 1997; Sirimongkonthaworn, 1997; Sanoamuang, 1998; Pipatcharoenchai, 2001; Saeng-aroon, 2001; Sanoamuang, Saeng-aroon and Kotethip, 2001; Sa-ardrit, 2002; Faitacum, 2003; Sa-adrit & Beamish, 2004; Maiphae *et al.*, 2004a) but few data are available on southern

Thailand. Pholpunthin (1997) reported 17 species from Thale-noi, Pattalung Province, including seven species new to the region and one first record for Southeast Asia, and Sa-ardrit (2002) added six other records from only one Province, bringing the Thai cladoceran list to 96 species. The number of species mentioned by the latter author, 68 species, indicates that this is probably not a final figure and a number of species remain to be discovered.

The present chapter aims to examine the cladoceran taxa of southern Thailand. Their specific status could not be determined in all cases, yet our result represents a further contribution and provides a tool for further investigations. An estimation of the total cladoceran species richness present from samples, a study of faunal complementarity at different levels as well as the discussion on their correlation with environmental factors was also included.

## 2. Materials and methods

### 2.1 Description of the study area

The selected sampling sites were representative of the variety of freshwaters of southern Thailand, such as swamps, peat swamps, marshes, rivers, dams, ponds and reservoirs. Most of sampling sites are important water resources at the national or local levels (fig.9).

### 2.2 Sampling and examination

Seven hundred qualitative samples were collected from 59 freshwater localities in southern Thailand across seasons, from September 1999 to April 2000. The samples were obtained from representative environments in each water body, using towed plankton nets of mesh sizes 20 and 60 µm. Samples were immediately preserved in 4% formaldehyde. Physical and chemical variables (temperature, turbidity, pH, conductivity and salinity) were measured with calibrated water analysis checker (Horiba U-10). In addition, the characteristics of the habitats i.e. type of habitats, vegetation type and percent cover of vegetation were noted. In the laboratory, specimens were sorted under an Olympus dissecting microscope and examined under an Olympus CH-2 compound microscope.

### 2.3 Data analysis

*The actual species richness*

A species list based on 183 qualitative samples (excluding the samples which had no species) was used to construct a species accumulation curve. Per sample series, 50 randomizations were carried out, such that a standard deviation for each data point could be calculated. The calculation was carried out by the estimate*s* program version 6.0 (http://viceroy.eeb.uconn.edu/estimates). Chao's non-parametric method, which is recognized as the most reliable estimator (Chao, 1987; Chao and Lee, 1992; Dumont and Segers, 1996), the Jacknife method, and the Bootstrap method were used as shortcuts to extrapolate from species number observed to expected number.

*The complementarity values*

The measurement of non-similarity (complementarity) is a method to compare different faunas. Here, species richness of the cladocerans was compared among habitat types in southern Thailand, among three parts of Thailand, and among several Asian countries. Literature sources (Boonsom, 1984; Idris and Fernando, 1981; Michael and Sharma, 1987; Rajapaksa and Fernando, 1982; Maiphae *et al.*, 2004a; Pholpunthin, 1997; Pipatcharoenchai, 2001; Sa-ardrit, 2002; Sanoamuang, 1998; Sanoamuang and Kotethip, 2001 and Sirimonkonthaworn, 1997) were used in the analysis. The calculation used the equation of Colwell and Coddington (1994).

*The species composition and the relationship with environmental factors*

To analyze the spatial distribution of cladoceran species, the Detrended Correspondence Analysis (DCA) was performed on the data matrix including all sites and species with abundance. The analysis was performed for ln (n+1)-transformed data, down-weighting of rare species and detrending-by-segments as a supplement to the Two Way Indicator Species analysis (TWINSPAN). The TWINSPAN is used to classify the habitats related to their species composition, which is the indicator by which species of each TWIN-group can be reported.

To order the species and samples in relation to environmental variables, the direct gradient analysis program of Canonical Correspondence Analysis (CCA) was performed for ln(n+1)-transformed data with Monte Carlo testing to evaluate the statistical significance of the outcome.

Rare species are routinely deleted from the data sets, believing that rare species contribute little to the community analysis but add noise to statistical solution (Cao *et al.*, 1998). The 10% rule was used, species that occurred in less than 10% of samples with a maximum relative abundance of 10% were omitted from the analysis so that the variance was decreased.

The evaluations using PC-ORD program version 3.1.

## 3. Results

### 3.1 The Cladoceran species found in southern Thailand

A total of 72 species in 31 genera and six families were identified (table 9). One was new to science, *Macrothrix* sp. (Kotov *et al.*, 2004) and twelve species, *Alona cheni* Sars, 1860; *A.* aff. *karelica* Stenroos, 1897; *A. sarasinorum* Stingelin, 1900; *Bosmina longirostris* (O.F. Muller, 1785); *Chydorus obscurirostris obscurirostris* Frey, 1987; *Ephemeroporus phintonicus* (Margaritona, 1969); *E. hybridus* (Daday, 1905); *Macrothrix malaysiensis* Idris & Fernando, 1980; *M. odiosa* Gurney, 1916; *M.* cf. *superaculeata* (Smirnov, 1982); *M.* cf. *gautheri* Smirnov, 1976 and *Notoalona freyi* Idris & Fernando, 1980 are new to the Thai fauna (indicated by an asterisk in table 9).

The number of species found in southern Thailand is comparable to that reported from northeast Thailand by Sanoamuang, 1998 (60 taxa) but superior to the number known from the center (25 taxa) and the west (28 taxa) (Pipatcharoenchai, 2001).

Chydoridae was the most diverse family (45 species), followed by Macrothricidae (11 species); Daphniidae (6 species); Sididae (6 species); Bosminidae

(3 species) and Ilyocryptidae (1 species). *Alona* was the most speciose genus followed by *Macrothrix* and *Chydorus*. The most frequently encountered cladoceran species, found in more than 65% of the samples, were *Alona verrucosa* Sars, 1901 (72.88%), *Ephemeroporus barroisi* Richard, 1894 (72.88%) and *Macrothrix flabelligera* Smirnov, 1992 (66.10%), while *E. hybridus* Daday, 1905, *Guernella raphaelis* Richard, 1892, *Leydigia* sp., *Leydigiopsis* sp., *Macrothrix paulensis* (Sars, 1900), *Nicsmirnovius eximius* (Kiser, 1948), *Notoalona freyi* Idris & Fernando, 1980 and *Pleuroxus uncinatus* Baird, 1850 were rare (low numbers and/or occurring in only one sample).

**Table 10** Cladoceran species recorded from southern Thailand. The number of a locality refers to figure 9. *: new record for Thailand.

**Family Bosminidae**
1. **Bosmina longirostris* (O.F.Muller, 1785): 24
2. *B.meridionalis* Sars, 1904: 59
3. *Bosminopsis deitersi* Richard, 1895: 3,4,12,13,14,18,19,24,26,33,35,39,40,50,54,55,56,58

**Family Chydoridae**
4. *Alona affinis* Leydig, 1860: 4,19,39,53,54,55,56,57,59
5. **A. cheni* Sars, 1860: 19,21,23,28,34,39,58
6. *A.*cf. *dentifera* Sars, 1901: 32
7. *A. diaphana* Richard, 1895: 3,4,9,18,19,28,29,41,42,44,48,51,59
8. *A. guttata* Sars, 1862: 2,4,19,25,39,45,57,58
9. **A.* aff. *karelica* Stenroos, 1897: 2,42,55
10. *A. macronyx* Daday, 1898: 14,51
11. *A. monacantha* Stingelin, 1905: 2,12,18,21,26,49,53,56
12. *A.*cf. *cambouei* King, 1853: 3,4,20,22,23,32,38,58
13. *A. quadrangularis* (O.F.Muller, 1785):16,53
14. *A. rectangula* Sars, 1862: 3,49
15. **A. sarasinorum* Stingelin, 1900: 28,34,49
16. *A. verrucosa* Sars, 1901: 1,2,3,4,5,9,11,12,16,19,21,22,23,25,26,28,29,30,31,32,33,34,38, 39,40,42,44,45,46,47, 48,49,50,51,52,53,54,55,56,57,58,59
17. *Alonella clathratula* Sars, 1896:2,4,19,41,57
18. *A. excisa* (Fischer, 1854):2,3,4,6,11,19,21,23,24,25,26,28,32,34,38,39,42,44,45
19. *A. nana* (Baird, 1850): 19,28,34,41,57,58,59
20. *Acroperus harpae* (Baird, 1834): 6,26,41,47,55,57,58
21. *Camptocercus australis* Sars, 1896: 4,54
22. *Chydorus eurynotus* Sars, 1901: 2,3,4,9,11,14,17,18,19,23,24,26,28,29,31, 32,34,35,38, 39, 42,43,45,46,47,48,49, 50,51,52,53,54,55,56,57,58
23. * *C. obscurirostris obscurirostis* Frey, 1987: 6,41,57
24. *C. obscurirostris tasekberae* Frey, 1987: 19,54,57
25. *C. parvus* Daday, 1898: 4,19,38,40,42,51,52,53,54,55,57
26. *C. pubescens* Sars, 1901: 2,19,45,49,53,55
27. *C. reticulatus* Daday, 1898:2,3,6,18,19,39,41,42,44,45,46,48,50,51,52,53,54,55,56,57,58,59
28. *C. ventricosus* Daday, 1898: 3,14,19,23,41,42,44,49,50,52,53,54,56,57,58,59
29. *Dadaya macrops* (Daday, 1898): 2,4,6,19,21,25,30,39,41,42,47,48,52,53,58,59
30. *Disparalona caudata* Smirnov, 1996: 16,56
31. *D. hamata* (Birge, 1879): 4,16
32. *Dunhevedia crassa* King, 1853: 3,4,5,16,17,28,31,38,42,52
33. *D. serrata* Daday, 1898: 4,22,38,42,46,49,52
34. *Ephemeroporus barroisi* Richard, 1894: 2,3,4,5,6,8,9,11,14,17,18,19,21,23,24,25, 26,28,32, 33,34,35,38,39,42,44, 45,46,47,48,49,50,51,52,53,54,55,56,57,58,59
35. **E. hybridus* (Daday, 1905): 18
36. **E. phintonicus* (Margaritora, 1969): 5,8,9,11,21,23,24,28,38,39,41,46,49,50,52,53,54,58
37. *E. tridentatus* (Bergamin, 1939): 3,5,9,19,26,34,42,45,48,49,50,52,53,54,56,57,59
38. *Euryalona orientalis* (Daday, 1898): 4,6,29,42,50
39. *Karualona iberica* Dumont&Silva-Briano, 2000: 2,3,4,14,16,17,18,19,20,21,23,25,28,32, 34,36,38,39,40,42,43, 46,49,52,53,54,56,59
40. *Kurzia longirostris* (Daday, 1898): 17,20,25,41,43,52,54,56

**Table 10.** (Continued)

41. *Leydigia* sp.: 59
42. *Leydigiopsis* sp.: 57
43. *Nicsmirnovious eximius* (Kiser, 1948): 6
44. *Notoalona globulosa* (Daday, 1898): 14,17,19,42,49
45. **N. freyi* Idris & Fernando, 1980: 19,28,34
46. *Oxyurella singalensis* (Daday, 1898): 2,3,9,17,18,19,20,25,29,35,38,39,42,43, 47,49,50,51, 52,53,56,57,59
47. *Picripleuroxus laevis* (Sars, 1862): 2,3,16,17
48. *Pleuroxus uncinatus* Baird, 1850: 59

**Family Daphniidae**

49. *Ceriodaphnia cornuta* Sars, 1885: 3,4,9,15,16,25,26,29,30,35,39,41,42,43,45,50,53,55
50. *Scapholeberis kingi* Sars, 1903: 2,18,19,24,25,32,42,44,50,52,55,56
51. *S. heilongjiangensis* Shi & Shi, 1994: 3,9,19,23,25,28,29,34,42,43,44,52,58,59
52. *S. serrulatus* (Koch, 1841): 2,9,18,19,25,26,28,29,31,34,38,39,42,46,47,48,51, 52,53,54, 57,58
53. *Moina micrura* Kurz, 1874: 3,4,15,35,40,49,50
54. *Moinodaphnis macleayi* (King, 1853) : 2,3,4,6,14,15,17,18,20,24,25,28,35,39,42,43,47,49, 50,52,54

**Family Ilyocryptidae**

55. *Ilyocryptus spinifer* Herrick, 1882: 4,6,9,14,19,21,23,24,25,28,29,31,34,35,39,42,43,51, 52, 54,57,58,59

**Family Macrothricidae**

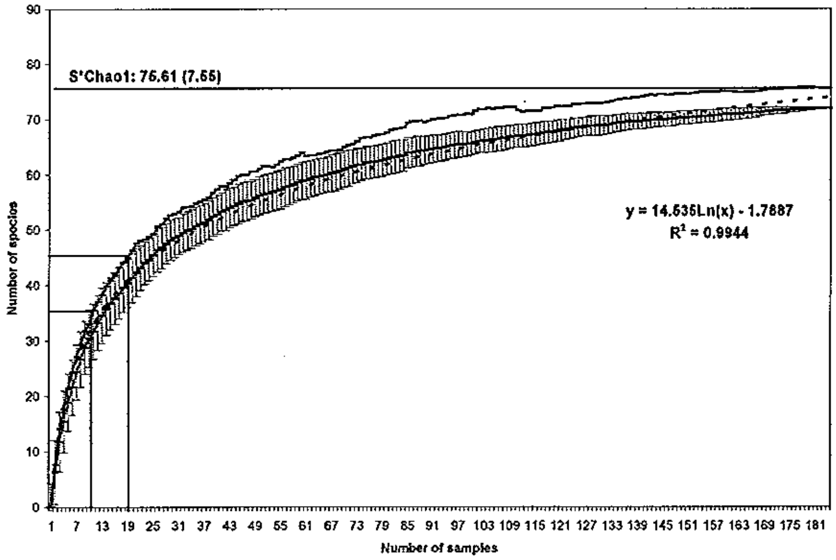
56. *Guernella raphaelis* Richard, 1892: 28
57. *Macrothrix flabelligera* Smirnov, 1992: 2,3,6,9,11,14,16,17,19,20,21,23,24, 25,26,28,29, 31,32,34,38,39,42,43, 45,46,47,48,49,50,51,52,53,54,55,56,57,58,59
58. **M.* cf. *gauthieri* Smirnov, 1976: 53,57
59. **M. malaysiensis* Idris & Fernando, 1980: 19,28,34
60. **M. odiosa* Gurney, 1916: 19,28,34,38,42,51,52
61. *M.* cf. *paulensis* (Sars, 1900): 52
62. **M.* sp.
63. *M. spinosa* King, 1852: 2,9,11,18,19,21,24,26,29,38,42,45,49,53,54,56,57,59
64. **M.* cf. *superaculeata* (Smirnov, 1982): 53,58
65. *M. triserialis* Brady, 1886: 2,3,5,6,9,14,16,23,24,26,29,31,32,38,39,42,47,53,54,55,57,58
66. *Sreblocerus pygmaeus* Sars, 1901: 2,8,9,19,23,26,41,42,50,52,54,57,58

**Family Sididae**

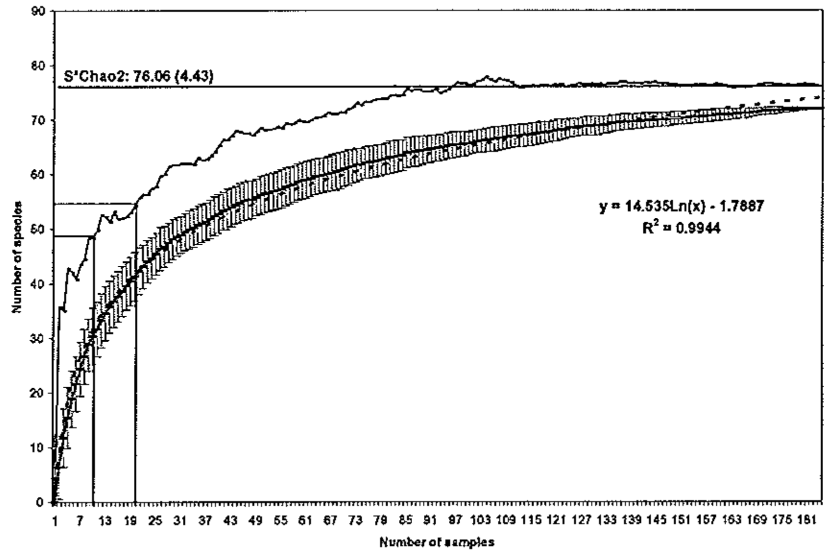
67. *Diaphanosoma excisum* Sars, 1885: 1,3,4,7,12,13,14,15,16,17,18,19,25,30, 35,36,39, 40,41, 42,43,50,54,55,58
68. *D. sarsi* Richard, 1895: 3,4,24,25,41,43
69. *Latonopsis australis* Sars, 1888: 4,5,15,16,23,24,28,31,33,34,38,39,42,46,49,51,52,54, 55, 57,58,59
70. *Pseudosida bidentata* Herrick, 1884: 2,3,9,11,25,29,36,41,42,46,49,52,53,54,58
71. *P. ramosa* Daday, 1904: 2,11,25,55
72. *Sida crystallina* (O.F.Muller,1776): 50

**3.2 The ultimate number of cladoceran species in southern Thailand**

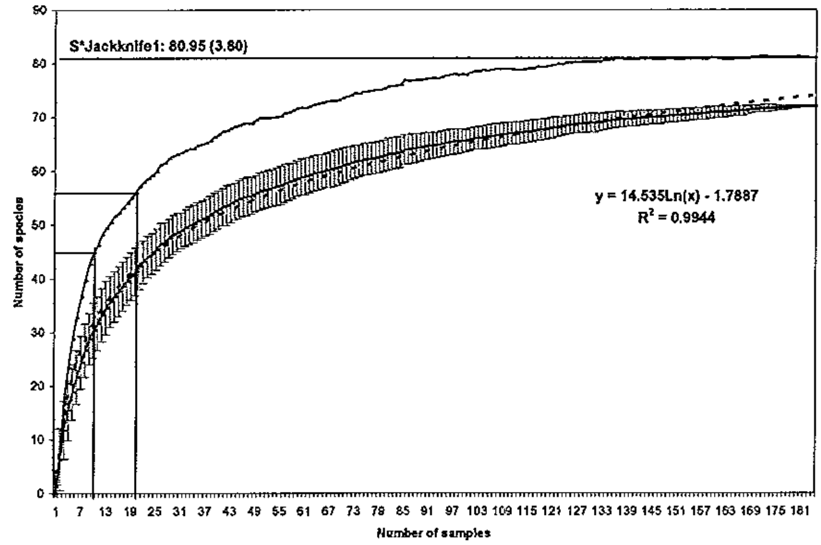
A species accumulation curve was fitted using a logarithmic equation, as well as Chao1, Chao2, Jackknife1, Jackknife2 and Bootstrap estimators (variance in brackets), shown in figure 71. The Chao 2 and second-order Jacknife estimators are known to provide the least biased estimates (Cowell and Coddington, 1994; Hellmann and Fowler, 1999) for S**max* (76.06 and 81.98 species), followed by the first-order Jacknife, the Bootstrap and Chao 1. The Chao 2 estimator produced an estimate of 49.75 species (72 species were observed), based on as few as 10 samples, while the Jackknife 2 estimator suggested 54 species at the same number of samples. The intersection of the regression equation with Chao 2 is a rough measure of the number of samples required to record total species richness present. In the case of the logarithmic equation (y= 14.535Ln(x)-1.7887), this leads to 212 samples for Chao 2 and 318 samples for Jackknife 2. Apart from computing Chao 2 and Jackknife 2, the ratio variance/estimator is interesting; the smaller the ratio, the better the estimation (Dumont and Segers, 1996). The ratio associated with both estimators was low, especially for Chao 2 (0.06) indicating that the true cladoceran species richness was well estimated from our number of samples (Hellmann and Fowler, 1999).


S*Chao1: 76.61 (7.55)
y = 14.535Ln(x) - 1.7887
R² = 0.9944
Number of species
Number of samples

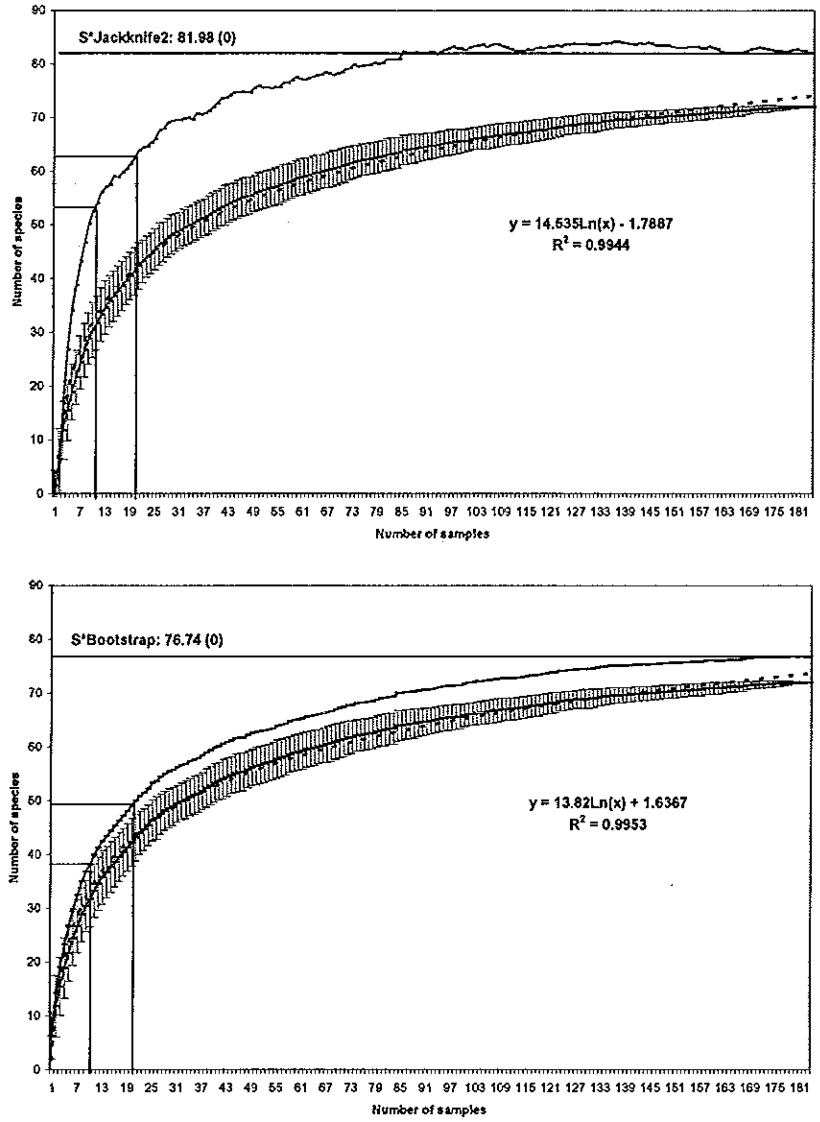
a)


S*Chao2: 76.06 (4.43)
y = 14.535Ln(x) - 1.7887
R² = 0.9944
Number of species
Number of samples

b)


S*Jackknife1: 80.95 (3.80)
y = 14.535Ln(x) - 1.7887
R² = 0.9944
Number of species
Number of samples

c)




d)

e)

**Figure 71** Performance of five non-parametric estimators of species richness for the present study data set a) $S_1$* Chao 1: b) $S_2$* Chao 2: c) $S_3$* Jackknife 1: d) $S_4$* Jackknife 2 and e) $S_5$* Bootstrap. The lower curve in each panel is the species accumulation curve plots the observed number of species. The upper curve in each panel displays the estimated total species richness based on successively larger number of samples from data set. For this data set, Chao 2 (b) provides the least biased estimates of species richness for small numbers of samples, with Jackknife 2 (d) is a close second. For all curves, each point is the mean of 100 estimates based on 100 randomization of sample accumulation order.

### 3.3 Complementarity

To evaluate complementarity, species numbers were compared pairwise between freshwater habitats sampled in the present study, the known cladoceran species richness in three parts of Thailand, and the species richness of Thailand with that of the neighbor countries: Malaysia, Singapore, Philippines, India, Sri Lanka and finally, Israel.

In pairwise habitat comparisons (table 11), complementarity was from 34-39% between stagnant vegetated habitats (i.e. swamps, marshes and peat-swamps) to 80% between stagnant vegetated habitats and running water habitats (including dams) and 48-70% between stagnant vegetated habitats and stagnant non-vegetated habitats (i.e. ponds and reservoirs).

The cladocerans from three parts of Thailand showed 35-70% complementarity (table 12). The south has typical tropical rainforest while the northeast is drier and the west more humid. The south and the northeast turn up close to each other while the west is lowest. This, however, could have technical reasons, not reflecting a true difference in richness. Few species, like *A. sarasinorum*, a saline-water species, have been found only along the coast in the south. Complementarity ranges from 40 to 80 % between countries (table 13), and the value increases with distance.

**Table 11** Matrix of percentage complementarity values for the cladoceran species richness in different habitats.

| | Swamp | Marsh | Peat swamp | Reservoir | Pond | Dam |
|---|---|---|---|---|---|---|
| **Dam (11)** | 83.9 | 85.0 | 85.7 | 83.0 | 80.8 | - |
| **Pond (20)** | 67.2 | 70.0 | 67.4 | 65.8 | - | |
| **Reservoir (31)** | 62.7 | 51.7 | 48.0 | - | | |
| **Peat swamp (45)** | 36.9 | 39.1 | - | | | |
| **Marsh (58)** | 34.7 | - | | | | |
| **Swamp (61)** | - | | | | | |

**Table 12** Matrix of percentage complementarity values for the cladoceran species richness in three parts of Thailand

| | Southern | Northeastern | Western |
|---|---|---|---|
| **West (28)** | 70.8 | 65.82 | - |
| **Northeast (66)** | 35.0 | - | |
| **South (84)** | - | | |

**Table 13** Matrix of percentage complementarity values for the cladoceran in other countries

| | Thailand | Malaysia & Singapore | India | Israel | Sri Lanka |
|---|---|---|---|---|---|
| **Sri Lanka (61)** | 58.1 | 43.0 | 53.8 | 77.8 | - |
| **Israel (60)** | 64.0 | 79.4 | 64.0 | - | |
| **India (91)** | 56.9 | 57.4 | - | | |
| **Malaysia (63)** | 48.6 | - | | | |
| **Thailand (104)** | - | | | | |

### 3.4 Species composition relation to the habitat characteristic and environmental factors

The analysis includes Twinspan analysis, Detrended correspondence analysis (DCA) and Canonical Correspondence Analysis (CCA) so that the species distribution in relation to habitat characteristics and environmental factors can be explained.

The present Twinspan analysis deals with 71 species from 55 localities, after eliminating out- liner species. The samples were grouped into 3 assemblages. Only the indicator species for the different splitting levels and the most important preferential taxa are presented. Figure 72 shows a TWINSPAN-dendrogram of the different assemblages with the indicator species for each splitting levels. Note that a taxon may be the indicator or preferential species at different splitting levels depending on differences in abundance.

Moreover, the analysis of the relationship of the species and environmental factors was carried out with CCA, which is a kind of technique that shows non-linear relations between species with environmental factors and chooses the best weights for environmental variables. According to tables 15-17, first axis (eigenvalue = 0.240) accounted for 2.1% variation in environmental factors data. Correlation between the first axis and species-environmental variables was 0.64 and Monte-Carlo permutation test for the first axis was not significant difference (P=0.06). The second axis (eigenvalue =0.214) explained 1.6% variation in data set. Correlation between the second axis and species-environmental variables was 0.658 and the Monte-Carlo permutation test for the second axis was highly significant (P=0.01). The third axis (eigenvalue =0.124) explained 1.2% variation in data set. Correlation between the second axis and species-environmental variables was 0.56 and the Monte-Carlo permutation test for the third axis was highly significant (P=0.01).

The Ordination analysis of the species-environmental dataset showed that five environmental factors are good predictors of changing cladoceran community within the freshwater habitats surveyed (Monte Carlo test for axis 2 and 3: P=0.01). Turbidity showed the highest correlated factor followed by percent vegetation coverage, conductivity, salinity and pH. The former three factors seem to be correlated to species composition in the same weight (fig. 74).

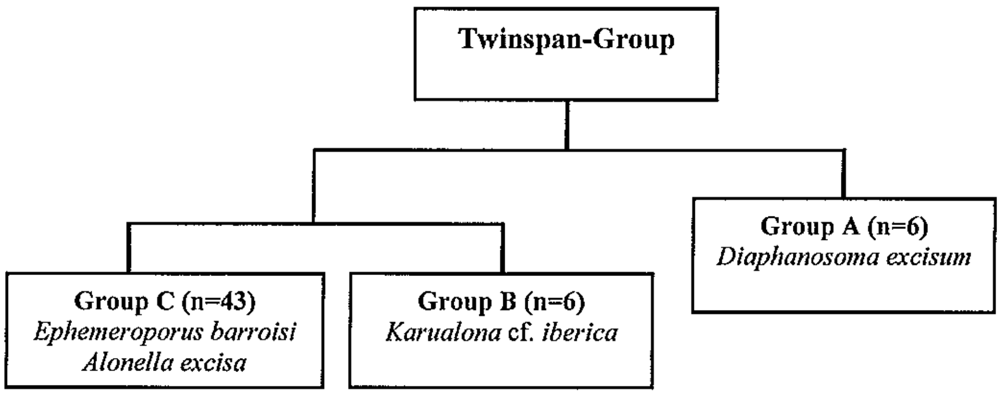



**Figure 72** TWINSPAN-dendrogram of samples indicating the subsequent splitting levels.

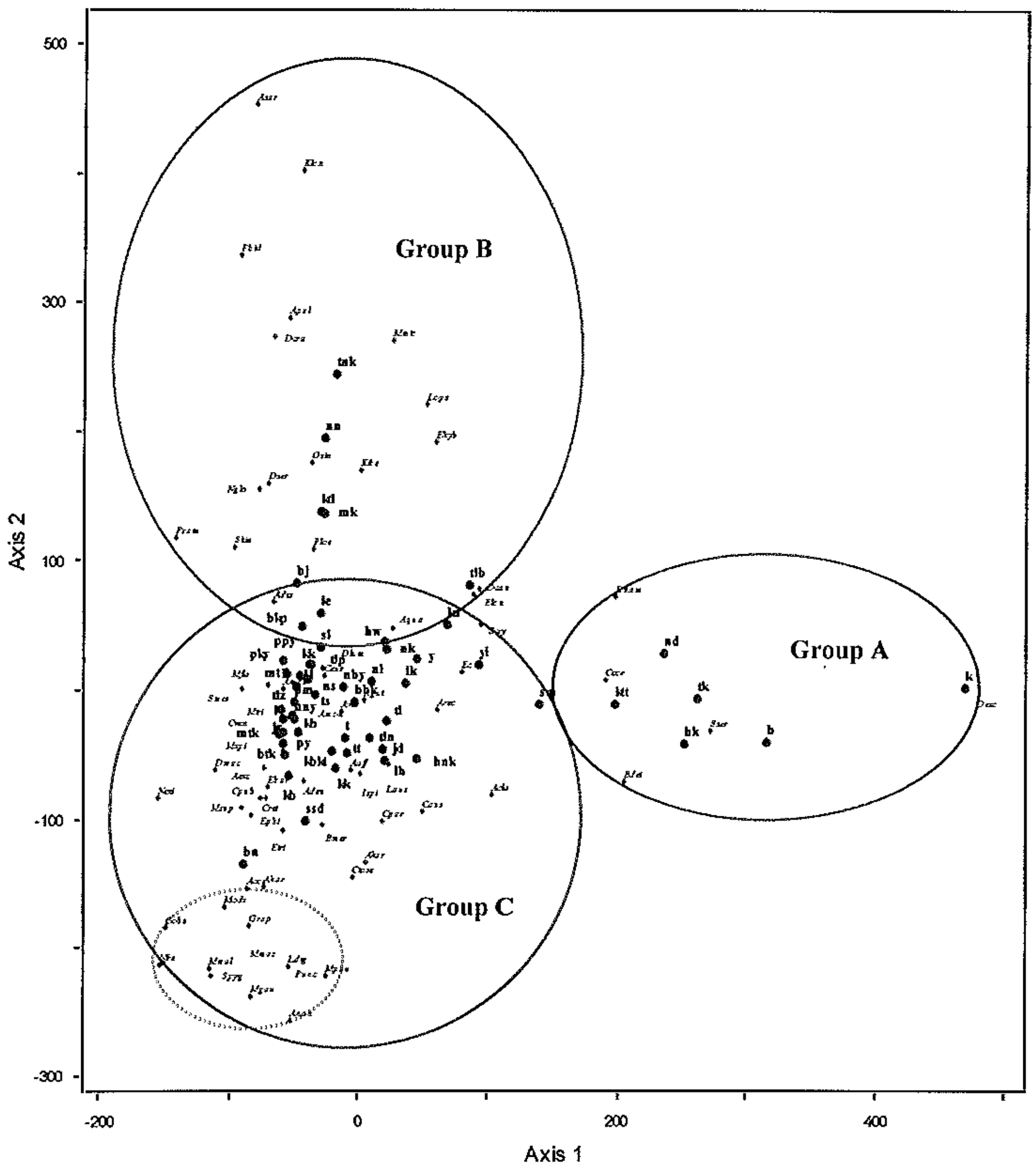



**Figure 73** DCA-ordination diagram of the cladoceran species and sampling sites, combination with the twinspan-group. Eigenvalue of axis 1 is 0.377 and the axis 2 is 0.216

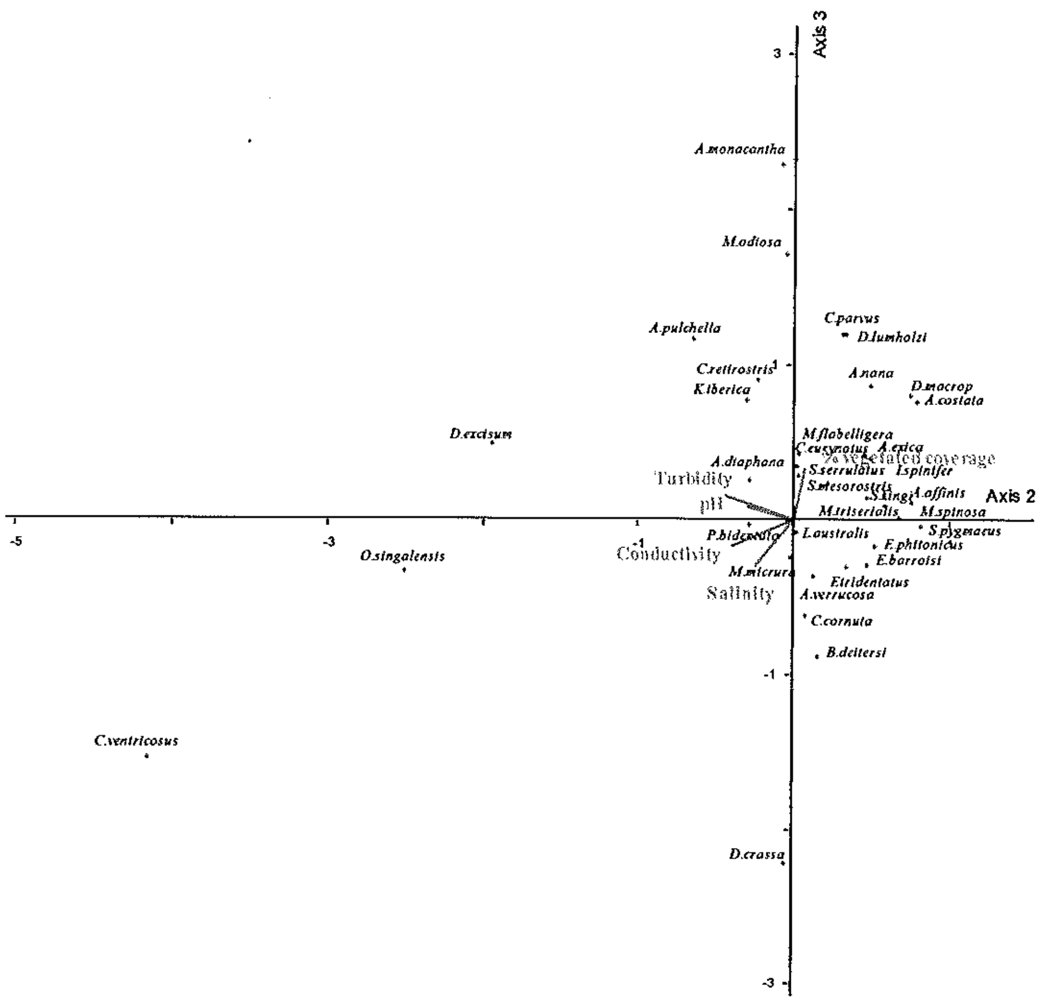



**Figure 74** Bi-plot of a Canonical Correspondence Analysis of cladoceran species composition. The analysis deal with 35 species from 181 samples related to 6 factors (Salinity, Conductivity, pH, Turbidity, Percentage vegetated cover and Temperature). Points indicate the optima of individual species in the two-dimensional environmental space described by ordination axes 2 and 3, which the relations show the significant difference (P=0.01). Vectors shows the correlations between an environmental factor and the two ordination axes, where the vector length indicates the strength of this correlation. Vectors pointing in the same direction are highly correlated, orthogonal vectors are not correlated, and vectors in opposing directions are negatively correlated. Only factors with significant effects (P<0.05) are shown as vectors in bi-plot.

