Diversity of Sessile Rotifers (Gnesiotrocha, Monogononta, Rotifera) in Thale Noi Lake, Phatthalung Province

Phuripong Meksuwan

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Science in Zoology

Prince of Songkla University

2011

Thesis Title Diversity of Sessile Rotifers (Gnesiotrocha, Monogononta, Rotifera) in Thale Noi Lake, Phatthalung Province

Author Mr. Phuripong Meksuwan

Major Program Zoology

Major Advisor:

…………………………………………

(Assoc. Prof. Dr. Pornsilp Pholpunthin)

Co-advisor:

……………………….........................

(Prof. Dr. Hendrik Segers)

Examining Committee:

……………………………..Chairperson

(Asst. Prof. Dr. Supenya Chittapun)

……………………………………………..

(Prof. Dr. Saowapa Angsupanich)

……………………………………………..

(Assoc. Prof. Dr. Pornsilp Pholpunthin)

The Graduate School, Prince of Songkla University, has approved this thesis as partial fulfillment of the requirements for the Master of Science Degree in Zoology

…………………………………....

(Prof. Dr. Amornrat Phongdara)

Dean of Graduate School

ชื่อวิทยานิพนธ์ ความหลากหลายของ Sessile Rotifers (Gnesiotrocha, Monogononta, Rotifera) ในทะเลน้อย จังหวัดพัทลุง

ผู้เขียน นายภูริพงศ์ เมฆสุวรรณ

สาขาวิชา สัตววิทยา

ปีการศึกษา 2553

บทคัดย่อ

ศึกษาความหลากหลายของโรติเฟอร์ประเภทยึดเกาะที่พบบนพืชน้ำ (เฉพาะส่วนที่อยู่ใต้ผิวน้ำ) จำนวน 15 ชนิด จาก 9 สถานีเก็บตัวอย่าง ใน 3 ช่วงฤดูกาล คือ ช่วงต้นฝน (กลางมิถุนายน – กลางสิงหาคม 2552) ช่วงฝน (พฤศจิกายน – ธันวาคม 2552) และช่วงแล้ง (มีนาคม – เมษายน 2553) ในทะเลน้อย จังหวัดพัทลุง พบโรติเฟอร์กลุ่มนี้ทั้งสิ้น 45 ชนิด ประกอบด้วยพวกเกาะติดฐาน 42 ชนิด และพวกยึดเกาะเป็นโคโลนีล่องลอย 3 ชนิด ในจำนวนนี้พบชนิดที่คาดว่าจะเป็นสกุลใหม่ 1 ชนิด ชนิดใหม่ 2 ชนิด ชนิดที่พบครั้งแรกในเขต Oriental ซึ่งครอบคลุมภูมิภาคเอเชียตะวันออกเฉียงใต้ 10 ชนิด และชนิดที่พบครั้งแรกในประเทศไทย 27 ชนิด และจากการศึกษาลักษณะทางสัณฐานวิทยาของ *Floscularia noodti* Koste พบว่าควรย้ายไปอยู่ในสกุล *Ptygura* Ehrenberg, 1832

ชนิดของโรติเฟอร์ประเภทยึดเกาะที่พบบนพืชน้ำชนิดต่าง ๆ มากชนิดที่สุด ได้แก่ *Limnias melicerta* Weisse และ *Ptygura barbata* Edmondson โดยพบบนพืชน้ำ 12 ชนิด รองลงมา ได้แก่ *Floscularia conifera* (Hudson) และ *Limnias ceratophylli* Schrank พบบนพืชน้ำ 10 ชนิด ส่วนโรติเฟอร์ชนิดที่พบบนพืชน้ำเพียงชนิดเดียว ได้แก่ *Acyclus* sp., *Collotheca heptabrachiata* (Schoch), *Floscularia wallacei* Segers & Shiel, *Lacinularia* cf. *pedunculata* Hudson, *Ptygura beauchampi* Edmondson และ *Stephanoceros fimbriatus* (Goldfusz) พืชน้ำที่มีโรติเฟอร์กลุ่มนี้เกาะอาศัยอยู่หลากชนิดที่สุด คือ ผักตบชวา และผักกระเฉด โดยพบโรติเฟอร์ทั้งสิ้น 24 ชนิด รองลงมา ได้แก่ หญ้าพองลม และแพงพวย พบโรติเฟอร์ 17 และ 16 ชนิด ตามลำดับ ส่วนพืชน้ำที่มีโรติเฟอร์เกาะอาศัยอยู่น้อย ได้แก่ บาแหนปากเป็ด และจูดหนู พบโรติเฟอร์ 2, 2 และ 1 ชนิด ตามลำดับ นอกจากนี้พบว่าความผันแปรของจำนวนชนิดและองค์ประกอบชนิดของโรติเฟอร์กลุ่มนี้ระหว่างฤดูกาลที่ศึกษาเกิดขึ้นน้อยกว่าเมื่อเปรียบเทียบกับความผันแปรที่พบระหว่างสถานีเก็บตัวอย่าง โดยปัจจัยสิ่งแวดล้อมที่มีความสัมพันธ์อย่างมีนัยสำคัญกับจำนวนชนิดของโรติเฟอร์ที่พบในแต่ละสถานีเก็บตัวอย่าง ได้แก่ pH และความขุ่นของน้ำ

Thesis Title	Diversity of Sessile Rotifers (Gnesiotrocha, Monogononta, Rotifera) in Thale Noi Lake, Phatthalung Province
Author	Mr. Phuripong Meksuwan
Major Program	Zoology
Academic Year	2010

ABSTRACT

A study of diversity of sessile rotifers inhabited on fifteen species of aquatic plants (submerged parts) from nine sampling stations in Thale Noi lake, Phatthalung province was conducted. Samples were collected during three seasonal periods including light rainy (mid of June – mid of August 2009), rainy (November – December 2009) and dry period (March – April 2010). A total of 45 species including 42 sessile and 3 planktonic colonial species was identified. Of these, one belongs to a new genus and three are new species. Ten species are new to the Oriental region which includes Southeast Asia, and twenty-seven species are new to Thailand. Moreover, investigation of the morphology of *Floscularia noodti* Koste established that this taxon should be transferred to the genus *Ptygura* Ehrenberg, 1832.

The species of sessile rotifers that were observed on the highest number of aquatic plant species are *Limnias ceratophylli* Weisse and *Ptygura barbata* Edmondson, which were both found on 12 plant species, followed by *Floscularia conifera* (Hudson) and *Limnias ceratophylli* Schrank, found on 10 plant species. On the other hand, the sessile rotifers that were observed on a single plant species only were *Acyclus* sp., *Collotheca heptabrachiata* (Schoch), *Floscularia wallacei* Segers & Shiel, *Lacinularia* cf. *pedunculata* Hudson, *Ptygura beauchampi* Edmondson and *Stephanoceros fimbriatus* (Goldfusz). The aquatic plants that served as substratum for the highest diversity of sessile rotifer species were *Eichhornia crassipes* (C.Mart.) Solms and *Neptunia oleracea* Lour. on which 24 species of the rotifers were observed, followed by *Hygroryza aristata* Nees and *Ludwigia adscendens* (L.) H. Hara on which 17 and 16 species, respectively, occurred. Plants that carried only few species of sessile rotifer were *Nymphoides indicum* (L.) Kuntze, *Potamogeton malaianus* Miq. and *Eleocharis ochrostachys* Steud. on which 2, 2 and 1 species occurred, respectively. The species richness and composition of sessile rotifers among seasons varied in a low degree compared with the variation observed among the sampling stations. The environmental variables that significantly correlated with species richness of sessile rotifers among the sampling stations were water pH and turbidity.

ACKNOWLEDGMENTS

This thesis cannot be completed without benevolent assistance from the following persons and organizations.

I would like to express my gratitude to my advisor, Assoc. Prof. Dr. Pornsilp Pholpunthin, who has sharpened my thought in developing research framework, forming a theoretical basis for this kind of research, defining the scope of the work, and suggesting appropriate methods. He has given me valuable suggestion not only for international standard literature resources and connections, but also all of my problems.

My deep gratefulness goes to my co-advisor, Prof. Dr. Hendrik Segers, who brought me to the frontier of this research area where awful lots of unanswered problems await our investigation which will occupy my whole career. Over the years, I enjoyed the privilege in getting access to his comprehensive collections of literature which are directly relevant to my own research. His kind assistance in various ways and rapport definitely determines the success of my work. Professor Segers always made himself available for discussion of my problems, offered insightful suggestions and comments. Moreover, he has been a source of inspiration, urging me to dream of and aim at becoming a specialist biologist.

My special appreciation goes to the chairperson of an examining committee, Asst. Prof. Dr. Supenya Chittapun, from Department of Biotechnology, Faculty of Science and Technology, Thammasat University Rangsit Center, Pathumthani province, and Professor Dr. Saowapa Angsupanich, from Department of Aquatic Science, Faculty of Natural Resources, Prince of Songkla University, Songkhla province, who helped broaden my thoughts and perspective in handling empirical data, gave me several valuable suggestions following which this thesis becomes more meaningful.

I would like to express my deep appreciation to Assoc. Prof. Dr. Sunthorn Sotthibandhu who has taught me how great scientists think and do, reminded me of an absolute necessity to maintain an originality and an independence in thinking, and research ethics, and kind suggested in the very nice English throughout this part of acknowledgments; Assoc. Prof. Ladda Eksomtramage who financially supported me on some occasions; Asst. Prof. Dr. Supiyanit Maiphae and Miss Pannee Sa-addrit who spent her precious time discussing with me and extended my ideas; and Miss Rattanawan Inpang for securing many literatures relating to Thale Noi Lake.

My special appreciation goes to Assoc. Prof. Dr. Kitichate Sridith and his colleagues, and Assoc. Prof. Choathip Purintavaragul for offering advice in the identification of aquatic plant species. Dr Kitichate's expertise in the science of taxonomy has shaped up my thought and understanding of taxonomic concepts and practices.

I am grateful to Dr. Sahut Chantanaorrapint and Mrs. Amornrat Chantanaorrapint who taught me many useful techniques in taking the photographs and video movies which were subsequently useful for clarifying many points in taxonomic discussions. Without these photographs and the movies, I could envisage some difficulties in the interpretation of my empirical data.

Special thanks go to Mrs. Ratana Hirunphan, Mr. Sutum Mayakul, and Mr. Chanawatt Choosang for their best service and support for laboratory instruments and necessary techniques involving microscopes, water quality checker, and the use of photographic apparatuses.

I am sincerely thankful to all my best research unit members and the members of Cephalopod Research Unit for all of kind helps and encouragements. The thanks are especially due to Miss Koraon Wongkamhaeng for sharpening my ideas in many discussing points along the work and, to Miss Kringpaka Wangkulangkul for clarifying certain statistical approaches, helping me understand the whole concept and how to put them into practice.

I am extremely thankful to Department of Biology, Faculty of Science, PSU, for the best facilitates, GIS Centre, PSU, for Thale Noi Lake map, SEM laboratory, Scientific Equipment Centre, PSU, for SEM photographs, and Khuan-Khanun district office, Phatthalung province, for the precipitation data, and to all of them for the excellent services.

I feel very much grateful to the Office of Thale Noi Non-hunting Area for granting me permission to roam around the place to collect specimens. My sincere gratefulness is also extended to all the people who provided the boat travelling service, gave me useful pieces of information and helped me in sample collection.

My deep gratefulness goes to the TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT T153007, Graduate school (Grant of Thesis Support), and Faculty of Science (Research Assistant Scholarship) for the necessary financial supports.

My heart-felt appreciation goes to my parents, Mr. Prasit Meksuwan and Mrs. Urai Meksuwan who have brought me up in an environment which is conducive to my intellectual growth and development. My humble success is owed to them. I would like to thank my elder sister, Miss Wipawee Meksuwan, my relatives, and Miss Yurachat Yodyotee, for their kind encouragement, care, and love.

Phuripong Meksuwan

CONTENTS

CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF ILLUSTRATIONS

Photographic plates

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

CHAPTER 1

INTRODUCTION

1.1 Background and Rationale

Sessile rotifers (Phylum Rotifera) are a group of microinvertebrates that are commonly found in almost every type of freshwater habitat. They are periphytonic, living permanently attached to substrates such as aquatic plants and filamentous algae, and they are usually observed in abundant within an investigated aquatic habitat (Edmondson, 1944; Wallace, 1980). Observation and identification of these animals requires having live specimens and studying the hard parts of their feeding apparatus, the trophi (Segers, 1997; Segers and Shiel, 2008). Therefore, studying them cannot be done using routine plankton sampling techniques in which involve hauling a plankton net in water body and search for them in preserved sample. As a result, they are mostly ignored in rotifer's biodiversity surveys (Chittapun *et al*., 2007; De Paggi and Koste, 1988; De Ridder, 1989; Fernando and Zankai, 1981; Pourriot, 1996; Sanoamuang, 1998; Sarma and Manuel, 1998; Segers, 1993; Sharma, 2005; Sharma and Sharma, 2001). And biodiversity knowledge of them has proposed poorly developed (Segers, 2001; Wallace *et al*., 2006). In addition, a new genus and several new species of the sessile rotifers have recently been described (Segers and Shiel, 2008), and even a study on a limited number of plant materials, many possible new species and new record of Oriental region were reported (Segers *et al*., 2010). These indicated that the knowledge of biodiversity of sessile rotifers seem to has a large gap.

In Thailand, knowledge of sessile rotifers is scarce because of almost lack of appropriate study on these animals. Sessile rotifers which are reported in species list of Thai fauna mostly originate from coincidental observations during routine zooplankton studies (Augsupanich, 1985; Augsupanish and Rukkheaw, 1984; Boonsom, 1984; Chittapun *et al*., 2007; Chittapun and Pholpunthin, 2001; Inpang, 2008; Pholpunthin, 1997; Pholpunthin and Chittapun, 1998; Sanoamung, 1998, 2007; Segers and Pholpunthin, 1997; Teeramaethee *et al*., 2006; Savatenalinton and Segers, 2005; Segers *et al*., 2004; except the study of Koste (1975)). Therefore, to increase our knowledge on biodiversity in Thailand, a focused study on these animals is interesting subject. That implies searching and investigating them on the substrates they inhabit such as aquatic plants.

Thale Noi Lake is the first Ramsar Site of Thailand and is characterized by its high biodiversity, complex ecosystem, and as being a valuable area for conservation. The lake is valuable not only in the ecological sense but also for the livelihoods of communities living around the lake, as the lake provides diverse ecosystem services such as fisheries, traveling, and transportation (Office of Environmental Policy and Planning, 2000). Thale Noi Lake can by subdivided in several zones (peat swamp zone, small inlet zone, for example) (Inpang, 2008), and many aquatic plant species were reported from the lake (Leingpornpan and Leingpornpan, 2005b; Office of Environmental Policy and Planning, 2000). These indicate that the lake may suite as habitat for several species of sessile rotifers since many species of them have been reported that their occurrences is linked to ambient water environments and specific preference of substrate features which here referred to the diversity of aquatic plant species in the lake and of their morphological differentiations (Edmondson, 1944, 1945; Wallace, 1978, 1980). Therefore, focus on diversity of sessile rotifers in Thale Noi Lake seems to be suitable to fill the gap of knowledge. Moreover, many species of waterfowl rely on Thale Noi Lake during migration for feeding and mating (Office of Environmental Policy and Planning, 2000). This is relevant to the plankton communities of the lake as the birds may carry propagules (resting eggs) of several plankton taxa, including sessile rotifers, from other habitats into the lake (Segers and De Smet, 2008). This study therefore expected that the diversity of sessile rotifers will be similarly high as that of planktonic and littoral rotifers, and contributes significantly to biodiversity of Thailand. The present study therefore focused on the diversity of the sessile rotifers inhabit on several species of aquatic plants in Thale Noi Lake, and intended to deliver a first comprehensive report on this fauna in Thailand.

1.2 Literature review

1.2.1 General background

1) Biodiversity and importance of biodiversity knowledge

Biodiversity or biological diversity means the total varieties of living things in all levels of biological organizations including genetic, species, ecosystem, and biome level as well as all aspects of them such as compositional, structural, and functional aspect. Moreover, number of evolutionary lineages and the degree of distinctness among them, taxonomic diversity, for example, can be taken into account (Groom *et al*., 2006; Magurran, 2004).

Biodiversity itself is very important since they provide instrumental values or ecosystem services including supporting, provisioning, regulating and cultural service, and they have intrinsic values (for details see Groom *et al*., 2006). Apart from these, knowledge of biodiversity, in particular species diversity that composed of richness (number of species) and evenness (number of individuals/biomass of each species) and considered as the most practical and effective level (Magurran, 2004), is vital to many disciplines under umbrella of "Biology". For example, species diversity study within a focal area and time unit is the way to gain focal materials of a taxon for "Taxonomy" study (Winston, 1999). Species diversity data constitute the studies of distribution pattern of organisms, diversity gradient along latitude, altitude, and mainland to archipelagos, provincialism and endemism, community compositions and their ecological affinity in which these works are in the areas of "Biogeography" and "Ecology" (Lomolino *et al*., 2006; Molles, 2010). "Conservation biology", principally, attempts to protect biodiversity against biodiversity crisis that clearly recognized in the present time. Thus, knowing of who are where or species diversity in a focal area is one of the top priorities of the subject. Besides Biology, "Politically" and "Economically" require biodiversity data for policy planning for decision of degree of lands and natural resource uses within their country, determining protected areas, managing high biodiversity areas for ecotourism, for example (Groom *et al*., 2006).