**Table 14** Abiotic characteristics of the TWIN-groups

| TWIN-group | Salinity (ppt) | Turbidity | pH | Temperature (°C) | Conductivity (µS/cm) |
|---|---|---|---|---|---|
| A | 0 | 11-231 | 6.27-8.45 | 29.9-38.0 | 0-0.183 |
| B | 0-0.01 | 6-140 | 6.05-8.31 | 28.9-35.7 | 0.027-0.455 |
| C | 0-0.4 | 1.0-309.0 | 3.43-8.86 | 26.1-37.8 | 0.003-6.96 |

**Table 15** Canonical correspondence analysis for environmental data

INTER-SET CORRELATIONS for 6 factors

| Variable | Correlations Axis 1 | Axis 2 | Axis 3 |
|---|---|---|---|
| 1 Sal | .234 | -.262 | -.297 |
| 2 Turb | -.291 | -.477 | .150 |
| 3 pH | -.309 | -.318 | .077 |
| 4 Temp | -.170 | -.063 | -.203 |
| 5 Cond | .397 | -.430 | -.172 |
| 6 %cover | .237 | .076 | .326 |

**Table 16** Canonical correspondence analysis for environmental data

Number of canonical axes: 3
Total variance ("inertia") in the species data: 8.539

| | Axis 1 | Axis 2 | Axis 3 |
|---|---|---|---|
| Eigenvalue | .240 | .214 | .124 |
| Variance in species data | | | |
| % of variance explained | 2.8 | 2.5 | 1.5 |
| Cumulative % explained | 2.8 | 5.3 | 6.8 |
| Pearson Correlation, Spp-Envt* | .644 | .658 | .560 |
| Kendall (Rank) Corr., Spp-Envt | .350 | .316 | .352 |

* Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables. Set to 0.000 if axis is not canonical.

**Table 17** Monte-Carlo test for species-environmental correlations

| Axis | Real data Spp-Envt Corr. | Randomized data Monte Carlo test, 99 runs Mean | Minimum | Maximum | p |
|---|---|---|---|---|---|
| 1 | .644 | .467 | .354 | .744 | .0600 |
| 2 | .658 | .405 | .304 | .592 | .0100 |
| 3 | .560 | .356 | .275 | .480 | .0100 |

p = proportion of randomized runs with species-environment correlation greater than or equal to the observed species-environment correlation; i.e., p = (1 + no. permutations >= observed)/(1 + no. permutations)

The relationship of species composition, habitat characteristics and environmental factors can be explained with TWINSPAN-group and DCA (figs. 72-73) together the results from CCA as the following:

**TWIN-groups**

TWINSPAN analysis initially divided the 55 localities into large group (n=49) and a small group (n=6: group C), indicated by the presence of abundant *Macrothrix triserialis*-group in the former and *Diaphanosoma excisum* in the latter (eigenvalue: 0.3023). At the second level only the larger group was subdivided (eigenvalue: 0.2212) into a large (n=43: group A) and smaller group (n=6: group B) indicated by the presence of *K.* cf. *iberica* and moderate to abundant *Ephemeroporus barroisi* and *Alonella excisa* (both positive for group A). Eigenvalues were weak (<0.200) for lower hierarchical levels of this division so the analysis was halted at this point.

**Group A:**

This is the first group of locality separated from the rest. The localities in this group are mostly non-vegetated open area (n=6 localities from 55 localities, 10.91 % of total). The localities compose of few kinds of habitats: freshwater swamps (50% of number of locality in this group), ponds (33.33%) and reservoirs (16.67%), comprise of Takein, Nhongdo, Kok, Banna, Hoai-kieat and Kratoontai. The localities showed the moderate to the lowest range of the environmental parameters compared with others group.

The preference species in this group are rare species (occurring in few localities but present in high number). They compose of *Ceriodaphnia cornuta, Bosminopsis deitersi, Dunhevedia hamata, Simocephalus serrulatus* and *Diaphanosoma excisum.* This group of locality was dominated by *Diaphanosoma excisum.*

**Group B:**

Number of locality in this group is equal to group A (n=6 localities from 55 localities, 10.91 % of total). The most representative habitats are vegetated-water habitats, composing of all several kinds of habitats, including running water area:

freshwater swamps (33.33%), peat swamp (16.67%), marshes (33.33 %) and dam (13.3%). Those localities compose of Huawang, Kradae, Khunthale, Thalebun Naneng and Thungnhongkwai. Range of all environmental parameters is similar to those in group C but conductivity is in lower range, more similar to group A (table 13).

The preference species of this group ranged in abundance from common to average: *Pseudosida bidentata, Kurzia longirostris, Alona sarasinorum, Moina micrura, Alona cambouei, Leydigiopsis* sp. *Dunhevedia crassa, Oxyurella singalensis, Karualona* cf. *iberica, Ephemeroporus hybridus, Pseudosida ramosa, Scapholeberis kingi, Notoalona globulosa, Picripleuroxus laevis, Bosmina longirostris, Sida crystalline* and *Disparalona caudata.* This group of locality was dominated by a number of *Karualona* cf. *iberica.*

**Group C (*wide range of environmental parameters*)**

As the largest group (n=43 localities from 55 localities, 78.18 % of total), composing of Maikhao, Soanluang, Lein, Yao, Yai, Samed, Thalezub, Knongkla, Lum, Bogkry, Bangnon, Suansomdet, A, Hoai-knongyai, Nakae, Thungtong, Torseid, Moontakua, Nalom, Bangjum, Kangkao, Hoaimuang, Bangkumprad, Preu, Hoainumkaew, Banthungkok, Changsai, Thalepron, Thale, Thalenoi, Pluckprayam Prayod, Taew, Pluckklayai, Maetae, Kaekae, Lankwai, Kabae, Numsai, Paumi, Buabakong, Juddang, Nabayo, Klaiban, Laha and Kubaekata. This group represents the commonest and most wide spread cladoceran species, and habitat conditions. Localities of the most habitat types were represented in this group, comprised of swamps (41% of number of locality in this group), peat swamps (28%), marshes (23%) and reservoirs (8%). Range of salinity and turbidity of localities in the group is similar to Group B (table 13) but this group showed the higher value of conductivity compared with the other groups.

The preference species of this group ranged in abundance from very common species to very rare species: *Alona verrucosa, Ephemeroporus barroisi, Macrothrix flabelligera, Macrothrix triserialis, Streblocerας pygmaeus, Alonella nana, Dunhevedia serrata, Acroperus harpae, Latonopsis australis, Chydorus obscurirostris tasekberae, Ephemeroporus tridentata, Dadaya macrops, Chydorus* *parvus, Alonella excisa, Picripleuroxus laevis, Alona diaphana, Macrothrix spinosa, Chydorus reticulatus, Scapholeberis kingi* and *Ilyocrptus spinifer*. This group was dominated by a number of *Epheneroporus barroisi* and *Alonella excisa.*

## 4. Discussions

***Species richness and complementarity***

The results provide a general idea of the species richness status but not all Taxa Biological Inventory. For an ATBI, any sizeable lowland freshwater area, regardless of latitude, is expected to yield around 50 species (Dumont and Segers, 1996). However, the number of species found in each of our environments ranged from zero to 36 species, and most localities produced 15-36 species, i.e. from 30% up to 70% of the ATBI. Low species richness at a locality may reflect a special environment, but more often undersampling. Species lists should therefore be based on a minimum of three samples, taken in different seasons of at least two different years, to minimize the under/over estimating of species richness (Dodson, 1992).

The 72 species recorded are not far from S**max* Chao 2 (highly accuracy) (Hellmann and Fowler, 1999) and the total is distinctly higher than the expected ATBI per locality. This demonstrates that parts of Thailand contain more species than can be packed in any single waterbody, i.e. there must be species turnover between localities. At least some of these localities are therefore expected to have unique, as yet unknown traits. The best examples for this status are those sites where rare species are found.

The complementarity results confirm the non-cosmopolitanism concept, even at the South East Asian level. A value of 60% complementarity among neighbor countries or zones indicates that the number of species in common (>50% found in total localities) is quite low. However, the data used in the calculations were based on different sampling methods and sampling efforts, which may handicap comparisons. Moreover, at the regional scale, the data used come from different habitats and are based on a different number of studies. Finally, taxonomic problems affect the species lists. The problem is not only what a species is called but also that, until recently, groups of related species tended to be lumped under one name. Thus, each species lists reflect the taxonomist's experience and the information available at his time. For example, it is expected that a renewed study effort in Malaysia and the Philippines will lead to the discovery of many extra species in these countries, possibly even to a doubling of their current species list. In pairwise habitat comparisons, clearly, more species co-occur in similar habitat types (vegetated, pelagic, lotic etc.) and their complementarity is low. The presence of a vegetation zone leads to more microhabitats. As a result, more cladoceran species live here than in non-vegetated habitats, and it makes little sense to compare the two types of habitats, except to demonstrate the simple fact that they are different.

We divided our species list into five categories according to their percentage occurrence in the total number of samples: very common (70-100%), common (50-70%), average (25-50%), rare (12.5-25%) and very rare (1-12.5%). The proportion of very common and common species relative to rare ones is small (2:3:15:14:39), i.e. there are few common but many rare species, a familiar fact in a tropical environment. Some exceptionally rare species such as *Alona* cf. *dentifera, A.* aff. *karelica* and *A. sarasinorum* were also found, and the discovery of rare mediterranean species such as *Ephemeroporus phintonicus* in the region, considerably widening its geographical distribution, suggests adaptation to a particular biotope.

***The relationship between the species and habitat characteristics***

The cladoceran shows association with the characteristics of freshwater bodies. A few species occur almost everywhere (*Alona verrucosa, Ephemeroporus barroisi* and *Macrothrix triserialis*), but the majority appear preferentially in definite kinds of aquatic environments. Considering the species found in all kinds of habitats, the number of cladoceran found in vegetated habitats (figs.72-73: Group B, C), was higher than in non-vegetated habitats and running water habitats. This indicated that the limnetic community is quite uniform and poor in species and the littoral community is more diverse (Miracle, 1978 and Cruz, 1981). Macrophytes provided not only habitats but also a refuge against predation for the filter-feeding and bottom-dwelling zooplankton (Timms and Moss, 1984; Sandilands and Hann, 1995).

The species-habitat associations showed clearly in group A and B-C, which can be identified as planktonic cladoceran and aquatic plant-associated and/or benthic cladoceran. Localities in group A can be characterized as the non-vegetated open area. The cladoceran mostly found in this group is the planktonic form as indicated by a number of *Diaphanosoma excisum,* a true planktonic species (Sars, 1901). This species are always found freely suspended in the water, more or less near the surface as well as *Bosminopsis deitersi*. However, the *Ceriodaphnia cornuta* which is often found in the littoral macrophyte zone of shallow water bodies (Pichlova, 1997) also has been often found in this type of habitats and it shows the same rate of co-occurrence (50% of the time found in the samples) with *Diaphanosoma excisum* as *Bosminopsis deitersi*.

Group B and C were characterized by the presence of vegetated coverage area. However, localities in group B showed some different traits; shallower water area with fine mud and sandy bottom, high organic material suspended, covering mostly with reed vegetation, algae or *Nymphea* spp. (Thale-bun). *Karualona* cf. *iberica*, the representative species of the group, is typical for ephemeral or semi-permanent clean water. It is also found in water with high organic material suspended but low conductivity (Alonso, 1996), which is consistent to the result from the analysis in fig. 74. Moreover, the association of cladoceran species and this type of habitat can be explained well with the coexistence of plant-associated species as *Leydigiopsis* sp., *Dunhevedia* spp., *Moina micrura, Picripleuroxus laevis* and *Scapholeberis kingi* (Van Damme, 1998; Sars, 1901; Knockaert, 2002). These species prefer wave-agitated shallow waters with particulate organic matter associated bacteria in continuous suspension, muddy substrates and water with high organic content (Fryer, 1968; Alonso, 1996; Amoros and Jacquet, 1987). Whereas the localities in Group C include more various microhabitats in single water body than the former two. It composes of all types of habitats which the unique trait for each still unclear. However, group of fauna found here comprise of plant-associated species and the benthic ones. The most members of chydorids can be found. Some of them live in vegetated littoral habitats where periphyton is their main food resource and some of them are bottom-dwelling that can be penetrate into various kinds of bottom materials (Fryer, 1968; Smirnov, 1971; Knockaert, 2002). They are able to tolerate a wide range of conditions in pH, temperature and water chemistry (Smirnov, 1971). *Alonella excisa*, one of the representatives of the group, has been observed both among vegetation and on vegetation-free habitats in the littoral zone (Alonso, 1996; Fryer, 1968; Hann and Zrum, 1997). Moreover Fryer (1968) suggests that *Alonella excisa* is an indication for reed swamps in Europe, of which the kind of reed swamps also present in southern Thailand. One of the most tolerant species is *Alona verrucosa*, the most abundant species in the present study. It can be found in all types of habitats (Idris, 1983; Sars, 1901). Van Damme (1998) reported this species from acid pools with very low oxygen values, suggesting that it has considerable tolerance to extreme or at least marginal conditions. Macrothricidid also has a wide distribution in every kind of habitats in this group, however it is usually highly dispersed in vegetation area. A group of bottom-dwelling species such as *Leydigia* sp., *Guernella raphaelis, Streblocerus pygmaeus, Moinodaphnia macleayi, Macrothrix odiosa, Acroperus harpae* was clumped together in dot-line circle (fig.73).

The environmental factors we measured in the present study have not shown much difference in each locality and sampling time. In addition, the analysis of CCA did not show a strong relation between species composition and the environmental factors measured explaning only 33.8 % of the data (fig. 74 and table 16; axis 2 and 3 together). The lengths of the indicated factors are not so long. It is possible that those factors may not be the most important ones affecting cladoceran species composition in the area and habitats/factors may more appear the correlation at community level rather than species level. Fryer (1968) is probably right to say that there have no direct correlations between the occurrence of particular anomopods and chemical conditions of the environment. This attempt using correlation analysis supports his demonstrations. When correlations appear to exist, they are often likely to be indirect and to reflect the chemical needs of plants among which they live. Many species are tolerant to a wide range of such environmental variables as temperature, pH and salinity. However direct correlations can occur in some cases which extreme conditions will obviously exclude species i.e. *Alona sarasinorum*. As old inhabitants of freshwater, they must have long time adjustments on their physiology, allowed them to tolerate such difference in their chemical environment as are general experienced. It suggested that studying the structural features and the habits with which they are inseparably linked, together with biotic factors, such as the nature of the substratum-whether muddy, sandy, rocky etc., the presence of particular aquatic plants, adequate supplies of food, the presence of particular predators, are in general more important than chemical factors in the ecology of them. Study of these factors seems likely to be more fruitful than attempted correlation with the chemistry of the environment have proved to be.

***Status of the cladoceran fauna in Thailand***

Although cladoceran studies in Thailand have had a short history, the species list is impressive (fig. 75; Boonsom, 1984; Pholpunthin, 1997; Sanoamuang, 1998; Sanoamuang *et al.*, 2001; Sa-ardrit, 2002; Maiphae *et al.*, 2004). The present new records take the Thai cladoceran fauna to 105 species. Compared to its neighbors, the current Thai fauna seems distinctly richer than that of Malaysia (63 species) (Idris, 1983) and the Philippines (49 species) (Mamaril and Fernando, 1978). The number is also high relative to other tropical countries (Dumont, 1994). However, the 72 species of the present study are similar to the 68 species of the latest study in the South (Sa-ardrit, 2002), restricted to only one province and 26 localities, but with five samplings per year. This suggests that in a survey, replicating samplings per locality might have the same effect as expanding the number of habitats sampled only once or twice. Thus, for a truly exhaustive, ATBI-type of survey, some combination of both seems required. Why this is so remains unclear. It may be that some form of *seasonal succession* of species is present in this "tropical" environment, but it is also possible that repeated sampling simply picks up more rare species. An experimental approach is needed to solve this ambiguous situation.

In addition, the prediction indicator shows the good trend of the observing number in the area. A half of the area has never been surveyed; also the other kinds of habitats such as caves and groundwaters have never been investigated. Thus, we are fully sure that an intensive survey will bring a sharp increase in the species number, allowing for a meaningful assessment of biological diversity including the conservation status of the Thai cladoceran fauna.

## Part 3 Biogeography of the Cladocera in tropical regions

### Background

The study of biogeography of the Cladocera still resides in a difficult phase as the taxonomical problems surrounding these animals have not been solved. Moreover, the Cladocera have been studied only in fragmented areas of the world, precluding generalizations. However, information on cladoceran species is rapidly increasing and reaching higher standards so that the geographical picture becomes clearer. In order to understand the distribution pattern of the Cladocera in a single region or on a worldwide scale, the theory of plate tectonics, earth's history and climate need to be discussed. The present is the result of the past, so that past events reflect on current distributions. Moreover, the environments that they may have lived in the past may be a sign of their boundaries and restrictions at present.

Thus, we discuss here possible biogeographical events that may have led to the present cladoceran species distribution in three zoogeographical regions of the world: the Oriental region (South East Asia), the Afrotropical region (Africa, south of the Sahara) and the Neotropical region (South America), including the dispersal mechanisms that support this distribution. The lists of cladoceran species from the countries in these three tropical regions are compiled from the literature (Chiambeng, 2004; Idris and Fernando, 1984; Pholpunthin, 1997; Sanoamuang, 1998; Sa-ardrit, 2001; Maiphae *et al.*, 2004).

## Geographical distribution of cladoceran in three zoogeographical regions (Oriental: South East Asia; Afrotropical: Africa and Neotropical: South America)

The total species recorded in these three tropical regions is 189 species (table 17), in two orders, seven families and 44 genera. The Oriental region records a total of 122 cladoceran species, in two orders, six families and 38 genera. The Neotropical region records a total of 92 cladoceran species, in two orders, seven families and 34 genera and the Afrotropical region records 94 species, two orders, six families and 39 genera.

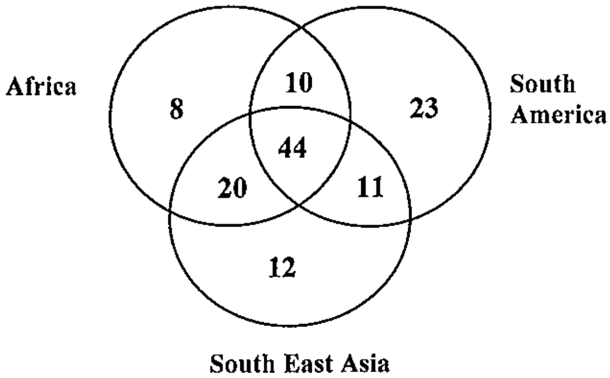



**Figure 76** Diagram modified from table 18 shows number of cladoceran species found in each continents, and the overlapping numbers between two and three continents

The comparison between number of the Cladocera in these regions shows that there is greater similarity at all levels between the Oriental region and Afrotropical regions than with the Neotropical region: order level (2/2), family level (6/6), genera level (38/39), species level (122/94). There is greater overlap in species between Oriental region and Afrotropical region (20 species) than with Neotropical region (11 species) (fig.76). A total of circumtropical 44 species (~23% of total) is overlap amongst all these regions. The number of endemics are different in three regions; 12 for Oriental region, 23 for Neotropical region and 8 for Afrotropical region.

Considering the complementarity between these continents (fig.77) we also find reduced differences from the couple of South America and South East Asia (66.46), followed by South America and Africa (61.70) and Africa and South East Asia (57.89), respectively.

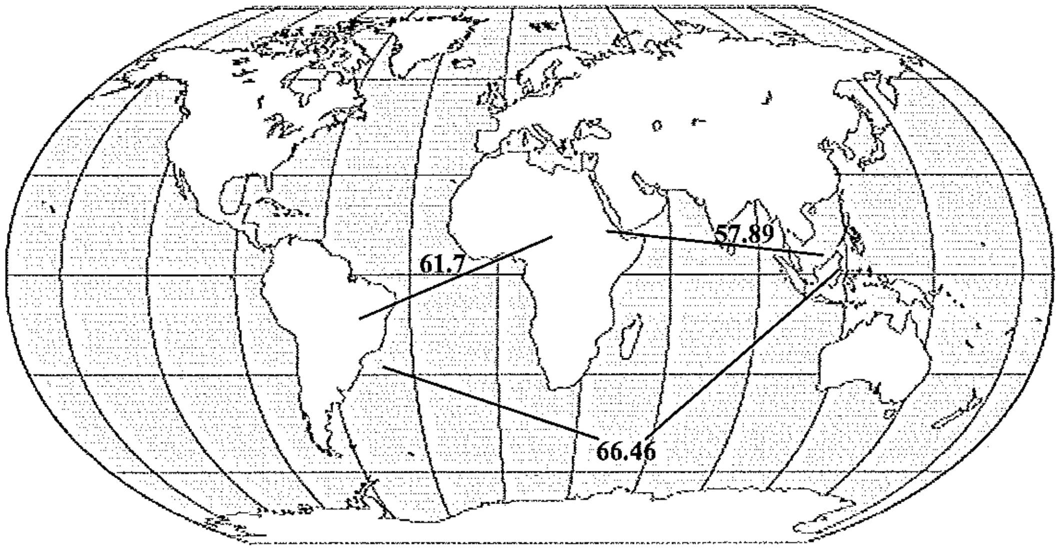



**Figure 77** The complementarity values of cladoceran species on the three continents: South East Asia, Africa and South America

**Considering these comparisons, we can now address the following questions;** How did the common species disperse between these three continents and how to explain the overlapping of the species between each two? Why should the fauna from South East Asia be richer than that of Africa and that of South America?

These questions can be explained basically by both historical events and ecological processes. Historical events must be invoked to explain how a taxon became confined to its present range and to reconstruct its geographic origin, spread and contraction. On the other hand, ecological explanations must be invoked to explain the present range limits of an endemic. The survival and extinction of its local populations affect its ability to persist in particular localities, and dispersal processes affect its ability to colonize favorable but isolated localities. Abiotic and biotic limiting factors determine the distribution of habitats within the geographic range and prevent species from expanding at the periphery of its range. Together, dispersal ability and limiting factors determine the nature of barriers that prevent the species from occurring in favorable but distant areas.

**How the common species disperse between these three continents and how to explain the overlapping of the species between each two?**

According to continental drift theory, prior to the Mesozoic all landmasses were united in a supercontinent, Pangaea, which was composed of two subunits, Gondwanaland in the south and Laurasia in the north. The breakup of this supercontinent was actually initiated in the early Jurassic (about 180 Myrs B.P.). Gondwanaland included the foundations of present-day South America, Africa, Madagascar, Arabia, India, Australia, Tasmania, New Guinea, New Zealand, New Caledonia and Antarctica. It fragmented into a western (Africa, South America and Arabian Peninsula) and an eastern bloc (India, Australia and Antarctica), then eventually fragmenting into the continents as known today.

The Cladocera based on fossil records arose in the late Paleozoic (about 543-248 Myrs) (Frey, 1987; Smirnov, 1971, 1972; Dumont and Negrea, 2003). According to the age of the Cladocera, the regional overlapping of 44 species suggests a common origin of species in Pangaea. Also, the similarity of extant species may indicates they arose from similar protospecies before the separation of continents.

Moreover, as noted by Snider-Pellegrini and Wegener (Scotese, 2001), the locations of certain fossil plants and animals present day in widely separated continents suggests that after fragmentation of Pangaea, continents continued to be united or there are still have a connection between the continents. At a time when South East Asian islands were still connected to the mainland, Africa connected with Asia through Arabia and connected with South America at the level of the present coast between Cameroon-Sierra Leone and Liberia or probably Nigeria in the early Cretaceous (Brown and Lomolino, 1998). Also, India separated from Gondwanaland about 195 Ma, and finally collided with Asia in the Late Eocene. India could have acted as a raft, carrying taxa from Africa to Asia, which could have spread over South East Asia and West Malaysia after the collision. These connections served as dispersal routes for organisms between the continents. This may be the case of higher similarity of species found between South East Asia and Africa.

But it might not be the major cause of the existence of some South American species in Thailand. So, how to explain this event? South America was part of the giant southern-hemisphere continent of Gondwanaland that drifted apart in the Mesozoic, and was a completely isolated island continent for most of the Tertiary. If these following species are named correctly, *Leydigiopsis* sp.; *Macrothrix* cf. *paulensis*; *M.* cf. *superaculeata*, one possible hypothesis that can explain the existence of these South American species in Thailand is they are relicts of a continuous distribution of Pre-Pleistocene rather than descendants that reached the rainforest during humid period of Pleistocene. This hypothesis also can explain the present of Palearctic/Holarctic species: *Ephemeroporus hybridus, E. tridentatus, Macrothrix hirsuticornis, M. laticornis.*

However, the range of environments in which these species are found in Thailand and in South America is the occurrence of shallow, acid, and brown-water, covered with sedge. Samples from Brazil, South America (Van Damme, 1998) show similar species composition as found in southern Thailand. Thus, such the localities may share some specific characteristics suited to contain these species.

There is also a high number of cladoceran species distributed restrictively in the oriental region. This may be the influence of the drifting of the islands and the long history of isolation of this region since the late Precambrian (about 500 Myrs) (Scotese, 2001). Vicariance and reproductive isolation in speciation were considering a role of these geographical consequences.

However, the complementarity values among these continents are relatively high. It means that a large part of the cladocera has a restricted range of distribution. This also may be the evidence of the differences of theirs existed microhabitats which affects to the different in diversity of the taxa. Consistent with the general rule of organism distribution, the more specific their environmental requirements, the more restricted their ranges.

Focusing to the number of the cladoceran species found in these three continents, why should the fauna from South East Asia be richer than that of Africa and that of South America? And why they have higher endemic species in South America and South East Asia than in Africa? The response of tropical South America and South East Asia to the changing climate at the end of the Miocene followed a different scenario, with pollen records from the Amazon lowlands suggesting that reduction of precipitation in the glacial period was not sufficient to fragment the rainforest and that savannas probably did not expand into what are now forested Amazon lowlands (Haffer, 1969, 1974, 1981; Colinvaux *et al.*, 1996, 2000, 2001). Persistence of a more or less continuous forest environment throughout the Pleistocene, again did not stimulate or favour speciation, but it did limit extinction, hence the superior species richness and endemism of both regions. On the other hand, aridification of the climate had a strong effect in Africa. We hypothesize that, in the process of climate changing and fluctuations between warm, cool, dry and humid in Pleistocene, more species went extinct in this region and did not succeed in reinvading afterwards. Thus, the African rainforest cladoceran became impoverished.

However, these periods of fragmentation during the 20+ ice ages which allowed evolutionary divergence to occur in many groups of plants and animals, but the cladoceran reflect only little speciation. This suggests that evolution in the Anomopoda is slowed by their parthenogenetic mode of reproduction, with little or no evidence for speciation since the (late?) Miocene. Support for the old age of most extant cladoceran species is found in the morphological relatedness between Permian and Lower Cretaceous fossils (g. *Archedaphnia* and *Propleuroxus*: Smirnov, 1970) and current taxa: they differ at the genus level, but belong to "modern" families. Furthermore, Cenozoic and Pleistocene fossils (see Dumont and Negrea, 2002, for a review) almost invariably pertain to modern genera and even species.

However, distribution of the Cladocera has been influenced not only by historical events and ecological processes but also the impact of passive dispersal. The behavior of birds like drinking, bathing may account for a transfer of resting eggs between areas on their migration route by transporting resting eggs (Smirnov, 1971; Chiambeng, 2004).

## Geographical distribution of the Cladocera in world scale

The distribution of the Cladocera varies from cosmopolitan, to a range shared between one or several zoogeographic regions (Nearctic, Neotropical, Paleartic, African, Oriental and Australian regions), which is the case of majority of species, or restricted to only narrow area (i.e. single island). In contrast to earlier ideas, true cosmopolitan species are now recognized to be few (Frey, 1971; Dumont and Negrea, 2003). As their morphological definition improves, it appears that species-groups can be distinguished composed of related, but distinct taxa, each with a limited geographical range.

Few species are truly cosmopolitan. However, many families and genera with exceptionally wide distributions contain at least some species that also have very broad geographic ranges, indicative of their ecological tolerances and their capacities for dispersing over long distances with or without human assistance. On the other hand, many high-rank taxa, such as families, are essentially cosmopolitan, because the ecological diversity within these groups is broad enough to include forms that can exist in most aquatic habitats, and also because these groups are old enough to have had historical opportunities to colonize most part of the world.

In Thailand, we found only a few species that can truly be called cosmopolitan (table 18) i.e. *Alona affinis, A. guttata, A. rectangula, Alonella excisa*, *Chydorus sphaericus*, Many species are circumtropical, *Alona verrucosa, Chydorus eurynotus, C. pubescens, C. reticulates, C. ventricosus, Dadaya macrops, Grimaldina brazzai, Guernella raphealis, Macrothrix odiosa, M. spinosa* and *M. triserialis*.

The occurrence of taxa which have been recorded from other regions, including the Holarctic species (*Alonella nana, Macrothrix laticornis*) and South American species (*Macrothrix superaculeata, M. paulensis, Strebloceras pygmaeus, Leydigiopsis* sp., *Ephemeroporus tridentatus, E. hybridus*) expand wider range of these species. However, most of them except *Alonella nana* were exceedingly low in number in samples. *Daphnia* is rare in the country and there was not found in the present study. This rarefaction is a multifactor phenomenon. However temperature-dependant predation is the pivotal variable (Dumont, 1994). Theirs large size are obvious for the predators which are more numerous in tropics than elsewhere.

**Table 18** Distribution of the Cladocera (Ctenopoda and Anomopoda) in three regions

| | Cladocera | Regions | | |
|---|---|---|---|---|
| | | **Oriental** (South East Asia) | **Neotropical** (South America) | **Afrotropical** (Africa) |
| | **Order Ctenopoda** | | | |
| | **Family Holopedidae** | | | |
| 1 | *Holopedium amzonicum* | | + | |
| | **Family Sididae** | | | |
| 2 | *Diaphanosoma aspinosum* | + | | |
| 3 | *D. brachyurum* | | + | |
| 4 | *D. brevireme* | | + | |
| 5 | *D. excisum* | + | | + |
| 6 | *D. fluviatile* | | + | |
| 7 | *D. modigliani* | + | | |
| 8 | *D. owenae* | | | + |
| 9 | *D. sarsi* | + | + | + |
| 10 | *D. spinulosum* | | + | |
| 11 | *D. volzi* | + | | |
| 12 | *Pseudosida bidentata* | + | + | + |
| 13 | *P. ramosa* | + | + | |
| 14 | *P. szalayi* | | | + |
| 15 | *Latonopsis australis* | + | + | + |
| 16 | *L. fasciculata* | + | + | + |
| 17 | *Sarsilatona serricauda* | + | | |
| 18 | *Sida crystallina* | + | | |
| | **Order Anomopoda** | | | |
| | **Family Bosminidae** | | | |
| 19 | *Bosminopsis detersi* | + | + | + |
| 20 | *B. negrensis* | | + | |
| 21 | *B. chilense* | | + | |
| 22 | *B. fatalis* | + | | |
| 23 | *B. hagmanni* | | + | |
| 24 | *Bosmina longirostris* | + | + | + |
| 25 | *B. longispina* | + | | |
| 26 | *B. meridionalis* | + | | |
| 27 | *B. tubicen* | | + | |

**Table 18.** (Continued)

| | Cladocera | Regions | | |
|---|---|---|---|---|
| | | **Oriental** (South East Asia) | **Neotropical** (South America) | **Afrotropical** (Africa) |
| | **Family Chydoridae** | | | |
| 28 | *Alona affinis* | + | + | + |
| 29 | *A. alonopsoides* | | | + |
| 30 | *A. archeri* | + | | |
| 31 | *A. archeroides* | + | | |
| 32 | *A. cambouei* | + | | + |
| 33 | *A. circumfimbriata* | + | | |
| 34 | *A. cheni* | + | | |
| 35 | *A. costata* | + | | + |
| 36 | *A. dentifera* | + | | |
| 37 | *A. diaphana* | + | + | + |
| 38 | *A. freyi* | + | | |
| 39 | *A. guttata* | + | | + |
| 40 | *A. holdeni* | | | + |
| 41 | *A. intermedia* | + | + | + |
| 42 | *A.* aff. *karelica* | + | | |
| 43 | *A. macronyx* | + | | |
| 44 | *A. milleri* | + | | |
| 45 | *A. monacantha* | + | | + |
| 46 | *A. poppei* | | + | |
| 47 | *A. pulchella* | + | + | + |
| 48 | *A. quadrangularis* | + | | + |
| 49 | *A. rectangula* | + | + | + |
| 50 | *A. rustica* | | + | |
| 51 | *A. sarasinorum* | + | | |
| 52 | *A. setigera* | | | + |
| 53 | *A.verrucosa* | + | + | + |
| 54 | *Alonella clathratula* | + | + | + |
| 55 | *A. excisa* | + | + | + |
| 56 | *A. exigua* | | + | + |
| 57 | *A. hamulatus* | + | | |
| 58 | *A. nana* | + | | |
| 59 | *A. orientalis* | + | | |
| 60 | *Acroperus harpae* | + | | + |

**Table 18.** (Continued)

| | Cladocera | Regions | | |
|---|---|---|---|---|
| | | **Oriental** (South East Asia) | **Neotropical** (South America) | **Afrotropical** (Africa) |
| 61 | *Bryospilus africanus* | | | + |
| 62 | *B. bifidus* | + | | |
| 63 | *B. repens* | | + | |
| 64 | *Camptocercus australis* | + | | + |
| 65 | *C. lillgeborgi* | | | + |
| 66 | *C. rectirostris* | + | | + |
| 67 | *C. uncinatus* | + | + | + |
| 68 | *Chydorus dentifer* | | + | |
| 69 | *C. eurynotus* | + | + | + |
| 70 | *C. faviformis* | + | + | |
| 71 | *C. gibbus* | | | + |
| 72 | *C. obscurirostris* | + | | |
| 73 | *C. opacus* | + | | |
| 74 | *C. parvus* | + | | + |
| 75 | *C. pubescens* | + | + | + |
| 76 | *C. reticulatus* | + | | |
| 77 | *C. sinensis* | + | | |
| 78 | *C. sphaericus* | + | + | + |
| 79 | *C. tilhoi* | | | + |
| 80 | *C. ventricosus* | + | + | + |
| 81 | *Dadaya macrops* | + | + | + |
| 82 | *Disparalona caudata* | + | + | + |
| 83 | *D. dadayi* | | + | |
| 84 | *D. hamata* | + | + | + |
| 85 | *D. leptorhyncha* | | + | |
| 86 | *D. rostrata* | + | | |
| 87 | *Dunhevedia crassa* | + | + | |
| 88 | *D. odontopax* | | + | |
| 89 | *D. serrata* | + | | + |
| 90 | *Ephemeroporus acanthodes* | | + | + |
| 91 | *E. barroisi* | + | + | + |
| 92 | *E. hybridus* | + | + | |
| 93 | *E. phintonicus* | + | | |
| 94 | *E. tridentatus* | + | + | + |

**Table 18.** (Continued)

| | Cladocera | Regions | | |
|---|---|---|---|---|
| | | **Oriental** (South East Asia) | **Neotropical** (South America) | **Afrotropical** (Africa) |
| 95 | *Euryalona brasilensis* | | + | |
| 96 | *E. occidentalis* | | + | + |
| 97 | *E.orientalis* | + | | + |
| 98 | *Graptoleberis testudinaria* | + | + | + |
| 99 | *Indialona ganapati* | | | |
| 100 | *I. globulosa* | | + | + |
| 101 | *Karualona iberica* | + | + | + |
| 102 | *Kurzia cf. brevilabris* | | | + |
| 103 | *K. latissima* | | + | + |
| 104 | *K. longirostris* | + | + | + |
| 105 | *Leydigia acanthocercoides* | + | | + |
| 106 | *L. australis* | + | | |
| 107 | *L. ciliata* | + | + | + |
| 108 | *L. laevis* | + | | |
| 109 | *L. schubarti* | | + | |
| 110 | *Leydigiopsis brevirostris* | | + | |
| 111 | *L. curvirostris* | | + | |
| 112 | *L. ornata* | | + | |
| 113 | *Monospilus dispar* | | | + |
| 114 | *Nicsmirnovious camerounensis* | | | + |
| 115 | *N. eximius* | + | | |
| 116 | *N. fitzpatricki* | | + | |
| 117 | *N. greeni* | | | + |
| 118 | *Notoalona freyi* | + | | |
| 119 | *N. globulosa* | + | | + |
| 120 | *Oxyurella ciliata* | | + | + |
| 121 | *O. longicaudis* | | + | |
| 122 | *O. singalensis* | + | | + |
| 123 | *Paralona pigra* | | + | + |
| 124 | *Picripleuroxus laevis* | + | | + |
| 125 | *Pleuroxus aduncus* | + | + | + |
| 126 | *P. denticulatus* | | | + |
| 127 | *P. quasidenticulatus* | + | + | |
| 128 | *P. similis* | + | + | + |
| 129 | *P. striatus* | | + | |

**Table 18.** (Continued)

| | Cladocera | Regions | | |
|---|---|---|---|---|
| | | **Oriental** (South East Asia) | **Neotropical** (South America) | **Afrotropical** (Africa) |
| 130 | *P. toumodensis* | | | + |
| 131 | *P. uncinatus* | + | | |
| 132 | *P. unispinus* | | | + |
| 133 | *Pseudochydorus globosus* | + | + | + |
| | **Family Daphniidae** | | | |
| 134 | *Ceriodaphnia cornuta* | + | + | + |
| 135 | *C. dubia* | + | | + |
| 136 | *C. pulchella* | + | + | |
| 137 | *C. reticulata* | | + | + |
| 138 | *Daphnia barbata* | | | + |
| 139 | *D. gessneri* | | + | |
| 140 | *D. laevis* | | + | + |
| 141 | *D. longispina* | + | | |
| 142 | *D. lumholzi* | + | | |
| 143 | *D. magna* | + | | |
| 144 | *D. pulex* | + | | + |
| 145 | *D. similis* | + | | |
| 146 | *Moina belli* | | | + |
| 147 | *M. brachiata* | + | | |
| 148 | *M. macrocopa* | + | | + |
| 149 | *M. micrura* | + | + | + |
| 150 | *M. minuta* | | + | |
| 151 | *M. reticulata* | | + | |
| 152 | *M. rostrata* | | + | |
| 153 | *M. weissmanni* | + | | + |
| 154 | *Moinodaphnia macleayi* | + | + | + |
| 155 | *Scapholeberis armata freyi* | | + | |
| 156 | *S. kingi* | + | + | + |
| 157 | *S. spinifera* | | + | |
| 158 | *Simocephalus acutirostratus* | + | + | |
| 159 | *S.* cf. *brehmi* | | + | |
| 160 | *S. exspinosus* | + | | |
| 161 | *S. iheringi* | | + | |
| 162 | *S. heilongjiangensis* | + | | |
| 163 | *S. latirostris* | + | + | + |

**Table 18.** (Continued)

| | Cladocera | Regions | | |
|---|---|---|---|---|
| | | **Oriental** (South East Asia) | **Neotropical** (South America) | **Afrotropical** (Africa) |
| 164 | *S. serrulatus* | + | + | + |
| 165 | *S. vetulus* | + | + | + |
| | **Family Ilyocryptidae** | | | |
| 166 | *Ilyocryptus halyi* | + | + | |
| 167 | *I. sarsi* | | + | + |
| 168 | *I. sordidus* | | | + |
| 169 | *I. spinifer* | + | + | + |
| | **Family Macrothricidae** | | | |
| 170 | *Grimaldina brazzai* | + | + | + |
| 171 | *Guernella raphaelis* | + | + | + |
| 172 | *M. flabelligera* | + | | |
| 173 | *M. laticornis* | + | + | + |
| 174 | *M. malaysiensis* | + | | |
| 175 | *M. mira* | | + | |
| 176 | *M. odiosa* | + | | + |
| 177 | *M. paulensis* | + | + | |
| 178 | *M. pholpunthini* | + | | |
| 179 | *M. rosea* | + | | |
| 180 | *M. sioli* | | + | |
| 181 | *M. spinosa* | + | + | + |
| 182 | *M. superaculeata* | + | + | |
| 183 | *M. triserialis* | + | + | + |
| 184 | *Streblocerus inexpectatus* | | | + |
| 185 | *S. pygmaeus* | + | + | |
| 186 | *Lathonura rectirostris* | | | + |
| | **Total** | **120** | **99** | **96** |

**Table 19** Distribution of the Cladocera found in Thailand (Sanoamuang, 1998; Pholpunthin, 1997; Saeng-aroon, 2001; Saeng-aroon & Sanoamuang, 2002; Sa-ardrit, 2002; Faitakum, 2003; Sa-ardrit & Beamish, 2004; Maiphae *et al.*, 2004 and present data).
Note: Pattern of Distribution is presented in Family Chydoridae and Macrothricidae

| | Species | Thailand | | | Pattern of Distribution |
|---|---|---|---|---|---|
| | | NE | W | S | |
| | **Order Ctenopoda** | | | | |
| | **Family Bosminidae** | | | | |
| 1 | *Bosmina longirostris* | | + | + | |
| 2 | *B. longispina* | + | | | |
| 3 | *B.fatalis* | + | + | | |
| 4 | *B.meridionalis* | + | + | + | |
| 5 | *Bosminopsis deitersi* | + | + | + | |
| | **Family Chydoridae** | | | | |
| 6 | *Alona affinis* | + | | + | Cosmopolitan |
| 7 | *A.archeri* | | | + | Central Asia, Indo-Malayan, Australian |
| 8 | *A. archeroides* | + | | | Sumatra, Java |
| 9 | *A.*cf. *cambouei* | + | | + | Africa, Tropical Asia |
| 10 | *A.cheni* | | | + | South East Asia |
| 11 | *A.costata* | + | + | | Cosmopolitan |
| 12 | *A.dentifera* | | | + | America |
| 13 | *A.diaphana* | + | + | + | Cosmopolitan |
| 14 | *A.guttata* | + | + | + | Cosmopolitan |
| 15 | *A.intermedia* | + | | + | Cosmopolitan |
| 16 | *A. aff. karelica* | | | + | Europe |
| 17 | *A.macronyx* | + | | + | Indo-Malayan |
| 18 | *A.milleri* | + | | | - |
| 19 | *A.monacantha* | + | | + | Circumtropical |
| 20 | *A.quadrangularis* | + | | + | Cosmopolitan |
| 21 | *A.rectangula* | + | + | + | Cosmopolitan |
| 22 | *A.verrucosa* | + | + | + | Cosmopolitan |
| 23 | *A.pulchella* | + | | | Ethiopian, Neotropical, Australian |
| 24 | *A. sarasinorum* | | | + | Indo-Malayan |
| 25 | *Alonella clathratula* | + | | + | Australian, Ethiopian, Neotropical |
| 26 | *A.excisa* | + | | + | Cosmopolitan |
| 27 | *A.nana* | | | + | Holarctic |
| 28 | *Acroperus harpae* | + | | + | Cosmopolitan |
| 29 | *Camptocercus australis* | + | + | + | Australian |
| 30 | *C.uncinatus* | + | + | + | Europe |
| 31 | *Chydorus eurynotus* | + | + | + | Circumtropical |
| 32 | *C. eurynotus reticulatus* | | | + | Circumtropical |

**Table 19.** (Continued)

| | Species | Thailand | | | Pattern of Distribution |
|---|---|---|---|---|---|
| | | NE | W | S | |
| 33 | *C. obscurirostris obscurirostris* | | | + | Australian |
| 34 | *C.obscurirostris tasekberae* | + | | + | Indo-Malayan |
| 35 | *C.opacus* | | | + | Australian |
| 36 | *C.parvus* | + | + | + | Ethiopian, Indo-Malayan |
| 37 | *C.pubescens* | + | + | + | Circumtropical |
| 38 | *C.reticulatus* | + | + | + | Circumtropical |
| 39 | *C.sinensis* | + | | | China |
| 40 | *C.sphaericus* | | | + | Cosmopolitan |
| 41 | *C.ventricosus* | + | + | + | Circumtropical |
| 42 | *Dadaya macrops* | + | + | + | Circumtropical |
| 43 | *Disparalona caudata* | + | | + | Cosmopolitan |
| 44 | *D.hamata* | + | + | + | Cosmopolitan |
| 45 | *D.rostrata* | | + | + | Palearctic |
| 46 | *Dunhevedia crassa* | + | + | + | Cosmopolitan |
| 47 | *D.serrata* | + | | + | Ethiopian, Oriental |
| 48 | *Ephemeroporus barroisi* | + | + | + | Circumtropical |
| 49 | *E. hybridus* | | | + | South America |
| 50 | *E.phintonicus* | | | + | Italian, Australian |
| 51 | *E. tridentatus* | | | + | South America |
| 52 | *Euryalona orientalis* | + | + | + | Circumtropical |
| 53 | *Graptoleberis testudinaria* | + | | + | Cosmopolitan |
| 54 | *Karualona iberica* | + | + | + | Africa + Mediterranean |
| 55 | *Kurzia longirostris* | + | + | + | Ethiopian, Indo-Malayan, Neotropical |
| 56 | *Leydigia acanthocercoides* | + | + | | Holarctic, Ethiopian, Indo-Malayan, Neotropical |
| 57 | *L.ciliata* | + | | + | Ethiopian, Neotropical, Australian |
| 58 | *L.laevis* | + | | | Northest Australian |
| 59 | *L.australis* | | | + | Africa, India, Australia, Ceylon |
| 60 | *Leydigiopsis sp.* | + | | + | South America |
| 61 | *Nicsmirnovius eximius* | + | + | + | South East Asian |
| 62 | *Notoalona globulosa* | + | + | + | Circumtropical |
| 63 | *N.freyi* | | | + | Indo-Malayan |
| 64 | *Oxyurella singalensis* | + | + | + | Ethiopian, Indo-Malayan, Northeast China |
| 65 | *Pleuroxus aduncus* | | | + | Cosmopolitan |
| 66 | *Picripleuroxus quasidenticulatus* | + | + | + | Cosmopolitan |
| 67 | *P.laevis* | + | + | + | Palearctic + West Africa |
| 68 | *Pseuchydorus globosus* | + | | | Cosmopolitan |

**Table 19.** (Continued)

| | Species | Thailand | | | Pattern of Distribution |
|---|---|---|---|---|---|
| | | NE | W | S | |
| | **Family Daphniidae** | | | | |
| 69 | *Ceriodaphnia cornuta* | + | + | + | |
| 70 | *Daphnia lumholzi* | + | + | + | |
| 71 | *D.similis* | | | | |
| 72 | *Scapholeberis kingi* | + | + | + | |
| 73 | *Simocephalus exspinosus* | + | | | |
| 74 | *S.mesorostris* | + | + | + | |
| 75 | *S.latirostris* | | | | |
| 76 | *S.vetulus* | + | | | |
| 77 | *S.serrulatus* | + | + | + | |
| | **Family Ilyocryptidae** | | | | |
| 78 | *Ilyocryptus spinifer* | + | + | + | |
| 79 | *Moina macrocopa* | | | | |
| 80 | *M.micrura* | + | + | + | Cosmopolitan |
| 81 | *Moinodaphnia macleayi* | + | | + | Circumtropical |
| | **Family Macrothricidae** | | | | |
| 82 | *Grimaldina brazzai* | + | + | + | Circumtropical |
| 83 | *Guernella raphaelis* | + | + | + | Circumtropical |
| 84 | *Macrothrix laticornis* | + | + | + | Holarctic |
| 85 | *M.cf.paulensis* | + | | + | South America |
| 86 | *M.flabelligera* | + | + | + | Circumtropical |
| 87 | *M. malaysiensis* | | | + | South East Asia, Tropical australia |
| 88 | *M.odiosa* | + | | + | Circumtropical |
| 89 | *M.*sp. | + | | + | Thailand |
| 90 | *M. spinosa* | + | + | + | Circumtropical |
| 91 | *M. cf. superaculeata* | | | + | South America |
| 92 | *M.triserialis* | + | + | + | Circumtropical |
| 93 | *Strebloceras pygmaeus* | + | + | + | South America |
| | **Order Ctenopoda** | | | | |
| | **Family Sididae** | | | | |
| 94 | *Diaphanosoma modigliani* | | | | |
| 95 | *D.volzi* | + | | + | |
| 96 | *D.excisum* | + | + | + | |
| 97 | *D.sarsi* | + | + | + | |

**Table 19.** (Continued)

| | Species | Thailand | | | Pattern of Distribution |
|---|---|---|---|---|---|
| | | NE | W | S | |
| 98 | *P.ramosa* | + | | + | |
| 99 | *Sarsilatona serricauda* | | | + | |
| 100 | *Sida crystallina* | + | | + | |
| | **Total** | **77** | **48** | **86** | |

# CHAPTER 4: CONCLUSIONS AND PERSPECTIVES

## Conclusions

The study of the Cladocera from Southern Thailand has resulted in the acquisition of substantial new data and findings. These can be pooled into four points:

### 1. At the morphological level

The morphological characters at species level of two large genera, *Alona* Baird, 1843 and *Macrothrix* Baird, 1843, were examined. A great number of differences in the morphology, not only of the trunk limb but also in general morphology such as ventral margin of valve, head pores, and first antenna were found.

Differences among *Alona* species (table 19) are seen in the pattern of the ventral setae of valves and their number, the number of aesthetascs of the first antenna (ranging from 7-9), the number of major and lateral head pores including their shape; and the detailed characters of the IDL, E3, E2, E1 of trunk limb 1, length and adornment of the scrapers on the endopodite of trunk limb 2, number of distal and lateral setae on exopodite and endopodite of trunk limbs 3, 4 including their shape, shape of epipodite, exopodite and endopodite of trunk limb 5 and the presence or absence of a terminal flap, often equated with trunk limb 6.

The differences between *Macrothrix* species (table 20) are seen at the postero-ventral angle of valve, denticles on the first antenna, the largest seta of the second antenna; and the detailed characters of the IDL, E3, number of teeth on the Fryer's forks, number of ejector hooks of trunk limb 1, length and strength of scrapers on endopodite of trunk limb 2, number and length of setae on exopodite and endopodite of trunk limbs 3-5. In basic structure and arrangement, the trunk limbs are similar to those of the Chydoridae and the principles involved in many of the feeding mechanisms are the same in both families. By numerous, sometimes subtle, sometime profound modifications of the components involved, this basic arrangement has been adapted to widely differing ways of life and different functions.

Trunk limb data show that the evolution of the anomopods limbs is one of progressive specialization with reduction in numbers of some structures and the modification of structural features. *Alona* and *Macrothrix,* which belong to the Chydoridae and Macrothricidae respectively, show a similar evolutionary pattern (Fryer, 1968, 1974, 1995, 2002; Dumont and Silva-Briano, 1998; Chiambeng, 2004). However, Macrothricidae are more primitive in limb morphology because of the greater number of setae and they possibly can be ancestral to the Chydoridae.

## 2. At the faunistic level

Our knowledge on the species richness of the Thai cladoceran fauna has increased considerably. Thai cladocerans belong to two orders, Ctenopoda and Anomopoda. These orders comprise six families: Bosminidae, Chydoridae, Daphniidae, Macrothricidae, Ilyocryptidae and Sididae. Of these, Chydoridae is the most diverse family, followed by Macrothricidae, Daphniidae, Sididae, Bosminidae and Ilyocryptidae. At the genus level, *Alona* is dominant followed by *Macrothrix* and *Chydorus*. These six families comprise a total of 72 species. The presence of one species new to science and of 14 new records for the county are quite high and take the species list of Thai cladocerans to 104 species, approximately 20% of the known world cladoceran fauna (~600 species, Korovchinsky, 1997). The proportion of common relative to rare species is small, a familiar fact in a tropical environment. Some exceptional rare species such as *Alona* cf. *dentifera, A.* aff. *karelica* and *A. sarasinorum,* the discovery of a rare Mediterranean species such as *Ephemeroporus phintonicus* and the finding of *Picripleuroxus laevis*, typical of the Palearctic/Holarctic region, in our region, considerably widen their geographical distribution, suggesting adaptation to a particular biotope.

To assess the actual species richness from our samples, the total of 72 species recorded are not far from S**max* Chao 2 (~76 species). The total is distinctly higher than the expected ATBI per locality (about 50 species) which demonstrates that our part of Thailand contains more species than can be packed in any single waterbody. The number of species found in each environment ranged from 0 to 36 species, and most localities produced 15-36 species. These records are based on samples which were taken into two seasons. Thus, we expect that a renewed study effort will lead to the discovery of some extra species in the region.

The complementarity results confirm the non-cosmopolitanism concept, even at small scale, South East Asia level. The high complementarity value among neighbor countries indicates that the number of species in common is relatively low. However, artifacts may arise from the quality of the original data compared with those of the present study, and this may handicap these comparisons to an unknown degree. Still, our results provide a reasonable general idea of the species richness status of each region.

## 3. At the ecological distribution level

The cladocerans shows an association with the characteristics of freshwater bodies: only a few species occur almost everywhere but most appear preferentially in definite type of aquatic environments. Also, littoral species are dominant in southern Thailand rather than limnetic species, and it is confirmed that the limnetic community is quite uniform and poor in species while the littoral community is more diverse.

The correlations between the occurrence of particular cladocerans and environmental conditions were analyzed. The results suggest that it is possible that the measured factors may be important to cladoceran species composition and their distribution in the area, and these factors may be operative at the community level rather than the species level. Consequently, the proposal of Frey (1968) "*There have no direct correlations between the occurrence of particular cladocerans and chemical conditions of the environment*" cannot be rejected. Thus, here we suggest that studying the structural features and the habits with which they are inseparably linked, together with biotic factors, such as the nature of the substratum-whether muddy, sandy, rocky etc., the presence of particular kinds of vegetation, adequate supplies of food, the presence of particular predators, are in general more important than abiotic factors. Study of these factors seems likely to be more fruitful than attempted correlation with the chemistry of the environment.

## 4. At the biogeographical distribution level

The results from our study at level of biogeography can be concluded into four points as the followings:

1) Because of the old age of the Cladocera, the overlap of some common species in different regions can be explained by their sharing a common before Pangaea was broken up. Also, the similarity of todays' species may have arisen from initially similar protospecies that existed since before the separation of continents and evolved slowly because of their parthenogenetic reproduction type.

2) After fragmentation of Pangaea, there remained connections between the continents which served as dispersal routes for organisms. Hence, the close overlap between the cladocerans of South East Asia and Africa compared with South America may be due to better dispersal routes between the two continents which lasted longer into more recent times.

However, the existence of some South American species in Thailand (e.g. *Leydigiopsis* sp., *Alona* aff. *karelica, Macrothrix* cf. *paulensis*) cannot be explained by those reasons. One possible hypothesis is they are relicts of a continuous distribution in Pre-Pleistocene times rather than descendants that reached the rainforest during humid periods of the Pleistocene. Moreover, the range of environments they encounter in Thailand are similar to their environments in South America. Thus, such the localities may share some specific characteristics suited to contain that species.

3) Concerning lesser numbers of species in Africa relative to other two regions, we hypothesize that the process of aridification of the climate in the Pleistocene had a stronger effect in this region than in the other two, so more species went extinct in African region and did not succeed in reinvading afterwards. Thus, the African rainforest cladoceran became impoverished.

4) As a result of high complementarity values among these regions, it means that a large part of the cladocera has a restricted range of distribution. This also may be the evidence of the differences of theirs existed microhabitats which affects to the different in diversity of the taxa. Consistent with the general rule of organism distribution, the more specific their environmental requirements, the more restricted their ranges.

## Perspectives

At the end of the thesis, some interesting questions arise that should be given attention in the future.

***Taxonomical aspect:***

A rather large number of species still await confirmation of their taxonomic status, redescription or revision. Particularly, the monospecific genera which mainly occur the tropical rainforest (*Guernella, Grimaldina, Dadaya*), some other confusing megagenera which a lack of studies (*Alonella, Chydorus*) should be investigated in more detail. Additionally, the information of molecular study is also being an important tool to clarify the phylogenetic relationship especially at family and genus level. Moreover, functional-morphological studies are needed as they may throw more light on cladoceran evolution. Finally, the zoogeography of the Cladocera, a field that has remained underdeveloped, should be further developed.

***Diversity and ecology aspect:***

The status of the diversity of the cladoceran fauna in Thailand will be given a better foundation once a better investigation has been done in every part of Thailand and in every kind of habitat.

**Table 20** Summary of morphological characters of *Alona* Baird, 1843 from southern Thailand

| | *A. affinis* | *A.* cf. *cambouei* | *A. cheni* | *A. diaphana* | *A. guttata* | *A. macronyx* | *A. monacantha* | *A.* aff. *karelica* | *A. rectangular* | *A. sarasinorum* | *A. verrucosa* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **shape** | sub-rectangular | oval | oval | oval to ovoid | oval to oviod | rounded to globular | oval | oval | rounded | rounded | oval to ovoid |
| **ventral margin** | almost straight, 18-20 marginal setae & 56-60 slender setae | almost straight | almost straight,~46 setae | V-shape formation, 56-65 setae, series of stules between them | rounded | convex, prominent in the middle, 18-20 short setules anteriorly, 48-52 setules posteriorly | almost straight, 26-30 setae posteroangle 2-3 denticles; pointing/leaf-like | | slightly concave, 29-32 setae, 3-7 setules with equal length posteriad between them | slightly concave, 86-90 setae pentagonal-shape value | rounded, slightly concave |
| **size (mm)** | L: 0.7-0.8<br>H: 0.34-0.4<br>L=1.6H | L: 0.32-0.34<br>H: 0.22-0.26<br>L=1.4H | L: 0.35-0.48<br>H: 0.24-0.30<br>L=1.5-1.6H | L: 0.38-0.7<br>H: 0.26-0.42<br>L=1.4-1.6 | L: 0.38-0.42<br>H: 0.23-0.24<br>L=1.6-1.7 | L: 0.26-0.38<br>H: 0.25-0.35<br>L=1.1H | L: 0.25-0.31<br>H: 0.2-0.25<br>L=1.2-1.3H | | L: 0.28-0.30<br>H: 0.18-0.20<br>L=1.5H | L: 0.34-0.44<br>H:0.24-0.32<br>L=1.3-1.4H | L: 0.26-0.32<br>H: 0.17- 0.21<br>L=1.5H |
| **head** | small | moderate | small | moderate | small | moderate | moderate | small | small | small | moderate |
| **head pore** | 2 major with connection + 2 small lateral PP=1.5-2 IP | 3 major without connection, 2 lateral pores small | 3 major with connection, the central smaller , close to posterior+ 2 sac-like lateral | 3 major with connection + 2 small lateral located ~1/2 of midline PP=1 IP | 3 major with connection, the middle smaller + 2 small lateral | | 3 major with connection, the middle smaller | | 2 major with connection, 2 lateral pores small | 3 major with connection, central in the middle | 2 major with connection, 2 lateral flower-like |
| **A1:aesthetascs** | 7 (9, Sinev, 1997) unequal in length | | 9, distalmost longest not protruding beyond tip of rostrum | 8, protruding beyond tip of rostrum | 9, distalmost longest, protruding beyond tip of rostrum | 9 | 9 | 9; 1/2 of antennular length | | 8; 2 longest | 9 |
| **AII** | spine 0-0-1/1-1-1<br>setae 1-1-3/0-0-3 | | spine 0-0-1/1-0-1<br>setae 1-1-3/0-0-3 | spine 0-0-1/1-0-1<br>setae 0(?)-1-3/0-0-3 | spines 0-0-1/1-0-1<br>setae 0-1-3/0-0-3 | | | spines 0-0-1/1-0-1 setae 0-1-3/0-0-3 | spines1-0-1/0-1-1 setae 0-0-3/0-1-3 | spine 0-0-1/0-0-1 setae 0-0-3/1-1-3 | spines 0-1-1/1-0-1<br>setae 0-1-3/0-0-3 |
| **labrum** | rounded-polygon like, 2 clusters of setules | large, rounded edge slightly form angle | rounded, blunt aoex with a row of setules | large, rounded, naked | rounded, row of spinules distally | rounded, margin has a minute denticle | large, rounded edge slightly form angle, margin has a minute denticle | | rounded, distal as triangular-shape | moderate, slightly curved around the middle, keel rounded with blunt apex | rounded, margin has a minute denticle |
| **postabdomen** | parallel, some narrow distally, | narrow distally, almost straight, | almost parallel, | broad, | narrow distally, triangle-like, | narrow distally, widest in postanal corner | | narrow distally, triangle-like, | narrow distally | narrow distally, distinc pre-&postanal corner, | broad distally, |

**Table 20** (Continued)

| | *A. affinis* | *A.* cf. *cambouei* | *A. cheni* | *A. diaphana* | *A. guttata* | *A. macronyx* | *A. monacantha* | *A.*aff. *karelica* | *A. rectangular* | *A. sarasinorum* | *A. verrucosa* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **marginal denticles** | 12-15 gr. of 0-5 merged spinules | 8-9 gr. of 3-4 spines | 8-11 gr. of 3-5 merged spinules | 9-11 gr. of 3-5 merged spinules | 10-11 gr. of 3-5 merge spinules | 8-10 gr. of 2-3 small spinules each | | 10-11 gr. of 3-5 merge spinules | 7-8 gr. of 2-3 spinules each | 9-10 of 2-4 spinules | 8-10 gr. of 8-10 spinules, 3-5 distally |
| **lateral fascicles** | 11-13 gr. of 4-6 denticles each | 6-7 gr. of 9-11 denticles each | 7-9 gr. of 5-9 denticles each | 7-8 gr. of 8-10 denticles each | 8-9 gr. of 4-8 denticles each | 9-10 gr. of 4-8 denticles each | | 8-9 gr. of 4-8 denticles each | 8 gr. of 5-9 denticles each | 5-7 gr. of lateral fascicles, | 10-11 gr. of 4-10 denticles each |
| **terminal claw** | basal spine = ½ of claw + 1 setule | long, slender=anal margin basal spine=1/2claw + 2 setules | long, slender=anal margin basal spine <1/3 claw | long, slender>pre-anal margin basal spine=1/2 claw + 3 setules | long, slender=anal margin | long, slender=anal margin basal spine=1/3claw + 3 setules | long, slender>pre-anal margin basal spine=1/2 claw | long, slender=anal margin basal spine=1/3 claw | long, slender=anal margin basal spine=1/3claw +3 spinules | long, slender=anal margin basal spine=1/3claw +3 spinules | long, slender=anal margin basal spine=1/4claw +2-3 spinules |
| **P1:IDL** | 3 setae | 2 slender setae+ 1 small hook-like seta | 3 setae; 1chitinized hook-like seta, 1 sn | 3 setae | 2 setae | | 2 setae, fork-like spines distally | 2 setae+1 hook-like chitinized seta | 3 setae with large distal setules | 3 setae; 1 large & 1 minute hook-like | 2 setae with large distal setules |
| **: ODL** | 1 long seta | 1 long seta+1smaller | 1 long seta | 1 long seta | 1 long seta | | 1 long seta | 1 long seta | 1 long seta | 1 long seta | 1 long seta |
| **: E3** | 4 plumose setae+1sn | 4 plumose seta, 4th more slender | 4 setae + 1sn | 4 plumose setae, 3rd more robust | 4 plumose setae, 4th more robust | | 4 setae, 4th more robust | 4 setae | 4 setae | 3 short setae | 4 setae |
| **: E2** | 2 seta | 3 setae | 3 large setae; 2 more robust spine distally | 3 setae | 3 setae, 3rd more robust | | 2 setae | 3 setae,1sn | 2 setae | 3 setae, 2 sn | 3 setae |
| **: E1** | 2 apical setae+1lateral | 2 setae | 2 setae | 2 setae | 2 setae | | 2 setae | 2 setae | 2 setae | 2 setae + 1 extra | 2 setae |
| **P2: ex** | elongate + single small seta | | elongate + single small seta | elongate | | sub-triangular | elongate with projection | elongate | | elliptical | elongate |
| **: en** | 8 scrapers increasing distally, 6 posteriormost more robust | | 8 scrapers, increasing distally, 3rd with robust setules distally& 7thwith spine-like comb | 8 scrapers increasing distally, 3rd shorter than 4th | 8 scrapers increasing distally, 6th < 7th | 8 scrapers increasing distally | 8 scrapers increasing distally, first three more robust setules distally | 8 scrapers increasing distally | 8 scrapers increasing distally | 8 scrapers increasing distally, the last three more robust, broad basally | 8 scrapers increasing distally, 3rd & 6th more robust |
| **: gn** | 3 elements, 7 filter combs | | 4 elements; 1 minute 7 filter combs; posteriormost shortest | 4 elements, 5 filter combs | rounded,-subtriangular, 3 elements, filter comb? | 3 elements, 5(?)filter comb | rounded lobe, 4 elements, 4(?) filter combs | rounded, elements?, filter comb? | | 3 elements(1 almost absent), 7 filter combs | 3 elements, 7 filter combs |

**Table 20** (Continued)

| | *A. affinis* | *A.* cf. *cambouei* | *A. cheni* | *A. diaphana* | *A. guttata* | *A. macronyx* | *A. monacantha* | *A.*aff. *karelica* | *A. rectangular* | *A. sarasinorum* | *A. verrucosa* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **P3: ex** | globular, 5 distal + 2 lateral setae | sub-rectangular, 2 distal setae+4 lateral setae | triangular, 5 distal+2 lateral setae | small, quadrangular, 5 distal + 2 lateral setae | | | | small, globular, 2 distal setae V-shape formaion+ 4 lateral setae | | sub-rectangular, 2 distal setae + 4 lateral setae | small, flat rectangular , 2 distal setae +4 lateral setae |
| **: en** | 3 distal setae, 4 basal setae+4soft setae | 3 distal setae, 3rd more robust, 4 basal setae +4 soft setae | 3 distal setae; 2 distalmost stout, 5 naked basal setae, 1sn | 2 distal setae, 4 basal setae+ 4 soft setae | | | | 3 distal setae + 4 soft setae | | 3 distal setae; 2 distalmost stout, 4 basal stiff setae + 4 soft setae | 3 distal setae, 3rd more robust + 4 soft setae |
| **: gn** | 3 elements, 7 filter combs | 3 elements, 7 filter combs | 3 elements, 6 filter combs | 3 elements, 7 filter combs | | | | 4 elements, 4(?) filter comb | | 3 elements, 7 filter combs | elements?, 4 filter combs |
| **P4:epi** | | | ? | | | | | | | globular, bilobed | |
| **:ex** | rounded, 6 setae | Rounded, 6 setae | quadrangular, 5 setae | rounded, 6 setae | | | | rounded, 6 setae | | rounded, 6 setae | rounded, 6 setae |
| **: en** | 4 flaming torch setae+1rod-like seta, 4soft setae | 1 stout with short setules distally +3 flaming torch setae +3 basal spines | 1 stout+4 flaming torch setae (9,6,8 setae)+1 naked, 1 sn | 1 naked spoon-like seta + 3 flaming torch setae, round elliptical sn + 3 soft setae | | | | 1 naked setae+3 smaller+1rod-like receptor +3soft setae | | 1 short stout + 3 flamimg torch setae + 3 basal spines | 1 naked setae+3 smaller+1 sn |
| **: gn** | 3 elements, filter comb? | 3 elements+1sn, 5(?)filter combs | 3 elements, 7 filter combs | 3 elements, filter comb? | | | | 3 elements, filter comb? | | 1 long element, 2 fused elements, 1sn, 5 filter combs | 2 elements, filter comb? |
| **P5:pre-epi** | rounded | small, no projection | elliptical, | rounded, no projection | | | | | rounded, no projection | ? | small, no projection |
| **: epi** | rounded | rounded | more ovoid + finger- like projection | rounded, no projection | | | | | rounded, no projection | elliptical, bilobed | larger, rounded with elongated projection |
| **: ex** | bilobed, 3+1 setae | bilobed, 3+1 setae | bilobed, one quadrangular with 3 setae+ one elongate with 1 setae | bilobed, 3+1 setae | | | | | bilobed, 3+1 setae | oval, bilobed, 3+1 minute seta | 4 setae, one is minute |
| **: en** | oval | large, elongated, 2 setae | oval | rounded, large | | | | | | large, rounded, 3 setae; one rod-like seta | elongated, 2 setae |
| **: gn** | 2 setae | small, rounded | 2 setae | 2 setae | | | | | | | small, rounded |
| **P6** | present | not present | present | present | not present | not present | not present | not present | not present | not present | |