2) Rotifera and the sessile rotifers

Rotifers are microscopic aquatic or semi-aquatic, predominantly freshwater Metazoa. They are bilaterally symmetrical, pseudocoelomate animals with three prominent body regions (corona, trunk, and foot) and they constitute Phylum Rotifera (Segers, 2008; Wallace, 2002; Wallace *et al*., 2006). Around two thousand and thirty valid species of the Phylum are known worldwide, and they are classified into two Classes, Class Eurotatoria [Subclass Monogononta (1,570 species) and Subclass Bdelloidea (461 species)] and Class Pararotatoria [Order Seisonacea (3 species)] (Segers, 2007; Wallace *et al*., 2006). Rotifers are the most important primary consumers in many aquatic ecosystems, especially in freshwater ecosystems. They have large population size and short generation times that make them a very important food source in aquatic food webs (Wallace, 2002; Wallace *et al*., 2006). Rotifers have the ability to disperse over long distances through passive transport of their propagules, either dormant stages, called resting eggs (produced when sexual reproduction occurs in monogononts) or anhydrobiotic specimens in bdelloids (produced by dehydration when the habitat dries out). These two types of dormant stage are small (most smaller than 100 μm.), airborne and buoyant propogules that can be passive dispersed by water current, wind and rain, or animal victors such as insects and waterfowl (Segers and De Smet, 2008). Although the propagules may be exposed to extreme physical and chemical conditions such as drought, cold, and enzyme of animal guts, they can remain viable and embryos can hatch and develop to adults or, in bdelloids, can revive to active stage when they arrive in new habitats (Segers and De Smet, 2008). Ecologically, rotifers can be divided in four groups, according to their life styles: they are planktonic, benthic, sessile (fixosessile), or parasitic rotifers (Wallace *et al*., 2006).

Sessile rotifers are defined as all members in the four families including Atrochidae, Collothecidae, Conochilidae, and Flosculariidae (Segers, 2002; Wallace, 1980; Wallace *et al*., 2006). Even though the members in Conochilidae and some species in Flosculariidae are planktonic colonial, this group hypothesized as advance form evolved from sessile habit, then colonial species, and the planktonic colonial habit, and usually they are taxonomically defined as sessile rotifer group (Wallace, 1980, 1987). Therefore, the present observation included this group in sessile rotifer diversity study. In total the sessile rotifers concerns 110 valid species recorded worldwide (Segers, 2007; Segers and Shiel, 2008). Of these, 45 species are recorded from the Oriental region (Segers, 2007; Segers, 2008; Segers *et al*., 2010) and 23 species are known in Thailand (e.g., Chittapun and Pholpunthin, 2001; Chittapun *et al*., 2007; Koste, 1975; Sanoamung, 1998, 2007; Savatenalinton and Segers, 2005; Segers *et al*., 2004; Teeramaethee *et al*., 2006). A brief overview of the classification of the sessile rotifer genera after Segers (2002) and Segers and Shiel (2008) is as showed below.

Class Eurotatoria De Ridder, 1957
- Subclass Monogononta Plate, 1889
  - Superorder Gnesiotrocha Kutikova, 1970
    - Order Collothecaceae Harring, 1913
      - Family Atrochidae Harring, 1913
        - Genus1 *Acyclus* Leidy, 1882
        - Genus2 *Atrochus* Wierzejski, 1893
        - Genus3 *Cupelopagis* Forbes, 1882
      - Family Collothecidae Harring, 1913
        - Genus1 *Collotheca* Harring, 1913
        - Genus2 *Stephanoceros* Ehrenberg, 1832
    - Order Flosculariaceae Harring, 1913
      - Family Conochilidae Harring, 1913
        - Genus1 *Conochilopsis* Segers & Wallace, 2001
        - Genus2 *Conochilus* Ehrenberg, 1834
      - Family Flosculariidae Ehrenberg, 1838
        - Genus1 *Beauchampia* Harring, 1913
        - Genus2 *Floscularia* Cuvier, 1798
        - Genus3 *Lacinularia* Schweigger, 1826
        - Genus4 *Limnias* Schrank, 1803
        - Genus5 *Octotrocha* Thorpe, 1893
        - Genus6 *Pentatrocha* Segers & Shiel, 2008
        - Genus7 *Ptygura* Ehrenberg, 1832
        - Genus8 *Sinantherina* Bory de St. Vincent, 1826

The members of order Collothecaceae are ambush predators whereas order Flosculariaceae are filter-feeders. Although sessile habit of these two groups has believed to be convergent evolution, there is empirical result from a recent molecular study that showed some interesting relationship between the two regarding under superorder Gnesiotrocha (Wallace *et al*., 2006). Studies on numerous species of the sessile rotifers confirmed that larvae of them show clear selection of substrate for settling. This holds for species as diverse as *Collotheca gracilipes* Edmondson (this name is synonym of *Collotheca campanulata* (Dobie) in the present (Segers, 2007)), *Cupelopagis vorax* (Leidy), *Floscularia conifera* (Hudson), *Ptygura beauchampi* Edmondson, *Ptygura brevis* (Rousselet). Moreover, many factors that effect the substrate selection of sessile larvae are physical features of the surface of substrate and the chemistry of water layers around them, such as pH, concentration of bicarbonate and calcium, magnesium, and conductivity (Edmondson, 1944, 1945; Wallace, 1978).

3) Rotifer researches and sessile rotifers in Thale Noi Lake

The knowledge of rotifers in Thale Noi Lake results from both direct rotifer studies and from general zooplankton studies and accumulated from 1984 to the present (Angsupanich, 1985; Angsupanich and Rukkheaw, 1984; Inpang, 2008; Pholpunthin, 1997; Segers and Pholpunthin, 1997). The first study reported rotifers at the genus level (17 genera were reported). Many genera found contained more than one species and the two most abundant genera (in term of individuals/liter) were *Anuraeopsis* and *Polyarthra* respectively (Angsupanich and Rukkheaw, 1984). In 1997, a paper by Segers and Pholpunthin (1997) added seventeen new records of rotifer species for Thailand from the lake and contributed two new species to science, *Cephalodella songkhlaensis* Segers & Pholpunthin, 1997 and *Trichocera siamensis* Segers & Pholpunthin, 1997. Three independent zooplankton studies found that rotifers showed the highest taxa richness of all zooplankton (Angsupanich, 1985; Pholpunthin, 1997; Inpang, 2008) and one of them concluded that rotifers are the most important group among zooplankton communities in the ecosystem of the lake (Angsupanich, 1985). In addition, not only direct studies on rotifers contributed to the knowledge of rotifer species richness of the Thai and/or Asian fauna, also general zooplankton community studies do so. Such a study, Pholpunthin (1997), reported 14 species as new records for Thailand, and 2 species that constitute new records for Asia.

Lack of a study focus on the sessile rotifers in Thale Noi Lake or almost lack even in Thailand except the only one study of Koste (1975) in which focused diversity of rotifers on floating root zone of water hyacinth, *Eichhornia crassipes* (Mart.) Solms grow in Borapet marsh, Nakornsawan province, central part of Thailand. However, the routine zooplankton researches in Thale Noi Lake mentioned above contributed three known genera of sessile rotifers such as *Collotheca*, *Floscularia*, and *Ptygura* from fifteen genera recorded worldwide (Segers, 2007; Segers, 2008; Segers and Shiel, 2008).

4) Species diversity and distribution of aquatic plants in Thale Noi Lake

Studies of aquatic plants in Thale Noi Lake especially regarding species diversity, have a quite long history [(Choathip Purintavaragul and Vachira Lheknim, 1983; Parinya Keawsukmanee, Choathip Purintavaragul and Pranom Chantaranothai, 1983; Thailand Institute of Scientific and Technological Research, 1982 (cited by Leingpornpan and Leingpornpan, 2005a)); Leingpornpan and Leingpornpan, 2005b; Office of Environmental Policy and Planning, 2000]. In the most recent work, 32 families concerning 60 species of aquatic plants were reported. These aquatic plant species all occur along the bank, in the littoral and pelagic zones, but about 20 species dominate the zones (Leingpornpan and Leingpornpan, 2005b; Office of Environmental Policy and Planning, 2000).

Over a year (e.g., Nov. 2004-May 2005), the species composition of aquatic plants changes slightly but their abundances exhibits more pronounced changes. For example, Leingpornpan and Leingpornpan (2005b) found the lowest abundances of many aquatic plants species in December and the highest in May. Most dominant aquatic plants are most abundant in the northern part of the lake and extend downward to both the eastern and western parts.

1.2.2 Diversity of sessile rotifers relating to the frontiers of knowledge

1) On Taxonomy and Biodiversity

There are the two aspects involve study of diversity of organisms that are taxonomic diversity study and biodiversity study within a focal space and time. Taxonomic diversity study is responsible for taxonomists or systematists while the biodiversity study is mostly responsible for ecologists and biogeographers. The former discipline works on the concept of natural unit (taxon) among organisms and tries to understand the historical relationship between them. Working on this job, a taxonomist faces, at least, the problems such as high morphological variation in observed organisms, closely related taxa, cryptic species, and convergent evolution (i.e., homoplasy phenomenon) that these may interfere with decision of the scientists to compete with a hidden natural system (Mayr, 1999; Minelli, 1993; Segers, 2008). On the other hand, the latter discipline does on diversity of living things in all levels and aspects as mentioned above [part 1.2.1, 1)]. This task tries to answer the question, for instance, how many species of focal organisms in a given habitat, why their composition of diversity look like that, what is a process that shape a pattern of diversity in space and time (Groom *et al*., 2006; Lomolino *et al*., 2006; Magurran, 2004)? The present study majority involve the letter discipline in which this study may provide the data to test proposing of large hidden diversity of sessile rotifers especially within Southeast Asia region since poor biodiversity knowledge of this animals has been recognized (Segers, 2001, 2008; Segers *et al*., 2010). Even though the aim is involved diversity in a focal area, this study has possibility to discover an undescribed taxon in which this job involved the former discipline, taxonomy, as well. Finally, observation on various aquatic plant species may provide the data of habitat diversity of the animals.

2) On Biogeography

Like other groups of organisms that their traditional paradigms in "Biogeography" such as geographic distribution pattern usually be argued when knowledge of other biology such as "Ecology" is emerged (Lomolino *et al*., 2006), rotifers as well they previously believed are cosmopolitan animals in the whole group because effect of absolutely long distant dispersal ability point of view in small organisms as far as the "Ubiquity theorem" is concerned (Finlay, 2002; Fenchel and Finlay, 2004). However, this view was argued from considering of many emerged evident in ecology researches that showed requirement conditions to be a best disperser. Besides ability to establish a tiny and resistant stage, the requirements are an appropriate condition for establishing such propagule, a hatch condition (Wallace *et al*., 2006), and re-colonization ability within a new habitat (e.g., Monopolization hypothesis) (De Meester *et al*., 2002). Moreover, a relevant research showed phenomena against the cosmopolitan view such as reporting species diversity gradient in some diverse taxa in rotifers (e.g., Segers and De Smet, 2008). Therefore, the present diversity study on one of the debated microinvertebrate groups will provide progressive data to make a position between the different schools. In addition, not only the debatable story where diversity study of sessile rotifers is involved, sessile rotifers may be one of the interesting groups to correct faunal affinity of Oriental region or at least Southeast Asian (Segers, 2001).

3) On Ecology

Habitat selection is one of the most important aspects in ecology study (Molles, 2010). Sessile animals (fixosessile) are the most relevant to this aspect since growth and reproduction through all of their life is determined by the first settlement of their larvae (Wallace, 1980). In sessile rotifers, the general conclusion of specific habitat selection (substrate type, regardless water chemistry and their biogeography) by sessile rotifer larvae still be unclear since the specific preference demonstrated in only a few species (Edmondson, 1944; Wallace, 1978) while many species have not revealed a clear possible relationship between species occurrence and their substrate types (e.g., plant species, category of plants) (Pejler and Bērziņš, 1993). Therefore, study of sessile rotifer's diversity on various aquatic plant species may provide information regarding specific habitat preference of them, but this will be strict to present/absent data of them on the investigated plants rather than having highest potential for survival and reproduction where their abundant and/or an experimental study must be concerned (Duggan, 2001; Wallace, 1980). In addition, potentials for carrying sessile rotifer's richness among different plant species can be compared.

4) The Contribution to Conservation Biology

Biodiversity in every hierarchical component is complex and always change naturally through space and time. However, if the complexity and changes of biodiversity are caused by human activities as in negative way which usually refer to decrease of complexity and biodiversity loss, "Conservation biology" will be responsible for the situation either of theoretically and pragmatically as the subject matter (Groom *et al*., 2006). Monitoring of biodiversity especially in a risk area of biodiversity threat is one of the important strategies in the discipline. Conservation is extremely different from preservation by that human can utilize ecological services around them, but should be sustainable. Thus, the monitoring is used to gain information that how much the utilization of human affect biodiversity. Ideally, the use should be without any threat to biodiversity either in short or long term scale. The area around Thale Noi Lake is known well intense of local people activities. Besides directly within the lake as mentioned above, release of contaminated and waste water into the lake, run off of sediments and organic matters, poor management of soil utilization, and activities impede water circulation have occurred to the lake (Office of Environmental Policy and Planning, 2000; Personal communication to local people). Therefore, the data of species richness and composition of sessile rotifers in Thale Noi Lake may contribute based knowledge for monitoring and evaluating an ecosystem functioning status and threat to fauna of the lake concerning activities from their own local community around the lake.

1.3 Objectives

1) To study taxon diversity and composition of sessile rotifers in Thale Noi Lake, Phatthalung province
2) To study species composition and distribution of sessile rotifers on the selected aquatic plant species, along the sampling stations, and its seasonal variations

CHAPTER 2

RESEARCH METHODOLOGY

2.1 Study area, sampling stations, and sampling periods

The present study carried out in Thale Noi Lake, Khuan-Khanun district, Phatthalung province, southern part of Thailand. The lake is relatively small, shallow, and round where located at northern end of the Songkhla Lake system. It is comprised between latitude 7^{o} 45’ 40’’ N to 7^{o} 48’ 26’’ N and longitude 100^{o} 7’ 31’’ E to 100^{o} 11’ 12’’ E (Leingpornpan and Leingpornpan, 2005b) and covers an area of about 30 km^2 (Office of Environmental Policy and Planning, 2000) (fig. 1).

Fifteen species of aquatic plants in Thale Noi Lake were selected for sessile rotifer collection. The considering criteria for selection of the aquatic plants were covering several life habits, being relatively abundance, and occurrence around the year. Nine sampling stations (TN 1 – TN 9) were designed according to distribution of the selected plant species in the lake (fig. 1, 2, table 1, 2). Identification of the aquatic plant species was done by assistance of the staffs of Plant Research Unit, Centre of Biodiversity Research of Peninsula Thailand, Department of Biology, Faculty of Science, Prince of Songkla University.

Three sampling periods were set up according to the precipitation patterns in Khuan-Khanun district, Phatthalung province (fig. 3) and the monsoon system in the area (cited in Inpang, 2008). The first one was conducted during mid of June to mid of August, 2009, the second one was during November to December, 2009, and the last one was during March to April, 2010, which these were represented as light rainy, rainy, and dry periods, respectively (fig. 3).

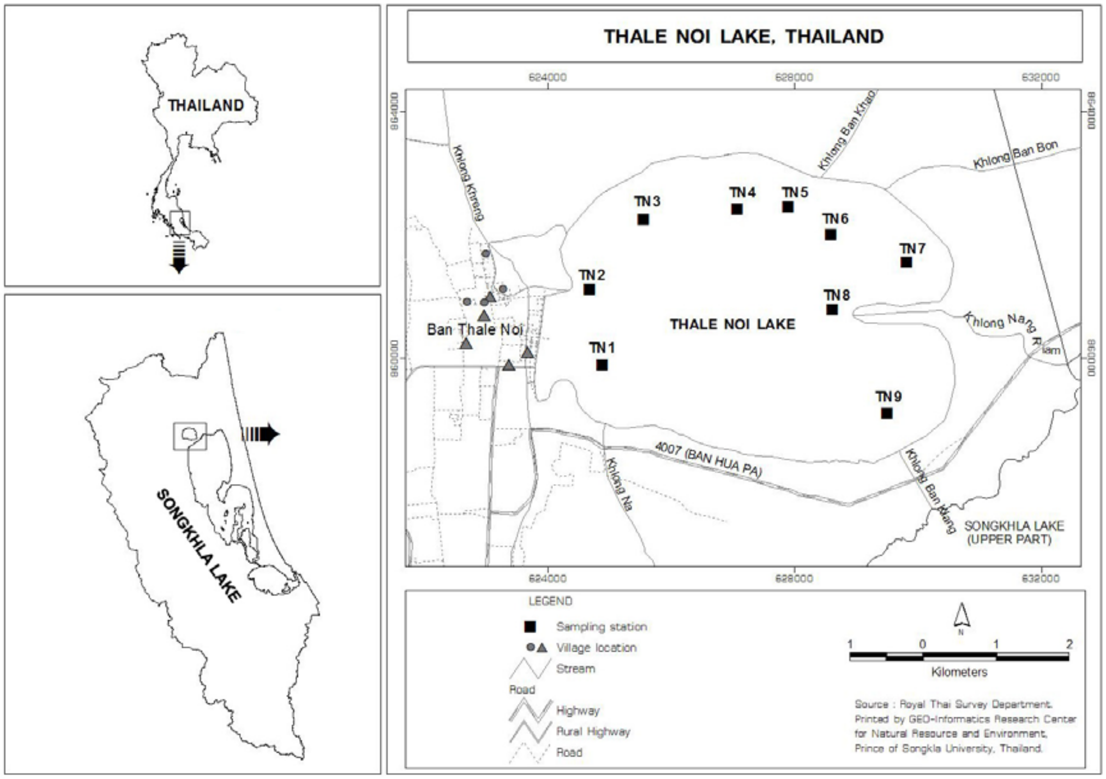

Figure 1. The study area, Thale Noi Lake, Phatthalung province, and the sampling stations (the map acquired from GIS center, PSU).