**Table 21** Summary of morphological characters of *Macrothrix* species found in southern Thailand, including all species described above

| Characters | *M. paulensis*-group | | | *M. rosea*-group | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***M. paulensis*** | ***M. odiosa*** | ***M. sioli* (Kotov & Hollwel, 2004)** | ***M.* sp.nov.** | ***M. malaysiensis*** | ***M.triserialis*** | ***M.superaculeata* (Kotov *et al.*, 2003)** | ***M. spinosa*** | ***M.laticornis* (Silva_Briano, 1998)** |
| **shape** | ovoid | ovoid | ovoid | sub-rhomboid to subovoid | sub-quadrangular | ovoid | ovoid | ovoid | sub-ovoid elongated |
| **size (mm)** | L=0.8, H=0.52 | L=0.9,H=0.57 | | L=1.01,H=0.45 | L=0.89,H=0.65 | L=0.6,H=0.6 | L=0.41, H=0.75 | L=0.3, H=0.25 | L=0.47, H=0.33 |
| **head pores** | | relatively small, thin ring | | large, ovoid, not projected under head | small, ovoid, not projected under head | small, | large, ovoid, with rough surface, very thin ring around | small | small, oval |
| **Valve:** | | | | | | | | | |
| **ventral value** | serration | serration | serration | serration | serration | serration | serration | serration | serration |
| **postero-dorsal angle of valve** | smooth | smooth | large, triangular spines | large, triangular spines | rudimentary spines | smooth, short pointing | smooth | smooth, short pointing | smooth |
| **dorsal edge of valve** | smooth | smooth | serration | serration | smooth | serration, not obvious | serration | serration | clearly serration |
| **dorsal margin of valves** | above margin of head | above margin of head | under margin of head | under margin of head | above margin of head | | | | |
| **between head and valves** | no gap | gap | deep gap | very deep gap | very deep gap | no gap | deep step from dorsal head pore to posterior border of head shield | no gap | no gap |
| **ventral head margin** | without projection | with small projections | regularly convex | regularly convex | with small projections | regularly convex | s-shaped, with clear reticulation, no projection | regularly convex | regularly convex |
| **A1** | rod-like 3-5 large denticles | rod-like large spine | rod-like large spine | rod-like 3-5 large denticles | rod-like 4-5 large denticles | rod-like rows of small spines | rod-like | widen distally rows of small spines | widen distally |
| **aesthetasces** | 9 | 9 | 9 | 9 | 9 | 9 | 9 short terminal setae | 8 (?) | 7 |
| **A2** | setae 0-0-1-3/1-1-3, spine 0-1-1-1/0-0-1 | setae 0-0-1-3/1-1-3, spine 0-1-0-1/0-0-1 | | setae 0-0-1-3/1-1-3, spine 0-1-0-1/0-0-1 | setae 0-0-1-3/1-1-3, spines 0-1-0-1/0-0-1 | setae 0-0-1-3/1-1-3 spine 0-0-0-1/0-0-1 | setae 0-0-0-3/1-13 spine 0-1-0-1/0-0-1 | setae 0-0-1-3/1-1-3 spine 0-0-0-1/1-0-1 | setae 0-0-1-3/1-1-3 spine 0-1-0-1/0-0-1 |

## Table 21 (Continued)

| Characters | *M. paulensis*-group | | | | *M. rosea*-group | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *M. paulensis* | *M. odiosa* | *M. sioli* (Kotov & Hollwel, 2004) | *M.* sp.nov. | *M. malaysiensis* | *M.triserialis* | *M.superaculeata* (Kotov *et al.*, 2003) | *M. spinosa* | *M.laticornis* (Silva_Briano, 1998) |
| **largest lateral seta** | small spinules along ventrally, more robust spinules distally | rows of robust spinules distally, small spinules among them | | rows of robust spinules distally | rows of robust spinules distally | 2-3 robust spines ventrally | | | rows of spinules unilaterally |
| **labrum** | large, sub-triangular | large, sub triangular, spade-shape | large, triangular | large, sub-triangular | small, rounded | moderately, triangular (not large as *paulensis*) | wide, sub-quadrangular, with minute tubercles at apex | moderately, triangular | concave |
| **postabdomen** | | | | | | | | | |
| **shape** | large, sub-quadrangular | large, sub-quadrangular | large, sub-quadrangular | large, sub-quadrangular | max. height in the middle, not quadrangular | medium, more ovoid | sub-ovoid, elongated, dorsal margin bi-lobed | medium, ovoid | sub-ovoid |
| **lateral flaps near the anus** | no | present | no | present | no | no | no | no | no |
| **anal margin of postabdomen** | hairs present | no hairs | no hairs | no hairs | no hairs | no hairs | no hairs | no hairs | no hairs |
| **natatorial seta** | short | short | short | short | short | very short | short, spinules along seta (present information) | very short | short |
| **P1** | | | | | | | | | |
| **IDL:** | 3 bi-segmented setae | 3 bi-segmented setae | | 4 bi-segmented setae | | 3 bi-segmented setae | 3 setae; 2 smaller hook-shaped | 3 setae | 3 setae |
| **ODL:** | 1 long+1 short | 1 long+1 short | 1 long+1 short | 1 long+1 short | | 1 long seta | 1 long seta | 1 long seta | 1 long seta |
| **E3:** | 1 curve-like + 3 bi-segmented setae | 1 curve-like + 3 bi-segmented setae | | | | 4 short setae | 1 long curved-like seta,2 short spine-like setae, 1 short bi-segmented seta | 1 small curve-like seta +3 bi-segmented setae | 4 setae |
| **E2:** | 3 bi-segmented setae | 3 bi-segmented setae | | | | 3 bi-segmented setae | 3 long bi-segmented setae | 3 bi-segmented setae | 3 bi-segmented setae |
| **E1:** | 2 bi-segmented setae | 2 bi-segmented setae | | | | 2 bi-segmented setae | 2 bi-segmented setae | 2 bi-segmented setae | 2 long bi-segmented setae |
| **Forks** | on E1, E2 L=0, R=2 length L=R/ shorter | on E2, E3 L=1, R=0 length L=R | | on E2, E3 L=2, R=0 length L=R | | on E1, E2 L=2 or 3, R=0 length L>R | | on E1, E3 L=2, R=0 length L>R | |
| **Seta on gnathobase** | 2 | 2 | | 2 | | 0 | | 2 | |

**Table 21** (Continued)

| Characters | *M. paulensis*-group | | | | | *M. rosea*-group | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *M. paulensis* | *M. odiosa* | *M. sioli* (Kotov & Hollwel, 2004) | *M.* sp.nov. | *M. malaysiensis* | *M.triserialis* | *M.superaculeata* (Kotov *et al.*, 2003) | *M. spinosa* | *M.laticornis* (Silva_Briano, 1998) |
| **Ejector hook** | single | single | single | single | single | two | two | two | two |
| **P2** | | | | | | | | | |
| **EX:** | sub-quadrangular | sub-quadrangular | | | | triangular-elongated lobe | sub-ovoid lobe with long, bilaterally setulated seta | small, elongated lobe | elongated with small mamillation at apex +1 long bilaterally seta |
| **Seta on EX** | large | small | | large | | typical ibis-like | | no | |
| **EN: (scraping spines)** | 8 scrapers, increasing distally | 8 scrapers increasing distally | | 8 scrapers increasing distally | | 8 scrapers increasing distally, | 8 scraping spines, increasing distally, | 8 scraping spines, increasing distally, 6 posteriormost more robust | 8 scraping spines,4th & 5th more robust, largest distally |
| **robust seta** | 5th, 11-12 tooth enlarged subapical teeth | 5th, 10 tooth enlarged subapical teeth | | 5th, 15 tooth | | 4th- 5th , 7 and 6 tooth respectively; enlarged subapical teeth | 3rd-8th ; 4th and/or 5th with enlarged subapical teeth | 3rd-5th , 6 tooth each; enlarged subapical teeth | |
| **GT:** | 3 elements, 4 filter combs | 4 elements, 4 filter setae | | 4 elements, 4 filter setae | | 3 elements, 4 filter setae | 4 elements, 4 filter setae | 3 elements, filter setae? | 3 elements, 5 filter setae |
| **Additional seta on GT** | large | large | | large | | very small | | not seen | |
| **posteriormost seta of filter comb** | broaden basally | similar as other | | broaden basally | | broaden basally | | | |
| **P3** | | | | | | | | | |
| **EX:** | 3 setae, 1st longest | 4 setae, 2nd longest | | 4 setae, 2nd longest | | 4 setae, 3rd longest | 4 setae | 4, 3rd longest | 4 setae |
| **between seta 1-seta 2** | row of long setules | 4 bunches of setules | | naked?? | | 3 bunches of setules | | row of long setules | |
| **seta 2** | seta 2 2.5x as long as seta 3 | seta 2 2.5x as long as seta 3 | | seta 2 3x as long as seta 3 | | seta 2 2x as long as seta 3 | | equal | |
| **seta 3** | normal, armed with setules | normal, armed with setules | | normal, armed with setules | | robust, armed with spines | | normal, armed with setules | |
| **EN:** | | | | | | | | | |
| **EE** | 3+3 | 3+3 | | 3+4 | | 3+3 | | 3+3 | |
| **IE** | 3+4 | 4+3 | | 4+3 | | 4+3 | | 4+4 | |
| **GT:** | | 4 elements, filter comb absent | | 4 elements, filter comb absent | | 3 elements | 4 elements | | |

**Table 21** (Continued)

| Characters | *M. paulensis*-group | | | | | *M. rosea*-group | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *M. paulensis* | *M. odiosa* | *M. sioli* (Kotov & Hollwel, 2004) | *M.* sp.nov. | *M. malaysiensis* | *M.triserialis* | *M.superaculeata* (Kotov *et al.*, 2003) | *M. spinosa* | *M.laticornis* (Silva_Briano, 1998) |
| **P4** | | | | | | | | | |
| **EX:** | 2 setae (1:2.5) | 2 setae (1:2.5) | | 2 setae (1:3) | | 2 setae (1:1) | 2 setae | 3 (1:1:1) | 3 setae |
| **EN:** | 5+5 | 4+5 | | 5+5 | | 5+5 | | 5+5 | |
| **GT:** | 3 elements | 4 elements, filter comb absent | | 3 elements | | 3 elements | 4 elements | 2(?) elements | |
| **P5** | | | | | | | | | |
| **PEP:** | | 3 lobes, globular large | | 3 lobes, globular, small | | 3 lobes, elongated, small | 3 lobed | | small |
| **EP:** | | small, globular | | large, elongated | | | elongated, large | | large |
| **EX:** | long single seta | small single seta | | small | | | 2 more robust setae | | 2 fine long setae |
| **EN:** | as large flap | as large flap | | as small flap | | | | | one seta on flap |

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Estimates Program for randomization:

http://viceroy.eeb.uconn.edu/estimates

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Vandamme, K., Chiambeng, G., **Maiphae, S** and Dumont, H. J. 2003. New species in the rheophilous genus *Nicsmirnovius* Chiambeng & Dumont, 1999 (Branchiopoda: Anomopoda: Chydoridae) and reassignment of *Alona eximia* Kiser, 1948 and *Alonella fitzpatricki* Chien, 1970. *Hydrobiologia* 499: 25-49.

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# New species in the rheophilous genus *Nicsmirnovius* Chiambeng & Dumont, 1999 (Branchiopoda: Anomopoda: Chydoridae) and reassignment of *Alona eximia* Kiser, 1948 and *Alonella fitzpatricki* Chien, 1970

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## Abstract

A morphological comparison of specimens previously assigned to *Alona eximia* Kiser, 1948 from tropical Africa, Eastern Asia and the Americas shows that this species-group shares a number of morphological characters on the postabdomen, head pores, first antenna and second and fourth limb that separate them from *Alona* Baird, 1843 but unite them with *Nicsmirnovius* Chiambeng & Dumont, 1999. *Alonella fitzpatricki* Chien, 1970, formerly believed to be a junior synonym of *A. eximia*, is separated from the latter and assigned to the genus *Nicsmirnovius*. Two new taxa, from Africa and the Island of Socotra (Yemen) are added to the genus. The relationship between the specialised habitat of these chydorids and their morphology is discussed. The geographic range of all known populations is figured and a key to species is presented.

## Introduction

The use of limb morphology as a taxonomic and phylogenetic tool and the step-wise acceptance of the non-cosmopolitanism concept of Frey (1982, 1987), have begun to raise chydorid taxonomy to a higher level. Although several species (-groups) and genera still await redescription or revision, the growth in our knowledge of the Chydoridae in the last decade has been spectacular (Korovchinsky, 2000) and continues to date. This is currently the case for *Alona*, a taxon that represents a heterogeneous group of genera and species, all in need of revision. Several *Alona*-like genera have recently been described (Rajapaksa & Fernando, 1987; Frey, 1991; Ciros-Pérez & Elías-Gutiérrez, 1997; Chiambeng & Dumont, 1999; Dumont & Silva-Briano, 2000) or redescribed (e.g., Sinev, 2001; Sinev & Kotov, 2001; Sinev et al., in press). Here, we separate *Alona eximia* Kiser, 1948 and *Alonella fitzpatricki* Chien, 1970 from *Alona* s.str., transferring it to *Nicsmirnovius* Chiambeng & Dumont, 1999, and describe a new species and subspecies, commencing with a historical note:

Based on a collection made by Robert Miller in the Pearl River in China, Kiser (1948) described a 'remarkable' ('*eximius*') chydorid, which he situated in the genus *Alona*:

> "The valves are subquadrate in form and are marked by fine longitudinal striations. The dorsal margin of the shell is evenly arched with a rounded supra-posteal angle and an unarmed, broadly rounded infro-posteal angle. The ventral margin of the shell is adorned with a row of hairs. The rostrum is very short and blunt, and measures

about half the length of that found in specimens of *Alona rectangula* Sars and *Alona intermedia* Sars, of comparable size. The antennules are short and thick and almost reach the tip of the rostrum. The olfactory setae with the exception of one are about one third the length of the rostrum. One elongated, jointed seta greatly exceeds the rostrum in length. The lateral sense hair is located about one third the distance from the distal end of the antennule. The tongue like keel of the labrum is angulated and without any notches or serrations on the anterior margin. The ocellus is slightly larger than the eye proper and is located in the proximity of the attachment of the antennules. The convoluted intestine is typical of the family. No anal caecum was observed in our specimens.
The short, exceedingly broad cleaver-like post-abdomen is wide at the apex as in *Alona intermedia* Sars, but breaks abruptly away at the anal indentation, and not continuing in a gradually tapering form as in *Alona intermedia* Sars. The basal spine of the claw is half as long as the claw itself. The dorsal margin of the post-abdomen is armed with a series of short marginal spines, and with 9–10 clusters of minute fascicles which exceed the margin of the post-abdomen in length. The summer eggs one in number. Size of females 0.3–0.4mm."

Green (1962) first recorded the animal from Africa (Sokoto River, Nigeria), and provided a drawing of the postabdomen and the main head pores. Chien (1970) subsequently described a new chydorid, *Alonella fitzpatricki* from the Pearl River, a branch of the Mississippi River, US, which was reassigned to *Alona eximia* by Frey (1974). Frey also compared Chien's types with all known material, including Green's and Kiser's specimens. His discussion and partial redescription was limited to the first limb, body, labrum, first antenna and postabdomen, yet he suggested that differences among the populations could be of species level:

"Because of the general belief that intercontinental distributions is common among the Cladocera, most persons would have little hesitation in calling all three populations *A. eximia*. But this is just a first approximation, valid only after having been demonstrated to be so. The population from Africa seems distinctively different from the others in morphology of the postabdomen and postabdominal claws, but these and other suspected differences are only suggestive. They can be defined and used taxonomically only by the study of many specimens from point-space collections in order to sort out the ontogenetic variability from the interpopulational variability. Until such is done, all three populations will have to be called *Alona eximia* Kiser, 1948."

In a letter to Dr. Green in 1973 (Green, pers. comm.), Frey wrote that the African population of *eximia* diverged more from the Chinese than does the American, and that both African and American populations could be designated as valid subspecies, provided enough material was studied. He also noted (Frey, 1974) several unique characters of *Alona eximia*: the *Cosmarium*-shaped lateral pores (Fig. 3), which is also found in *A. verrucosa* Sars, 1901, the postabdomen, the head shield and the long aesthetasc on the antennule.

The first comprehensive morphological description, including limb features, and accompanied by accurate drawings, was provided by Paggi (1979) using specimens from the Paraná River basin, Argentina. He confirmed Frey's findings 'que se trata de una especie de *Alona* bastante atípica'.

Between Kiser's first record and today, the animal was reported only sporadically from the tropics (Green, 1971; Dumont & Van de Velde, 1977; Van de Velde et al., 1978; Idris, 1983), each time in very low number, and notes were accompanied by few drawings. Being unmistakable in morphology, no confusion occurred in nomenclature after Chien (1970).

In 1999, Chiambeng and Dumont described a new genus and species from ephemeral water bodies in the rainforest at Korup Park, Cameroon. It was named *Nicsmirnovius camerounensis* – in honour of the cladocerologist N.N. Smirnov. Later that year, Cammaerts & Mertens (1999) erected a new genus, *Hydrospilus degreefi*, based on material from the same locality. Both descriptions undoubtedly refer to the same species: the first provides drawings of all features including limbs, while the last also contains SEM micrographs. In both articles, brief reference is made to the similarity with *Alona eximia* Kiser, 1948.

Taking into consideration that chydorid populations consist mainly of parthenogenetic females, the biological species concept is hardly applicable. Therefore we characterize a chydorid morpho-species as: a group of individuals, morphologically recognisable by a unique set of consistent (micro-) characters.

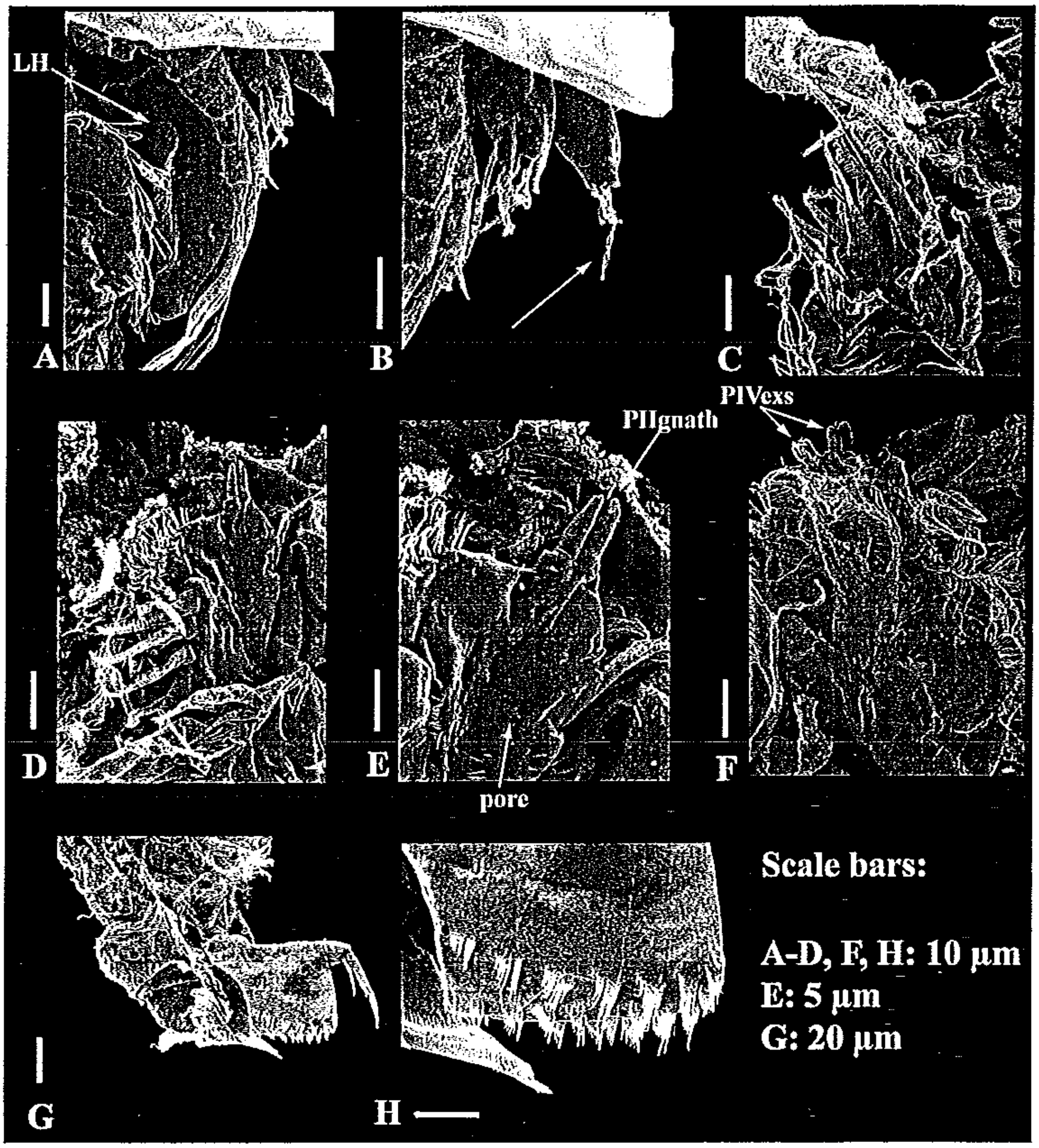


*Figure A–H. Nicsmirnovius eximius*, parthenogenetic females from Southern Thailand. (A) Second antenna and labral keel, lateral view; LH indicates 'lateral horns' on labral keel; (B) first and second antenna (partim): arrow indicates long aesthetasc on first antenna; (C), endites on limb I; (D), scrapers 5–8 and gnathobasic region of limb II; (E), gnathobasic elements of same limb; arrows indicate pore on inner portion and fish-hook shaped element; (F), exopodites of limb III and IV (partim); arrow indicates fifth and sixth exopodite setae of limb IV; (G), postabdomen, lateral view; (H), detail postabdomen, showing postanal armature.

This choice and interpretation of diagnostic characters is subjective, and therefore, wherever possible, reinforcement by independent arguments, such as ecological and chorological ones, is actively pursued.

## Abbrevations

*Collections:* GU, general collection kept in Laboratory of Ecology at Ghent University, Ghent; KVD, personal collection of Kay Van Damme, Ghent University, Ghent; RBIN, Royal Belgian Institute of Natural Sciences, Brussels. *In text and pictures*: IDL, inner distal lobe of first trunk limb; IP, interpore distance; ODL, outer distal lobe of first trunk limb; PI-PV, first to fifth limb. *In key*: am, anal margin; tc, terminal claw; pm, postanal margin.

## Material and methods

Samples from Cameroon and Socotra were taken using a conical plankton net, mesh width 100 $\mu$m. Animals were either selected from the samples or removed from slides under a binocular stereomicroscope and subsequently placed on slides in a 1:2 glycerol–formaldehyde mixture. Drawings were made using a *camera lucida* mounted on a Leitz Wetzlar Orthoplan microscope.

## Results

### Nicsmirnovius Chiambeng & Dumont, 1999

syn: *Hydrospilus* Cammaerts & Mertens, 1999 (the article of Cammaerts & Mertens (1999) appeared on July 31, while that of Chiambeng & Dumont (1999) was published on June 20).
Type species: *Nicsmirnovius camerounensis* Chiambeng & Dumont, 1999.
Etymology: the name '*Nicsmirnovius*' was given by Chiambeng & Dumont (1999) in honor of Dr. Nikolai Smirnov.

## Diagnosis

Easily separable from *Alona* and all other members of the Aloninae by the following features: embayment at ventral margin near middle (Fig. 2). Three main head pores, narrowly connected and two lateral pores with 'flower'– or '*Cosmarium*'–shaped structure (Fig. 3). Labrum with relatively large labral keel and depression near apex (Fig. 6). First antenna (antennule) with long aesthetasc, and extra subapical aesthetasc implanted next to sensory seta (Fig. 4). Second antenna with setal formula 0-0-3/0-1-3 (Fig. 5). IDL of first trunk limb with chitinized hook-like seta (Fig. 12a). Second trunk limb with proximally elongated gnathobasic lobe (Fig. 15). Fifth and sixth exopodite setae on fourth trunk limb with blunt spoon-like apex and apical aggregation of setules curved over them (Fig. 20). Broad axe-like or '5'-shaped postabdomen with terminal claw bearing long basal spine, implanted at some distance from claw base (Figs 7a-b).

## Description parthenogenetic females

*General* (Fig. 2): body in lateral view oval to ovoid, dorsally arched. Postero-dorsal angle rounded, postero-ventral margin rounded or with three weakly pronounced angles (Fig. 10). Most species with valve margin ventral embayment near middle. Marginal setae forming different size groups, longest situated in anterior quarter of valve rim. Valve ornamentation consisting of longitudinal stripes (visible in posterior half, in some species only faintly).

*Intestine* with up to three convolutions.

*Head*: rostrum short, truncated, pointing ventrally (Fig. 1). Compound eye absent in *N. camerounensis* (Fig. 75), present in other known species. Three large median head pores connected by a narrow channel (not observed in all species, noted by Frey (1974), Green (1962) and Paggi (1979)), two small lateral pores with subcuticular 'flower'-shape ('*Cosmarium*-shaped') (Figs 3, 91).

*Labrum*: with rounded, relatively large, naked labral keel ending in elongated blunt apex (Fig. 50) (the labrum is shorter in *N. eximius* and *N. greeni*: Figs 6, 30).

*Postabdomen* (Figs 7–9): compressed, '5'-shaped, exceedingly broad distally (Kiser, 1948), postanal part rectangular, with straight parallel dorsal and ventral margins and straight posterior margin. Anal margin slightly concave, preanal corner small. Embayment between base of terminal claw and posterior margin present to prominent, at right angles with posterior margin. Terminal claw of same length as anal margin, bearing basal spinules, and basal spine reaching halfway basal claw, situated at some distance from base of terminal claw. Pecten on terminal claw present. Marginal denticles about eight groups, single and stout distally with small basal denticles, gradually transforming to small groups of more uniform spines towards anal margin. Lateral fascicles long, decreasing in size towards anal margin.

*Valves* (Figs 2, 31): with straight free ventral margin, bearing setae in several groups of unequal length, the largest being situated anteriorly. Posteroventral corner rounded or with three rounded, moderately pronounced angles (Fig. 10).

*First Antenna (antennule)*: Body cylindrical, with peg-like projection at base in some species (Fig. 49b).

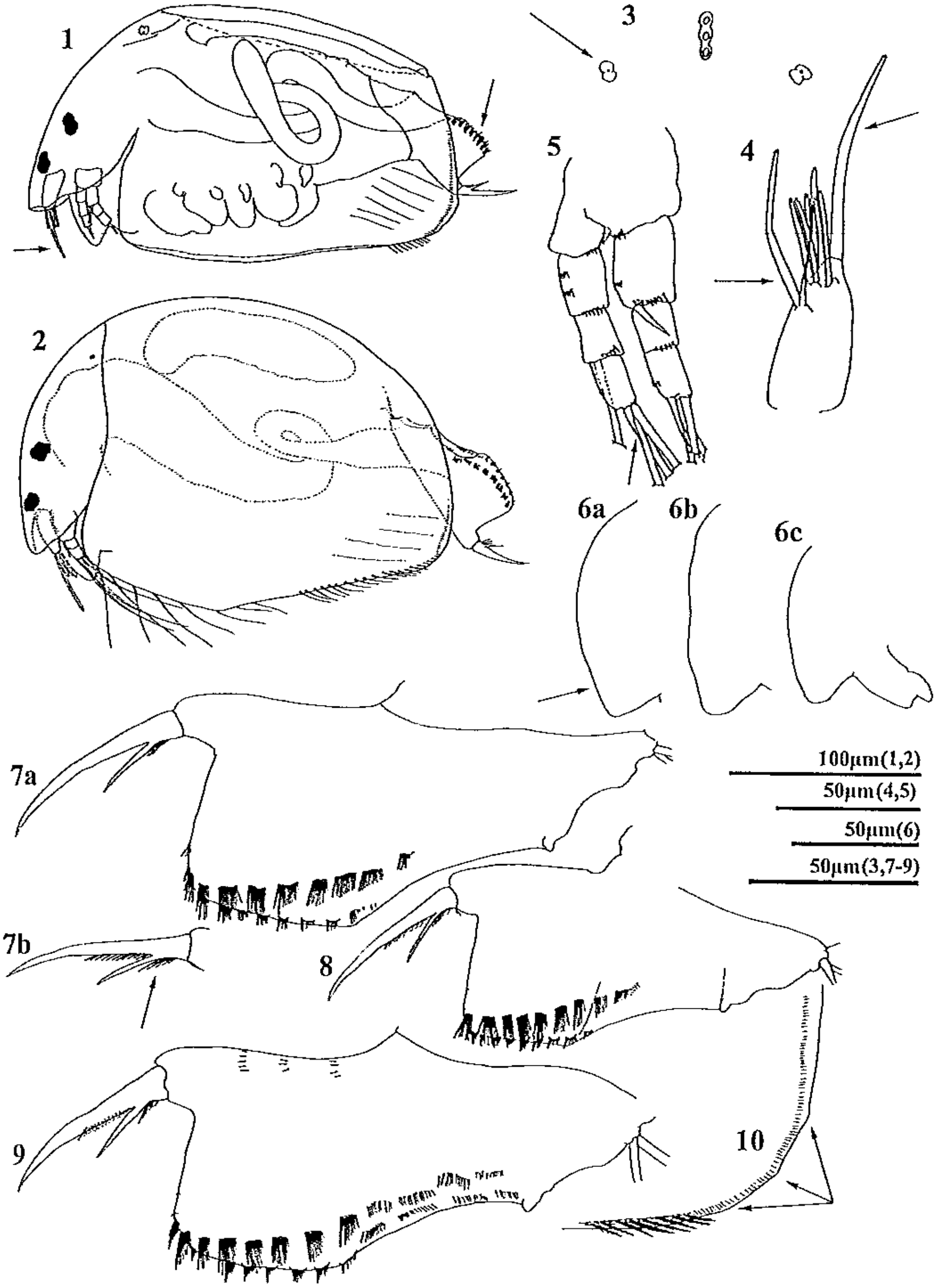


*Figure 1–10. Nicsmirnovius eximius*, parthenogenetic females: Kiser's types from China (Smithsonian, Cat. no. 89667: Figs 4, 5, 7a, 7b; Cat. no. 89668: Figs 1, 6a, 8) and additional material from Southern Thailand (Figs 2, 3, 6b, 6c, 9, 10). (1), habitus, lateral view; remark that carapace is not in natural state; arrows indicate long aesthetasc and '5'-shaped postabdomen typical for the genus; (2), Habitus, lateral view. (3), Head pores; arrow indicates flower-shaped structures around lateral pores typical for the genus. (4) First antenna; arrows indicate long apical and long subapical aesthetasc, typical for the genus. (5) Second antenna; arrow indicates apical endopodal spine, which is shorter than exopodal spine in this species (vs *N. greeni*, see text). (6) Labral keels of three specimens in lateral view; arrow indicates apex and shallow depression near apex, typical for the genus. (7). Postabdomen in lateral view; arrow in (7b) indicates distance between basal spine and terminal claw base and basal spinules, typical for the genus. (8) Postabdomen in lateral view. (9) Postabdomen in lateral view. (10) Posteroventral corner of valves; arrows indicate posteroventral angles, relatively pronounced in this species.

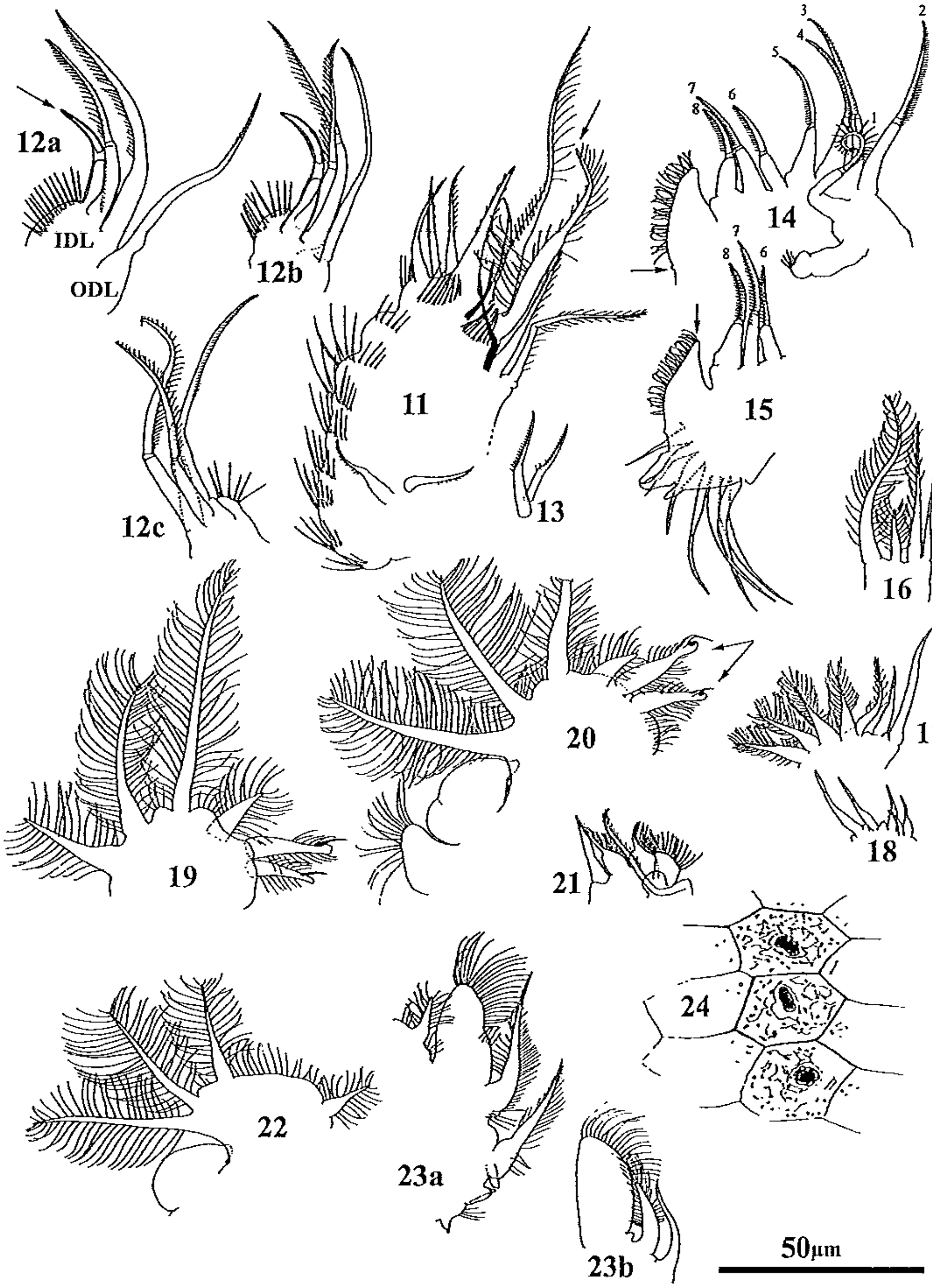


*Figure 11-24. Nicsmirnovius eximius*, limbs of parthenogenetic females: Kiser's types from China (Smithsonian, Cat. no. 89667: Figs 12c, 16, 19; Cat. no. 89668: Fig. 22) and additional material from Northern Thailand (Fig. 12b) and Southern Thailand (Figs 11, 12a, 13, 14, 15, 17, 18, 20, 21, 23a, 23b, 24). (11) Inner view of limb I, distal lobe omitted; arrow indicates second seta of second endite. (12a,b) IDL and ODL of limb I, inner view; arrow indicates chitinized seta typical for the genus. (12c) Idem, outer view. (13) Ejector hooks of limb I. (14) Inner view of limb II; arrow indicates receptor near gnathobase. (15). Limb II, gnathobasic area; arrow indicates elongated gnathobasic lobe, typical for the genus. (16) Exopodite of limb III, partim. (17) Endite of limb III, partim. (18) Soft setae on basal endite of limb III. (19, 20) Exopodites of limb IV; arrows indicate modified fifth and sixth exopodite setae, typical for the genus. (21) Endite of limb IV, partim. (22) Exopodite of limb V. (23) Endite and gnathobasic area of limb V. (24) Subcuticular epidermis cells of valve.

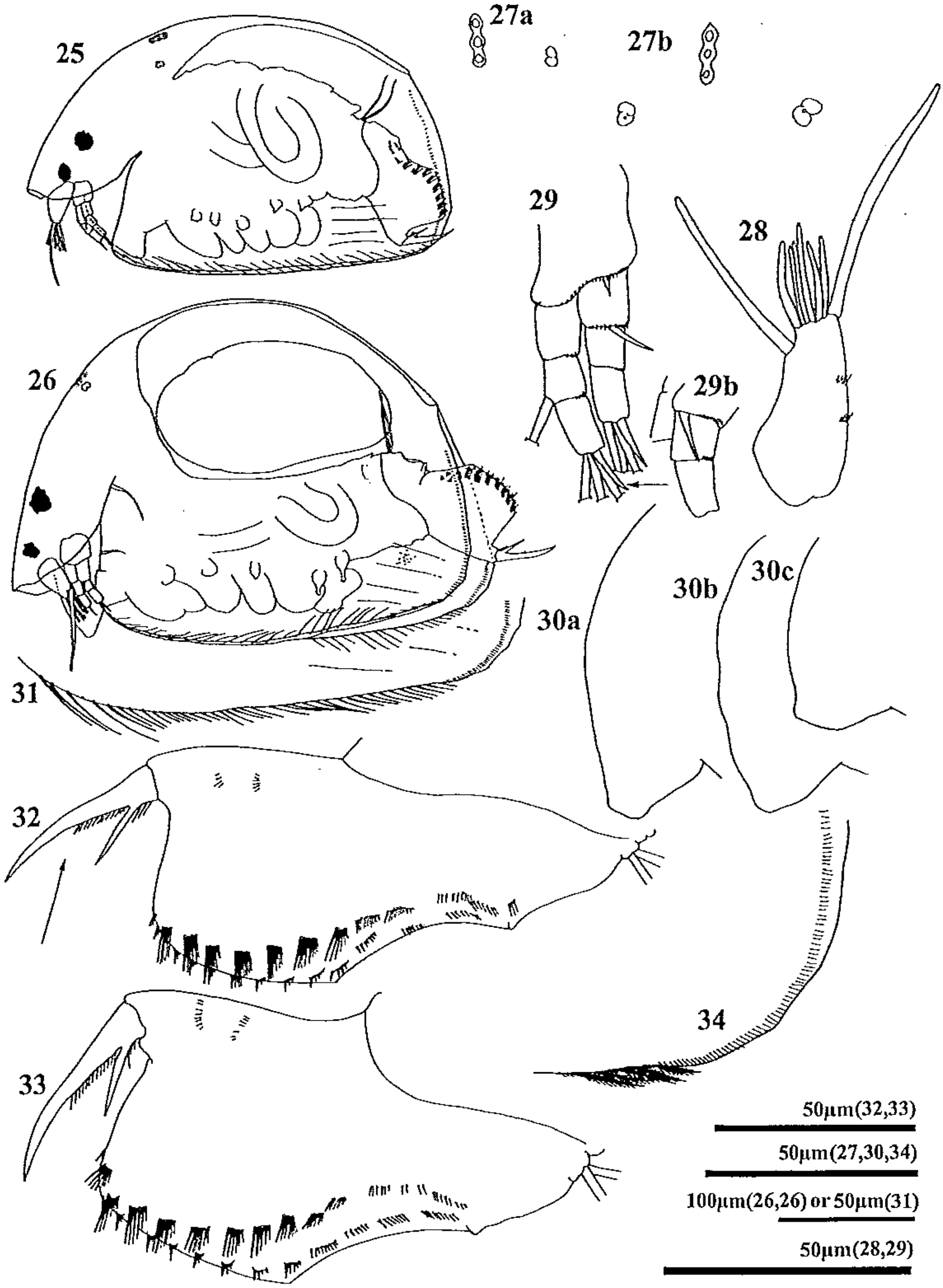


*Figure 25–34. Nicsmirnovius greeni* n. sp., parthenogenetic females: specimens from Cameroon, Stream at Science Camp, Korup National Park. (25–26) Habitus, lateral view. (27) Head pores. (28) First antenna. (29) Second antenna; arrow indicates length of apical endopodal spine, diagnostic for this species. (30) Labral keels of three specimens in lateral view. (31) Valve margin. (32, 33) Postabdomen in lateral view; arrow indicates pecten on basal claw. (34), Posteroventral corner of valve.

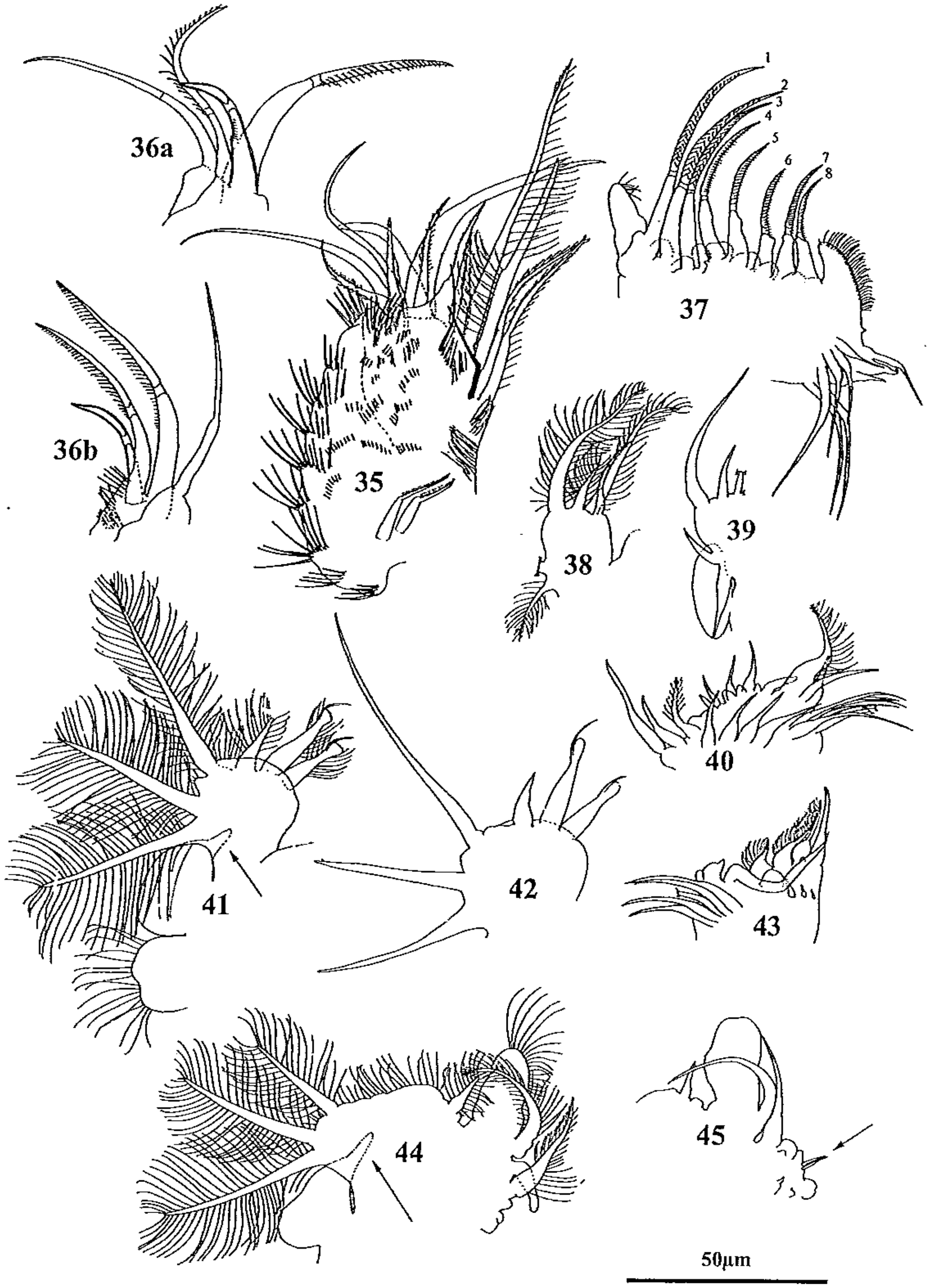


*Figure 35–45. Nicsmirnovius greeni* n. sp., parthenogenetic females: specimens from Cameroon, Stream at Science Camp, Korup National Park. (35) Internal view of limb I. (36) IDL and ODL of limb I. (37) Inner view of limb II; (38, 39) Exopodites of limb III; (40) Endite of limb III. (41, 42) Exopodites of limb IV; arrow indicates digitiform projection on epipodite, diagnostic for the species. (43) Endite of limb IV. (44) Limb V; arrow indicates digitiform projection on epipodite. (45) Limb V, gnathobase; arrow indicates filter setae.

Nine aesthetascs, of which seven normal, one situated on apical projection and at least twice as long as seven normal aesthetascs and one in lateral position, implanted at the level of the antennular sensory seta (Fig. 4).

*Second Antenna* (Fig. 5): antennal formula 0-0-3(1)/0(1)-0-3(1). Basal segment with short distal spine. Large spines on endopod and exopod relatively slender.

*Maxilla* and *mandible* not studied. Five pairs of thoracic or trunk limbs present.

*First Trunk Limb* (*P1*) (Figs 11, 12): Outer distal lobe with long, slender seta with hardly visible serrulation. Inner distal lobe bearing group ('brush') of large spines and three bisegmented setae, of which one is heavily chitinized and hook-like. Third endite with four setae similar in length. Second endite bearing three setae, of which 6 (second on the endite) is the longest. First endite with two setae. Inner base of second and first endites each with slender additional seta (not studied in all species). Groups of slender spinules present basally on inner sides of second and third endites. Long slender ejector hooks basally. Epipodite and Gnathobase not studied.

*Second Trunk Limb* (*P2*) (Figs 14, 15): exopodite elongated, bearing setules on apex. Endopodite with eight scrapers, similarly armed with fine denticles and decreasing in length towards gnathobase. Reduced seta present in some species. Gnathobase consisting of elongated lobe with setules, followed by a small receptor and three gnathobasic elements, the middle of which has a fish-hook shaped apex. Gnathobasic filter comb with seven setae.

*Third Trunk Limb* (*P3*) (Figs F, 16–18): exopodite small, rectangular, bearing six setae, of which the third or fifth are the longest. Distal endite with three setae, armature of first two hardly visible. Basal endite with four plumose setae and one bottle-shaped sensillum close to gnathobase. Four soft setae on inner portion, alternating with four small regressed setae. Gnathobase consisting of three setae, one large curved inwards, two more slender, and a filter comb with seven(-eight?) setae.

*Fourth Trunk Limb* (*P4*) (Figs 19–21, 41, 43): pre-epipodite present. Epipodite with globular body and short (*N. eximius*) to strongly elongated (*N. camerounensis*) digitiform projection. Exopodite oval to subquadrangular, bearing six setae, of which the third is the longest. Fifth and sixth exopodite setae with blunt apex, with subapical aggregated cluster of setules, unilaterally curved over the spoon-like apex. Three last setae implanted subapically on inner side of exopodite and a little lower than first three. Endopodite or inner portion with four marginal setae: one finely serrulated stout seta and three 'flaming-torch' setae, followed by round to oval shaped receptor on posterior surface. Gnathobase consisting of one large, recurved seta and two reduced elements basally. Filter comb with five setae.

*Fifth Trunk Limb* (*P5*) (Figs 22, 23): pre-epipodite bipartite, armed with long setules. Epipodite rounded, single, or with elongated digitiform projection. Exopodite with four setae, three large on ventral portion of limb, one shorter, oriented dorsally. Inner limb portion with elongated setulated lobe and two large setae (one endopodite seta, one gnathobase seta), finely setulated. Gnathobase with at least one receptor. Filter comb (only observed in two species) bearing two filter setae (Fig. 74).

**1. Nicsmirnovius eximius** (Kiser, 1948) comb. nov.
Kiser (1948): *Alona eximia* 315–316, Figs 1–3. Chiang & Du, 1979: 218, Figs A–D.
**Type locality**: Pearl River, Canton, China.
**Material examined:**
**Type material**:

*China*: holotype: 1 parthenogenetic ♀♀, complete, in slide, labeled '*Alona eximia* n. sp.' from Pearl River, Canton China, 05.08.1931, coll. R.C.Miller, id. R.W. Kiser, Smithsonian (Acc. No. 183178, Cat.No. 89668); *China*: paratypes: five parthenogenetic ♀♀, of which four complete and one dissected, from Pearl River, Canton China, 09.12.1930, coll. R.C.Miller id., don. R.W. Kiser, Smithsonian (Acc. No. 183178, Cat.No. 89667);*China*: one parthenogenetic ♀♀, from Pearl River, Canton China, 19.11.1930, Coll. R.C.Miller, id., don. R.W. Kiser, Smithsonian (Acc. No. 183178, Cat.No. 89669)

**Additional material:** *Thailand, South*: four parthenogenetic ♀♀, dissected, from Angtong waterfall, Trang Province, SW Thailand (7°32.94'N, 99°25.05'E), coll. August, 1999 by Ms. Punnee Sa-ardrit, KVD. *Thailand*, 12 parthenogenetic ♀♀, same data, SM; *Thailand, North*: two parthenogenetic ??, dissected, from a reservoir at Khon Kaen University Campus, connected with the Pong River, Khon Kaen province, coll. 13.08.1993 by L. Sanoamuang, UG.

**Etymology**: the epitheton '*eximius*' is Latin for 'remarkable'.

**Species diagnosis:** *N. eximius* can be recognised by the relatively short body of first antenna (Fig. 4) (about twice as long as wide) and the short, rounded lab-

*Table 1.* Morphological differences between South East Asian *Nicsmirnovius eximius* (Kiser) and *Nicsmirnovius greeni* n.sp. from Continental Africa

| | *Nicsmirnovius eximius* (Kiser) | Figures | | *Nicsmirnovius greeni* n.sp. |
|---|---|---|---|---|
| Habitus | More oval than round | 2 | 26 | Mostly, more round than oval |
| Labral keel, apex | Blunt, pointed more anteriorly than ventrally | 6, A | 30 | Blunt, pointed more ventrally than anteriorly |
| Second Antenna, length apical spines | Endopodal < exopodal | 5, A | 29 | Endopodal = exopodal |
| PA, Length of terminal claw in comparison to anal and postanal margin | Am=tc>pm | 7–9 | 32, 33 | Am=pm=tc |
| PA, anal margin | Relatively straight, not arched | | | Concave, arched |
| PA, Projection on base of terminal claw | Prominent, more than half of length basal spine | | | Not prominent, less than half of length basal spine |
| PA, number of marginal denticles per group | 5–7 | | | 2–3 |
| PA, number of spinules per lateral fascicle | 9–10 | | | 7–8 |
| P3, lengths of third and fifth exopodal setae | Third = fifth | 16, F | 38, 39 | Third > fifth |
| Epipodites IV-V | Mostly rounded or with small bump | 20, 22 | 41 44 | Always with elongated digitiform projection |

rum (Fig. 6). The species closest in morphology is the African congener *N. greeni* n.sp., from which it can be distinguished mainly by the shape of the postabdomen (Figs 7–9). Other characters: length of the endopodal spine on the second antenna (Fig. 5), the absence of long fingerlike projections on epipodites IV-V (Figs 20, 22), though these could be subject to variability (Kotov, pers. comm.). Other features listed in Table 1.

## Description parthenogenetic females

*General*: Length 0.22–0.29 mm, 1.2–1.4 times maximal height ($n$=8). Body in lateral view (Figs 1, 2) oval to ovoid, largest height around the middle and narrowing posteriorly. Postero-dorsal angle not prominent, postero-ventral margin with three moderately pronounced angles (Fig. 10). These angles are correlated with the carapace striation. Ventral carapace margin forming a wide V-shape, ventral embayment before middle (Fig. 2). Ventral setae relatively short, end before posteroventral corner (Fig. 10). Longitudinal valve striation best visible in posteroventral quarter of valve. Granulate polygons (Fig. 24), which are internal structures, easily mistaken for valve ornamentation.

*Head*: relatively small, rostrum typically short, truncated, pointing ventrally. Compound eye present, about same size as ocellus, sometimes larger; distance between eye and the latter same as between ocellus and rostral tip (Figs 1, 2). Head shield not studied. Three major head pores (Fig. 3) of same size and according to Frey (1974) connected by a narrow channel, margins of pore field constricted between main pores; two lateral pores, each surrounded by internal 'flower'-shaped structure, situated at about 2.3 IP from midline.

*Labrum*: labral keel (Figs A, 6) naked, with 'lateral horns' and rounded to blunt apex. Shallow depression (Fig. 6a) in ventral margin near short to slightly elongated apex.

*Postabdomen*: as for genus, broad quadrangular in terminal half, dorsal margin and ventral postanal margin parallel, posterior margin straight, at right angles with each other (Figs 7–9, g). Postanal margin markedly shorter than anal margin and slender terminal claw. Preanal corner present but small, situated more ventrally than postanal corner. Anal margin relatively straight, angle with postanal margin between 135° and 145°. Lateral fascicles: seven to eight postanal groups, consisting of eight to 10 denticles. As Frey (1974) noted, the third or fourth distalmost the largest within each fascicle. Spinules of four most distal groups reaching beyond dorsal margin of postabdomen, continuing proximally in groups of about 10–13 smaller denticles. Marginal denticles nine to 10 groups of merged spinules (Fig. H), of which distalmost slightly larger than following four to six.

*Terminal claw*: long and slender (Fig. 7). Base of terminal claw prominent, more than half of length basal spine; bearing five or more basal spinules (Fig. G) followed by basal spine reaching half of claw length and implanted at half its own length from claw base. Pecten short, reaching half of basal claw.

*First Antenna (antennule)*: reaching, but not protruding beyond tip of rostrum (Figs 1, 2). Body compact, about twice as long as wide (Fig. 4). Distalmost aesthetasc, implanted on elongated apex (Fig. B), 1.5 times as long as antennule and about 2.5 times as long as seven 'normal' aesthetascs. Subapical aesthetasc of same length as antennule, accompanied by antennular sensory seta (Figs 4, B), implanted at about one third of distal end.

*Second Antenna*: basal segment with conical distal spine (Fig. 5). Antennal formula spines 0-0-1/1-0-1 setae 0-0-3/0-1-3 (Figs 5, A). Spine on first exopod segment just reaching base of apical exopodal segment (Fig. B), apical exopodal spine larger than endopodal apical spine.

*First Trunk Limb (P1)*: Hook-like chitinized seta on IDL relatively slender, reaching half the size of largest IDL seta (Fig. 12). Group of large spines present on IDL, close to base of hook-like seta. Two largest IDL setae subequal in length, their second segment unilaterally armed with well-spaced setules. Smallest of IDL setae – not hook-like seta – of same length as ODL seta, the latter more slender and bearing short, hardly visible setules (Fig. 12). Third endite (Fig. 11) with four plumose setae; fourth one slightly more robust and larger than other three. Additional basal seta implanted on inner side of third endite slender, about same length as first apical seta of second endite. Second endite bearing three apical setae, of which 6 (second on the endite) is the longest. First endite with two apical setae, of which the second is the longest and bent towards the gnathobase. One extra seta on inner base of second endite, bent towards same endite and slightly longer than additional seta on third endite. Groups of slender spinules present basally on inner side of second and third endites. Long and slender ejector hooks, unequal in size (Figs 11, 13). Epipodite and gnathobase not seen.

*Second Trunk Limb (P2)*: exopodite elongated, bearing setules on slightly inflated apex (Fig. 14). Endopodite with eight scrapers, similarly armed with fine denticles and generally decreasing in size towards gnathobase, but seventh scraper longer than scrapers 6 and 8. Gnathobase an elongated lobe oriented towards the scrapers (Figs 14, 15, C) and apically armed with setules, followed by a small receptor and three gnathobasic elements (Fig. 15), the middle of which distinctively fish-hook shaped at apex (Fig. E). A pore was observed on the inner side of the gnathobase (Fig. E). Gnathobasic filter comb with seven setae, of which the first three relatively shorter than the last (Fig. 15).

*Third Trunk Limb (P3)*: Epipodite oval. Exopodite small, rectangular, with six setae (Fig. 16, F): two lateral in typical V-formation, first longer than second, followed by four apical setae. Third exopodite seta curved basally, in length about twice first exopodal seta, followed by fourth seta, about same length of second. Third and fifth exopodite setae of equal length. Distal endite (Fig. 17) with three setae, armature of first two short and hardly visible, third sparsely plumose. Basal endite with four plumose setae, equal in length. Four soft setae on inner portion (Fig. 18), alternating with one regressed seta and three small bumps. One receptor close to gnathobase. Gnathobase with three setae, one large, setulated, curved inwards and two naked and shorter. Filter comb with seven setae.

*Fourth Trunk Limb (P4)*: epipodite (Fig. 20) with globular body and with small bump, no digitiform projection. Exopodite (Figs 19, 20) more round than oval, bearing six setae, of which the first two are of equal length, although the first may be the shorter. Third exopodite seta 1.5–2 times as long as second, followed by short conical fourth seta and typically modified fifth and sixth exopodite setae with blunt apex (Fig. 20), and curved subapical aggregation of setules (Fig. F). Endopodite or inner portion (Fig. 21) with one finely serrulated seta and three 'flaming-torch' setae, followed by round receptor on posterior surface, comparable in size to flaming torch setae. Gnathobase not studied.

*Fifth Trunk Limb (P5)*: Epipodite (Fig. 22) without elongated digitiform projection. Exopodite with four apical setae, three large on ventral portion, of which first is the largest and the following two, slightly smaller, are of equal size, and one short, half as long as third seta, followed by small setulated tuft and elongated setulated lobe. Endopodite and gnathobasic seta (Fig. 23) about equal in size, not curved over elongated lobe. Gnathobase (Fig. 23a) with at least one globular receptor.

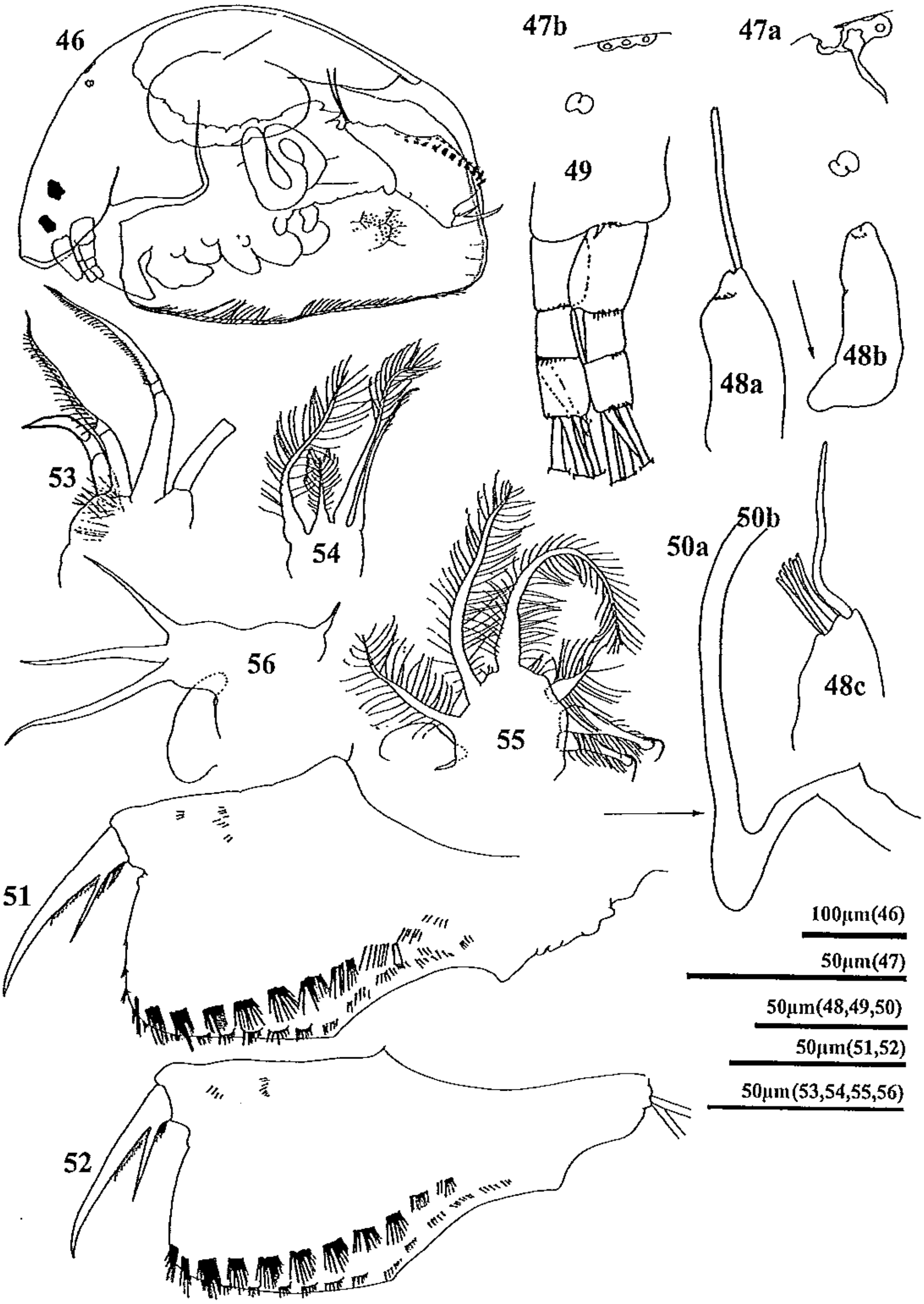


*Figure 46–56. Nicsmirnovius fitzpatricki*, parthenogenetic females: Chien's types from Mississippi River, US (Smithsonian, Cat. no. 134094 (paratypes): 46, 47b, 48b, 49, 50b, 52; Cat no. 134093 (holotype): 47a, 50a, 51, 53, 54, 55, 56) **(46)** Habitus, lateral view. **(47)** Head pores, lateral view. **(48)** First antenna ('normal' aesthetascs not visible). **(49)** Second antenna. **(50)** Labral keel of two specimens; arrow indicates elongated apex. **(51, 52)** Postabdomen in lateral view. **(53)** IDL and ODL of limb I, partim. **(54)** Exopodite of limb III, partim. **(55)** Exopodite of limb IV. **(56)** Exopodite of limb V, setules omitted.

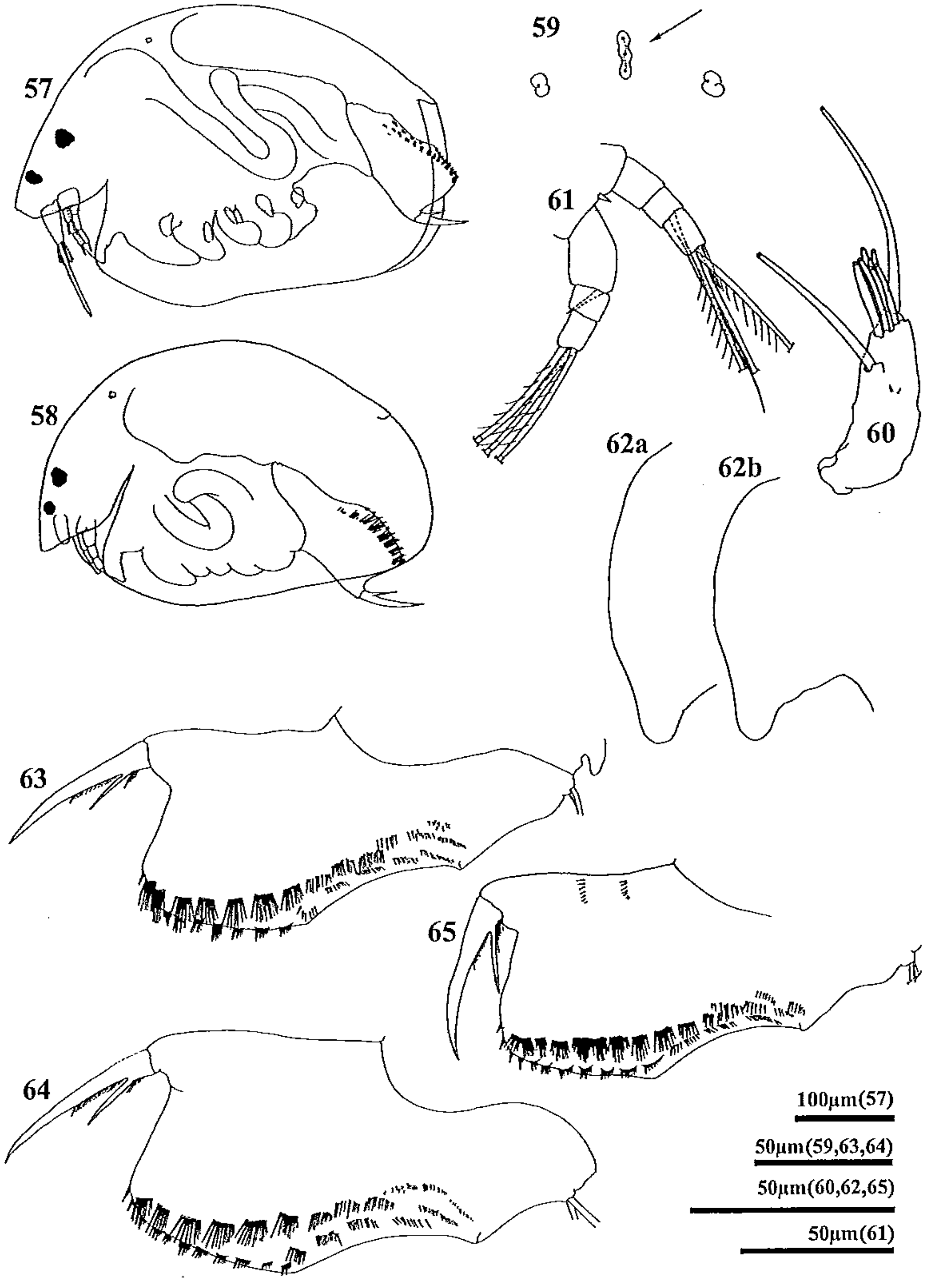


*Figure 57–65. Nicsmirnovius fitzpatricki*, parthenogenetic females from Puerto Rico (Figs 59, 61, 62b, 63, 64) and Argentina (Figs 57, 58, 62a, 65). (57) Habitus, lateral view; (58) Habitus, lateral view (redrawn after Paggi, 1979). (59) Head pores; (60) First antenna, (61) Second antenna. (62) Labral keels. (63, 65) Postabdomen in lateral view.

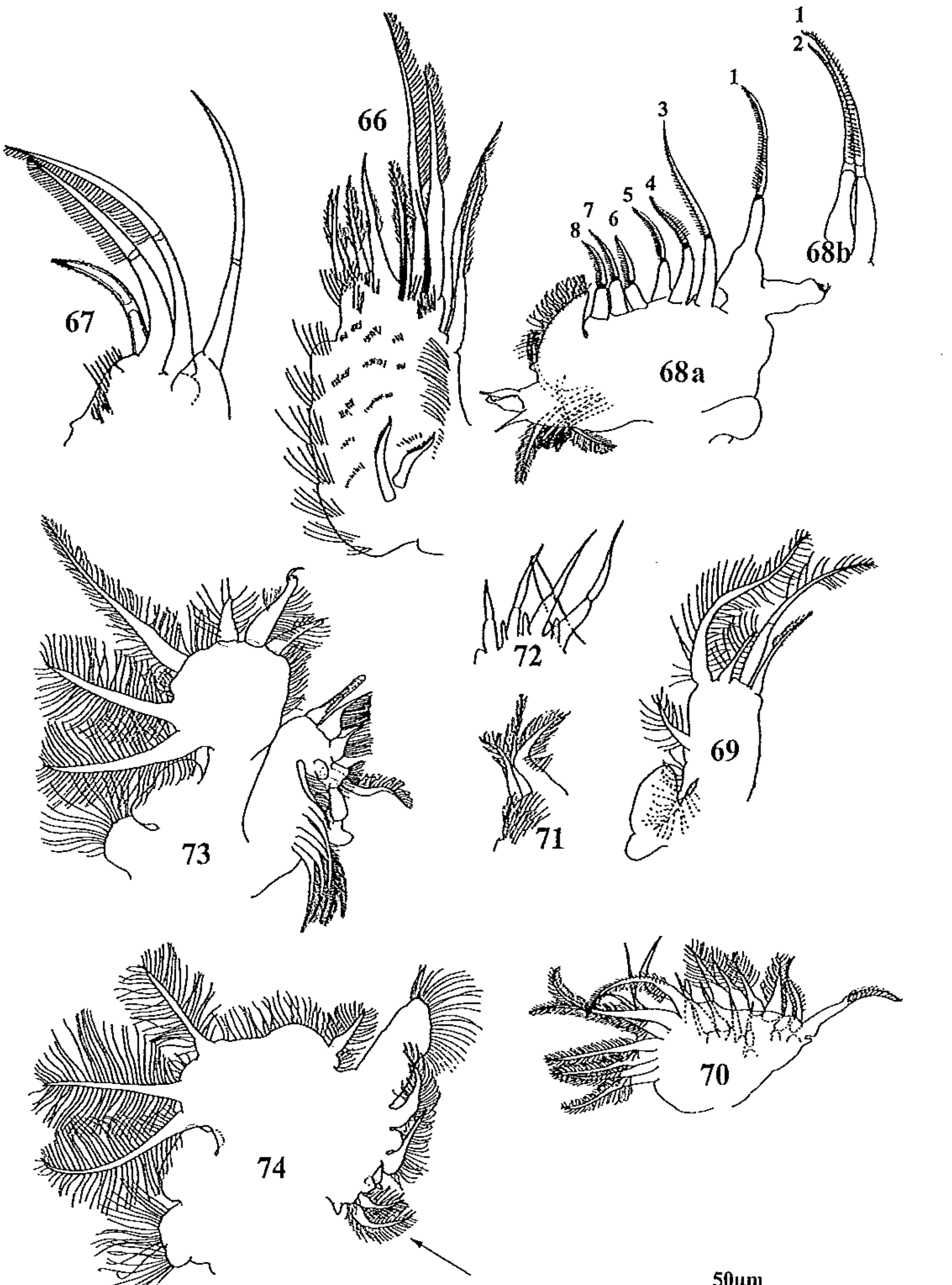


*Figure 66–74. Nicsmirnovius fitzpatricki*, parthenogenetic females from from Puerto Rico and Argentina; (66) Inner view of limb I, ODL and IDL omitted. (67) ODL and IDL of limb I. (68) Outer view of limb II. in(68a) Second scraper is missing, redrawn in (68b). (69) Exopodite of limb III. (70) Endite of limb III. (71) Gnathobase of limb III redrawn. (72) Soft setae on basal endite of limb III. (73) Inner view of limb IV. (74) Limb V; arrow indicates gnathobasic filter setae.