Table 1. List and details of the selected aquatic plant species.

Life habit	**Family**	**Plant species and their abbreviation**		**Common name**	**Vernacular name**
Emerged plant	Cyperaceae	1. *Eleocharis ochrostachys* Steud.	EO	Spikerush	Chut nu
	Hanguanaceae	2. *Hanguana malayana* (Jack.) Merr.	HM	-	Kong
	Nelumbonaceae	3. *Nelumbo nucifera* Gaertn.	NN	Sacred lotus	Bua luang
Floating plant	Mimosaceae	4. *Neptunia oleracea* Lour.	NO	Water mimosa	Phak kra chet
	Onagraceae	5. *Ludwigia adscendens* (L.) H. Hara	LA	Creeping waterprimrose	Phaeng phuai
	Poaceae	6. *Hygroryza aristata* Nees	HA	Floating grass	Ya phong lom
	Pontederiaceae	7. *Eichhornia crassipes* (C.Mart.) Solms	EC	Water hyacinth	Phak top chawa
	Salviniaceae	8. *Salvinia cucullata* Roxb. ex Bory	SC	Floating moss	Chok hu nu

Table 1. (contined).

Life habit	Family	Plant species and their abbreviation		Common name	Vernacular name
Root with floating leaf plant	Menyanthaceae	9. *Nymphoides indicum* (L.) Kuntze	NI	Water snow flake	Taptao yai, Bua ba, Ba
	Nymphaeaceae	10. *Nymphaea lotus* L. var. *pubescens* Hook.f. & Thomson	NL	-	Chong konni, Sai bua
Submerged plant	Ceratophyllaceae	11. *Ceratophyllum demersum* L.	CD	-	Sarai hang ma, Sarai phungchado
	Hydrocharitaceae	12. *Hydrilla verticillata* (L.f.) Royle	HV	Hydrilla	Sarai hang krarok
		13. *Potamogeton malaianus* Miq.	PM	-	Nae pak pet, Di pli nam
	Lentibulariaceae	14. *Utricularia aurea* Lour.	UA	Common bladderwort	Sarai khao niao
		15. *Utricularia* sp.	US	Common bladderwort	Sarai khao niao

Table 2. Distribution of selected aquatic plants along the sampling stations (abbreviation of the plants are according to table 1).

Sampling stations / Aquatic plant species	TN 1	TN 2	TN 3	TN 4	TN 5	TN 6	TN 7	TN 8	TN 9
EO						X			
HM		X			X			X	X
NN			X						X
NO		X		X		X		X	X
LA			X					X	
HA			X		X				
EC		X	X						X
SC					X				
NI									X
NL			X					X	X
CD	X								
HV				X					X
PM									X
UA					X		X		
US					X		X	X	

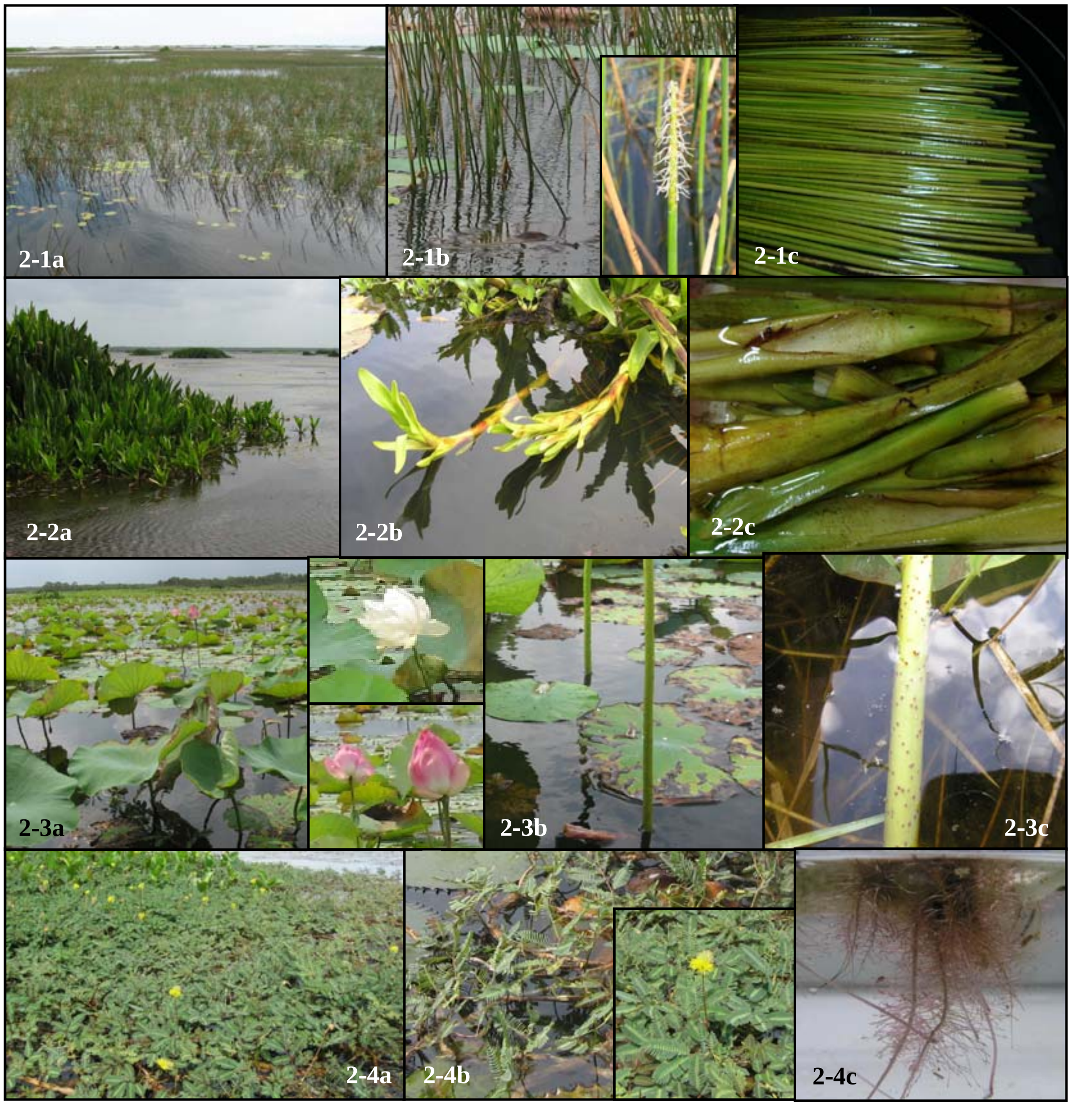

Figure 2. Photographs of the selected aquatic plants: **2-1**: *Eleocharis ochrostachys* Steud., 2-1a: patches of the plant, 2-1b: the plant in the field and their flowers, 2-1c: the investigated part; **2-2**: *Hanguana malayana* (Jack.) Merr., 2-2a: clusters of the plant, 2-2b: lateral braches as target for investigated part collecting, 2-2c: the investigated part; **2-3**: *Nelumbo nucifera* Gaertn., 2-3a: patch of the plant and their flowers (different colours have been considered as different variety within the same species – Plant Research Unit, PSU), 2-3b, c: the investigated parts; **2-4**: *Neptunia oleracea* Lour., 2-4a: cluster of the plant, 2-4b: the plant in the field and their flowers, 2-4c: the investigated part, their roots.

Figure 2 (condtinued). **2-5**: *Ludwigia adscendens* (L.) H. Hara, 2-5a: cluster of the plant, 2-5b: their flowers, 2-5c: investigated roots; **2-6**: *Hygroryza aristata* Nees, 2-6a: cluster of the plant, 2-6b: the plant in the field, 2-6c: investigated roots; **2-7**: *Eichhornia crassipes* (C.Mart.) Solms, 2-7a: clusters of the plant, 2-7b: investigated roots; **2-8**: *Salvinia cucullata* Roxb. ex Bory, 2-8a: clusters of the plant, 2-8b: investigated roots.

Figure 2 (condtinued). **2-9**: *Nymphoides indicum* (L.) Kuntze, 2-9a: the plant in the field, 2-9b: their flowers, 2-9c: investigated under leaf; **2-10**: *Nymphaea lotus* L. var. *pubescens* Hook.f. & Thomson, 2-10a: patch of the plant and their flowers, 2-10b: their flower, 2-10c: investigated under leaf; **2-11**: *Ceratophyllum demersum* L., 2-11a: the plant in the field, 2-11b, c: investigated parts; **2-12**: *Hydrilla verticillata* (L.f.) Royle, 2-12a: the plant in the field, 2-12b, c: investiagated parts.

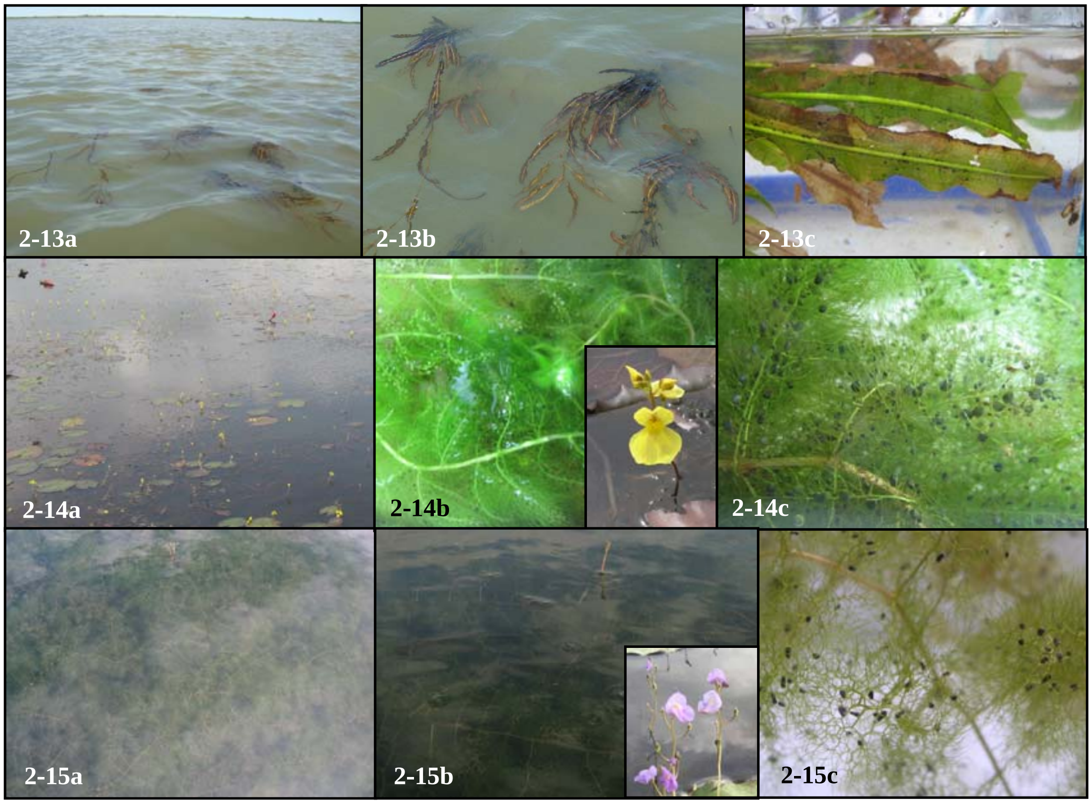

Figure 2 (condtinued). **2-13**: *Potamogeton malaianus* Miq., 2-13a, b: the plant in the field, 2-13c: investigated leaves; **2-14**: *Utricularia aurea* Lour., 2-14a: patch of the plant, 2-14b: collected plant sample, 2-14c: investigated parts; **2-15**: *Utricularia* sp., 2-15a, b: the plant in the field, 2-15c: investigated parts.

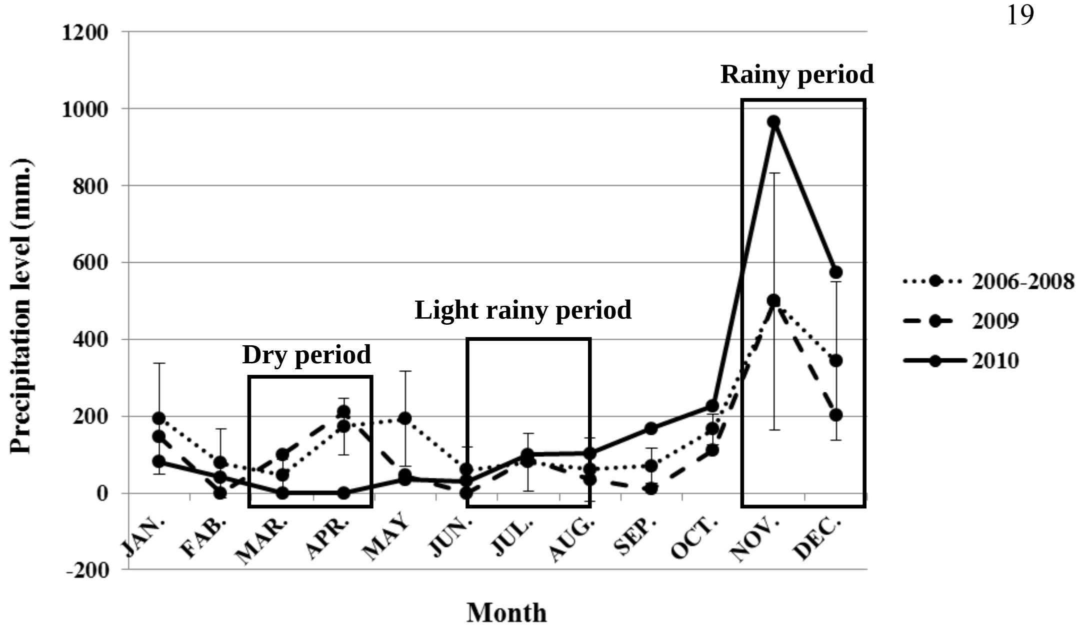

Figure 3. Precipitation patterns of the years, 2006-2010, in Khuan-Khanun district, Phatthalung province, and the sampling periods (data were acquired from Khuan-Khanun district office, Phatthalung province).

2.2 Specimen collecting and studying methods

In each sampling station, the selected aquatic plants were collected qualitatively. In emerged plants, the emerged parts were cut out and only the submerged parts were cut at around thirty centimeter depth in order to collect as investigated parts, except *Hanguana malayana* (Jack.) Merr. that only young submerged leaves from a young shoot (laterally-around a plant tussock) were collected (fig. 2-2b, 2-2c). In the other forms of life habits, submerged parts of the plants that were under water surface to around thirty centimeter depth were cut, rinsed in the field with local, filtrated lake water (the lake water was filtered with 60 µm mesh size plankton net and contained in a 10 liters plastic jar) to remove as much as possible free-living predators of the sessile rotifers, and placed into a large container (e.g., plastic bag) filled with local, filtrated lake water. Afterwards, the collected plants were brought to laboratory, under slightly cooled conditions to avoid biochemical and biological changes in the samples during transport. At arrival, the samples were placed into aquariums in the laboratory as soon as possible. The aquariums were placed near the windows under day light and oxygenated.

In laboratory, small parts of the plants were selected randomly (via cutting or peels) and immediately put into a plastic chamber with a small amount of filtrated lake water. The plant materials were observed under a stereo microscope to search for sessile rotifers. All observed sessile rotifers were picked up for further investigation. The observation was done until no new recorded of sessile rotifers was found in the sample.

Observation and identification of the sessile rotifers were performed under SZ 51 Olympus stereo microscope and CH 30 Olympus compound microscope. The photographs of an observed specimen were taken using BX 51 Olympus compound microscope with DP 71 and DP 12 photographic apparatuses linked to the computers. And free hand drawing of sessile rotifers was done from the photographs and real observation via the microscopes. Trophi were prepared for observing with a scanning electron microscope (SEM) following the method of De Smet (1998).

The major literatures used for identification of the sessile rotifers were Koste (1978), Segers (1997) and Segers and Shiel (2008). Moreover, there are the literatures used for taxonomic discussion that were Colledge (1918), Edmondson (1939, 1949), Harring (1913), Hudson and Gosse (1886, 1889), Penard (1914), Segers (2007), Segers *et al*. (2010), Shephard (1899), Vidrine *et al*. (1985), Western (1891).

2.3 Measurement of environmental variables

To characterize the seasonal periods and sampling stations by their environmental features, *water temperature*, *conductivity*, and *pH* were measured with the water proof portable meter (PC 300, EUTECH), and *turbidity* and *salinity* were measured with the calibrated water quality checker (U-10, HORIBA). All of the variables were measured at about 20 cm depth from water surface.

2.4 Data analyses

1) Measurement of community similarity

The present/absent similarity of Sørensen (1948) [C_S] cited in Magurran (2004) was obtained to measure species composition similarity of sessile rotifers among focal assemblages.

The index formula is

$$C_S = 2a/2a+b+c$$

where a = the total number of species present in both communities; b = the number of species present only in community 1; and c = the number of species present only in community 2.

2) Comparison of water environmental variables

To compare water environmental variables measured during the seasonal periods and along the sampling stations, one-way ANOVA test was used due to the JMP 8-trial package (SAS, 2008). For comparison among the seasonal periods, the data of temperature, conductivity, and turbidity were transformed using ln (X+1). For comparison among the sampling stations, during the rainy period, the data of pH and conductivity were transformed using X^2 and 1/X, respectively, and during the dry period, the data of pH and turbidity were transformed using 1/X and ln (X+1), respectively.

3) Correlation analysis

Analysis of correlation between species richness of sessile rotifers and water environmental variables investigated along the sampling stations during rainy and dry period was analyzed using Pearson correlation due to the JMP 8-trial package.

4) Measurement of frequency of occurrence

Frequency of occurrence of each observed sessile rotifer species was calculated by presence of that species on the total plant samples. A total of plant samples was originated from all investigated plant species collected from all sampling stations (33 samples; see table 2.) in the three sampling seasonal periods. However, because there was the problem in reference to the light rainy period (see part 3.2, chapter 3), therefore the total plant samples using for the calculation were from the rainy and dry periods (33 x 2 = 66 plant samples; n = 66).

5) Commonness and rarity determination

Commonness and rarity of observed species were represented by their frequency of occurrence. However, the 100 % of the occurrence (the most common) originated from a species that contained a highest percentage of frequency of occurrence among the observed species.

Ranges of rarity classes were determined according to modification of Gaston's first quartile cutting point (Magurran, 2004). Rare class was cut at 25 % and very rare class was cut at first quartile of the rare one. For common group above the rare first quartile, common and very common classes, were cut into equal classes. Therefore, commonness and rarity were categorized into four classes that were very rare (0.01-6.25 %), rare (6.26-25.00 %), common (25.01-62.51 %) and very common (62.52-100 %).

2.5 Limitation in the present study

The present study confine observation to species richness of sessile rotifers, even though either of species richness and evenness are the components constitute species diversity (Magurran, 2004). Nevertheless, the major aim is to discover the poorly known fauna, sessile rotifers, as much as possible. And investigation of the number of each sessile rotifer per a unit area on an inhabiting plant is complicated due to different shapes of different parts of the plant are concerned, and different substrate types have different methods of investigation (Edmondson, 1945). These are reasonable, therefore, to neglect the part of species evenness. Nevertheless, only species recorded data can be vital to many subjects as mentioned above [part 1.2.1, 1); 1.2.2], and frequency of occurrence of them demonstrated here might reflect their relative abundance on which this could be enough to represent species diversity of sessile rotifers in Thale Noi Lake to some extent.

CHAPTER 3

RESULTS

3.1 Taxon diversity and taxonomy of sessile rotifers in Thale Noi Lake

A total of 45 species including 42 sessile and 3 planktonic colonial species were identified in the present study (table 3). The taxa observed belong to two orders, four families, and twelve known genera. One new genus and two new species were proposed here. Ten species are new recorded of Oriental region, and twenty-seven species are new to Thai fauna. Moreover, *Acyclus* sp. has potential to be a new species but the number of the specimens was inadequate for accomplishing; *Floscularia noodti* Koste should be transferred to the genus *Ptygura*; *Limnias ceratophylli* Schrank was recognized at least two different forms of a certain diagnostic character that might reflect species complex; *Collotheca algicola* (Hudson), *Collotheca ambigua* (Hudson), *Lacinularia* cf. *pedunculata* Hudson, and *Ptygura* sp.2 reveal need for further investigations. In addition, the present data supported that *Octotrocha speciosa* Thorpe is likely to be changed their geographical distribution from worldwide distribution to restrict within Southeast Asia and China. The taxonomic and biogeographic notes on these taxa mentioned were below.

Table 3. List of sessile rotifers in Thale Noi Lake, Phatthalung province (* = new record of Oriental region and Thailand, ** = new record of Thailand, *** = proposed new taxa).

Sessile taxa

Acyclus inquietus Leidy, 1882**
Acyclus sp.
Beauchampia crucigera (Dutrochet, 1812)
Collotheca algicola (Hudson, 1886)
C. ambigua (Hudson, 1883)
C. campanulata (Dobie, 1849)**
C. campanulata var. *longicaudata* (Hudson, 1883)*
C. heptabrachiata (Schoch, 1869)*
C. ornata (Ehrenberg, 1832)**
C. stephanochaeta Edmondson, 1936*
C. tenuilobata (Anderson, 1889)**
C. trilobata (Collins, 1872)**
Collotheca sp.***
Floscularia armata Segers, 1997**
F. bifida Segers, 1997**
F. conifera (Hudson, 1886)
F. pedunculata (Joliet, 1883)*
F. ringens (Linnaeus, 1758)
F. wallacei Segers & Shiel, 2008*
Lacinularia flosculosa (Muller, 1773)**
L. cf. *pedunculata* Hudson, 1889
Limnias ceratophylli Schrank, 1803
L. melicerta Weisse, 1848
Melicerta coloniensis Colledge, 1918*,***
Octotrocha speciosa Thorpe, 1893**
Pentatrocha gigantea Segers & Shiel, 2008**
Ptygura agassizi Edmondson, 1948*
P. barbata Edmondson, 1939**
P. beauchampi Edmondson, 1940**
P. crystallina (Ehrenberg, 1834)**
P. ctenoida Koste & Tobias, 1990*
P. elsteri Koste, 1972
P. furcillata (Kellicott, 1889)
P. longicornis (Davis, 1867)*
P. mucicola (Kellicott, 1888)
P. noodti (Koste, 1972) comb. nov.*
P. pedunculata Edmondson, 1939**
P. tacita Edmondson, 1940**
P. wilsonii (Anderson & Shephard, 1892)*
Ptygura sp.1***
Ptygura sp.2
Sinantherina socialis (Linnaeus, 1758)
Stephanoceros fimbriatus (Goldfusz, 1820)**
S. fimbriatus var. *millsii* (Kellicott, 1885)*

Planktonic colonial taxa

Conochilus (Conochilus) hippocrepis (Schrank, 1803)**
Sinantherina semibullata (Thorpe, 1893)
S. spinosa (Thorpe, 1893)

The propose of a new genus of sessile rotifer from Thailand

Melicerta coloniensis **Colledge, 1918** (plate 1)

The present study identified the observed specimens are conspecific with *M. coloniensis* by the original description of Colledge (1918), although this species name was not included in the recent annotated checklist of the phylum Rotifera where might be the recognition of this species has been uncertain (Segers, 2007). From critical investigation, their morphological characters in particular the corona features and absent of oviferon (egg carrier) (plate 1c-1e) show that they cannot match with the current diagnoses of either their genus as the author proposed (indeed in the present time *Melicerta* is an invalid genus, and other members of the genus have been distributed into other genera) or other known genera (Harring, 1913; Koste, 1978; Segers, 2007; Segers and Shiel, 2008). For instance, their five-lobe corona resemble the member in *Pentatrocha*. However, absent of oviferon, in which the character has proposed as autapomorphic character at generic level of *Pentatrocha*, lead them out of the genus (Segers and Shiel, 2008). General individual and colony features of *M. coloniensis* remind us of *Lacinularia* species. However, the five-lobe corona and strongly differentiated unci teeth lead them away from this genus. Therefore, the present study is going to establish their own generic identity for *M. coloniensis*.

Moreover, the present study also recognized that this species resemble *Octotrocha speciosa* Thorpe recorded from western hemisphere and Australia, but these reports have already proposed as misidentification (Segers *et al*., 2010). Therefore, the present study supported the study that *O. speciosa* should be changed their geographic distribution from cosmopolitan to restrict within Southeast Asia and China (Segers, 2007; Segers *et al*., 2010), and *M. coloniensis* are cosmopolitan species (Meksuwan *et al*., in prep).

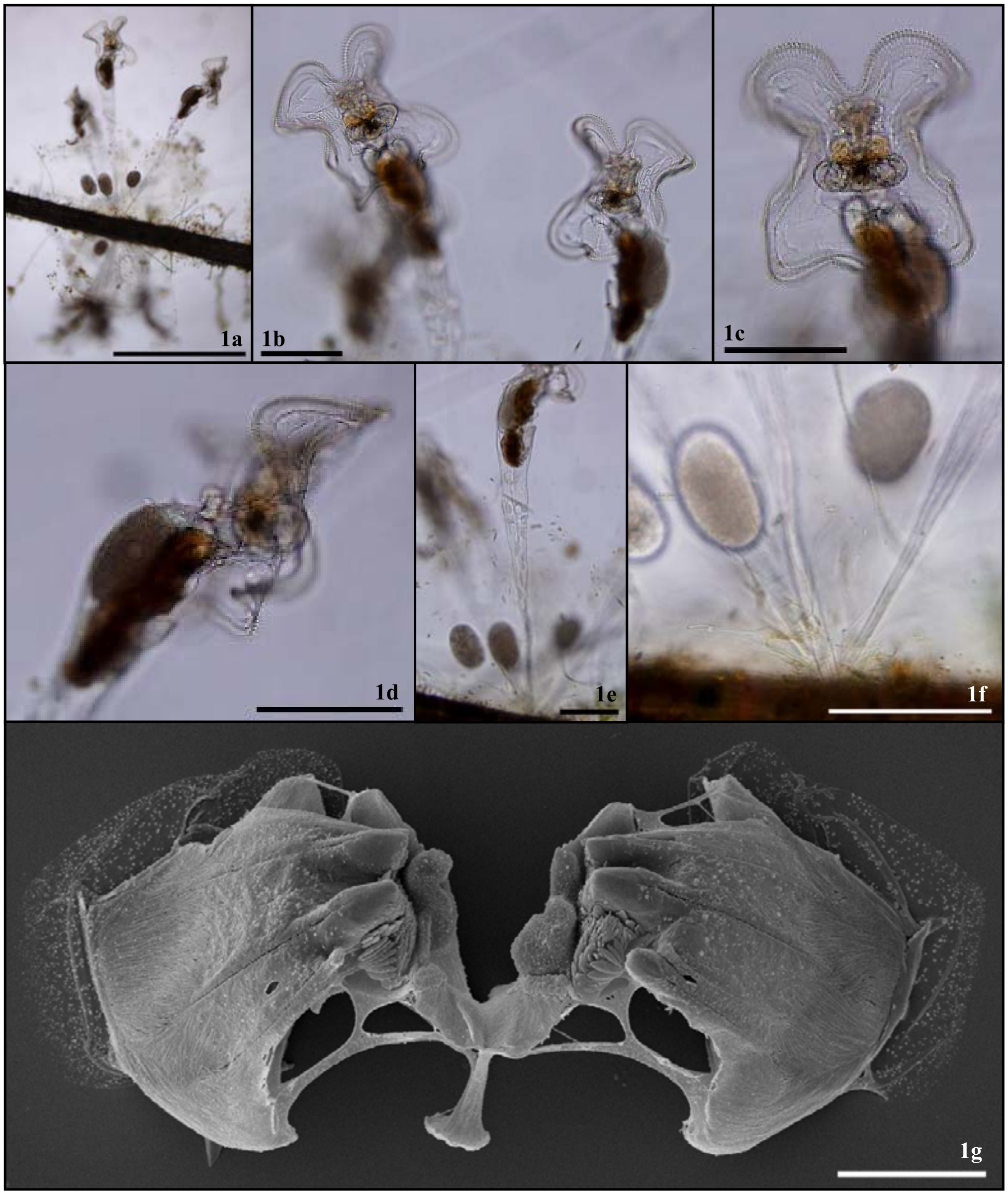

Plate 1. *Melicerta coloniensis* Colledge, 1918: 1a: a colony; 1b: females; 1c-1d: corona features in different views; 1e: their body and foot; 1f: their eggs and attached points; 1g: trophi in frontal view. Scale bars: 1a = 1 mm.; 1b-1f = 200 µm.; 1g = 20 µm.

The propose of two new species of sessile rotifer from Thailand

***Collotheca* sp.** (plate 2)

This species has broad five-lobed corona and short foot compare with trunk width and length, respectively. Dorsal lobe of the corona is large, rather parallel at the middle to nearly the tip, with dorsal transversally sinuate. Ventral lobes of the corona are larger than lateral lobes, smoothly rounded, with a large and deep sinus separate each ventral lobe. These characters are distinct from other relative members including *C. ambigua* (Hudson), *C. bilfingeri* Bērziņš, *C. campanulata* (Dobie), and *C. ferox* (Penard) (Koste, 1978; Penard, 1914). Therefore, it is going to be described as a new species of the genus *Collotheca* Harring, 1913 by the present study.

***Ptygura* sp.1** (plate 3)

This species clearly show one of the specific significant characters that separate them from other congeners within the genus (Edmondson, 1949; Koste, 1978). It has a pair of apical hooks with a tongue-shaped projection in between (plate 3e-3f, pointed). The species is also going to be described as a new member of the genus *Ptygura* Ehrenberg, 1832.

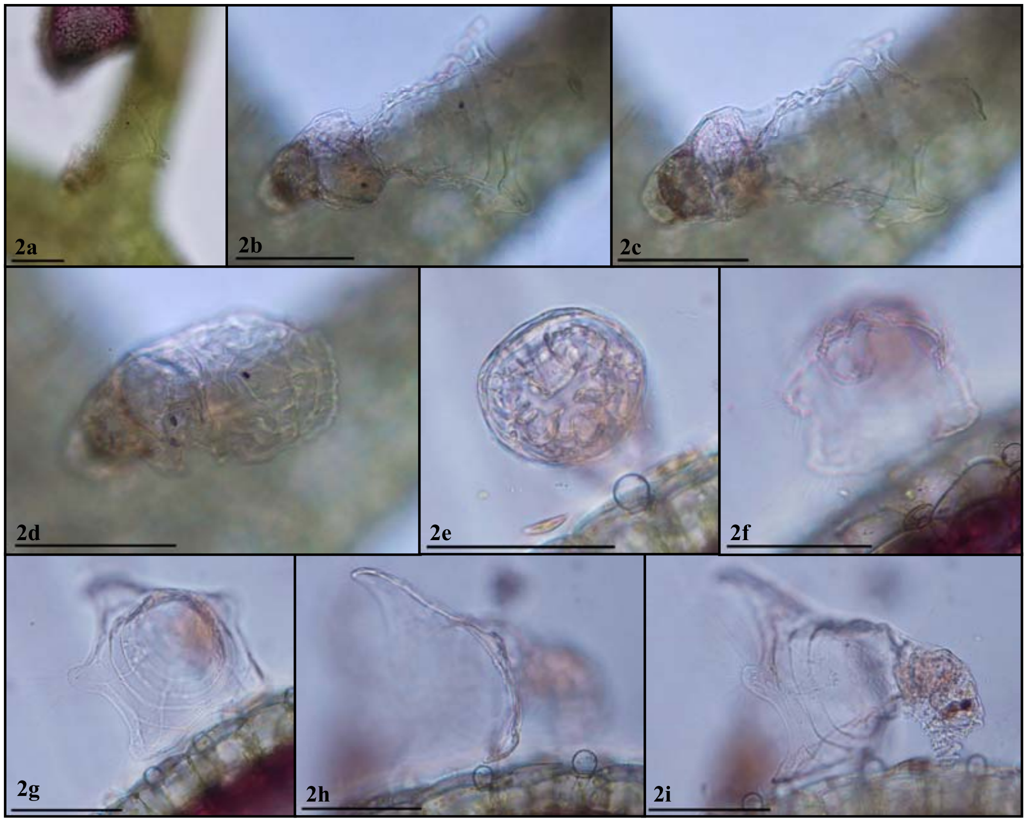

Plate 2. *Collotheca* sp.: 2a: a female; 2b: a female with their prey, *Lacane* sp.; 2c: their infundibulum, and lobes on the largest corona lobe; 2d: retracted animal; 2e: retracted corona in frontal view; 2f: un-complete extend corona (blurred picture); 2g-2i: the corona in different views. Scale bars: 2a-2i = 100 µm.

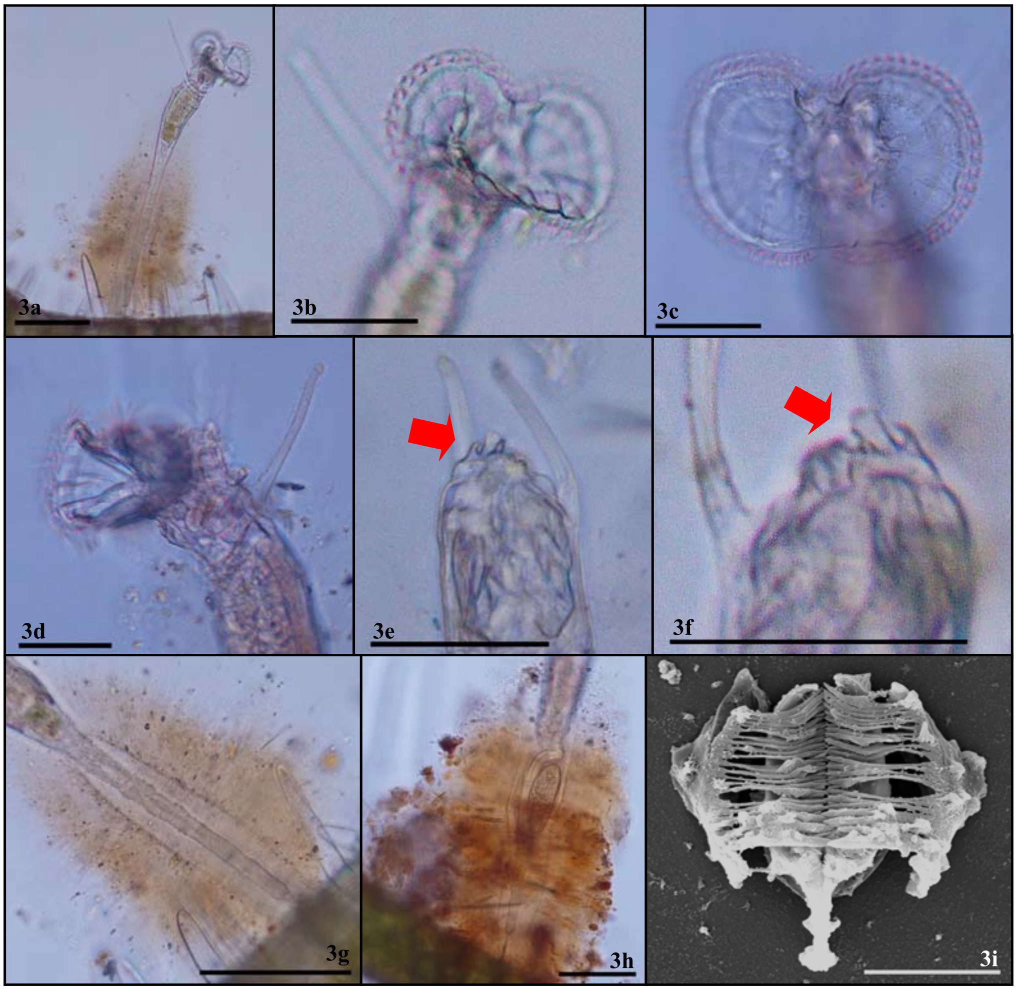

Plate 3. *Ptygura* sp.1: 3a: a female; 3b-3d: corona and buccal area features; 3e-3f: the dorsal projections (pointed); 3g-3h: tube features and their foot stalks; 3i: their trophi. Scale bars: 3a, 3g, 3h = 100 µm.; 3b-3f = 50 µm.; 3i = 10 µm.