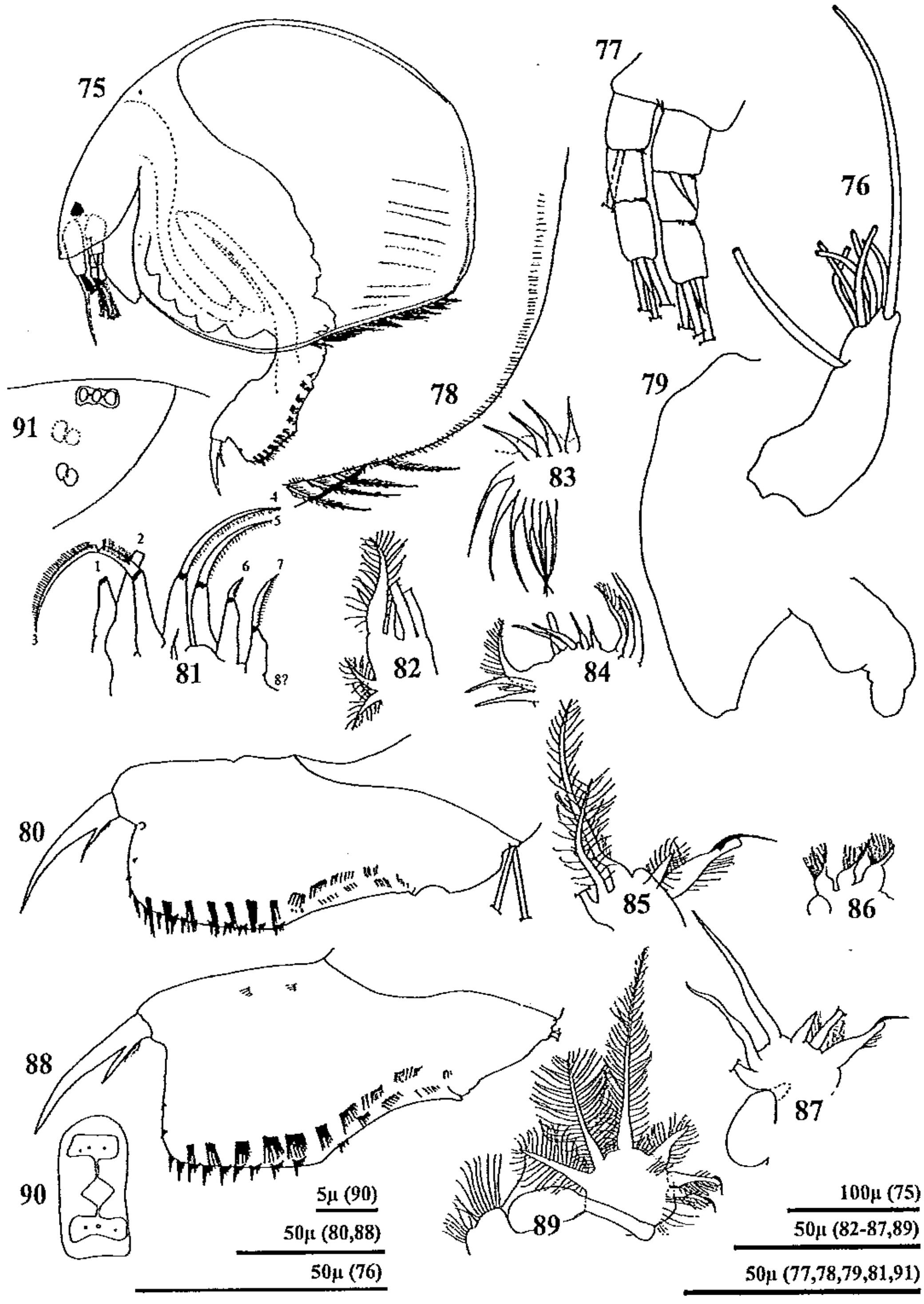


*Figure 75–91.* (75–87) *Nicsmirnovius camerounensis dioscoridus*, parthenogenetic female from Socotra Island, Yemen. (88–91) *Nicsmirnovius camerounensis camerounensis*, parthenogenetic females from Cameroon. (75). Habitus, lateral view; (76) First antenna. (77) Second antenna. (78) Posteroventral corner. (79) Labral keel, lateral view. (80) Postabdomen, lateral view; (81) Limb II, partim. (82) Exopodite of limb III, partim. (83) Endite of limb III, partim. (84) Endite of limb III, partim. (85, 86) Exopodites of limb IV, partim. (87) Endite of limb IV, partim; *Nicsmirnovius camerounensis camerounensis*. (88) Postabdomen, lateral view. (89) Epipodite and exopodite of limb IV. (90) Pore plate, redrawn after Chiambeng & Dumont (1999); lateral pores not shown!. (91) Head pores of holotype, RBIN IG 28.693a, lateral view, lateral pores visible.

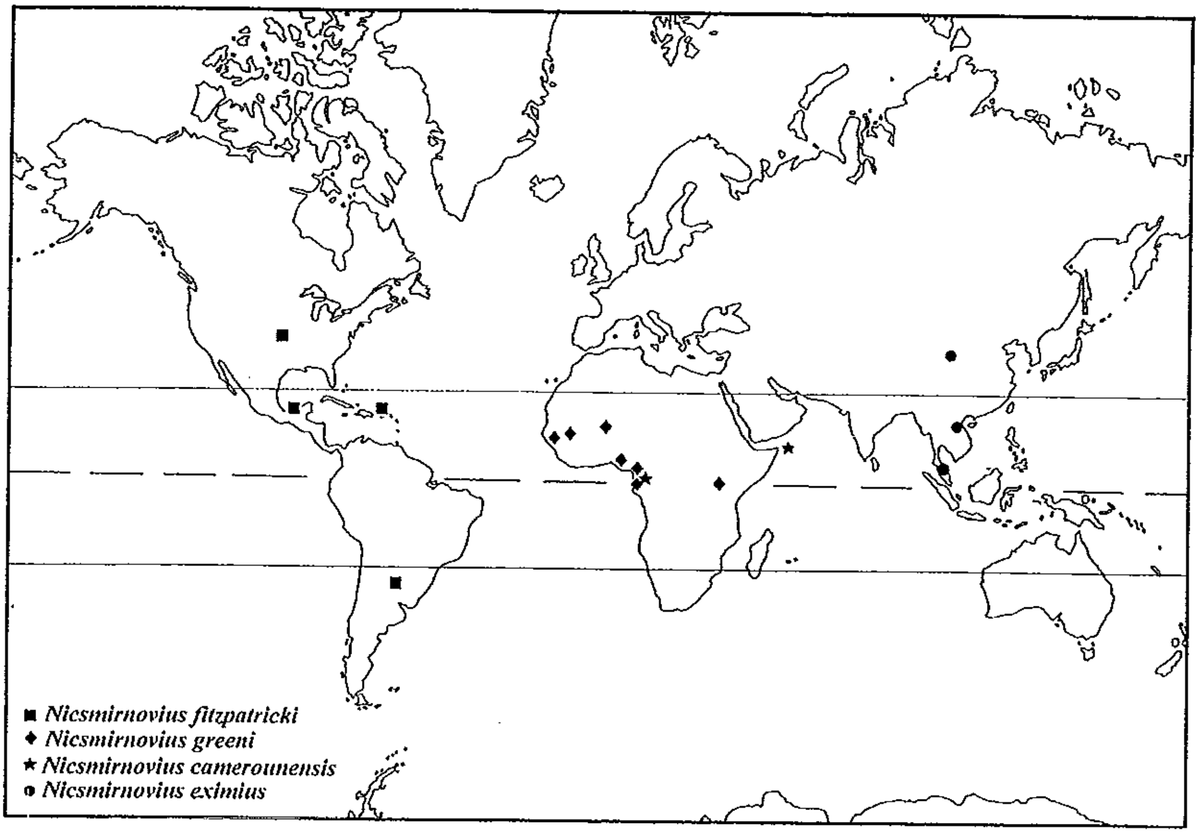


*Figure 92.* Map showing world distribution of *Nicsmirnovius* species. The two records of *Nicsmirnovius camerounensis* represent a subspecies each: *N. camerounensis camerounensis* for Cameroon (star on the left) and *N. camerounensis dioscoridus*, found on Socotra Island (right). The American *N. fitzpatricki* may be a complex of several species, in need of closer study (see under Discussion).

**Male.** We were not able to examine males, but one is depicted (*Alona eximia*) in Chiang & Du (1979, p. 218), showing a gonopore situated on the posterior margin, ventrally from base of terminal claw, the latter implanted subventrally. Although the depicted male postabdomen seems relatively slender in general view, the accompanying drawings of the female also show an atypical postabdomen, probably a result of the drawing style. Also noted in the authors' drawings, is the long aesthetasc on the first antenna. Kotov (pers. comm.) recently reported males from northern Thailand, which will be described in the near future.

**Variability:** some variability for parthenogenetic females was noted in the following characters: size of main head pores, ventral margin of labral keel (Fig. 6), stoutness of chitinized seta on IDL (Fig. 12), length of first exopodal seta of PIV (Figs 19, 20) and spinal armature of postabdomen (Figs 7–9). Kotov (pers. comm.) noted specimens from northern Thailand to have long fingerlike projections on epipodites IV and V, this can be subject to variation: these structures have a respiratory function and the presence of digitiform projections could be the result of low oxygen concentrations, though this remains unstudied.

**Biology:** *N. eximius* is predominantly found in the littoral of clear, slow-running streams or rivers (Frey, 1974), waterfalls, dams and canals. It has occasionally been found in ponds (Sanuamoang, 1998), peat swamps (Maiphae, pers. obs.), lakes and rice fields (Idris, 1983). In Angtong Waterfall (Southern Thailand), populations were most abundant in August–September. Extensive sampling of the same locality in March–April failed to produce specimens. The examined specimens from Northern Thailand were found in a reservoir connected to the Pong River, at Khon Kaen University Campus under a temperature of 31 C and conductivity of 170 $\mu S\ cm^{-1}$. Another locality where it was found is Chao Phrya River, Nakhon Sawan Province, central Thailand, collected on 02.05.1993 at a water temperature of 32 °C, pH 6.0, and conductivity 180 $\mu S$ cm$^{-1}$ (Sanuamoang, pers. comm.). Kotov (pers. comm.) found male specimens in a sample from northern Thailand, dating from March, on which more will be written in a separate paper.

**Distribution (Fig. 92):** South East Asia: Northern (Sanuamoang, 1998) and Eastern Thailand, Malaysia (Idris, 1983) and Southern China (Kiser, 1948; Chiang & Du, 1979).

**2. Nicsmirnovius greeni spec. nov.**

*Alona eximia* in Green, 1962: 423, Figs 15–17 and in Dumont & Van De Velde, 1977: 89, figs E–G

**Type locality:** Second and third streams after Manna Camp on the way to Korup Park, Korup National Park Mundemba, Ndian division of the South West Province of Cameroon, 5°01′-4°56′N 8°48′-8°56′E.

**Type material:** Holotype: 1 parthenogenetic ♀♀, complete, mounted in slide, from type locality, coll. in August, 1998 by G. Chiambeng. RBIN Accession number I.G. 29.856a Paratypes: two parthenogenetic ♀♀, dissected, mounted in two slides, from type locality, collected August, 1998 by G. Chiambeng. RBIN Accession numbers I.G. 29.856b and I.G. 29.856c; five parthenogenetic ♀♀, complete, mounted in three slides, from type locality, coll. in October, 2002 by G. Chiambeng. RBIN Accession numbers I.G. 29.856d, I.G. 29.856e and I.G. 29.856f

**Additional material:** *Guinea*: one parthenogenetic ♀♀, dissected, from River Koloulo a Pita, coll. 29.04.1980 by C. Lévêque, GU; *Senegal*: three parthenogenetic ♀♀, complete, from sidestream of Gambie River, at Niéri Ko, 13°23′N 13°19′W, coll. 15.05.1975 by I. Van De Velde and H. Dumont, GU; *Mali*: one parthenogenetic ♀♀, dissected, from Goundam, Goundam-Faguibine region, 'laisses de décrue sur banc sablo-vaseux en aval du village', coll. 25.12.1972 by Th. Monod, GU; *Cameroon*: five parthenogenetic ♀♀, complete, and five parthenogenetic ♀♀, dissected, from three localities in South Western Cameroon, coll. August 1998 and November, 1999 by G. Chiambeng, UG. No details of localities are noted on the slides, but all are in close vicinity of each other: Loc. 1. Stream at Science Camp, Korup National Park Mundemba, Ndian division of the South West Province of Cameroon, 5°01′–4°56′N 8°48′–8°56′E,. Coll. in August, 1998 by G. Chiambeng, KVD; Loc. 2. Mbalmayo Forest, 3°21′–3°31′ N and 11°51′–11°31′ E, alt. 650 m. Shallow forest stream. November, 1999; Loc. 3. Idenau Forest, 8°29′E, 4°16N, shallow stream close to Idenau C.D.C palm Estate, at the bridge just after the main office on the way to Sanje. August, 1999.

**Etymology:** the new species is named in honour of Dr. J. Green, who contributed significantly to limnology in the tropics, and was the first to note *Alona eximia* from Africa (Green, 1962).

**Differential diagnosis:** *N. greeni* n.sp. is similar in morphology to *N. eximius*. Table 1, which includes references to figures, should be used in combination with the following for differentiation between the two species:

1. Habitus: in general body-shape, specimens of *N. greeni* are higher, more arched and hence more round in lateral view than *N. eximius*. Some African specimens, however, show a body shape closer to the *eximius*-type.
2. Labrum: labral keel in lateral view with relatively more blunt, wide apex in *greeni*, oriented more anteriorly than in *eximius*.
3. Second Antenna: the two apical spines on the second antenna are about equal in length in *greeni*, while in *eximius*, the endopodal spine is markedly shorter than the exopodal spine.
4. Postabdomen: in general shape, postabdomen of *greeni* is stouter, with anal, postanal margin and terminal claw of equal length while *eximius* specimens have a shorter postanal margin in comparison to the terminal claw or anal margin. Distance between posterior margin and base of terminal claw is clearly larger in Asian than in African species. Groups of marginal denticles three to four in *greeni*, while four or more in *eximius*. Terminal claw and basal spine are relatively longer and more slender in *eximius* than in *greeni*.
5. First limb: the chitinized hook-like seta on the IDL, seems more slender in *greeni* than in *eximius*.
6. Epipodites P4–P5: digitiform projections on epipodites of fourth and fifth limb are clearly longer in *greeni* than *eximius*, reaching almost center of exopodite. This character, however, could be subject to variability and should be evaluated (see under *eximius*).

The clearest and most consistent features to distinguish both forms, are found in the shape of the postabdomen and the apical spines on the second antennae.

**Description parthenogenetic female**

Note: as mentioned earlier, this species is close to *N. eximius*; description is limited to features in which it differs from the latter. The same will be done for subsequent species.

*General*: body in lateral view (Figs 25, 26) more spherical than ovoid, arched, largest height in middle. Dorsal outline circular, not narrowing posteriorly. Posteroventral angles weakly pronounced (Fig. 34). Ventral carapace margin straight (Fig. 26) to V-shaped (Fig. 15 in Green, 1962), if so, deepest point of ventral embayment in middle. Longitudinal valve striation well visible. Ventral setae relatively short, end before posteroventral corner.

*Head*: Compound eye present, slightly larger than ocellus, distance from the latter little longer that between ocellus and rostral tip (Figs 25, 26). Major head pores (Fig. 27) round, all three relatively large, of same size and connected by a narrow channel; two lateral pores, surrounded by typical structure, situated at about 1.6 IP from midline (Fig. 27b).

*Labrum*: labral keel (Fig. 30) naked with wide, blunt to flattened apex, oriented more anteriorly than ventrally. Depression in ventral margin present near apex.

*Postabdomen*: generally compact (Figs 32, 33). Postanal, anal margin and terminal claw of approximately same length. Preanal corner small to absent. Anal margin concave. Lateral fascicles: seven to eight postanal groups consisting of seven to eight denticles each. Spinules of four most distal groups reaching beyond dorsal margin of postabdomen. Marginal denticles about 10 postanal groups of two to three spinules, of which distalmost is markedly larger.

*Terminal claw*: relatively shorter than in previous species (Figs 32, 33). Bearing three basal spinules, followed by basal spine reaching half of claw length; the latter implanted at one third its own length from claw base. Pecten reaching half of basal claw. Base of terminal claw short, less than half of length basal spine.

*First and second antenna*: as in *N. eximius*, first antenna (Fig. 28) sometimes protruding beyond tip of rostrum; antennular sensory seta not noted, and second antenna (Fig. 29) with apical exopodal spine of same size as endopodal apical spine.

*Trunk Limbs*: as in *N. eximius*, with the following noticeable differences: chitinized seta on IDL of P1 (Fig. 36) slightly more slender and less curved. Two setae on first endite (Fig. 35) of equal size. Exopodite on P2 (Fig. 37) not inflated apically; first gnathobasic element appears to be a fine seta. P3 (Figs 38, 39) with fifth exopodite seta shorter than third. P4 (Figs 41, 42) with digitiform projection on epipodite, not reaching centre of exopod. Endopodite of same limb (Fig. 43) with three small structures behind globular receptor, gnathobase with one long seta, recurved over posterior surface, and two basal elements. Filter comb with five setae, equal in length. P5 (Fig. 44) with elongated digitiform projection on epipodite, not reaching middle of exopodite. Second exopodite seta larger than third. Endopodite seta (Figs 44, 45) larger than gnathobasic seta, and curved over elongated setulated lobe. Elongated, naked structure was visible between gnathobasic and endopodite seta. Gnathobase (Fig. 45) with one globular receptor and two reduced filter comb setae.

**Male** unknown.

**Variability**: variability was noted in the following characters: size of main head pores (Fig. 27), ventral margin of labral keel (Fig 30), length of third exopodal seta of PIV (Figs 41, 42), marginal and lateral spine armature of postabdomen (Figs 32, 33).

**Biology**: *N. greeni* is found in the littoral of slow running rivers and streams. In Cameroon, we found the animal in shallow forest streams with a pH between 6 and 6.5, a low conductivity (11–25 $\mu S$ $cm^{-1}$) and a water temperature of 22–23 °C.

It appears to be more common towards the end of the year, as Green (1962), in a study on the River Sokoto, noted the animal's presence from June to November and from September to November, and only a few specimens in February. This is confirmed by our findings in the regions studied in Cameroon, where it is relatively abundant from August to November.

**Distribution (Fig. 92)**: Reported mainly from Western Africa: River Sokoto (Green, 1962), Guinea (Dumont, 1981), Mali (Dumont et al., 1981), Cameroon (Chiambeng & Dumont, 1999; Cammaerts & Mertens, 1999) and Nigeria (Egborge et al., 1994). Identification of a record from Uganda (Green, 1971) should be checked, but is included in the distribution map.

### 3. Nicsmirnovius fitzpatricki (Chien, 1970) comb. nov.

syn. *Alonella* (*Paralonella*) *fitzpatricki* Chien, 1970.
*Alona eximia* in Frey (1974): 165, figs 5, 6

**Type locality**: Strong River, Simpson county, Mississippi, USA.

**Material examined:**

**Type material:**

*USA*: one parthenogenetic ♀♀, holotype of *Alonella fitzpatricki*, from Strong River, Simpson county, Mississippi, 04.06.1967, collected by Shih Ming Chien, USNM 134093, ACC 289470, Smithsonian Institute. one parthenogenetic ♀♀, paratype of *Alonella fitzpatricki* from Bogue Chitto River, Lincoln county, Mississippi, 24.06.1967, collected by Shih Ming Chien, USNM 134094, ACC 289470, Smithsonian Institute.

**Additional material:**

*Puerto Rico*: two parthenogenetic ♀♀, complete and one parthenogenetic ♀♀, dissected, from Tortugueso Fern Swamp, June 1999, coll. by Carlos Jose Santos Flores, KVD; *Argentina*: one parthenogenetic ♀♀, complete, and two parthenogenetic ♀♀, dissected, from Paraná River main stream near Ramallo, stream near Santo Tome and Correntoso River near Santo Tome, 1979, coll. by J.C. Paggi, KVD; *Mexico*: three parthenogenetic ♀♀, complete, from tributary of the Ucumacinta on the road Villahermosa-Palenque, 12.10.1974, coll. by I. Van De Velde and P. Grootaert, GU.

**Etymology:** The epitheton "fitzpatricki" was given by Chien (1970) in honor of Dr. Fitzpatrick.

**Diagnosis:** *N. fitzpatricki* can be distinguished from other species by the long antennular body, about 2.5–3 times as long as wide (Figs 48, 60), the elongated tip of the labral keel (Figs 50, 62), absence of digitiform projections on fourth (Figs 55, 73) and fifth (Figs 56, 74) epipodites and dimensions of the postabdomen (Figs 51, 52).

**Description parthenogenetic female**

*General*: Length 0.22 mm, about 1.5 times maximal height ($n$=3) (Figs 46, 57, 58). As *N. eximius*, but postero-ventral angles less pronounced. Ventral embayment of valve margin situated between one third and half of total carapace margin (Figs 57, 58).

*Head*: As in *N. eximius*, but compound eye little larger than ocellus (Figs 46, 57, 58); margin of main head pores less constricted between pores, which are smaller in a population from Puerto Rico (Fig. 59), which is not the case in type specimens of *fitzpatricki* (Fig. 47).

*Labrum*: labral keel naked, with ventrally elongated, digitiform apex (Figs 50, 62). Depression in ventral margin near apex is shallow and wide (Fig. 50a).

*Postabdomen*: as in *eximius*, but anal margin markedly shorter than postanal margin and slender terminal claw (Figs 51, 52, 63, 64). In specimens from Argentina (Fig. 65) and Mexico, postabdomen seems more compact. Anal margin relatively straight to slightly concave, angle with postanal margin quite constant, between 145° and 148°. Lateral fascicles: six to eight postanal groups, consisting of nine to 11 denticles (Figs 51, 52). Spinules of three to four most distal groups reaching beyond dorsal margin of postabdomen. Marginal denticles eight to 10 groups of spinules, consisting of clearly separated denticles, not merged at the base. Distalmost, primary denticles of each group (consisting of about three denticles distally to four to five towards anal margin) larger than secondary spinules.

*Terminal claw*: relatively long and slender, with slender basal spine, reaching half of claw length and implanted at less than half its length from claw base (Figs 51, 52, 63–65). Base of terminal claw prominent (Figs. 52, 63), less than half of length basal spine; five to six basal spinules. Pecten protruding beyond half of basal claw. In specimens from Mexico, basal spinules four, relatively robust and thick, about half thickness of basal spine.

*First Antenna (antennule)*: reaching (Fig. 58) or protruding (Figs 46, 57) beyond tip of rostrum. Body elongated, about 2.5–3 times as long as wide and with 'peg-like' projection at base (Figs 48, 60). Distalmost aesthetasc 1.2 times as long as antennule and 2.5 up to 3.5 times as long as 'normal' aesthetascs. Subapical aesthetasc of same length as antennule, implanted at less than one third of distal end (Fig 60).

*Second Antenna*: basal segment with small distal spine (Figs 49, 61). Spine on first exopod segment reaching (Fig. 49) or protruding (Fig. 61) beyond base of apical exopodal segment, apical exopodal spine larger than endopodal apical spine (Fig. 49).

*Trunk Limbs*: as in *N. eximius*, with the following differences: chitinized seta on IDL of P1 (Figs 53, 67) relatively thicker and larger, two other setae on IDL bear relatively longer setules than *eximius*. Extra setae on inner bases of second and third endites relatively large, about same size as apical setae on second endite (Fig. 66). P2 with markedly shorter fourth and fifth scrapers as compared to third scraper and a regressed seta basally of scraper 4 (Fig. 68). P3 with fifth exopodal seta larger than third (Fig. 54), also sixth exopodal seta is remarkably long. In specimens from Argentina (Fig. 69), however, exopodal setae 3–6 as in *N. eximius*. Four soft setae on inner portion of endite of P3 (Fig. 72), alternating with one bump and three regressed setae instead of bumps. P4 (Figs 55, 73) without digitiform projection on epipodite, small bump may be present (Fig. 55). In types, second exopodal seta on P4 larger than first exopod seta (Fig. 55), which is not the case in Argentinian (Fig. 73) or Puertorican specimens. However, this could be variability, as noted also in *N. eximius*. Endopodite of same limb (Fig. 73) identical with that of *N. greeni*, but with extra seta next to globular receptor. P5 (Figs 56, 74) without elongated digitiform projection on epipodite (Fig. 56). Second exopodite seta of same limb larger than third. Endopodite seta only little larger than gnathobasic seta, and curved towards elongated setulated lobe (Fig. 74). Naked bump present between gnathobasic and endopodite seta. Gnathobase with one globular receptor and two large filter comb setae.

**Male** unknown.

**Variability**: variability was noted in the following characters: size of main head pores (Figs 47, 59), elongation of labral apex (Figs 50, 62), length of first exopodal seta of PIV (Figs 55, 73) and spinal armature of postabdomen. Perhaps these differences are more than just variation, see Discussion.

**Biology:** *N. fitzpatricki* is found in the littoral of rivers and occasionally in swamps and standing waters. According to Paggi (1979), in association with *Eicchornia* and *Salvinia*.

**Distribution (Fig. 92):** The species is known from South and Middle America, up to the southern USA: Mississippi River, US (Chien, 1970), Puerto Rico, Mexico (Van de Velde et al., 1978; Elías-Gutiérrez et al., 1997) and Argentina (cf. *fitzpatricki* in Paggi, 1979).

**4. Nicsmirnovius camerounensis** Chiambeng & Dumont, 1999

**Diagnosis:** two subspecies are recognised here, both sharing the main following characters separating them from other *Nicsmirnovius*: (*1*) absence of compound eye, (*2*) long marginal valve setae near rounded posteroventral corner, (*3*) long antennular body, (*4*) elongated apex on labral keel pointing downwards, with shallow or no depression at ventral margin near apex, (*5*) postabdomen with relatively short terminal claw and large marginal denticles.

**4a. Nicsmirnovius camerounensis camerounensis** Chiambeng & Dumont, 1999 syn.: *Hydrospilus degreefi* Cammaerts & Mertens, 1999 *Nicsmirnovius camerounensis* Chiambeng & Dumont, 1999: 261–265, plates 1–2; Cammaerts & Mertens, 1999: 328–333, figs 1–3 (*Hydrospilus degreefi*).

**Type locality:** Stream at Science Camp, Korup National Park Mundemba, Ndian division of the South West Province of Cameroon.

**Material examined**

**Type material:** *Cameroon*: holotype of *Nicsmirnovius camerounensis*, one parthenogenetic ♀♀, RBIN IG 28.693a; paratype: one parthenogenetic ♀♀, RBIN IF 28.693b; holotype of *Hydrospilus degreefi*, one parthenogenetic ♀♀, RBIN: IG 28510a (details in Cammaerts & Mertens, 1999).

**Additional material:** *Cameroon*, two parthenogenetic ♀♀, dissected, same data as holotype: Korup National Park, 5°01′–4°56′N 8°48′–8°56′E. Stream at Science Camp, Korup National Park Mundemba, Ndian division of the South West Province of Cameroon; coll. August, 1998 by G. Chiambeng, KVD.

**Diagnosis:** *Nicsmirnovius c. camerounensis* can be easily distinguished from other species by the absence of a compound eye, long posteroventral marginal valve setae, a typical pore plate (Fig. 90) and a very long digitiform projection on the epipodite of PIV (Fig. 89). Dimensions of postabdomen close to those in *N. greeni*, but the latter has a relatively larger basal spine (Fig. 32). It differs from *N. camerounensis dioscoridus* in second antenna (large spine on basal segment), the length of sixth scraper of second limb (Fig. 81) (remarkably short in *dioscoridus*, normal in *camerounensis*), shorter digitiform projections on the epipodite of fourth limb (Fig. 87), length of fifth and sixth exopodite setae relative to fourth on fourth limb (compare Figs 85, 87 with Fig. 89), and the small spine on the distal segment of second antenna (compare Fig. 77 with drawing in Chiambeng & Dumont, 1999: Plate 2, Fig. 10). It should be emphasized, however, that only one specimen of *N. camerounensis dioscoridus* was found.

**Description of parthenogenetic female** in Chiambeng & Dumont, 1999 (*Nicsmirnovius camerounensis*) and Cammaerts & Mertens, 1999 (*Hydrospilus degreefi*). A more extensive description, based on more material is desirable as the information at present is rather fragmentary.

*General*: Length 0.37–0.38 mm, about 1.4 times maximum height, largest height in middle, carapace narrowing posteriorly (see SEM micrograph in Cammaerts & Mertens, 1999: 333: Fig. 3a). Ventral embayment of valve margin situated just before middle. Postero-ventral corner round, long marginal postero-ventral setae (Cammaerts & Mertens, 1999: 333: Fig. 3f). Striation clearly visible.

*Head*: compound eye absent; head pores on a 'pore plate' with three large pores (Fig. 90), connected by a channel. Anterior and posterior pores are rectangular in shape, central pore rhomboidal. Lateral pores surrounded by typical 'flower-shaped' structures (Fig. 91).

*Labrum*: labral keel with ventrally elongated apex. Depression in convex ventral margin of labral keel near apex shallow, nearly absent.

*Postabdomen*: postanal margin, anal margin and terminal claw of similar length (Fig. 88, see also SEM micrograph in Cammaerts & Mertens, 1999: 333: Fig. 3d). Anal margin arched, angle about 145°. Preanal corner small to completely absent. Lateral fascicles: about seven postanal groups, consisting of five to eight denticles each. Marginal denticles 10–11 groups, clearly separated in a large primary and two to three secondary spinules.

*Terminal claw*: not longer than postanal or anal margin and with slender basal spine (Fig. 80 and SEM in Cammaerts & Mertens, 1999: 333: Fig. 3d), reaching less than half of claw length and implanted at more than half its length from claw base. Base of terminal claw prominent, about half or more of length basal spine; three to four small basal spinules, continuing in shorter spinules on basal spine margin. Pecten not studied. In SEM scans mentioned earlier, basal spine clearly curved dorsally, giving it a more claw-like appearance.

*First Antenna (antennule)*: protruding significantly beyond tip of rostrum (Cammaerts & Mertens, 1999: 333: Fig. 3c; Chiambeng & Dumont, 1999: 263: Plate 2, Fig. 8). Body elongated and narrowing distally, in length about 2.5–3 times as long as wide and with 'peg-like' projection at base. Distalmost aesthetasc 1.7 times as long as antennule and between 3 and 3.5 times as long as 'normal' aesthetascs. Subapical aesthetasc about as long as antennular body, implanted at about one third of distal end.

*Second Antenna*: basal segment with large distal spine (Chiambeng & Dumont, 1999: 263: Plate 2: Fig. 10). Spine on first exopod segment not reaching base of apical exopodal segment, apical exopodal spine larger than endopodal apical spine.

*Trunk Limbs*: Description in Chiambeng & Dumont (1999); additional observations: first limb also bears extra setae on inner bases of second and third endites . Second limb lacks a small seta basally of scraper 4, and scrapers 6, 7 and 8 are unequal in size, shaped as in *N. eximius* (Figs 14, 15) unlike drawing in Chiambeng & Dumont (1999: 263: Plate 2, Fig. 2). Third limb with relatively long first and second exopodite setae, exaggerated in Chiambeng & Dumont (1999: 263: Plate 2, Fig. 4); third exopodal seta about as large as previous two, followed by a more slender and smaller fourth seta, a fifth seta of about the same size as the third and again a more slender and smaller sixth seta, slightly larger than the fourth. Endopodite not re-examined. Fourth limb (Fig. 89) with long digitiform projection on epipodite, reaching beyond centre of exopodite. First and second exopodite setae equal in size, sometimes second slightly larger (Fig. 89); third exopodal seta about twice the size of the first; fourth exopodital seta about half in length of first seta, and about as long as fifth and sixth, typically modified setae. Endopodite as in Chiambeng & Dumont (1999). Fifth limb also with large digitiform projection on epipodite, reaching beyond centre of exopodite; exopodite setae as in *N. eximius*, but with relatively larger fourth seta; endopodite seta larger than gnathobasic seta, followed by globular receptor on gnathobase and two relatively large filter setae (Chiambeng & Dumont, 1999: 263: Plate 2: Fig. 7).

Male unknown.

**Biology and distribution** (Fig. 92): We believe *N. c. camerounensis* to be endemic to the rainforest of Cameroon, where it was found together with *N. greeni* in stagnant portions of a shaded, slow running stream in Korup National Park, SW Cameroon, at a pH of 6 and conductivity of 11 $\mu$S cm$^{-1}$.

Note: Chiambeng & Dumont (1999) did not observe the flower-like structures under the lateral pores, which we observed to be present nevertheless in the holotype of *N. camerounensis* and are shown here in Fig. 91. In the original description only the pore plate, redrawn in Fig. 90, was shown, but in closer examination, we found that the lateral pores with flower-like structures are very clear. This was not noted before.

**4b. Nicsmirnovius camerounensis dioscoridus** subsp. nov.

**Type locality:** mountain stream in Haggeher Mountains, Socotra Island (Yemen), N12°33.206′ E54°00.421′, alt. 1100 m.

**Material examined:** one parthenogenetic ♀♀, dissected, holotype, from type locality, coll. 23.02.1999 by K. Van Damme, RBIN Accession number I.G. 29.857.

**Etymology:** the epitheton 'dioscoridus' originates from 'Dioscorida', an ancient (1st century AD) Greek name used for the Island of Socotra, where this animal was found.

**Subspecies Diagnosis:** *Nicsmirnovius camerounensis dioscoridus* differs from *N. camerounensis camerounensis* in the length of the sixth scraper of the second limb (Fig. 81) (short in *dioscoridus*, 'normal' in *camerounensis*), shorter digitiform projections on the epipodite of fourth limb (Fig. 87), length of fifth and sixth exopodite setae relative to fourth on fourth limb (compare Figs 85, 87 with Fig. 89), and the small spine on the basal segment of the second antenna (compare Fig. 77 with Chiambeng & Dumont, 1999: 263: Plate 2, Fig. 10).

**Description parthenogenetic female**

*General*: Length 0.35 mm, about 1.3 times maximal height, largest height in middle (Fig. 75). Ventral embayment of valve margin situated at midlength. Postero-ventral corner round, bearing relatively long marginal setae (Fig. 78).

*Head*: compound eye absent (Fig. 75); head pores not seen (note that pores shown in Fig. 91 belong to the holotype of *N. c. camerounensis*!).

*Labrum*: labral keel with ventrally elongated apex, more or less truncated. Depression in ventral margin of labral keel near apex shallow and wide.

*Postabdomen*: postanal margin slightly longer than anal margin and terminal claw (Fig. 80, note that this is slightly shifted due to compression in the slide as compared to the postabdomen shown in Fig. 75). Anal margin relatively straight. Lateral fascicles: seven postanal groups, consisting of 3 denticles each. Marginal denticles 11 groups of spinules not continuing on postanal margin, distalmost strong singular denticles, other groups with of two to three denticles, equal in length.

*Terminal claw*: relatively short, with slender, relatively short basal spine (Fig. 80), not reaching half of claw length and implanted at less than half its length from claw base. Base of terminal claw prominent, about half of length basal spine; two basal spinules, continuing in shorter spinules on basal spine margin. Pecten not studied.

*First Antenna (antennule)*: protruding significantly beyond tip of rostrum (Fig. 75). Body elongated, about 2.5 as long as wide and with 'peg-like' projection at base (Fig. 76). Distalmost aesthetasc 1.4 times as long as antennule and between 3 and 3.5 times as long as 'normal' aesthetascs. Subapical aesthetasc shorter than antennular body, implanted at about one third of distal end.

*Second Antenna*: basal segment with small distal spine (Fig. 77). Spine on first exopod segment not reaching base of apical exopodal segment, apical exopodal spine larger than endopodal apical spine.

*Trunk Limbs*: first limb not studied. P2 with a small basal seta on scraper 4 (Fig. 81). Sixth scraper of second limb remarkably small. Third limb (Fig. 82) with first and second setae of equal size, third seta about double in size. Distal endite (Fig. 84) of same limb with three setae, third sparsely plumose. Four soft setae on inner portion of endite of P3, alternating with small bumps (second more like regressed seta), gnathobasic filter comb (Fig. 83) with seven setae. P4 (Figs 85–87) with short projection on epipodite. Fifth and sixth setae as typical for genus, but with relatively long subapical aggregation of setules; both setae are about twice the size of fourth exopodite seta. Only the flaming torch setae and globular receptor were seen of the endopodite (Fig. 86). Fifth limb not studied.

**Male** unknown.

**Biology and distribution (Fig. 92):** One specimen of *N. camerounensis dioscoridus* was found in a shallow mountain stream in granite rock, from the Haggeher Mountains, Socotra Island (Yemen) at an altitude of 1100 m. This part of the stream was clear, and slow running and had pH of 6.3, conductivity 480 $\mu S\ cm^{-1}$.

**Discussion**

**Biology**

Frey (1974) called attention to the riverine habitat of *A. eximia*, observed earlier by Chien (1970) for *A. fitzpatricki*: 'prefers permanent, clear running waters with sandy bottoms'. In most cases, members of this genus are indeed found in littoral of lotic environments with sandy bottoms, where they occur in shallow, clear, oxygen-rich and slow running stretches or waterbodies connected to rivers and streams with low conductivity (11 – 180 $\mu$S cm$^{-1}$), with the exception of *N. camerounensis dioscoridus* (conductivity of 480 $\mu$S cm$^{-1}$), and a pH ranging between 6 and 7.5. Occasionally, they can be found in swamps, rice fields or flooded fruit cavities, most of which can become lotic during rains.