The propose of new combination

***Ptygura noodti* (Koste, 1972) comb. nov.** (plate 4)

The specimens found in the present study contained the trophi and the tube concordant with the description of *Floscularia noodti* by Koste (1972). However, the genus *Floscularia* has been characterized by their unique four-lobed corona whereas the present specimens are bilobed and more or less elliptical (4b-4c). Therefore, the new recombination, *Ptygura noodti* (Koste, 1972), and redescription of the species is going to be published.

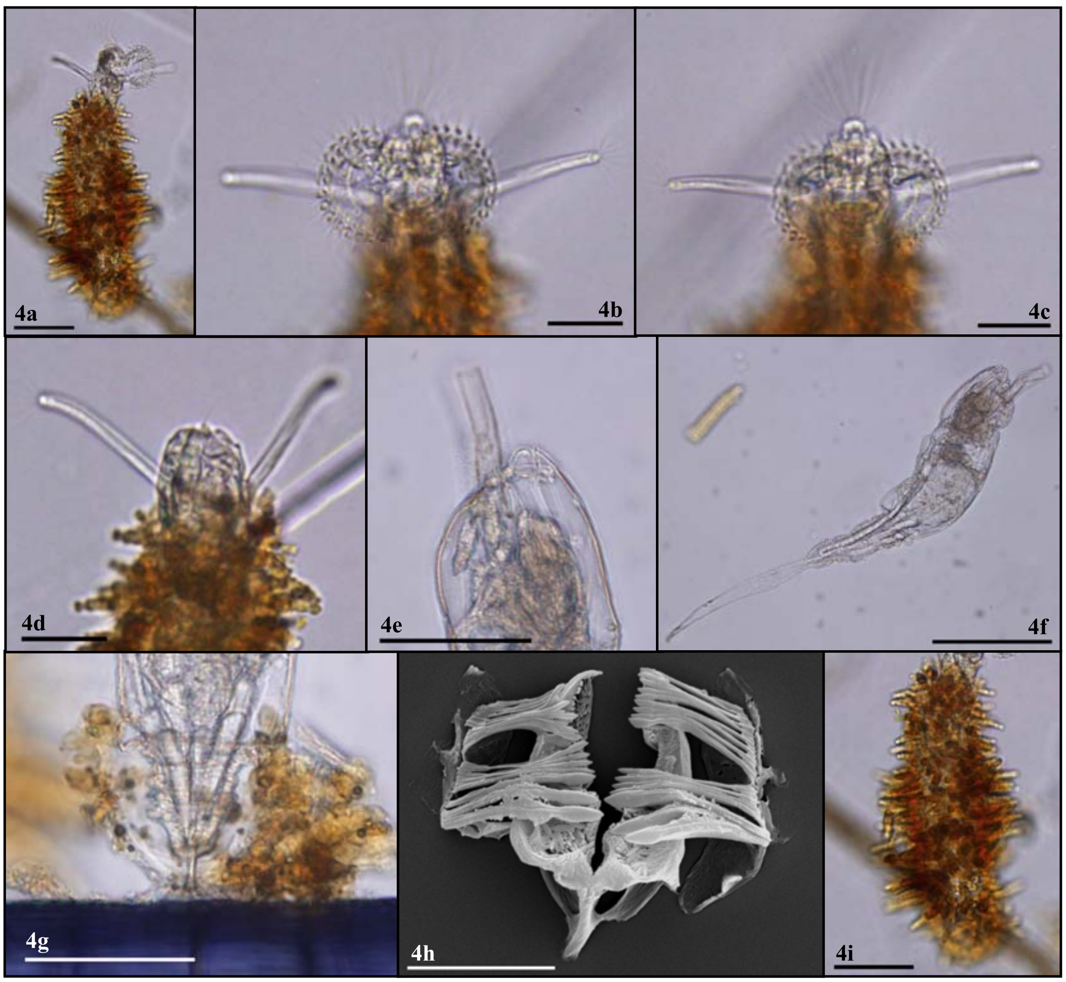

Plate 4. *Ptygura noodti* (Koste, 1972) comb. nov.: 4a: a female; 4b-4c: corona features; 4d: contracted specimen; 4e: dorsal projection features; 4f: their body outside the tube; 4g: contracted foot and foot stalk; 4h: their trophi; 4i: their tube structure. Scale bars: 4a, 4f, 4g, 4i = 100 µm.; 4b-4e = 50 µm.; 4h = 10 µm.

The remarks on species identification

***Acyclus* sp.** (plate 5)

A single specimen of this taxon shows the characters that likely to be an additional member of the genus *Acyclus* Leidy, 1882. One of the specific characters this study believes is a prominent two hooked-like at the tip of their corona (plate 5d, pointed) in which this character absent in other species of the genus. Moreover, it has been observed only on a colony of *Lacinularia flosculosa* (Muller) while *Acyclus inquietus* Leidy observed only on a colony of *Sinantherina socialis* (Linnaeus). Because of inadequacy in the specimen in hand, therefore, the present study pointed out that this taxon is waiting to establish as a new species.

***Collotheca algicola* (Hudson) & *Collotheca ambigua* (Hudson)**
(plate 6 & plate 7)

The present study identified and considered these two taxa as separate species, although the most recent annotated checklist of the rotifers considered *C. algicola* (Hudson) is synonymous of *C. ambigua* (Hudson) (Segers, 2007). The two species observed here are much different in body size. Separation between trunk and foot of *C. algicola* (Hudson) (plate 6c-6f, SR pointers) more or least less prominent compare with *C. ambigua* (Hudson) (plate 7a, pointed). Moreover, dorso-lateral lobes of the corona of the former species are more prominent than the latter one (compare plate 6c-6d, pointer LL, with plate 7b-7d, pointed). However, only a few numbers were observed especially found only a single specimen for *C. algicola* (Hudson). Therefore, these two species need a more comprehensive investigation.

***Lacinularia* cf. *pedunculata* Hudson, 1889** (plate 8)

The present taxon agrees with descriptions and illustrations of *Lacinularia pedunculata* Hudson (Hudson and Gosse, 1889; Shephard, 1899). However, two eyes on the corona are absent and their corona shape is relatively rounded while the description of *L. pedunculata* Hudson shows the presence of eyes and heart-shaped corona. Nowadays, moreover, this name has considered as *species inquirenda* status (Segers, 2007) which means the name have been doubtful in their identity and need for further investigation (see ICZN (1999)).

***Ptygura* sp.2** (plate 9)

There are three obvious morphological characters recognized in this species which are corona relatively rounded, but with very shallow ventral depression, dorsal gap is tiny (plate 9b, pointed); lateral antenna is large, triangular shape (plate 9c, 9g, pointed); and the buccal and nearby region features (plate 9e-9f, pointed). The present study considered they belong to the genus *Ptygura* by their rounded corona and the peculiar lateral antenna which these characters often recognize in this genus such as *Ptygura pedunculata* Edmondson, and they might close to *Ptygura stygis* (Gosse) (Hudson and Gosse, 1886; Koste, 1978; Segers, 2007). However, they are similar to some extent to *Lacinularia natans* Western in which the taxon now considered as a synonymy of *L. ismailoviensis* (Poggenpol). It is recognized as planktonic colonial animals while the present species is sessile and have been observed in solitary (Koste, 1978; Segers, 2007; Vidrine *et al*., 1985; Western, 1891). Because of the observation on a few specimens, the present study proposed they need a further taxonomic study either their generic or specific identity.

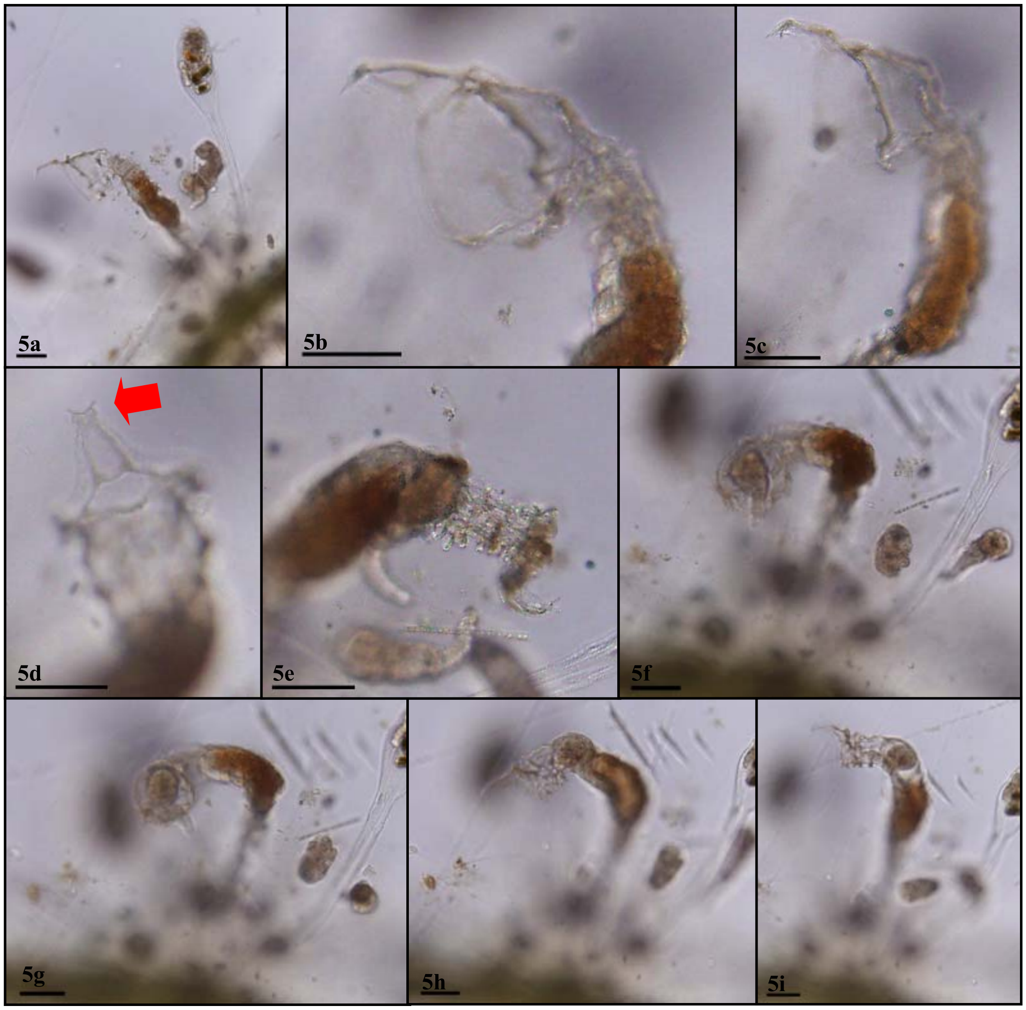

Plate 5. *Acyclus* sp.: 5a: a female on a colony of *L. flosculosa*; 5b, 5c, 5d: corona feature with two distinct hooks on the tip (pointed); 5e: a behavior; 5f, 5g, 5h, 5i: the rotifer was feeding a larva in the colony. Scale bars: 5a-5i = 100 µm.

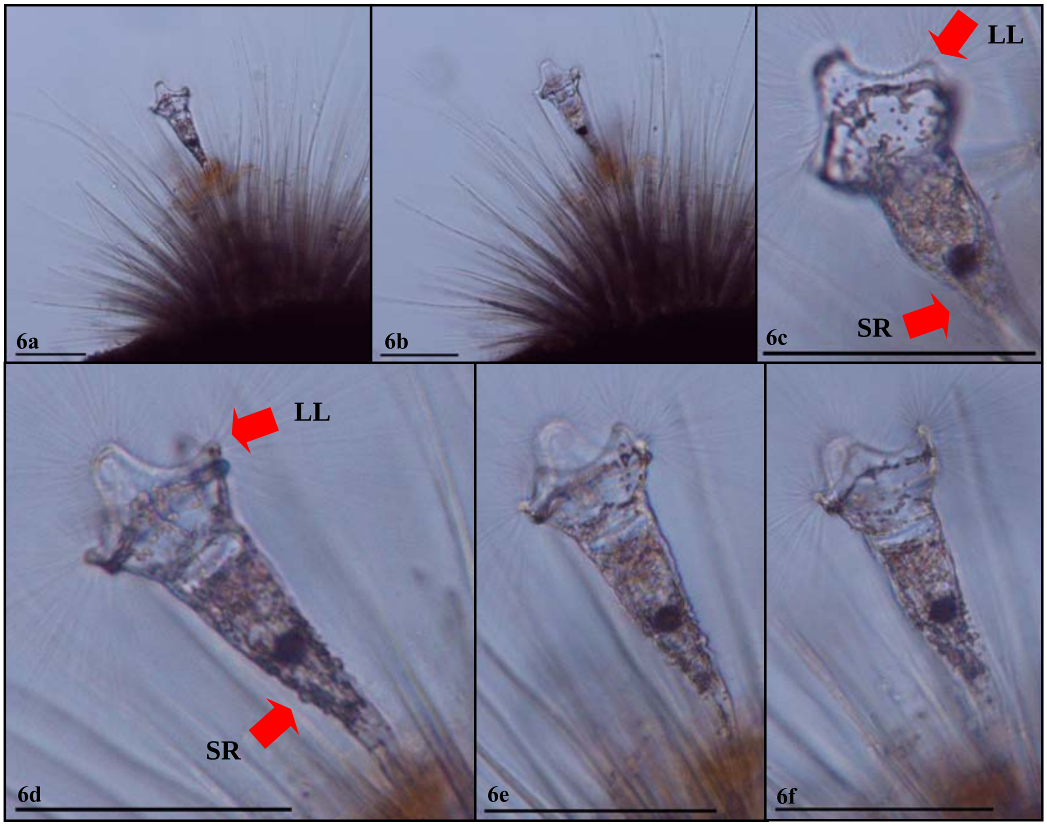

Plate 6. *Collotheca algicola* (Hudson, 1886): 6a-6b: a female on colony of blue-green algae; 6c-6d: the rotifer in dorsal view, with demonstration of dorso-lateral lobe (pointer LL) and separation between trunk and foot (pointer SR). 6e-6f: the rotifer in ventral view. Scale bars: 6a-6f = 100 µm.

Plate 7. *Collotheca ambigua* (Hudson, 1883): 7a: a female, with showing the separation between trunk and foot (pointed); 7b-7d: the corona lobes in different views, with demonstration of dorso-lateral lobe feature (pointed); 7e: un-completed expand corona; 7f: their foot and eggs. Scale bars: 7a-7f = 100 µm.

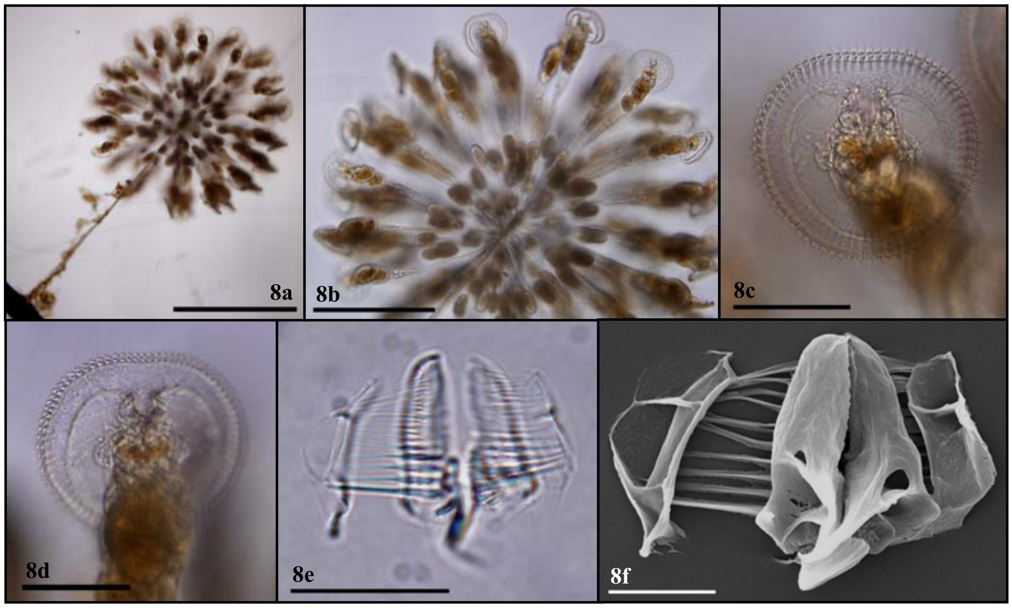

Plate 8. *Lacinularia* cf. *pedunculata* Hudson, 1889: 8a-8b: a colony and their eggs; 8c: corona features (dorsal view); 8d: buccal area features (ventral view); 8e: light microscope photograph of their trophi **(took from caudal view)**; 8f: SEM of trophi (caudal view). Scale bars: 8a = 1 mm.; 8b = 500 μm.; 8c-8d = 100 μm.; 8e = 20 μm.; 8f = 10 μm.

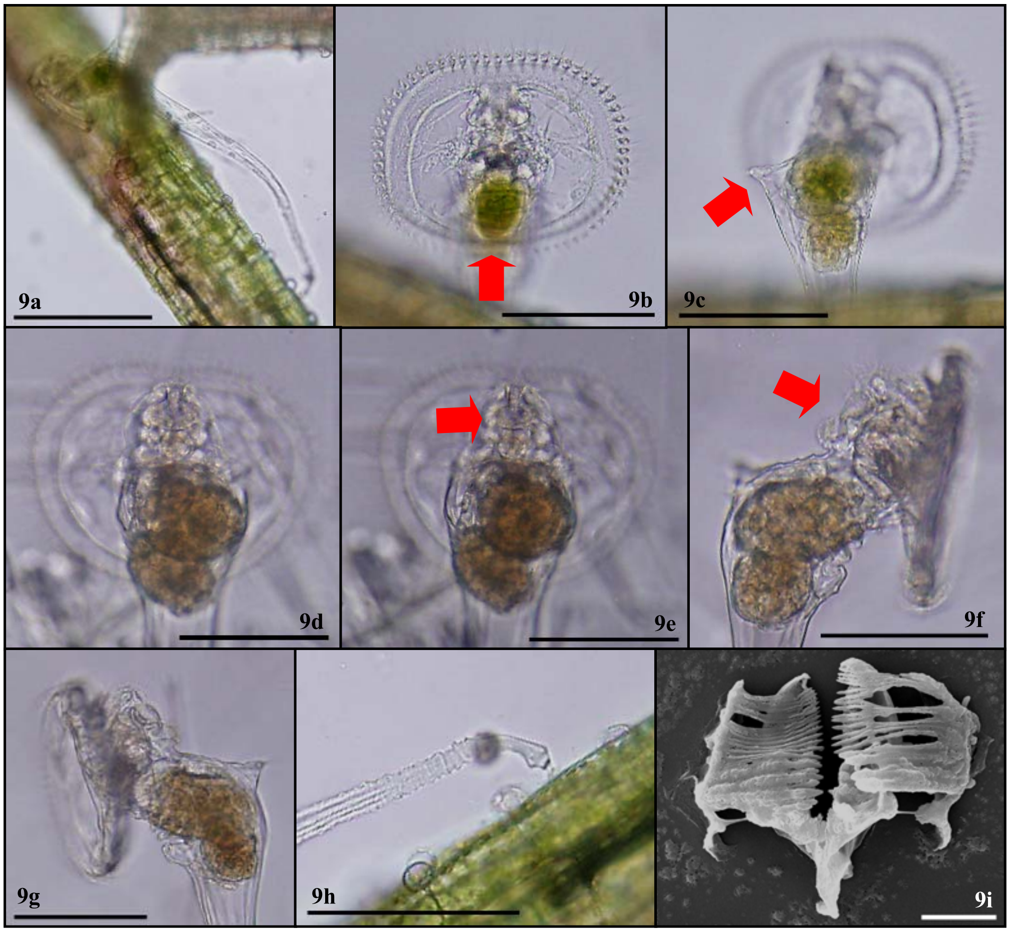

Plate 9. *Ptygura* sp.2: 9a: a female; 9b: corona shape, with showing of dorsal gap (pointed); 9c: the large triangular lateral antenna (pointed); 9d-9g: buccal area features (pointed); 9h: foot and attachment stalk; 9i: their trophi. Scale bars: 9a = 200 µm.; 9b-9h: = 100 µm.; 9i = 10 µm.

Note on the selected taxa

***Limnias ceratophylli* Schrank, 1803** (plate 28)

Besides other diagnostic characters including opaque tube covered with debris without ring structure described elsewhere, this species has no any processes on their dorsal plate. However, at least two forms of dorsal plates were recognized in the present observation. One was mask-like plate with one pore near top-central margin of the plate (plate 28e-28f). Another one was weaker and much transparent, and might not be an obvious form (plate 28j, pointed). The former form may be linked to the specimens that their tube looked strong and quite slender, brown, and lesser opaque than as of the specimens of the latter; corona shallow ventral depression; they have been found only in solitary; and the specimens can be easier confused with *L. melicerta* Weisse (plate 28a). Whereas, the latter form may be linked to the specimens that tube looked thinner and more tapering to the tube base than as of the former, black, and more opaque; corona nearly absent ventral depression but two lobes still be distinct by wide dorsal gap; they were often found in branching colony (plate 28g). These forms of this important character have not reported in previously which the taxon could be called for a taxonomic investigation on which they may reflect species complex.

***Limnias melicerta* Weisse, 1848** (plate 29)

Tubes of the observed specimens vary in typical clearly transparent rings to very dark one where covered with debris (but lesser on the initial-based region). The dark tube specimens may be confused with *L. ceratophylli* Schrank in somehow. However, they can be identified by dorsal horny processes located at the neck region (plate 29b, 29f, 29g; pointed). The present study recommends that a researcher should always look at this character in their identification.

***Ptygura barbata* Edmondson, 1939** (plate 33)

Many features of the examined specimens of this species agreed with the original description (Edmondson, 1939) such as corona shape, having of clustered cilia on buccal area and the way they waged (even though some specimens not showed obviously), long lateral antenna, having particularly one of diagnostic character, “bun-shaped process” (the term used after the author) (plate 33f-33g, pointed), tube structures, and inhabiting within acid water (pH of the lake = 5.91±1.57). However, there were different points in the morphological features. On the corona, the median keel was not obvious or absent in the examined specimens which this character is also one of the diagnostic character as the author pointed out; dorsal gap small or rather wide, but might be not in the sense of minute as in the literature. Clustered cilia on buccal area relatively long, might be not in the sense of “extremely long”. In addition, the features such as length of foot stalk, and general form of tube features including structure, component, and color, were varied greatly which these did not mention in the literature. However, the dorsal process feature is unique in many species such as in genus *Ptygura*, for example, *P. linguata* Edmondson, *P. tacita* Edmondson, and *Ptygura* sp.1, which the present study relied mostly upon this character to identify the examined specimens to this species.

***Ptygura beauchampi* Edmondson, 1940** (plate 34)

In the present study, this species was dominated and observed only on *Utricularia aurea* Lour. which this agreed with the previous experiment that proposed *P. beauchampi* Edmondson is specific preference to *Utricularia* species as substratum (Wallace, 1978). However, although many taxa have been observed only on one plant species (appendix I), there is no an experiment supported habitat specific preference of them, and they were observed in a few numbers which these cannot lead the present study to any conclusion to a special habitat preference of them.

The underrepresented species

There is a group of sessile rotifers should be noted that their distributions on the observed plants were possibly underrepresentation (table 4, appendix I). Most of them are called *Ptygura melicerta* group and the closely related taxa (Koste, 1978). They are relatively small, and usually inhabit within a tiny damaged plant tissue (plate 37a, 38b) where they were nearly completely hidden when they retract themselves during plant material investigations. Thus, these animals might be over looked in the present observation where dealing with a large number of plant materials to search for as much as plant surfaces rather than a specific point. In the case of *Ptygura wilsonii* (Anderson & Shephard), in addition, the present study have just recognized at nearly the end of observation that their general characters look like *P. crystallina* (Ehrenberg) but they can be completely separated by specialized features on apical field of their corona (plate 43e-43f, pointed). As just known, they might be included with occurrence of *P. crystallina* (Ehrenberg) in routine observation, but identity of *P. crystallina* (Ehrenberg) was always checked when new plant species was investigated. For the save side of result interpretations, therefore, the underrepresented species were excluded from any comparisons in the further parts below.

Table 4. List of the underrepresented species.

Ptygura agassizi Edmondson	plate 32
P. ctenoida Koste & Tobias	plate 36
P. elsteri Koste	plate 37
P. furcillata (Kellicott)	plate 38
P. mucicola (Kellicott)	plate 40
P. wilsonii (Anderson & Shephard)	plate 43

3.2 Species composition of sessile rotifers in Thale Noi Lake

In the present study, there were the problems in reference to the light rainy period. Since, the period was the beginning of the study where identification of sessile rotifers was puzzled, sampling and observing efforts as well as the systematic of water environmental measurement were rather weak compare with rainy and dry period. Therefore, species occurrence data of sessile rotifers as well as water quality data in the light rainy period were excluded from any result interpretations below.

Sessile rotifer species that most frequently found in the lake were *Limnias melicerta* Weisse (56.06 %), followed by *Ptygura barbata* Edmondson (46.97 %), *Ptygura crystallina* (Ehrenberg) (34.85 %), *Floscularia conifera* (Hudson) (30.30 %), and *Lacinularia flosculosa* (Muller) (25.76 %) whereas the least found (1.52%) were *Acyclus* sp., *Collotheca heptabrachiata* (Schoch), *C. stephanochaeta* Edmondson, *Floscularia wallacei* Segers & Shiel, *Lacinularia* cf. *pedunculata* Hudson, *Pentatrocha gigantea* Segers & Shiel, *Ptygura* sp.2, and *Stephanoceros fimbriatus* (Goldfusz) (appendix II; n = 66).

According to the commonness and rarity determination (chapter 2), most of the observed sessile rotifers fell into rare class, followed by common, very rare, and very common class, respectively (fig. 4, table 5, appendix II).

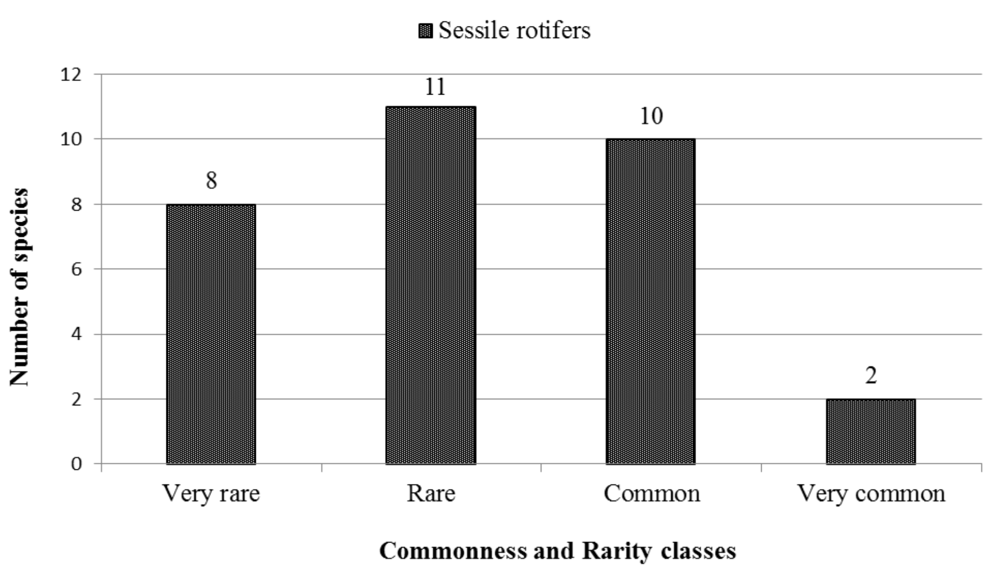

Figure 4. Pattern of commonness and rarity of sessile rotifers in Thale Noi Lake.

Table 5. List of the sessile rotifer species in commonness and rarity classes.

Very rare (0.01-6.25%)	**Rare (6.26-25.00%)**	**Common (25.01-62.51%)**	**Very common (62.52-100%)**
Acyclus sp.	*Acyclus inquietus*	*Beauchampia crucigera*	*Limnias melicerta*
Collotheca heptabrachiata	*Collotheca ambigua*	*Floscularia bifida*	*Ptygura barbata*
C. stephanochaeta	*C. campanulata*	*F. conifera*	
Floscularia wallacei	*C. ornata*	*F. pedunculata*	
Lacinularia cf. *pedunculata*	*C. tenuilobata*	*Limnias ceratophylli*	
Ptygura sp.2	*Floscularia armata*	*Lacinularia flosculosa*	
Pentatrocha gigantea	*F. ringen*	*Octotrocha speciosa*	
Stephanoceros fimbriatus	*Melicerta coloniensis*	*Ptygura crystallina*	
	Ptygura longicornis	*P. tacita*	
	P. pedunculata	*Sinantherina socialis*	
	Ptygura sp.1		

3.3 Environmental characteristics of water quality during study period

All of the average values of environmental variables including temperature, pH, conductivity, turbidity, and salinity measured in rainy period were lower than dry period (table 6). These variables were significantly different between the two periods, except turbidity (table 7).

During rainy period, there were significantly different values of pH and conductivity among the sampling stations. The pH value was lowest at station 6 and trended to increase gradually along the other stations in both sides. The conductivity values trended to increase from station 1 to rather sharp increasing at station 7, 8, and 9. During dry period, there were significantly different values of pH and salinity among the sampling stations. The pH values were lowest at station 5, followed by station 3 and 4 respectively whereas highest at station 1, followed by station 9 and 8, respectively. Salinity value was lowest at station 6 and trended to increase gradually along the other stations in both sides (table 8, fig. 5, appendix IV).

Table 6. Average (with standard deviation, S.D.) and range values of measured water environmental variables during rainy (November-December, 2009) and dry period (March-April, 2010) within Thale Noi Lake.

Environmental variables	**Rainy period**		**Dry period**	
	$\overline{X}$ ± S.D. (n = 27)	Range	$\overline{X}$ ± S.D. (n = 27)	Range
Temperature (^{o}C)	30.09 ± 1.06	27.2-32.4	32.30 ± 1.52	29.3-35.6
pH	5.09 ± 1.32	3.15-7.31	6.72 ± 1.37	5.66-11.35
Conductivity (µS/cm)	222.52 ± 444.30	20.3-1,833	1,238.69 ± 655.78	41.2-2,060
Turbidity (NTU)	4.89 ± 8.08	0-25	23.11 ± 37.82	0-132
Salinity (%)	0.00	0-0.05	0.05 ± 0.03	0-0.1

Table 7. One-way ANOVA test of the measured environmental variables between seasons. An asterisk indicates significant difference (P<0.05). ("M" indicates there were missing data).

Sources	Temperature				Sources	Turbidity			
	df	MS	F	p		df	MS	F	p
Season	1	0.063	38.6933	<.0001*	**Season**	1	7.365	2.809	0.1001
Error	52	0.002			**Error**	49[M]	2.622		
	pH					Salinity			
Season	1	36.211	19.983	<.0001*	**Season**	1	0.024	38.983	<.0001*
Error	52	1.812			**Error**	49[M]	0.001		
	Conductivity								
Season	1	82.193	55.275	<.0001*					
Error	52	1.487							

Table 8. One-way ANOVA test of the measured environmental variables among sampling stations during rainy and dry period. An asterisk indicates significant difference (P<0.05). ("M" indicates there were missing data).