We predominantly observed a relatively higher abundance of *Nicsmirnovius greeni* in August–November in Cameroon, June to November and from September to November in Nigeria (Green, 1962), and August–September for *N. eximius* in Thailand. These periods coincide with post-monsoon periods in the regions (McGregor & Nieuwolt, 1998) and this suggests a seasonal pattern in abundance, of which the onset is given during the monsoon periods.

*Nicsmirnovius* invariably occur in relatively low numbers compared to other chydorids, even after extensive sampling. The habitat – atypical for a chydorid – and assumed seasonality may contribute towards the apparent scarcity of this animal.

## Distribution

Figure 92 shows the circumtropical distribution of *Nicsmirnovius*. African and Asian populations are classified as separate species (see earlier), and American populations are all regarded as belonging to *N. fitzpatricki*, although some morphological differences were noted. From the map, we assume *Nicsmirnovius* to be present in the littoral of large tropical river systems, like the Amazon River in South America, Indus and Ganges in India, Zaire (Congo) and Zambezi Rivers in Africa.

## Taxonomy

The clearest and most consistent features to distinguish *Nicsmirnovius* species, are found in the shape of the labral plate, the postabdomen, the presence of fingerlike projections on the epipodites and the apical spines on the second antennae. In primitive Aloninae like *Leydigia* (see Kotov, 2002) and *Leydigiopsis* (see Van Damme, 1998), small differences like those on postabdomen are indeed relevant, and in some cases one of few reliable tools to distinguish species visually. The degree of variability versus reliability of features remains unstudied in most chydorids, and is complicated by taxon-specificity.

### Heterogeneity of N. fitzpatricki populations: a species complex?

Differences were noted among populations of *N. fitzpatricki*, and these could well be significant at the species level. Specimens from Mexico had a different postabdomen from the types from USA: at the base of the basal spine, there were four thick spinules, in width about half the thickness of the basal spine: the postabdomen, in overall view, was more compact, as in specimens from Argentina, and the posteroventral corner was completely rounded. A more extensive comparative study between American populations is needed, as it may prove that the Argentinian and Mexican populations represent a separate species, even not closely related to *fitzpatricki*. Until such a detailed study is conducted, these populations are all united under *N. fitzpatricki*, and more morphologically different groups such as those from Mexico should be called *N.* cf. *fitzpatricki*.

### *N. camerounensis dioscoridus* subsp. nov. from Socotra Island

The morphological affinities between the single specimen from a river in the Haggeher Mountains (Socotra Island) and *N. c. camerounensis* from the rain forest of Cameroon are striking. Both areas have a relatively high diversity and a large number of endemic species; no connection between both was suggested previously. More on this will be said in a separate paper on the Cladocera of Socotra Island (Van Damme & Dumont, in prep). We decided to raise this specimen to subspecies level because it is unmistakeably different from true *camerounensis*, with which it shows most similarities as compared to other species. Clearly, more specimens should be investigated to establish its correct taxonomic status, as assigning any status to a single specimen is open to discussion. However, we find the specimen interesting enough to be given separate attention.

## Functional morphology

The unique synapomorphic characters of this genus are undoubtedly the result of an adaptation to interstitial life in lotic environments. Reduction of the eyes in *N. camerounensis*, is probably correlated with interstitial life, also known from stygobiotic chydorids like *Alona sketi* Brancelj, 1992 or ground-water inhabitants like *Alona phreatica* Dumont, 1983.

The prolongation of an aesthetasc on the first antenna, which serves as an additional sensory equipment, can be seen as an adaptation to the lotic interstitial environment where a relatively larger sensitisation is needed, as compared to stagnant systems. The uniquely modified setae on the fourth limb may also be sensory.

Noteworthy is also the smaller size of the head pores in some populations, a character of which the phylogenetic significance needs to be further investigated. In the *N. fitzpatricki* population from Tortugueso Swamp in Puerto Rico, the pores were remarkably small; the same is noted for populations of *N. eximius* from ricefields in Malaysia, shown in Idris (1983). This may be a morphological adaptation to low oxygen levels; however, the function and amount of variablitity in the head pores of the Chydoridae remains too poorly studied to speculate on this.

**Key to the species of Nicsmirnovius (parthenogenetic females):**

1a. Labral keel with short apex (Figs. 6, 30); antennular body (Fig. 4) about twice as long as wide ........................ 2

1b. Labral keel with elongated apex (Figs 50, 79); antennular body 2.5-3 times as long as wide (Figs 48, 60), peg-like projection at base (not always clear; Fig. 48) ...... 3

2a. Dimensions of postabdomen: am = tc > pm(Fig. 9); endopodal apical spine on second antenna shorter than exopodal spine (Fig. 5) ..... *Nicsmirnovius eximius* (Kiser)

2b. Dimensions of postabdomen: am = pm = tc (Fig. 32); endopodal and exopodal apical spines on second antenna of same length (Fig. 29) .... *Nicsmirnovius greeni*

3a. Compound eye present (Fig. 46); valve setae near posteroventral corner short; basal spine on terminal claw long and slender (Figs 51–52) ...... *Nicsmirnovius fitzpatricki* (Chien)

3b. Compound eye absent (Fig. 75); valve setae near posteroventral corner long (Fig. 78); basal spine on terminal claw short (Figs 80, 88) ........ *Nicsmirnovius camerounensis* ..................... 4

4a. Digitiform projection on epipodite of PIV not extending beyond center of exopodite (Fig. 87); Sixth scraper of PII remarkably small (Fig. 81); lateral fascicles on postabdomen consisting of groups of about three denticles each (Fig. 80); pores unknown ..*Nicsmirnovius camerounensis dioscoridus*

4b. Digitiform projection on epipodite of PIV extending beyond center of exopodite (Fig. 89); Sixth scraper of PII of 'normal' size; lateral denticles on postabdomen consisting of groups of more than three each (Fig. 88); typical pore plate (Figs 90, 91) ............ *Nicsmirnovius camerounensis camerounensis*

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*งานวิจัย*

# ปัญหาทางอนุกรมวิธานของแพลงก์ตอนสัตว์อันดับอะโนโมโพดา (Order Anomopoda): กรณีศึกษาในสกุลอะโลนา (Genus *Alona*) จากตัวอย่างในเขตพื้นที่ภาคใต้ของประเทศไทย

สุปิยนิตย์ ไม้แพ[1] พรศิลป์ ผลพันธิน[1] ละออศรี เสนาะเมือง[2] และ Henri J. Dumont[3]

จากการศึกษาปัญหาทางด้านอนุกรมวิธานของแพลงก์ตอนสัตว์อันดับอะโนโมโพดาในสกุลอะโลนา 14 ชนิด พบว่า สามารถจำแนกปัญหาทางอนุกรมวิธานได้ 2 ประการ คือ 1) ปัญหาในการจำแนกกลุ่มของสิ่งมีชีวิตมี 1 ชนิดคือ *A. sarasinorum* Stingelin, 1900 และ 2) ปัญหาในการระบุชนิด โดยแบ่งออกเป็น 4 กลุ่มย่อยคือ 2.1) ชนิดที่มีคำบรรยายลักษณะดั้งเดิมน้อยมากมี 2 ชนิด คือ *A. dentifera* Sars, 1901 และ *A. sarasinorum* Stingelin, 1900 2.2) กลุ่มของชนิดที่มีลักษณะทางสัณฐานวิทยาคล้ายคลึงกันมากมี 8 ชนิด คือ *A. affinis* Leydig, 1860, *A. costata* Sars, 1860, *A. diaphana* Richard, 1895, *A. guttata* Sars, 1862, *A. macronyx* Daday, *A. monacantha* Stingelin, 1905, *A rectangular* Sars, 1862 และ *A. verrucosa* Sars, 1901 2.3) ชนิดที่มีความ แปรผันของลักษณะทางสัณฐานวิทยาสูงมี 2 ชนิด คือ *A. verrucosa* Sars, 1901 และ *Karualona iberica* Alonso & Pretus, 1989 และ 2.4) ชนิดที่ต้องมีการตรวจสอบเพิ่มเติม มี 4 ชนิด คือ *A. dentifera* Sars, 1901, *A. karelica* Stenroos, 1897, *A. pulchella* King, 1853 และ*A. quadrangularis* (O.F.Muller, 1785)

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# Taxonomic Problems of the Anomopoda: A Study Based on Specimens from Southern Thailand, with Specific References to *Alona* Baird, 1843

**Supiyanit Maiphae**[1], **Pornsilp Pholpunthin**[1], **La_orsri Sanoamuang**[2] **and Henri J. Dumont**[3]

The study on the taxonomic problems of fourteen *Alona* species indicated that there are two taxonomic problems in this genus 1) the problem in the classification: *A. sarasinorum* Stingelin, 1900 and 2) the problem in the identification. The latter can be divided into 2.1) poor original description species: *A. dentifera* Sars, 1901 and *A. sarasinorum* Stingelin, 1900 2.2) the 'species-group' species: *A. affinis* Leydig, 1860, *A. costata* Sars, 1860, *A. diaphana* Richard, 1895, *A. guttata* Sars, 1862, *A. macronyx* Daday, *A. monacantha* Stingelin, 1905, *A. rectangular* Sars, 1862 and *A. verrucosa* Sars, 1901 2.3) high morphological variation species: *A. verrucosa* Sars, 1901 and *Karualona iberica* Alonso & Pretus, 1989 and 2.4) need to be confirmed species: *A. dentifera* Sars, 1901, *A. karelica* Stenroos, 1897, 1898, *A. pulchella* King, 1853 and *A. quadrangularis* (O.F.Muller, 1785).

**Key words:** taxonomy, anomopoda, *Alona*, Thailand

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## บทนำ

การศึกษาแพลงก์ตอนสัตว์อันดับอะโนโมโพดายังขาดองค์ความรู้อีกมากในทุกๆ ด้าน โดยเฉพาะอย่างยิ่ง ปัญหาทางด้านอนุกรมวิธาน ซึ่งยังมีข้อผิดพลาดและยังไม่ได้รับการแก้ไขให้ถูกต้อง ทั้งนี้อาจเนื่องมาจากสาเหตุหลายประการ เช่น อะโนโมโพดาเป็นแพลงก์ตอนสัตว์ที่มีขนาดเล็ก ลักษณะทางสัณฐานวิทยามีความซับซ้อนและมีความแปรผันสูง (high morphological variation) อีกทั้งลักษณะบางอย่างมีการเปลี่ยนแปลงไปตามสภาพแวดล้อมและฤดูกาล (cyclomorphic change) นอกจากนี้แนวความคิดที่ว่าอะโนโมโพดามีการกระจายอยู่ทั่วโลก (cosmopolitanism concept) ได้ส่งผลอย่างมากต่อการศึกษาทางด้านอนุกรมวิธานของอะโนโมโพดา เนื่องจากแนวความคิดดังกล่าว ทำให้นักวิทยาศาสตร์ในภูมิภาคต่างๆขาดความระมัดระวังในการระบุชนิด ส่งผลให้เกิดความผิดพลาดในการจำแนกชนิด อย่างไรก็ตาม แม้ว่าปัญหาทางอนุกรมวิธานของอะโนโมโพดายังไม่ได้รับการแก้ไข แต่ก็ยังคงมีงานวิจัยปรากฏออกมาอย่างต่อเนื่อง โดยเฉพาะในประเทศแถบยุโรป อเมริกา ออสเตรเลียและอาฟริกา ส่วนประเทศในแถบเอเชีย เพิ่งเริ่มมีการศึกษาเมื่อประมาณ 30 ปีที่ผ่านมา[1,2,3,4] และจนถึงปัจจุบันก็ยังมีการศึกษาเพียงบางบริเวณในบางประเทศเท่านั้น

การศึกษาทางด้านอนุกรมวิธานของอะโนโมโพดาได้มีการพัฒนาเรื่อยมา โดยในระยะแรกของการศึกษา (ค.ศ. 1776-1973) [5] ได้ให้ความสำคัญกับรูปร่างลักษณะทางสัณฐานวิทยาภายนอก เช่น รูปร่างลำตัว, ลวดลายบนลำตัว, ขนาดลำตัว, ส่วนหัว, หนวดคู่ที่ 1, หนวดคู่ที่ 2 และ postabdomen เป็นต้น สำหรับคำบรรยายลักษณะซึ่งแต่เดิมมักจะปรากฏอยู่สั้นๆ โดยอธิบายลักษณะที่แตกต่างออกไปจากชนิดอื่น และมีภาพประกอบเพียงภาพวาด ในช่วงหลังปี ค.ศ. 1973 แนวความคิดเรื่องอะโนโมโพดาไม่ได้มีการกระจายอยู่ทั่วโลก (non-cosmopolitanism concept) เริ่มได้รับการยอมรับ[6] และลักษณะสำคัญที่นำมาใช้ในการจำแนกกลุ่ม (classification) และการระบุชนิด (identification) ของอะโนโมโพดาได้เปลี่ยนแปลงไป รวมทั้งได้มีการศึกษาลักษณะโครงสร้างทางสัณฐานวิทยาโดยละเอียดด้วยกล้องจุลทรรศน์อิเลกตรอนแบบส่องกราด (Scanning Electron Microscope) ทำให้ได้ข้อมูลของลักษณะทางสัณฐานวิทยามากขึ้น นอกจากนี้ ยังได้ให้ความสำคัญกับลักษณะของรยางค์ขามากขึ้น ทั้งนี้เนื่องจากรยางค์ขาเป็นอวัยวะที่มีความ สัมพันธ์กับหน้าที่ที่มีความสำคัญต่อการดำรงชีวิตของ อะโนโมโพดาหลายประการ ทั้งการกินอาหาร การเคลื่อนที่และการสืบพันธุ์แบบอาศัยเพศ เป็นต้น ในปัจจุบัน ลักษณะของรยางค์ขาจึงได้รับการยอมรับว่าเป็นลักษณะที่มีความสำคัญต่อการศึกษาในเรื่องวิวัฒนาการของอะโนโมโพดา ควบคู่กับการศึกษาลักษณะทางสัณฐานวิทยาอื่นๆ แม้ว่าลักษณะดังกล่าวเพิ่งเริ่มเข้ามามีบทบาทสำคัญในการศึกษาอนุกรม วิธานของอะโนโมโพดา แต่โครงสร้างของรยางค์ขามีบทบาทต่อการเปลี่ยนแปลงทางด้านอนุกรมวิธานของ อะโนโมโพดามากมาย เช่น การยกสกุล *Ilyocryptus* ขึ้นเป็น Family ใหม่ คือ Family Ilyocryptidae ซึ่งแต่เดิมถูกรวมอยู่ใน Family Macrothricidae[7] นอกจากนี้การศึกษาเพิ่มเติมเกี่ยวกับลักษณะรยางค์ขาก็ได้ช่วยในการแก้ปัญหาทางอนุกรมวิธานในกลุ่มของชนิดที่มีลักษณะทางสัณฐานวิทยาคล้ายคลึงกัน (species-group) หลายกลุ่ม เช่น *Alona karua* group[8], *Alona costata* group [9] และ *Alona eximia* group[10,11] เป็นต้น

ในปัจจุบัน ทั่วโลกมีรายงานการพบอะโนโมโพดาประมาณ 600 ชนิด [12] ซึ่งส่วนใหญ่เป็นชนิดที่มีรายงานการพบในประเทศแถบยุโรป อเมริกาและออสเตรเลีย สำหรับประเทศในแถบเอเชียมีการศึกษากันค่อนข้างน้อย แต่ในขณะเดียวกันผลการรายงานชนิดของอะโนโมโพดาจากหลายประเทศ เช่น มาเลเซีย[2] ฟิลิปปินส์ [4] ศรีลังกา[13] และไทย [14,15,16,17,18,19] เป็นต้น ก็ได้บ่งชี้ว่าอะโนโมโพดาในเขตร้อนไม่ได้มีความหลากหลายต่ำอย่างที่เข้าใจกันในระยะแรกของการศึกษา[1] สำหรับในประเทศไทยพบว่ามีความหลากชนิดของอะโนโมโพดาค่อนข้างสูง โดยพบมากถึง 96 ชนิด [14,15,16,17,18,19] แต่การ

ศึกษาส่วนใหญ่จะมุ่งเน้นไปที่การศึกษาความหลากหลายของชนิด ยังไม่มีการศึกษาถึงปัญหาทางอนุกรมวิธานอย่างชัดเจน ซึ่งแท้จริงแล้วอนุกรมวิธานเป็นงานวิจัยสำคัญที่ควรได้รับการศึกษาเป็นเบื้องต้นก่อนที่จะพัฒนาไปสู่การวิจัยเชิงประยุกต์

จากการสำรวจชนิดของอะโนโมโพดาในพื้นที่ภาคใต้ พบอะโนโมโพดาทั้งสิ้น 85 ชนิด [15,18] และในจำนวนนี้จัดอยู่ในสกุลอะโลนามากที่สุดคือ 13 ชนิด (ในประเทศไทยมีรายงานการพบทั้งสิ้น 17 ชนิด) และยังพบชนิดที่เคยถูกจัดรวมอยู่ในสกุลนี้อีก 2 ชนิด [6,11] ดังนั้นการวิจัยในครั้งนี้จึงได้มุ่งเน้นศึกษาอนุกรมวิธานของอะโนโมโพดาในสกุลอะโลนาซึ่งเป็นสกุลที่มีสมาชิกมากที่สุดเป็นสกุลแรก

## วิธีการศึกษา

ศึกษาลักษณะทางสัณฐานวิทยาของอะโนโมโพดาในสกุลอะโลนา 13 ชนิด คือ *Alona affinis* Leydig, 1860, *A. costata* Sars, 1860, *A. dentifera* Sars, 1901, *A. diaphana* Richard, 1895, *A. guttata* Sars, 1862, *A. karelica* Stenroos, 1897, *A. macronyx* Daday, 1898, *A. monacantha* Stingelin, 1905, *A. pulchella* King, 1853, *A. quadrangularis* (O.F.Muller, 1785), *A. rectangular* Sars, 1862, *A. sarasinorum* Stingelin, 1900 และ *A. verrucosa* Sars,1901 รวมชนิดที่เคยถูกจัดรวมอยู่ในสกุลอะโลนา 1 ชนิด คือ *Karualona iberica* Alonso & Pretus, 1989 โดยศึกษาจากตัวอย่างที่เก็บจากแหล่งน้ำจืด 64 แหล่งในเขตพื้นที่ภาคใต้ของประเทศไทย (รายละเอียดของพื้นที่ศึกษาติดต่อผู้วิจัย)

วิเคราะห์เปรียบเทียบลักษณะทางสัณฐานวิทยาภายนอกและลักษณะของชิ้นส่วนรยางค์ต่างๆ โดยวิเคราะห์เปรียบเทียบกับคำบรรยายลักษณะดั้งเดิม (original description), type specimens และเปรียบเทียบกับตัวอย่างจากภูมิภาคอื่นๆของประเทศไทยและภูมิภาคอื่นๆทั่วโลก โดยเน้นศึกษาในระดับตัวแทนของประชากรมากกว่าศึกษาลักษณะจากตัวอย่างเดียว (single specimen) วาดภาพส่วนต่างๆ ของอะโนโมโพดาด้วยกล้องจุลทรรศน์ที่ต่อกับ camera lucida และนำบางตัวอย่างไปถ่ายภาพด้วยกล้องจุลทรรศน์อิเลกตรอนแบบส่องกราด

## ผลการศึกษา

จากการศึกษาเปรียบเทียบลักษณะทางสัณฐานวิทยาของอะโนโมโพดาในสกุลอะโลนาและชนิดที่เคยถูกจัดรวมอยู่ในสกุลอะโลนาที่เป็นปัญหาในการศึกษาทางอนุกรมวิธานทั้งสิ้น 14 ชนิด พบว่า สามารถจำแนกปัญหาทางอนุกรมวิธานของสกุลอะโลนาได้ 2 ประการ คือ 1)ปัญหาในการจำแนกกลุ่ม ของสิ่งมีชีวิต (classification) มี 1 ชนิด คือ *A. sarasinorum* Stingelin, 1900 เนื่องจากอะโลนาชนิดนี้ปรากฏลักษณะที่มีความสำคัญทางอนุกรมวิธานของ อะโลนา [20,21] บางลักษณะ ที่มีความแตกต่างไปจากลักษณะเฉพาะของสกุลอะโลนา และ 2) ปัญหาในการระบุชนิด (identification) ซึ่งสามารถแบ่งออกได้เป็น 4 กลุ่มย่อยคือ 2.1) เป็นชนิดที่มีคำบรรยายลักษณะดั้งเดิมน้อยมาก (poor original description) มี 2 ชนิด คือ *Alona sarasinorum* Stinegelin, 1900 และ *A. dentifera* Sars, 1901 2.2) กลุ่มของชนิดที่มีลักษณะทางสัณฐานวิทยาคล้ายคลึงกัน (species group) มี 8 ชนิด คือ *Alona affinis* Leydig, 1860, *A. costata* Sars, 1860, *A. diaphana* Richard, 1895, *A. guttata* Sars, 1862, *A. macronyx* Daday, 1898, *A. monacantha* Stingelin, 1905, *A. rectangular* Sars, 1862 และ *A. verrucosa* Sars, 1901 2.3) ชนิดที่มีความแปรผันของลักษณะทางสัณฐานวิทยาสูง (high morphological variation) มี 2 ชนิด คือ *A. verrucosa* Sars, 1901 และ *Karualona iberica* Alonso & Pretus, 1989 และ 2.4) ชนิดที่จำเป็นต้องตรวจสอบเพิ่มเติมมี 4 ชนิด คือ *A. dentifera* Sars, 1901, *A. karelica* Stenroos, 1897, *A. pulchella* King, 1853และ *A. quadrangularis* (O.F.Muller, 1785) เนื่องจากพบตัวอย่างในการศึกษาครั้งนี้เพียง 1-2 ตัว (specimens) (ตารางที่ 1)

ตารางที่ 1 แสดงการจำแนกปัญหาทางอนุกรมวิธานของแพลงก์ตอนสัตว์อันดับอะโนโมโพดาในสกุลอะโลนาแต่ละชนิดที่พบในพื้นที่ภาคใต้ของประเทศไทย

| ปัญหาทางอนุกรมวิธาน | ชนิด |
|---|---|
| 1. ปัญหาในการจำแนกกลุ่มของสิ่งมีชีวิต (classification) | *Alona sarasinorum* Stingelin, 1900* |
| 2. ปัญหาในการระบุชนิด (identification) | |
| - ชนิดที่แสดงคำบรรยายลักษณะไว้น้อยมาก (poor description) | *Alona dentifera* Sars, 1860 |
| | *Alona sarasinorum* Stingelin, 1900 |
| - กลุ่มของชนิดที่มีลักษณะคล้ายคลึงกัน (species-group) | *Alona affinis* Leydig, 1860 |
| | *Alona costata* Sars, 1860 |
| | *Alona diaphana Richard, 1895* |
| | *Alona guttata* Sars, 1862 |
| | *Alona macronyx* Daday, 1898 |
| | *Alona monacantha* Stingelin, 1905 |
| | *Alona rectangula* Sars, 1862 |
| | *Alona verrucosa* Sars, 1901 |
| - ชนิดที่ลักษณะทางสัณฐานวิทยามีความแปรผันสูง (high morphological variation) | *Alona verrucosa* Sars, 1901 |
| | *Karualona iberica* Alonso & Pretus, 1989 |
| - ชนิดที่ต้องมีการตรวจสอบเพิ่มเติม (need to be confirmed) | *Alona dentifera* Sars, 1860 |
| | *Alona karelica* Stenroos, 1897 |
| | *Alona pulchella* King, 1853 |
| | *Alona quadrangularis* (O. F. Muller, 1785) |

หมายเหตุ *ยังอยู่ในระหว่างการตรวจสอบ

## วิจารณ์และสรุปผลการศึกษา

จากผลการจำแนกปัญหาทางอนุกรมวิธานในสกุลอะโลนาทั้งสองประการ พบว่า ชนิดที่มีปัญหาในการจำแนกกลุ่มของสิ่งมีชีวิต คือ *A. sarasinorum* Stingelin, 1900 (ภาพที่ 1ก, 4ก) ปรากฏลักษณะที่มีความสำคัญทางอนุกรมวิธานของอะโลนาหลายลักษณะที่มีความแตกต่างไปจากลักษณะเฉพาะของสกุลอะโลนา คือ spine บริเวณ Inner distal lobe ของรยางค์ขาคู่ที่ 1 มีลักษณะโค้งงอคล้ายตะขอขนาดใหญ่ (ภาพที่ 1ข ลูกศรชี้, 4ก) ซึ่งแตกต่างไปจากอะโลนาชนิดอื่น ซึ่ง spine บริเวณเดียวกันนี้จะมีลักษณะเรียวยาว รูปร่างเหมือนกับ spine อื่นๆ บนรยางค์ขาคู่ที่ 1 และมีลักษณะพิเศษอีกประการหนึ่งคือ บริเวณรอยต่อระหว่าง anal margin กับ preanal margin ของ postabdomen ทำมุมกันประมาณ 80-90° (ภาพที่ 1ค, 4ข) เนื่องจากลักษณะของรยางค์ขาคู่ที่ 1 ดังกล่าวเป็นลักษณะที่มีความสำคัญทางอนุกรมวิธานของอะโลนา ในเบื้องต้นนี้จึงสันนิษฐานว่า *A. sarasinorum* น่าจะถูกจัดแยกออกไปจากสกุลอะโลนา แต่อย่างไรก็ตาม ข้อสันนิษฐานนี้กำลังรอการตรวจสอบจาก type specimen และผู้เชี่ยวชาญอีกครั้งหนึ่ง

นอกจากนี้ *Alona sarasinorum* Stinegelin, 1900 และ *A. dentifera* Sars, 1901 มีความจำเป็นที่จะต้องเขียนคำบรรยายลักษณะใหม่ (Redescription) เนื่องจากคำบรรยายลักษณะและภาพประกอบในการรายงานครั้งแรกให้รายละเอียดน้อยมาก[22] และไม่มีการศึกษาเพิ่มเติมอีก ทำให้ขาดข้อมูลและมีความยากลำบากในการศึกษาเปรียบเทียบลักษณะทางสัณฐานวิทยา ในการศึกษาครั้งนี้พบตัวอย่าง *A. sarasinorum* เป็นจำนวนมากบริเวณพรุไม้ขาว จ.ภูเก็ต ซึ่งจะได้จัดทำคำบรรยายลักษณะ รวมทั้งวาดภาพประกอบ ทั้งภาพที่วาดด้วย camera lucida และภาพถ่ายอิเลกตรอนโดยละเอียดในภายหลัง และจะวิเคราะห์เปรียบเทียบลักษณะทางสัณฐานวิทยากับ type specimen รวมทั้งตรวจสอบกับอะโลนาอีกชนิดหนึ่งซึ่งมีลักษณะคล้ายกันมากคือ *A. taraporevalae* Shirgue & Naik, 1977 ที่พบรายงานครั้งแรกจากอ่าวแบค (Back Bay) เมืองบอมเบย์ ประเทศอินเดีย[23] ในเบื้องต้นคาดว่าทั้งสองชนิดนี้น่าจะเป็นชนิดเดียวกัน เนื่องจากมีลักษณะสำคัญหลายลักษณะเหมือนกัน เช่น ลักษณะโครงสร้างภายนอก ขาคู่ที่ 1 และ postabdomen เป็นต้น อีกทั้งลักษณะแหล่งน้ำที่พบทั้งสองชนิดยังมีปัจจัยหลายประการใกล้เคียงกัน เช่น ทั้งสองชนิดมีรายงานจากแหล่งน้ำที่มีค่าความเป็นกรดด่างในช่วง 5-8 และมีความเค็มในช่วง 0-8 ppt เป็นต้น ซึ่งข้อสันนิษฐานนี้กำลังรอการตรวจสอบ type specimens ของทั้งสองชนิด

นอกจากชนิดที่กล่าวมาข้างต้น ชนิดอื่นๆ ส่วนใหญ่จะมีปัญหาที่ยังไม่สามารถแก้ไขและมักถูกรวมเป็น species-group เนื่องจากการตรวจสอบจะต้องอาศัยการวิเคราะห์เปรียบเทียบตัวอย่างจากหลายบริเวณทั่วโลก แต่สิ่งที่สามารถศึกษาได้ในขณะนี้คือ ตัวอย่างอะโลนาทุกชนิดที่พบในพื้นที่ภาคใต้ของประเทศไทยมีลักษณะทางสัณฐานวิทยาหลายลักษณะที่มีความแปรผันไปจากตัวอย่างที่พบจากภูมิภาคอื่นๆ และในขณะเดียวกันก็แสดงความแปรผันของลักษณะภายในตัวอย่างจากแหล่งน้ำเดียวกัน และระหว่างประเภทของแหล่งน้ำที่พบอีกด้วย ซึ่งสามารถพบได้ใน *Karualona iberica* Alonso & Pretus,1989 [8] ลักษณะที่แสดงความแปรผันอาจปรากฏในลักษณะของรูปร่างทั่วไปของลำตัว (ภาพที่ 2ก, 2ข, 4ง), ความยาวของ scraping spine ที่ 1 และ 2 ของขาคู่ที่ 2 (ภาพที่ 2ค), ความยาวของ internal และ external setae บน Inner distal lobe (IDL) ของขาคู่ที่ 1 (ภาพที่ 2ง), อุ้งเล็บ (ภาพที่ 2จ) และส่วน postero-ventral corner of valve (ภาพที่ 2ฉ) นอกจากนี้อะโลนาชนิดอื่น เช่น *A. verrucosa* Sars, 1901 ก็อาจมีความแปรผันของลักษณะปุ่มที่อยู่บนเปลือกซึ่งอาจปรากฏหรือไม่ปรากฏอยู่ก็ได้ (ภาพที่ 3ก, 3ข, 4จ) หรือความแปรผันของลักษณะการเรียงตัวของซีตีบน postabdomen (ภาพที่ 4ฉ) เป็นต้น

สำหรับในบางชนิด เช่น *A. quadrangularis, A. dentifera, A. pulchella* และ *A. karelica* เป็นชนิดที่พบตัวอย่างเพียง 1-2 ตัวและบางตัวอย่างอยู่ในสภาพที่ไม่สมบูรณ์ อีกทั้งชนิดดังกล่าวยังเป็นชนิดที่เคยมีรายงานการพบในเขตอบอุ่นมากกว่า ทำให้ยังมีข้อสงสัยในการจำแนกชนิด จึงต้องรอหาตัวอย่างให้มากขึ้นเพื่อตรวจสอบว่าการจำแนกชนิดถูกต้องหรือไม่

แม้ว่าการศึกษาในปัจจุบัน จะยังไม่สามารถหาข้อสรุปถึงสถานภาพทางอนุกรมวิธานของอะโลนาทุกชนิดที่พบในพื้นที่ภาคใต้ของประเทศไทยได้ แต่ผลจากการศึกษาเปรียบเทียบลักษณะทางสัณฐานวิทยาของแต่ละชนิด สามารถให้ข้อมูลของลักษณะที่มีความแปรผันและแสดงแนวโน้มของความสัมพันธ์กับตัวอย่างชนิดเดียวกันในภูมิภาคต่างๆ นอกจากนี้จะยังสามารถจัดทำคำบรรยายลักษณะ ภาพประกอบ รวมทั้งจัดทำคู่มือการจำแนกชนิดอะโนโมโพดาของประเทศไทยได้ต่อไปในอนาคต

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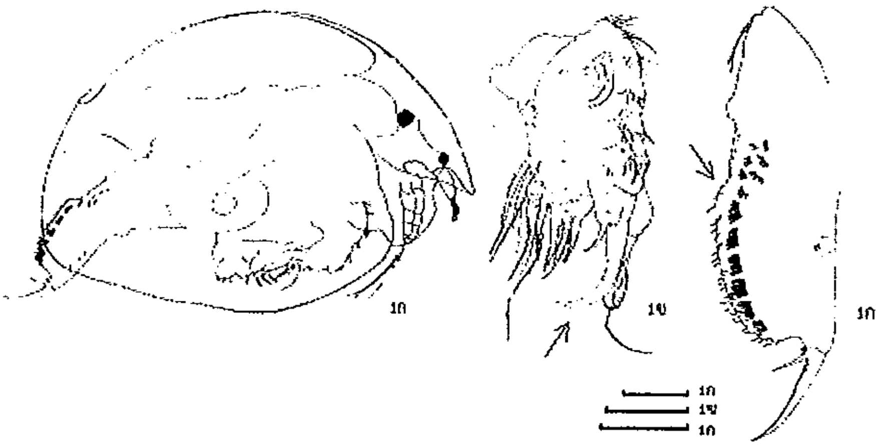
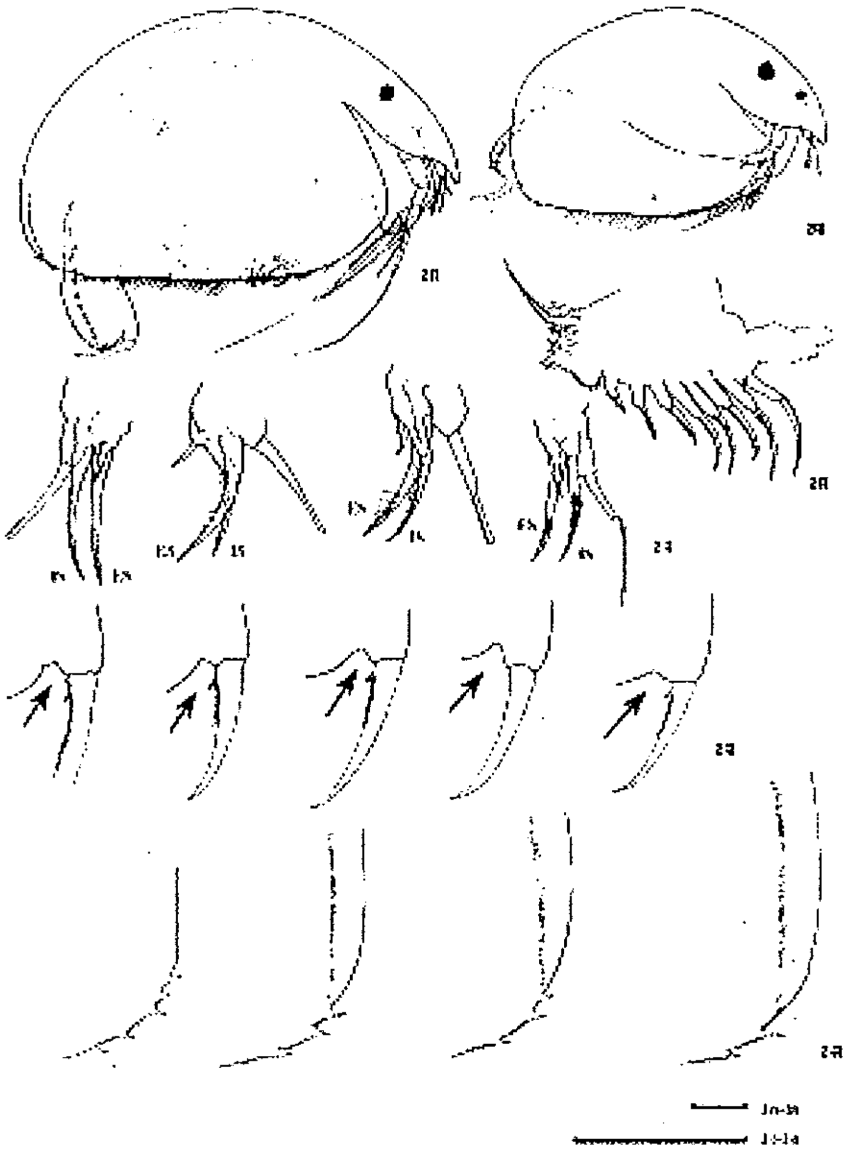
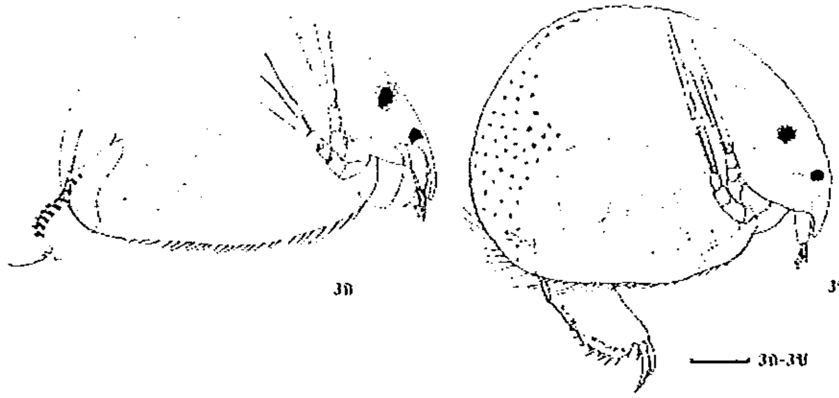