Rainy period					Dry period				
Sources	Temperature (^oC)				Sources	Temperature (^oC)			
	df	MS	F	p		df	MS	F	p
Station	8	1.446	1.461	0.239	**Station**	8	0.324	0.101	0.9987
Error	18	0.990			**Error**	18	3.20778		
	pH					pH			
Station	8	344.355	4.069	0.0064*	**Station**	8	0.001	3.397	0.0148*
Error	18	84.639			**Error**	18	0.000		
	Conductivity (µS/cm)					Conductivity (µS/cm)			
Station	8	0.001	7.042	0.0003*	**Station**	8	603995	1.712	0.1634
Error	18	0.000			**Error**	18	352741		
	Turbidity (NTU)					Turbidity (NTU)			
Station	8	85.917	1.388	0.278	**Station**	8	5.66336	2.375	0.0608
Error	15[M]	61.911			**Error**	18	2.38455		
	Salinity (%)					Salinity (%)			
Station	8	0.000	0.819	0.598	**Station**	8	0.002	2.689	0.0388*
Error	15[M]	0.000			**Error**	18	0.001		

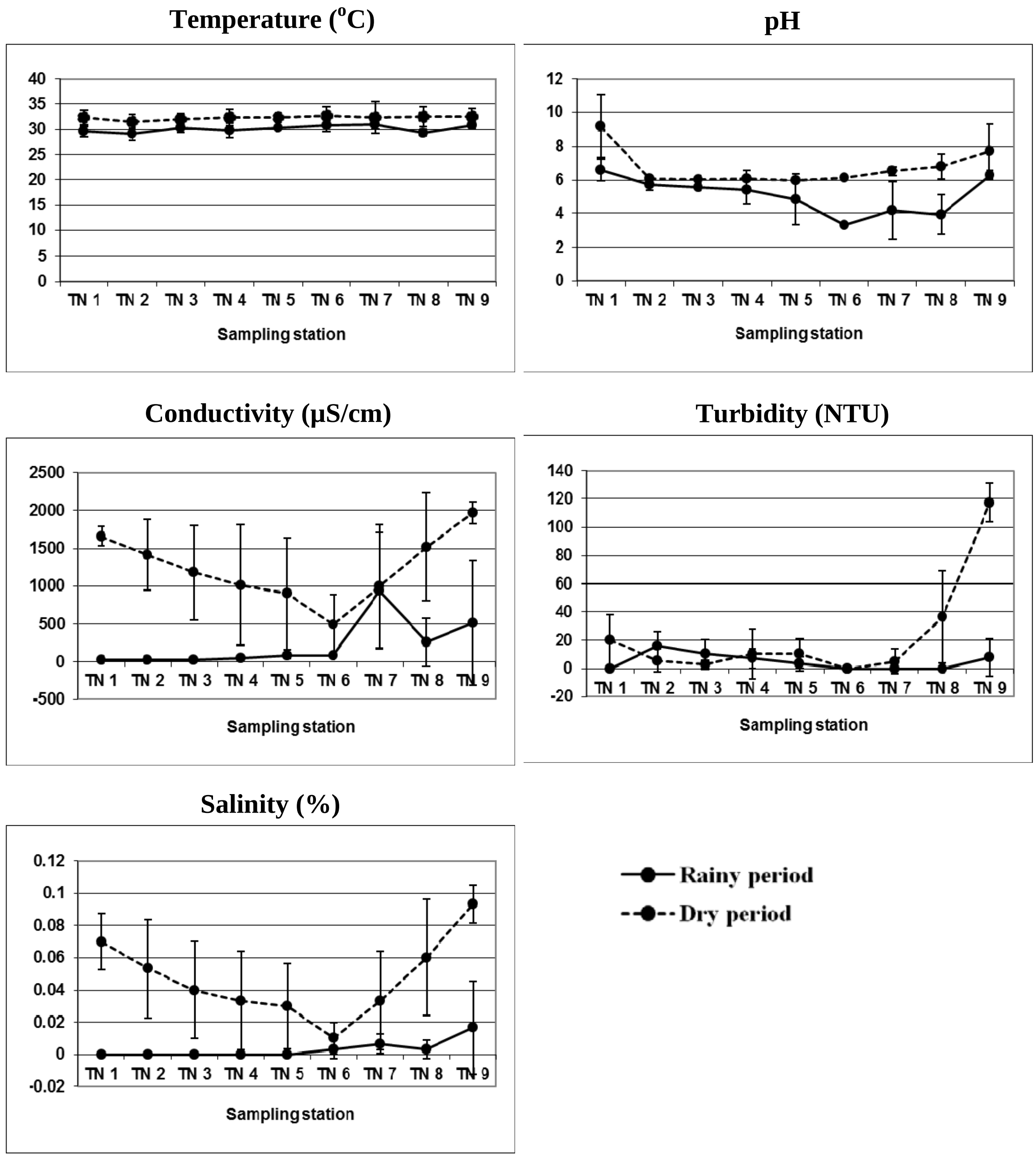

Figure 5. Patterns of water environmental variables measured (average $\overline{X}$ ± S.D.; n = 3) along the sampling stations during rainy and dry period.

3.4 Species composition and distribution of sessile rotifers in the seasonal periods

Number of sessile rotifer species observed between rainy and dry period were nearly the same, and species compositions were slightly different (table 9). The most four common species were similar between the two periods except for *Ptygura crystallina* (Ehrenberg) which dominated in rainy period while *Limnias ceratophylli* Schrank dominated in dry period. On the other hand, the most four rare species was nearly completely different between the two periods except for *Ptygura longicornis* (Davis) (table 9).

Table 9. Species richness, community similarity and frequency of occurrence of selected species within rainy and dry period. The percentages within parentheses do not put the species into those categories in that period.

	Rainy period	**Dry period**
Number of species	26	28
Community similarity	0.81 (22 shared species)	
	% occurrence (n = 33)	
Common species		
Limnias melicerta Weisse	55	58
Ptygura barbata Edmondson	39	55
Floscularia conifera (Hudson)	30	30
Ptygura crystallina (Ehrenberg)	42	(27)
Limnias ceratophylli Schrank	(18)	30
Rare species		
Ptygura tacita Edmondson	6	(24)
Ptygura pedunculata Edmondson	3	(6)
Ptygura sp.1	3	(12)
Collotheca campanulata (Dobie)	(15)	3
Collotheca tenuilobata (Anderson)	(24)	3
Melicerta coloniensis Colledge	(21)	3
Ptygura longicornis (Davis)	6	3

There were sessile rotifer species observed within only each period. Although there were the problems in light rainy period mentioned above, the species presented in light rainy period but absented in rainy and dry period are reasonable to make a comparison since even observation in the latter two periods was intense, the taxa that observed only in light rainy period have not found during those periods. However, the species presented only in the rainy or dry periods have not known that they were absent in the light rainy period. Thus, the data from the rainy and dry period were compared with each other. A total of five (included one infrasubspecific variant), four, and six species were observed only in the light rainy, rainy, and dry period, respectively (table 10).

Table 10. The sessile rotifers observed only in one seasonal period.

Seasonal periods / **Sessile rotifers**	**Light rainy**	**Rainy**	**Dry**
Acyclus sp.			+
Collotheca algicola (Hudson)	+		
C. ambigua (Hudson)			+
C. campanulata var. *longicaudata* (Hudson)	+		
C. heptabrachiata (Schoch)		+	
C. stephanochaeta Edmondson			+
C. trilobata (Collins)	+		
Collotheca sp.	+		
Floscularia wallacei Segers & Shiel		+	
Lacinularia cf. *pedunculata* Hudson		+	
Pentatrocha gigantea Segers & Shiel			+
Ptygura beauchampi Edmondson			+
P. noodti (Koste)	+		
Ptygura sp.2			+
Stephanoceros fimbriatus (Goldfusz)		+	

3.5 Species composition and distribution of sessile rotifers along the sampling stations

The highest species number of sessile rotifer was observed within station 3, followed by station 2, whereas the low species numbers were observed within station 6 and 8, respectively, and the lowest were station 1 and 7 (fig. 6). This pattern, more or less, was the same between rainy and dry period (fig. 7). Within the high richness stations, rainy period contained higher species numbers than dry period (or equal) while within the low richness stations were vice versa (except station 1). In addition, difference of species richness of sessile rotifers among the stations varied greater in rainy period than dry period (fig. 7).

Among the sampling stations, similarity values of species composition of the sessile rotifers were high in station 2 – 5 (range from 0.71-0.84) where represented high richness stations. However broadly, similarity values were high among comparing stations nearby (table 11).

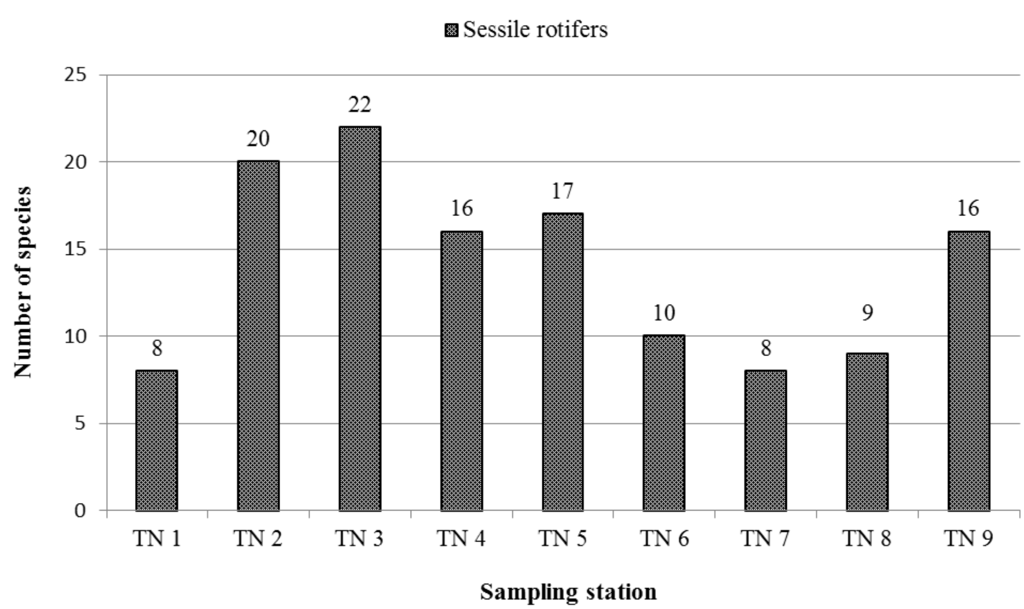

Figure 6. Species richness pattern of sessile rotifers along the sampling stations.

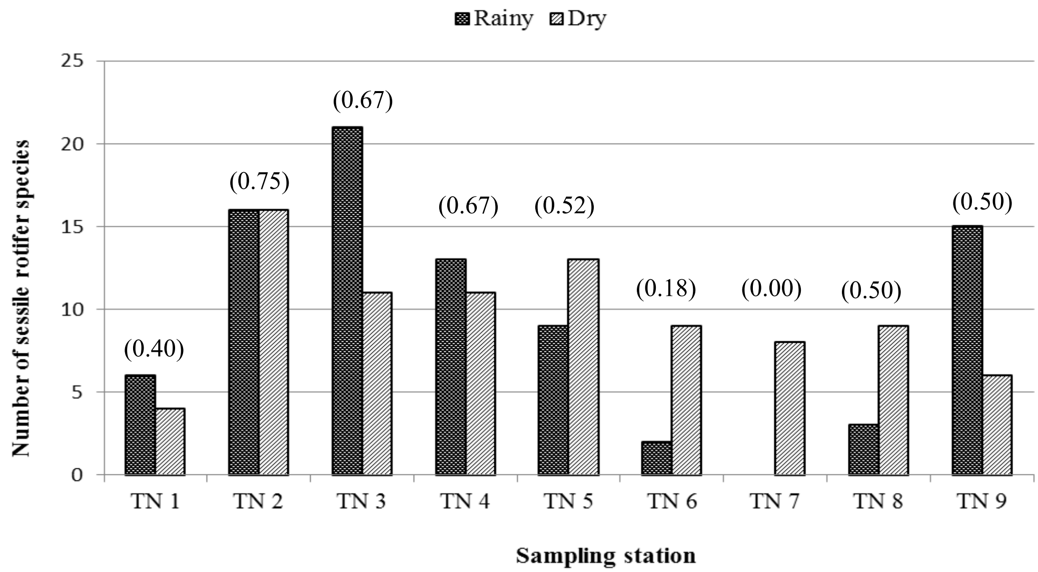

Figure 7. Species richness patterns of sessile rotifers along the sampling stations during rainy and dry period, and similarity values of the sessile rotifer community between the two periods in each station.

Table 11. Species richness and similarity of species composition of sessile rotifers among the sampling stations (bolded numbers indicated the high similarity).

	TN 1	TN 2	TN 3	TN 4	TN 5	TN 6	TN 7	TN 8	TN 9
richness	8	20	22	16	17	10	8	9	16
TN 9	0.58	0.67	0.68	0.63	0.56	0.38	0.42	0.64	-
TN 8	0.35	0.48	0.45	0.48	0.40	0.42	0.59	-	
TN 7	0.25	0.43	0.40	0.50	0.50	0.44	-		
TN 6	0.11	0.40	0.56	0.59	0.69	-			
TN 5	0.35	0.61	**0.82**	**0.81**	-				
TN 4	0.50	**0.72**	**0.84**	-					
TN 3	0.47	**0.71**	-						
TN 2	0.50	-							
TN 1	-								

According to the specimen collecting method (chapter 2), there were three possible factors that may be responsible for difference in species richness of observed sessile rotifers along the sampling stations. They were 1) difference in numbers of the observed plants in each station; 2) different investigated plant species; and 3) local water environments of each station.

Numbers of observed plants relates to observed substrate areas in which species richness of observed sessile rotifers should be higher in station that contained higher in numbers of investigated plants, according to species-area relationship phenomenon (Connor and McCoy, 2001). However, there were the sampling stations that contained lower numbers of investigated plants but higher in species richness than the stations that contained higher number of investigated plants. For example, station 2 and 3 contained three and five investigated plants, respectively, but species richness of the observed sessile rotifers were higher than station 8 and 9 in which contained five and eight plants, respectively (fig. 8).

In addition, different observed plant species among the sampling stations may cause difference in species richness of inhabiting sessile rotifers among the stations because different plants may reflects difference either substrate preference or habitat heterogeneity for the sessile rotifers (Wallace and Edmondson, 1986; Duggan, 2001). However, species richness of sessile rotifers observed on the same plants among different stations were much different. For example, species richness observed on *Neptunia oleracea* Lour. in station 2 (16 species) was higher than station 8 (2 species), and also on *Eichhornia crassipes* (C.Mart.) Solms in station 3 (17 species) contained higher richness of observed sessile rotifers than station 9 (7 species) (table 12). The results from the present study showed that the factors affected species richness of sessile rotifers among the sampling stations were local water environments in each station rather than neither number of the investigated plants nor plant species.

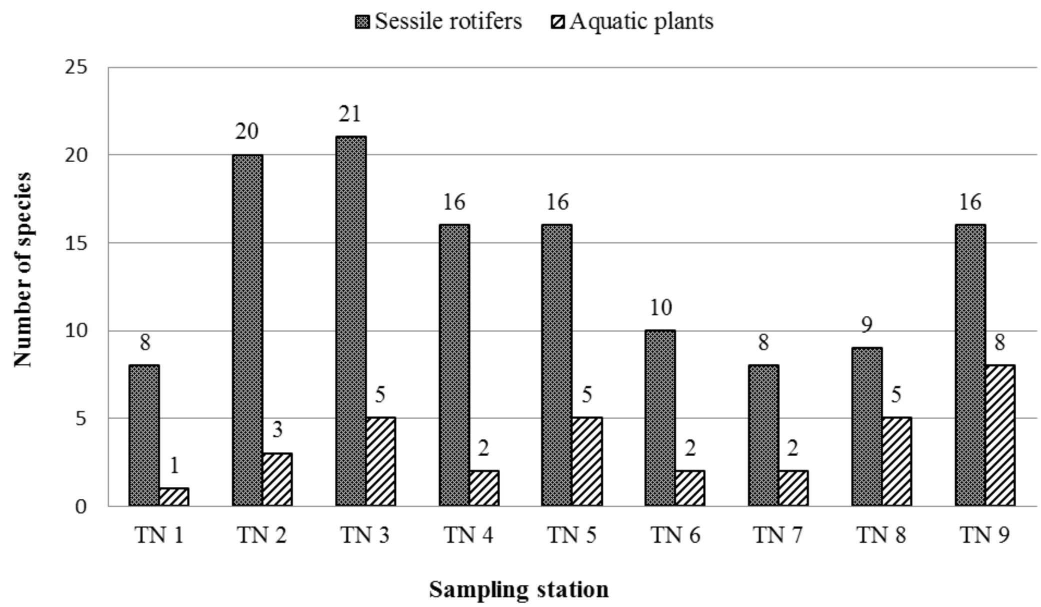

Figure 8. Species richness of sessile rotifers and number of the observed plant species in each sampling station.

Table 12. Species number of sessile rotifers observed on each plant species in different sampling stations.

Aquatic plant species \ Sampling station		TN 1	TN 2	TN 3	TN 4	TN 5	TN 6	TN 7	TN 8	TN 9
1. *Eleocharis ochrostachys* Steud.	EO						1			
2. *Hanguana malayana* (Jack.) Merr.	HM		8			2			2	3
3. *Nelumbo nucifera* Gaertn.	NN			3						3
4. *Neptunia oleracea* Lour.	NO		15		16		6		2	14
5. *Ludwigia adscendens* (L.) H. Hara	LA			14					8	
6. *Hygroryza aristata* Nees	HA			9		14				
7. *Eichhornia crassipes* (C.Mart.) Solms	EC		17	17						7
8. *Salvinia cucullata* Roxb. ex Bory	SC					4				
9. *Nymphoides indicum* (L.) Kuntze	NI									2
10. *Nymphaea lotus* L. var. *pubescens* Hook.f. & Thomson	NL			4					4	4
11. *Ceratophyllum demersum* L.	CD	8								
12. *Hydrilla verticillata* (L.f.) Royle	HV				8					2
13. *Potamogeton malaianus* Miq.	PM									2
14. *Utricularia aurea* Lour.	UA					5		6		
15. *Utricularia* sp.	US					3		4	4	

Analysis of correlation between the water environmental variables and the species richness patterns demonstrated that species richness of sessile rotifers has positive significant correlation with pH and turbidity in rainy period whereas only pH has significant correlation in dry period but negatively (table 13).

Table 13. Pearson correlation coefficient between the water environmental variables and species richness of the sessile rotifers within each seasonal period. An asterisk indicates significant correlation ($P<0.05$).

Environmental variables	**Pearson correlation coefficients**
Rainy period	
Temperature	-0.2877
pH	0.8761*
Conductivity	-0.4952
Turbidity	0.8849*
Salinity	-0.2299
Dry period	
Temperature	-0.6720
pH	-0.8385*
Conductivity	-0.3554
Turbidity	-0.6688
Salinity	-0.4356

3.6 Species composition and distribution of sessile rotifers on the selected aquatic plant species

The results showed that all of the fifteen aquatic plant species (their submerged parts) can be employed as inhabiting substratum by sessile rotifers (appendix I). However, different plant species contained different species richness of the sessile rotifers even within the same sampling station (table 12). In total, the plant that contained the highest richness of the sessile rotifers were *Eichhornia crassipes* (C.Mart.) Solms (24 species) and *Neptunia oleracea* Lour. (24 species) whereas the lowest was *Eleocharis ochrostachys* Steud. (1 species) (fig. 9).