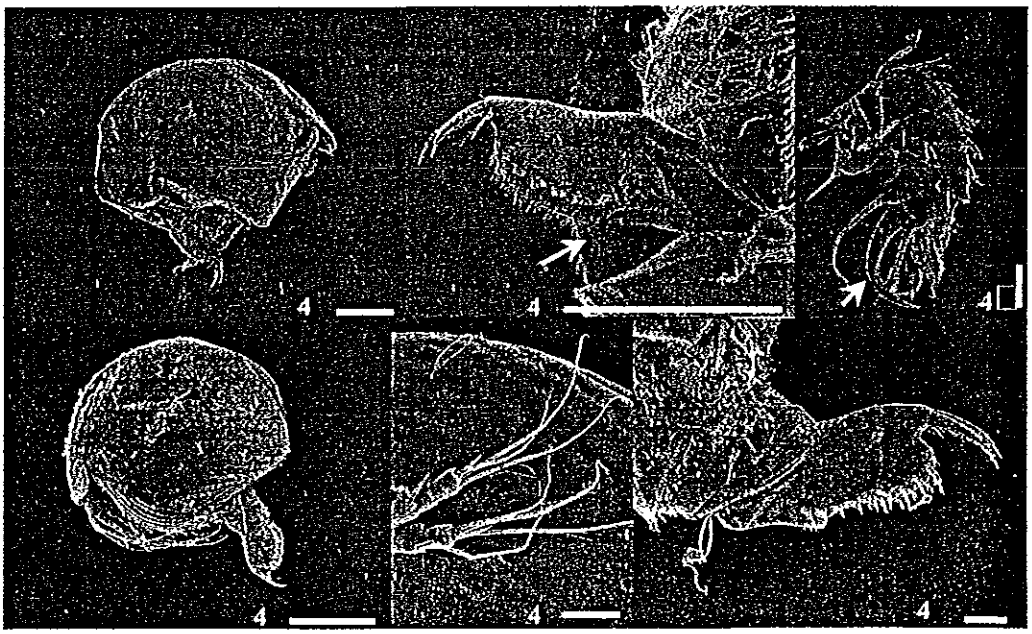

**รูปที่ 1** *Alona sarasinorum* Stingelin, 1900: 1ก: ตัวเต็มวัย เพศเมีย, 1ข: รยางค์ขาคู่ที่ 1 แสดงลักษณะ spine คล้ายตะขอขนาดใหญ่บริเวณ inner distal lobe, 1ค :postabdomen; scale bar 50 um



รูปที่ 2 *Karualona iberica* Alonso & Pretus, 1989: 2ก-ข: ตัวเต็มวัย เพศเมีย, 2ค: รยางค์ขาคู่ที่2, 3ง : Inner distal lobe ของรยางค์ขาคู่ที่ 1; IS=internal setae, ES= external setae, 2จ : อุ้งเล็บ, 2ฉ: postero-ventral of valve; scale bar 50 um




รูปที่ 3 *Alona verrucosa* Sars, 1901: 3ก: ตัวเต็มวัย เพศเมีย ตัวอย่างจากหนองทุ่งทอง จ.สุราษฎร์ธานี, 3ข: ตัวเต็มวัย เพศเมีย ตัวอย่างจากพรุยน จ.ตรัง; scale bar 50 um



รูปที่ 4 4ก: *Alona sarasinorum* Stingelin, 1900: ตัวเต็มวัย เพศเมีย; 4ข: *A. sarasinorum* : postabdomen; 4ค: *A. sarasinorum* : spine ที่มีลักษณะคล้ายตะขอขนาดใหญ่บริเวณ inner distal lobe ของรยางค์ขาคู่ที่ 1; 4ง: *Karualona iberica* Alonso & Pretus, 1989 : ตัวเต็มวัย เพศเมีย; 4จ: *Alona verrucosa* Sars, 1901 : ลักษณะปุ่มบนเปลือก, 4ฉ : *A. verrucosa* : postabdomen : scale bar: 4ก-4ข, 4ง-4จ: 100 μm, 4ค, 4ฉ : 20 μm

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# Species richness of the cladocera (Branchiopoda: Anomopoda and Ctenopoda) in southern Thailand, and its complementarity with neighboring regions

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*Key words:* cladocera, Thailand, species richness, complementarity

**Abstract**

Seventy-two cladoceran species from southern Thailand include eleven first records. Species accumulation curves were used to estimate the total number of species present, and Chao's estimator was used to extrapolate the species number observed in 212 samples to the total number present. This $S^*max$ amounted to 76.06 species, with a low ratio of variance/estimator. Cladoceran faunas were compared by a complementarity index at three levels: between habitat types, between different zones of Thailand, and between Thailand and other countries. The geographical gradient was quite strong, but because not all areas have been studied to the same degree and with the same taxonomic accuracy, some comparisons are robust while others are not.

## Introduction

Knowledge on the Cladocera from Thailand made considerable progress during the last two decades (Boonsom, 1984; Pholpunthin, 1997; Sirimongkonthaworn, 1997; Sanoamuang, 1998; Pipatcharoenchai, 2001; Saeng-aroon, 2001; Sanoamuang et al., 2001; Sa-ardrit, 2002) but few data are available on southern Thailand. Pholpunthin (1997) reported 17 species from Thale-noi, Pattalung Province, including seven species new to the region and one first record for Southeast Asia, and Sa-ardrit (2002) added six other records from only one Province. Including previous records from other parts of Thailand, 77 and 48 species from the northeast and the west, respectively, our records bring the Thai cladoceran list to 105 species. The number of new records added by every single contribution so far indicates that this is probably not a final figure and a number of species remains to be discovered.

The present paper aims to examine the cladoceran taxa of southern Thailand. Their specific status could not be determined in all cases, yet our result represents a further contribution and provides a tool for further investigations. An estimation of the total cladoceran species richness present from samples, as well as a study of faunal complementarity at different levels was also included.

## Materials and methods

### *Description of the study area*

The selected sampling sites were representative of the variety of freshwaters of southern Thailand, such as swamps, peat swamps, marshes, rivers, dams, ponds and reservoirs. Most of sampling sites are important water resources at the national or local levels (Fig. 1).

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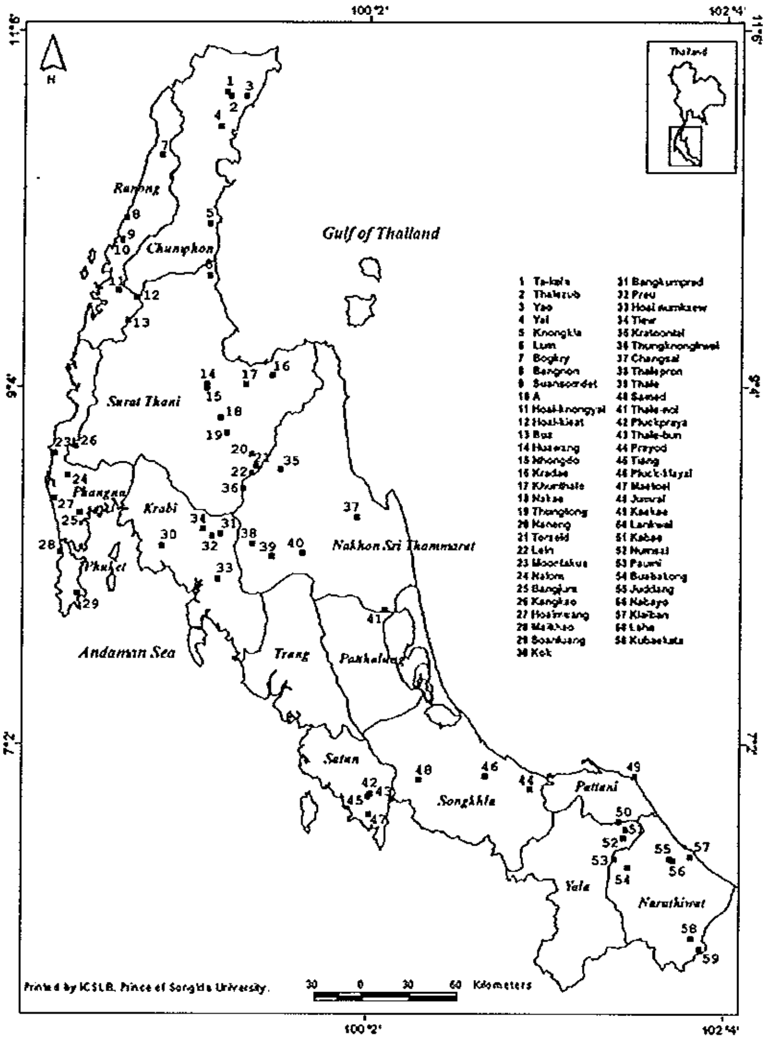


*Figure 1.* Sampling sites in southern Thailand.

*Sampling and examination*

Three hundred qualitative samples were collected from 59 freshwater localities in southern Thailand across seasons, from September 1999 to April 2000. The samples were obtained from representative environments in each water body, using towed plankton nets of mesh size 20 and 60 $\mu$m. Samples were immediately preserved in 4% formaldehyde. In the laboratory, specimens were sorted under an Olympus dissecting microscope and examined under an Olympus CH-2 compound microscope. A list of the localities sampled during this study is shown in Figure 1.

## Data analysis

*The actual species richness*

A species list based on 183 qualitative samples (excluding the samples which had no species) was used to construct a species accumulation curve. Per sample series, 100 randomizations were carried

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out, such that a standard deviation for each data point could be calculated. The calculation was carried out by the estimates program version 6.0 (http://viceroy.eeb.uconn.eud/estimates). Chao's non-parametric method, which is recognized as the most reliable estimator (Chao, 1987; Chao & Lee, 1992; Dumont & Segers, 1996), the Jacknife method, and the Bootstrap method were used as shortcuts to extrapolate from species number observed to true number present.

*The complementarity values*

The measurement of non-similarity (complementarity) is a method to compare different faunas. Here, species richness of the cladocerans was compared among habitat types in southern Thailand, among three parts of Thailand, and among several Asian countries. Literature sources (Mamaril & Fernando, 1978; Idris & Fernando, 1981; Rajapaksa & Fernando, 1982; Idris, 1983; Boonsom, 1984; Michael & Sharma, 1988; Bromley, 1993; Pholpunthin, 1997; Sirimonkonthaworn, 1997; Sanoamuang, 1998; Sanoamuang et al., 2001; Pipatcharoenchai, 2001; Saeng-aroon, 2001; Sa-ardrit, 2002) were used in the analysis. The calculation used the equation of Colwell & Coddington (1994).

## Results

*The cladoceran species found in southern Thailand*

A total of 72 species in 31 genera and six families were identified (Table 1). Eleven species, *Alona* cf. *dentifera* (Leydig, 1860); *A.* prope *karelica* (Stenroos, 1897); *A. sarasinorum* (Stingelin, 1900); *Bosmina longirostris* (Muller, 1785); *Ephemeroporus phintonicus* (Margaritona, 1969); *E. hybridus* (Daday, 1905); *E. tridentatus* (Bergamin, 1939); *Macrothrix malaysiensis* Idris & Fernando, 1980; *M.* cf. *superaculeata* (Smirnov, 1982); *M.* cf. *gauthieri* (Smirnov, 1976) and *Notoalona freyi* (Idris & Fernando, 1980) are new to the Thai fauna (indicated by an asterisk in Table 1).

The number of species found in southern Thailand is comparable to that reported from northeast Thailand, 66 taxa (Sirimongkholthaworn, 1997; Sanoamuang, 1998) but superior to the number known from the west (28 taxa) (Pipatcharoenchai, 2001).

Chydoridae was the most diverse family (45 species), followed by Macrothricidae (11 species); Daphniidae (six species); Sididae (six species); Bosminidae (three species) and Ilyocryptidae (one species). *Alona* was the most speciose genus followed by *Macrothrix* and *Chydorus*. The most frequently encountered cladoceran species, found in more than 65% of the samples, were *Alona verrucosa* (Sars, 1901) (72.88%), *Ephemeroporus barroisi* Richard, 1894 (72.88%) and *Macrothrix flabelligera* (Smirnov, 1992) (66.10%), while *E. hybridus* (Daday, 1905), *Guernella raphaelis* (Richard, 1892), *Leydigia* sp., *Leydigiopsis* sp., *Macrothrix* cf. *paulensis* (Sars, 1900), *Nicsmirnovius eximius* (Kiser, 1948), *Notoalona freyi* (Idris & Fernando, 1980) and *Pleuroxus uncinatus* (Baird, 1850) were rare (low numbers and/or occurring in only one sample).

*The ultimate number of cladoceran species in southern Thailand*

A species accumulation curve was fitted using a logarithmic equation, as well as Chao 1, Chao 2, Jackknife 1, Jackknife 2 and Bootstrap estimators (variance in brackets), shown in Figure 2. The Chao 2 and second-order Jacknife estimators are known to provide the least biased estimates (Cowell & Coddington, 1994; Hellmann & Fowler, 1999) for $S^*max$ (76.06 and 81.98 species), followed by the first-order Jacknife, the Bootstrap and Chao 1. The Chao 2 estimator produced an estimate of 49.75 species (72 species were observed), based on as few as 10 samples, while the Jackknife 2 estimator suggested 54 species at the same number of samples. The intersection of the regression equation with Chao 2 is a rough measure of the number of samples required to record total species richness present. In the case of the logarithmic equation ($y = 14.535\mathrm{Ln}(x)-1.7887$), this leads to 212 samples for Chao 2 and 318 samples for Jackknife 2. Apart from computing Chao 2 and Jackknife 2, the ratio variance/estimator is interesting; the smaller the ratio, the better the estimation (Dumont & Segers, 1996). The ratio associated with both estimators was low, especially for Chao 2 (0.06) indicating that the true cladoceran species richness was well estimated from our number of samples (Hellmann & Fowler, 1999).

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*Table 1.* Cladoceran species recorded from southern Thailand

**Family Bosminidae**
1. **Bosmina longirostris* (Muller, 1785: 24)
2. *B.meridionalis* (Sars, 1904: 59)
3. *Bosminopsis deitersi* (Richard, 1895: 3,4,12,13,14,18,19,24,26,33,35,39,40,50,54,55,56,58)

**Family Chydoridae**
4. *Alona affinis* (Leydig, 1860: 4,19,39,53,54,55,56,57,59)
5. *A. costata* (Sars, 1860: 19,21,23,28,34,39,58)
6.**A*.cf. *dentifera* (Sars, 1901: 32)
7. *A. diaphana* (Richard, 1895: 3,4,9,18,19,28,29,41,42,44,48,51,59)
8. *A. guttatta* (Sars, 1862: 2,4,19,25,39,45,57,58)
9. **A*. prope *karelica* (Stenroos, 1897: 2,42,55)
10. *A. macronyx* (Daday, 1898: 14,51)
11. *A. monacantha* (Stingelin, 1905: 2,12,18,21,26,49,53,56)
12. *A. pulchella* (King, 1853: 3,4,20,22,23,32,38,58)
13. *A. quadrangularis* (Muller, 1785: 16,53)
14. *A. rectangula* (Sars, 1862: 3,49)
15.**A. sarasinorum* (Stingelin, 1900: 28,34,49)
16. *A. verrucosa* (Sars, 1901: 1,2,3,4,5,9,11,12,16,19,21,22,23,25,26,28,29,30,31,32,33,34,38,39,40,42,44,45,46,47,48,49,50,51,52,53,54, 55,56,57,58,59)
17. *Alonella clathratula* (Sars, 1896: 2,4,19,41,57)
18. *A. excisa* (Fischer, 1854: 2,3,4,6,11,19,21,23,24,25,26,28,32,34,38,39,42,44,45)
19. *A. nana* (Baird, 1850: 19,28,34,41,57,58,59)
20. *Acroperus harpae* (Baird, 1834: 6,26,41,47,55,57,58)
21. *Camptocercus australis* (Sars, 1896: 4,54)
22. *Chydorus eurynotus* (Sars, 1901: 2,3,4,9,11,14,17,18,19,23,24,26,28,29,31,32,34,35,38,39,42,43,45,46,47,48,49, 50,51,52,53,54,55, 56,57,58)
23. *C. obscurirostris obscurirostis* (Frey, 1987: 6,41,57)
24. *C. obscurirostris tasekberae* (Frey, 1987: 19,54,57)
25. *C. parvus* (Daday, 1898: 4,19,38,40,42,51,52,53,54,55,57)
26. *C. pubescens* (Sars, 1901: 2,19,45,49,53,55)
27. *C. reticulatus* (Daday, 1898: 2,3,6,18,19,39,41,42,44,45,46,48,50,51,52,53,54,55,56,57,58,59)
28. *C. ventricosus* (Daday, 1898: 3,14,19,23,41,42,44,49,50,52,53,54,56,57,58,59)
29. *Dadaya macrops* (Daday, 1898: 2,4,6,19,21,25,30,39,41,42,47,48,52,53,58,59)
30. *Disparalona caudata* (Smirnov, 1996: 16,56)
31. *D. hamata* (Birge, 1879: 4,16)
32. *Dunhevedia crassa* (King, 1853: 3,4,5,16,17,28,31,38,42,52)
33. *D. serrata* (Daday, 1898: 4,22,38,42,46,49,52)
34. *Ephemeroporus barroisi* (Richard, 1894: 2,3,4,5,6,8,9,11,14,17,18,19,21,23,24,25,26,28,32,33,34,35,38,39,42,44, 45,46,47,48,49,50, 51,52,53,54,55,56,57,58,59)
35. **E. hybridus* (Daday, 1905: 18)
36. **E. phintonicus* (Margaritora, 1969: 5,8,9,11,21,23,24,28,38,39,41,46,49,50,52,53,54,58)
37. **E. tridentatus* (Bergamin, 1939: 3,5,9,19,26,34,42,45,48,49,50,52,53,54,56,57,59)
38. *Euryalona orientalis* (Daday, 1898: 4,6,29,42,50)
39. *Karualona iberica* (Dumont & Silva-Briano, 2000: 2,3,4,14,16,17,18,19,20,21,23,25,28,32,34,36,38,39,40,42,43,46,49,52,53,54,56,59)
40. *Kurzia longirostris* (Daday, 1898: 17,20,25,41,43,52,54,56)
41. *Leydigia* sp.: 59
42. *Leydigiopsis* sp.: 57
43. *Nicsmirnovious eximius* (Kiser, 1948: 6)

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*Table 1.* (Continued).

44. *Notoalona globulosa* (Daday, 1898: 14,17,19,42,49)
45. **N. freyi* (Idris & Fernando, 1980: 19,28,34)
46. *Oxyurella singalensis* (Daday, 1898: 2,3,9,17,18,19,20,25,29,35,38,39,42,43,47,49,50,51,52,53,56,57,59)
47. *Picripleuroxus laevis* (Sars, 1862: 2,3,16,17)
48. *Pleuroxus uncinatus* (Baird, 1850: 59)

**Family Daphniidae**

49. *Ceriodaphnia cornuta* (Sars, 1885: 3,4,9,15,16,25,26,29,30,35,39,41,42,43,45,50,53,55)
50. *Scapholeberis kingi* (Sars, 1903: 2,18,19,24,25,32,42,44,50,52,55,56)
51. *Simocephalus mesorostris* (Stingelin, 1906: 3,9,19,23,25,28,29,34,42,43,44,52,58,59)
52. *S. serrulatus* (Koch, 1841: 2,9,18,19,25,26,28,29,31,34,38,39,42,46,47,48,51,52,53,54,57,58)
53. *Moina micrura* (Kurz, 1874: 3,4,15,35,40,49,50)
54. *Moinodaphnia macleayi* (King, 1853: 2,3,4,6,14,15,17,18,20,24,25,28,35,39,42,43,47,49,50,52,54)

**Family Ilyocryptidae**

55. *Ilyocryptus spinifer* (Herrick, 1882: 4,6,9,14,19,21,23,24,25,28,29,31,34,35,39,42,43,51,52,54,57,58,59)

**Family Macrothricidae**

56. *Guernella raphaelis* (Richard, 1892: 28)
57. *Macrothrix flabelligera* (Smirnov, 1992: 2,3,6,9,11,14,16,17,19,20,21,23,24,25,26,28,29,31,32,34,38,39,42,43,45,46,47,48,49,50,51,52, 53,54,55,56,57,58,59)
58. **M.* cf. *gauthieri* (Smirnov, 1976: 53,57)
59. **M. malaysiensis* (Idris & Fernando, 1980: 19,28,34)
60. *M. odiosa* (Gurney, 1916: 19,28,34,38,42,51,52)
61. *M.* cf. *paulensis* (Sars, 1900): 52
62. *M.* cf. *sioli* (Smirnov, 1982)
63. *M. spinosa* (King, 1852: 2,9,11,18,19,21,24,26,29,38,42,45,49,53,54,56,57,59)
64. **M.* cf. *superaculeata* (Smirnov, 1982: 53,58)
65. *M. triserialis* (Brady, 1886: 2,3,5,6,9,14,16,23,24,26,29,31,32,38,39,42,47,53,54,55,57,58)
66. *Srebloceras pygmaeus* (Sars, 1901: 2,8,9,19,23,26,41,42,50,52,54,57,58)

**Family Sididae**

67. *Diaphanosoma excisum* (Sars, 1885: 1,3,4,7,12,13,14,15,16,17,18,19,25,30,35,36,39,40,41,42,43,50,54,55,58)
68. *D. sarsi* (Richard, 1895: 3,4,24,25,41,43)
69. *Latonopsis australis* (Sars, 1888: 4,5,15,16,23,24,28,31,33,34,38,39,42,46,49,51,52,54,55,57,58,59)
70. *Pseudosida bidentata* (Herrick, 1884: 2,3,9,11,25,29,36,41,42,46,49,52,53,54,58)
71. *P. ramosa* (Daday, 1904: 2,11,25,55)
72. *Sida crystallina* (Muller,1776: 50)

The number of a locality refers to Figure 1. *: new record for Thailand.

### *Complementarity values*

To evaluate complementarity, species numbers were compared pairwise between freshwater habitats sampled in the present study, the known cladoceran species richness in three parts of Thailand, and the species richness of Thailand with that of the neighbor countries: Malaysia, Singapore, Philippines, India, Sri Lanka and finally, Israel.

In pairwise habitat comparisons (Table 2), complementarity was from 34 to 39% between stagnant vegetated habitats (i.e. swamps, marshes and peat-swamps) to 80% between stagnant vegetated habitats and running water habitats (including dams) and 48–70% between stagnant vegetated habitats and stagnant non-vegetated habitats (i.e. ponds and reservoirs).

The cladocerans from three parts of Thailand showed 35–70% complementarity (Table 3). The south has typical tropical rainforest while the northeast is drier and the west more humid. The south and the northeast turn up close to each other

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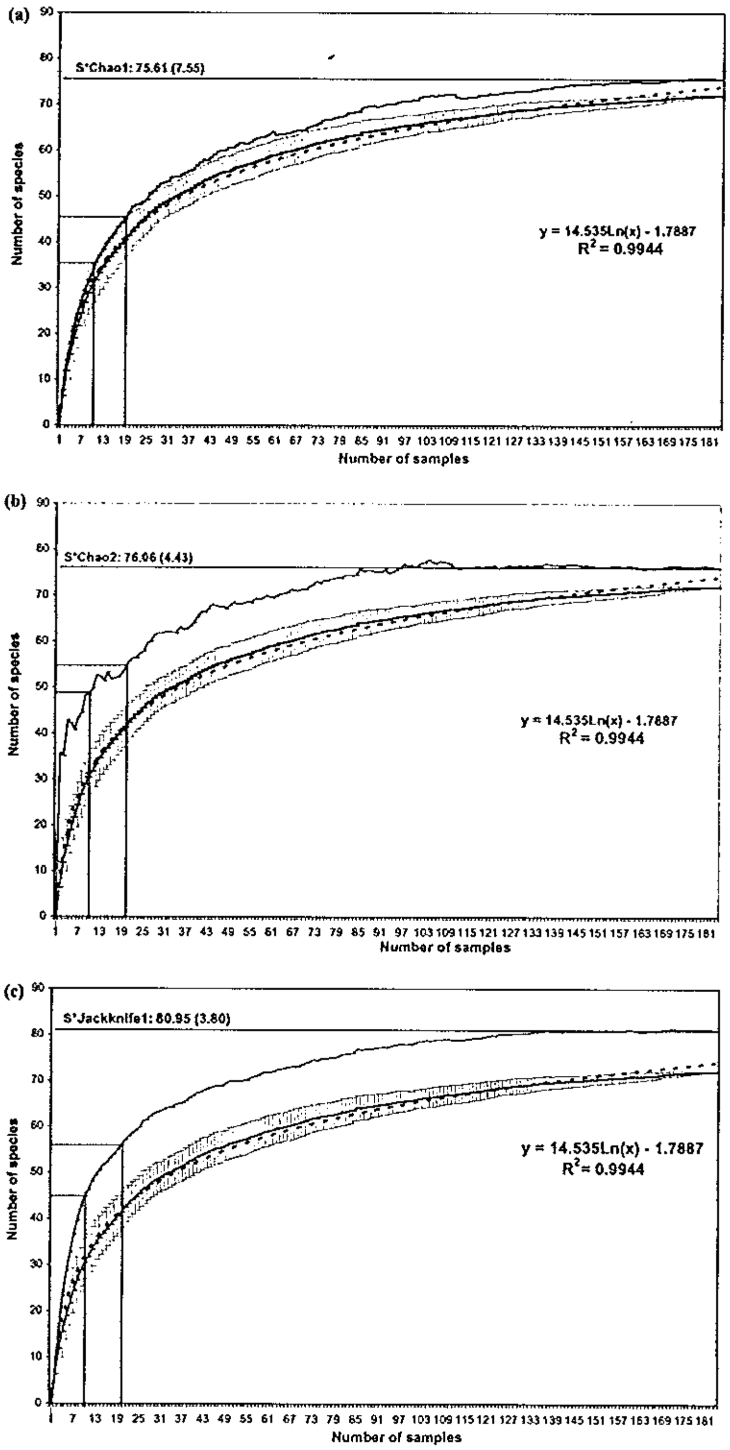


*Figure 2a.* (continued).

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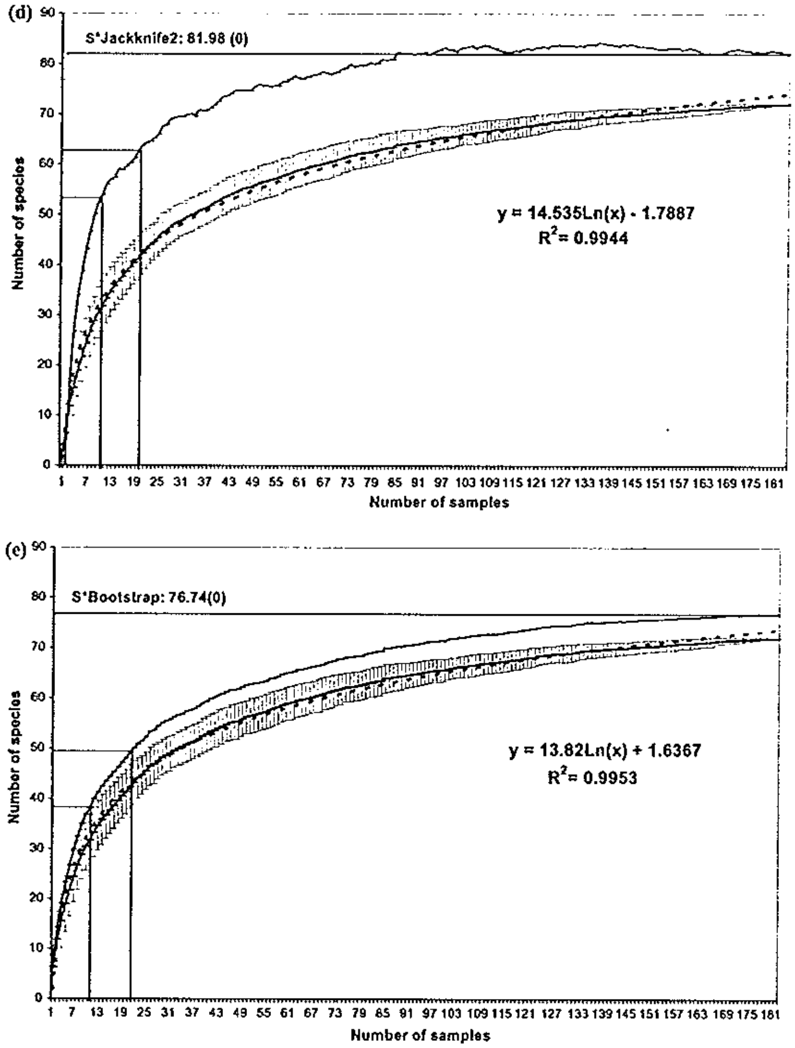


*Figure 2.* Performance of five non-parametric estimators of species richness for the present study data set (a) $S_1$* Chao 1, (b) $S_2$* Chao 2, (c) $S_3$* Jackknife 1, (d) $S_4$* Jackknife 2 and (e) $S_5$* Bootstrap. The lower curve in each panel is the species accumulation curve showing the observed number of species. The upper curve in each panel displays the estimated total species richness based on successively larger number of samples from the data set. For this data set, Chao 2 (b) provides the least biased estimates of species richness for a small numbers of samples; with Jackknife 2 (d) as a close second. For all curves, each point is the mean of 100 estimates based on 100 randomization of sample accumulation order.

while the west is lowest. This, however, could have technical reasons, not reflecting a true difference in richness. Few species, like *A. sarasinorum*, a saline-water species, have been found only along the coast in the south. Complementarity ranges from 40 to 80% between countries (Table 4), and the value increases with distance.

## Discussion

Our results provide a general idea of the species richness status but not an ATBI (All Taxa Biological Inventory). For an ATBI, any sizeable lowland freshwater area, regardless of latitude, is expected to yield around 50 species (Dumont &

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*Table 2.* Matrix of percentage complementarity values for Cladoceran species richness in different habitats

| | Swamp | Marsh | Peat swamp | Reservoir | Pond | Dam |
|---|---|---|---|---|---|---|
| Dam (11) | 83.9 | 85.0 | 85.7 | 83.0 | 80.8 | – |
| Pond (20) | 67.2 | 70.0 | 67.4 | 65.8 | – | |
| Reservoir (31) | 62.7 | 51.7 | 48.0 | – | | |
| Peat swamp (45) | 36.9 | 39.1 | – | | | |
| Marsh (58) | 34.7 | – | | | | |
| Swamp (61) | – | | | | | |

*Table 3.* Matrix of percentage complementarity values for the Cladocera richness in three parts of Thailand

| | Southern | Northeastern | Western |
|---|---|---|---|
| West (28) | 70.8 | 65.82 | – |
| Northeast (66) | 35.0 | – | |
| South (84) | .. | | |

*Table 4.* Matrix of percentage complementarity values for Cladocera in other countries

| | Thailand | Malaysia & Singapore | India | Israel | Sri Lanka |
|---|---|---|---|---|---|
| Sri Lanka (61) | 58.1 | 43.0 | 53.8 | 77.8 | – |
| Israel (60) | 64.0 | 79.4 | 64.0 | – | |
| India (91) | 56.9 | 57.4 | – | | |
| Malaysia (63) | 48.6 | – | | | |
| Thailand (104) | – | | | | |

Segers, 1996). However, the number of species found in each of our environments was from zero to 36 species, and most localities produced 15–36 species, i.e. from 30 up to 70% of the ATBI. Low species richness at each locality may reflect a special environment, but more often undersampling. Species lists should therefore be based on a minimum of three samples, taken in different seasons of at least two different years, to minimize the under/over estimating of species richness (Dodson, 1992).

The 72 species recorded are not far from S**max* Chao 2 (highly accuracy) (Hellmann & Fowler, 1999) and the total is distinctly higher than the expected ATBI per locality. This demonstrates that our part of Thailand contains more species than can be packed in any single waterbody, i.e. there must be species turnover between localities. At least some of these localities are therefore expected to have unique, as yet unknown traits. The best candidates for this status are those sites where rare species are found. The complementarity results confirm the non-cosmopolitanism concept, even at the South East Asian level. A value of 60% complementarity among neighbor countries or zones indicates that the number of species in common is quite low (>50% found in total localities). However, the data used in our calculations were based on different sampling methods and sampling efforts, which may handicap comparisons. Moreover, at the regional scale, the data used come from different habitats and are based on a different number of studies. Finally, taxonomic problems affect the species lists. The problem is not only what a species is called but also that, until recently, groups of related species tended to be lumped under one name. Thus, each species lists reflect the taxonomist's experience and the information available at his time. For example, we expect that a renewed study effort in Malaysia and the Philippines will lead to the discovery of many extra species in these countries, possibly

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even to a doubling of their current species list. In pairwise habitat comparisons, clearly, more species co-occur in similar habitat types (vegetated, pelagic, lotic etc.) and their complementarity is low. The presence of a vegetation zone leads to more microhabitats. As a result, more cladoceran species live here than in non-vegetated habitats, and it makes little sense to compare the two types of habitats, except to demonstrate the simple fact that they are different.

We divided our species list into five categories according to their percentage occurrence in the total number of samples: very common (70–100%), common (50–70%), average (25–50%), rare (12.5–25%) and very rare (1–12.5%). The proportion of very common and common species relative to rare ones is small (2:3:15:14:39), i.e. there are few common but many rare species, a familiar fact in a tropical environment. Some exceptionally rare species such as *Alona* cf. *dentifera*, *A.* prope *karelica* and *A. sarasinorum* were also found, and the discovery of a rare mediterranean species such as *Ephemeroporus phintonicus* in the region, considerably widening its geographical distribution, suggests adaptation to a particular biotope.

### *Status of the cladoceran fauna in Thailand*

Although cladoceran studies in Thailand have had a short history, the species list is impressive (Boonsom, 1984; Pholpunthin, 1997; Sanoamuang, 1998; Sanoamuang, et al., 2001; Sa-ardrit, 2002). The present new records take the Thai cladoceran fauna to 105 species. Compared to its neighbors, the current Thai fauna seems distinctly richer than that of Malaysia (63 species) (Idris, 1983) and the Philippines (49 species) (Mamaril & Fernando, 1978). The number is also high relative to other tropical countries (Dumont, 1994). However, the 72 species of the present study are similar to the 68 species of the latest study in the South (Sa-ardrit, 2002), restricted to only one province and 26 localities, but with five samplings per year. This suggests that in a survey, replicating samplings per locality might have the same effect as expanding the number of habitats sampled only once or twice. Thus, for a truly exhaustive, ATBI-type of survey, some combination of both seems required. Why this is so remains unclear. It may be that some form of *seasonal succession* of species is present in this "tropical" environment, but it is also possible that repeated sampling simply picks up more rare species. An experimental approach is needed to solve this ambiguous situation.


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