Among the investigated plant species, high similarity values of species composition of the sessile rotifers represented the plants that contained high richness and/or represented co-occurred plants within the same and nearby sampling stations. While, low similarity values among the plants represented the comparisons between high and low richness plants, and/or between two low richness, and/or faraway sampling stations (table 14, and see table 12).

The sessile rotifers that were observed on the highest number of aquatic plant species were *Limnias melicerta* Weisse (12 plant species) and *Ptygura barbata* Edmondson (12 plant species), followed by *Floscularia conifera* (Hudson) (10 plant species) and *Limnias ceratophylli* Schrank (10 plant species), whereas the sessile rotifers that were observed on only one plant species were *Acyclus* sp., *Collotheca heptabrachiata* (Schoch), *Floscularia wallacei* Segers & Shiel, *Lacinularia* cf. *pedunculata* Hudson, *Ptygura beauchampi* Edmondson, and *Stephanoceros fimbriatus* (Goldfusz) (appendix I).

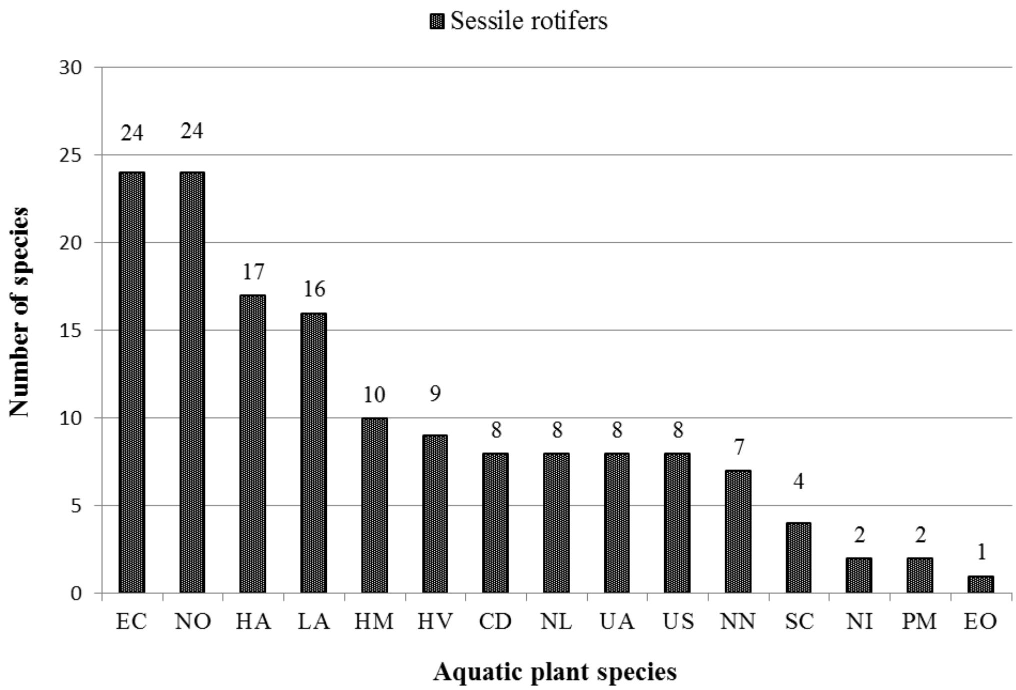

Figure 9. Species richness of the sessile rotifers on the aquatic plant species (abbreviations of the plants see table 2, chapter 2).

Table 14. Species richness and composition of sessile rotifers among the plant species [bolded and underlined numbers indicated the high similarity (>0.70) and the low similarity (<0.20), respectively].

	EO	**HM**	**NN**	**NO**	**LA**	**HA**	**EC**	**SC**	**NI**	**NL**	**CD**	**HV**	**PM**	**UA**	**US**
richness	1	10	7	24	16	17	24	4	2	8	8	9	2	8	8
US	0.22	0.22	0.53	0.44	0.50	0.40	0.44	0.33	0.20	0.63	0.25	0.47	0.20	0.63	-
UA	0.22	0.33	0.40	0.38	0.42	0.40	0.38	0.50	0.00	0.50	0.13	0.35	0.00	-	
PM	0.00	0.33	0.44	0.15	0.22	0.11	0.15	0.33	1.00	0.40	0.20	0.36	-		
HV	0.20	0.63	0.63	0.55	0.56	0.54	0.55	0.31	0.36	**0.71**	0.24	-			
CD	0.00	0.44	0.40	0.50	0.58	0.40	0.44	0.17	0.20	0.25	-				
NL	0.22	0.56	**0.80**	0.44	0.50	0.40	0.44	0.33	0.20	-					
NI	0.00	0.33	0.44	0.15	0.22	0.11	0.15	0.33	-						
SC	0.40	0.43	0.36	0.29	0.30	0.29	0.29	-							
EC	0.08	0.59	0.47	**0.88**	**0.80**	**0.78**	-								
HA	0.11	0.44	0.42	**0.78**	**0.79**	-									
LA	0.12	0.69	0.61	**0.80**	-										
NO	0.08	0.58	0.45	-											
NN	0.25	0.59	-												
HM	0.18	-													
EO	-														

CHAPTER 4

DISCUSSION

4.1 Taxon diversity and composition of sessile rotifers in Thale Noi Lake

In the present study, the observed numbers of species was about 40%, and the number of genera was 80% of the total taxonomic richness of sessile rotifers reported worldwide. These are the highest numbers of sessile rotifer taxa ever reported from a single lake (e.g., Edmondson, 1940, 1944; Koste, 1975; Segers and Shiel, 2008; Segers *et al*., 2010). This result concurs with the hypothesis that long distant dispersal and ubiquitous abilities of small organisms (micro-scale) results in cosmopolitan distribution patterns of such organisms. Indeed, one of the predictions of the model is that the ratio of local/global diversity will turn out to be relatively high, as most microorganisms can readily dispersed over large geographical scale and live everywhere. As a result, it makes relatively high alpha-diversity of the microorganisms within a habitat (Finlay, 2002; Fenchel and Finlay, 2004). This view is, however, challenged as it follows from a dearth of studies on sessile rotifers (Segers, 2001), poor taxonomic knowledge (see part 3.1), and occurrence of cryptic speciation across several taxa in Phylum Rotifera (Gómez and Snell, 1996; Schröder and Walsh, 2007). Thus, a large proportion of the diversity may still be hidden and this view of cosmopolitanism which is here based on the local/global diversity ratios can change with reports of new species or taxa revealed by further studies. Moreover, a high proportion of endemic species in the phylum has been demonstrated as well (Dumont, 1983; Segers, 2001; Segers and De Smet, 2008). Therefore, a solid conclusion of this controversial story requires more empirical evidence. Nevertheless, the present result points out that future rotifer biodiversity studies should put as much sampling efforts into a single focal habitat to cover both its micro-habitat as well as temporal heterogeneity rather than trying to increase the number of different habitats, in order to find novelties.

As a result of the discovery of new taxa at the genus and species level, as well as of many new records of sessile rotifers for the Oriental region, the present study contributes significantly to our knowledge on biodiversity at global, regional as well as local scale, including to the report of as the faunal richness of Thailand. Moreover, many of the observed species require further taxonomic and biogeographic study. These results therefore reveal that our knowledge of the biodiversity, taxonomy and zoogeography of sessile rotifers remains of scientific interest and a large gap of knowledge is waiting to be filled.

In the present study, some frequently observed species are identical to the most abundant species reported during a previous study in the central part of Thailand (Koste, 1975). Because frequency of occurrence is usually positive correlate with local abundance (Hessen and Walseng, 2008), those common species reflect their high abilities to succeed or occupy most of the niches within the habitats. There are two major approaches to answer why some species are common whereas some are rare within a focal community. These alternatives are the “Niche” and “Neutral” approaches. The present study supports the niche view as the major factor shaping the relative abundance among species in a community. This view involves intrinsic abilities, for example, recruitment ability, food acquisition ability, predation defense, and disease tolerance, and extrinsic factors, for example, food availability, predator density, and range of appropriate physical and chemical environments. On the other hand, the neutral view involves ability and chance to immigrate or to be colonized and random mortality, and these vary randomly from place to place and through time (Krebs, 2009).

The pattern of commonness and rarity classes recognized here (fig. 4) is broadly concordant with a log normal pattern of species abundance distribution (the log normal model), although a significant fit to various models requires some data transformation (i.e. goodness of fit test: X^2 test, GOF test) (Magurran, 2004). The general pattern of the log normal model is that most species are moderately abundant while very common and very rare species are fewer (Molles, 2010). Although the present class determination is based on frequency of occurrence data, this type of data usually are positive correlation with numerical abundance as mentioned above and can be used to estimate species abundance (Hessen and Walseng, 2008; Magurran, 2004). Therefore, the frequency of occurrence of the sessile rotifers observed here might reflect their relative abundance within Thale Noi Lake to some extent (appendix II), apart from the two major approaches which try to explain the log normal pattern that are Sequential Niche Breakage Hypothesis and The Neutral Theory of Biodiversity (Krebs, 2009).

In addition, the left-skewed curve that is usually recognized in log normal patterns and which is also recognized here, indicates that a lot of very rare species were recorded (fig. 4). Apart from some of debatable explanations on the left-skewed phenomenon (e.g., immigration of the occasional species, more generality of the log series model rather than the log normal model), there is the explanation that this left-skewed curve is actually an incomplete normal curve came resulting from insufficient sampling effort. It implied that a number of rare species is still waiting to be discovered (Magurran, 2004; Molles, 2010). Accordingly, a further study of sessile rotifers in Thale Noi Lake may reveal a number of unobserved species, which may either be resolved by collecting many more samples or by more frequently visiting and sampling the study area.

4.2 Factors affect composition and distribution of sessile rotifer species in Thale Noi Lake

4.2.1 Water quality

The higher amount of precipitation during the rainy period compared to the dry period may cause all of the environmental variables measured to be lower in the former than during the letter period (table 6). During rainy season, water surface temperature basically decreased because of low penetration of sunlight and high wind action. In Thale Noi Lake, which is bordered by peat swamp forests in the North, rainy time causes influx of acid water into the lake via connecting canals. As a result, the average pH of the lake decreases during this period. In addition, the high amount of precipitation during the rainy period dilutes its water and causes a decrease in conductivity and turbidity, while at the same time, flushes brackish water that may flow in the lake during dry period back into Songkhla Lake through the connecting canal, resulting in a lower average salinity value. Significant differences in most of the environmental variables between the rainy and dry period (table 7) reflect that the season boundary the present study used (fig. 3) seems to be reasonable to get a good representation of a focal fauna in the lake both for studying diversity as well as enabling comparison of the temporal variation in species composition.

Because Thale Noi Lake is connected with various different zones around the lake, including a residential zone (around TN 1-2), peat swamp forests (around TN 3-7), Songkhla Lake connecting canals (around TN 8-9), and other small canals, these connections may be responsible for significant differences of some environmental variables measured in different parts of the lake, here represented by sampling stations (table 8, appendix IV). The result is that it is reasonable to collect interesting plant species in more than one sampling station, if possible, as in the present study. This is not only necessary for getting a good representation of the diversity of sessile rotifers in the lake, but also to compare aspects such as horizontal variation among the different parts of the lake.

4.2.2 Seasonal variation of the sessile rotifers

Although most environmental factors investigated, including temperature, pH, conductivity, and salinity were significant different between the two seasons (table 7), the degree of seasonal fluctuating of these features only weakly affect species richness and composition of sessile rotifers in Thale Noi Lake on a whole-lake scale (table 9). This implies that, at scale of the lake, niche requirements and suitable chemical and physical water features were only slightly affected by seasonal changes. This result is not surprising considering that Thale Noi is a lake with low water level fluctuation during the year (Inpang, 2008), is located at low altitude and at tropical latitudes (Office of Environmental Policy and Planning, 2000), when compare to lakes situated elsewhere (Arora and Mehra, 2003; Wallace *et al*., 2006). In addition, the result broadly agrees with a recent study carried out on the generic composition of zooplankton communities of Thale Noi Lake (Inpang, 2008). However, effects of seasonal changes are more noticeable regarding commonness and rarity of sessile rotifer species (table 9). It is common that some species react opportunistically to changing environments while other species lose their competitive ability to some extent in changing environmental conditions, resulting in a decrease of their population. This, however, normally does not affect the presence of species (Molles, 2010; Wallace *et al*., 2006).

Some of the species were only present during one seasonal period (table 10). There are a number of possible factors which may cause this, for instance, water temperature, food availability, or their historical adaptations for such as predator avoidance, dispersal ability, and reproductive success (Arora and Mehra, 2003; Krebs, 2009; Wallace, 1980; Wallace *et al*., 2006). The result points at the importance of repeated sampling over time to represent species diversity in a focal study area, at least, for the study of sessile rotifer biodiversity.

4.2.3 Local spatial variation of the sessile rotifers

Results showed that different parts of the lake (sampling stations) affect species richness or distribution and composition of the sessile rotifers observed (fig. 6, 7, table 11). Apart from the influence of different plants investigated (see further part 4.2.4), the correlation between the number of species observed and water environmental variables showed that pH seems to be one of the important factors determining species richness of sessile rotifers (table 13). The analysis shows that there is a suitable pH range for most of the sessile rotifers around 5.9-6.6. Above the upper and below the lower range, a smaller number of sessile rotifer species can be observed. This may reflect the optimum range of physiological functioning in sessile rotifers (Wallace *et al*., 2006). The result agrees with the conclusion of a previous study that periphytic rotifers including sessile species are usually found in acidic water habitats (Bērziņš and Pejler, 1987). In addition to the correlation, a pH effect can also be noticed in the stations near the point where runoff of acidic water from peat swamp forests at the North of the lake (around TN 5-8). During rainy period, a large amount of acidic water enters this zone and the present study observed only few sessile rotifers (fig. 7), whereas during dry period, the runoff of acidic water is lower and pH value increases, resulting in a higher number of sessile rotifers observed (fig. 7).

The positive correlation between species richness of sessile rotifers and turbidity during rainy period (table 13) may result from higher turbidity implying higher food availability of various kinds, such as, tiny particles, bacteria, organic detritus, and various sizes of phytoplankton (Molles, 2010; Pollard *et al*., 1998). Moreover, higher turbidity reduces the effectiveness of visual predators (Bruton, 1985; Miner and Stein, 1993; Vinyard and O'Brien, 1976 cited in Pollard *et al*., 1998). However, too high turbidity may negatively affect the settling ability of sessile rotifer larva (Wallace, 1980), as this revealed in the decrease of sessile rotifers in the sampling stations that had quite high turbidity values (compare fig. 5 and 7).

Nevertheless, many additional factors should be concerned in a future study to obtain a solid conclusion on those factors that affect local spatial distribution of sessile rotifers within the lake. Potential such factors are, density of zooplanktivorous predators, either of invertebrates and vertebrates, substrate heterogeneity, chlorophyll a concentration from various size fractions, flow rates, and sampling effort. In conclusion, and as far as the present data allow, water pH as well as turbidity may be two of the major factors determining distribution and diversity of sessile rotifers in different parts of Thale Noi Lake.

4.2.4 The sessile rotifers on the inhabiting plant substrates

The result indicate that all observed aquatic plants species can be employed as substratum by sessile rotifers (fig. 9), and sessile rotifers can indeed reach very high densities (Wallace *et al*., 2006). Sessile rotifers may therefore be an important group of primary consumers who run ecosystem functioning, in particular within a shallow lake with aquatic plant beds, in particular as the bed zone usually contains higher diversity of fauna than the pelagic zone (Kuczyn´ska-Kippen, 2007). Moreover, the results illustrate how easy these animals can be found and, as noted in the taxonomy section above, how much new knowledge on this animal group is waiting to be discovered. Thus, sessile rotifers are opportunistic and worth being studied to increase knowledge on, at least, biodiversity in Thailand.

Besides the water quality, aquatic plant species themselves influence species richness and composition of sessile rotifers assemblages in each sampling station (fig. 9, table 12, 14). The plants that serve as substratum for the more diverse communities of sessile rotifer are in general those that are more structurally diverse. Differences in diversity of the communities on structurally diverse versus morphologically more homogeneous aquatic plants have quite long been recognized, not only in epiphyton, which including sessile rotifers, but also in various periphytic rotifer communities (Duggan, 2001; Edmondson, 1944; Pejler and Bērziņš, 1993). The reasons may relate to different potentials of the two plants groups to provide nutritional sources (i.e. amount of ambient organic particles and phytoplankton), effective refuges to avoid predators, and decrease of water current in between more structurally complex plants, (Duggan, 2001; Krebs, 2009). However, *Utricularia* species and possibly also *Salvinia cucullata* Roxb. ex Bory are structurally heterogeneous but have relatively low diverse associated rotifer communities. This is in particular surprising for

Utricularia species, which has been reported to in general be associated with a highly diverse sessile rotifer community (Edmondson, 1944; Pejler and Bērziņš, 1993; Wallace and Edmondson, 1986). The reason for this may be that these particular plants are usually present, and were only collected from, those sampling stations that are characterized by environments conditions that are less suitable for sessile rotifers. That external, environmental factors are indeed responsible is confirmed by initial observations in a small bed of *Utricularia* species in the vicinity of sampling station 2 and 3. Here indeed, the observed sessile rotifer community was as diverse as what is further recorded from Water hyacinth roots. On *Salvinia cucullata* Roxb. ex Bory, however, the low richness of sessile rotifers might result from features of their root system which makes them less suitable for sessile rotifers: the roots are rather densely packed and covered with sediment (Wallace, 1980). Other factors may be relevant as well but further research will be needed to unravel the issue. In addition, the same kind of explanations as for *Utricularia* species can explain why a plant such as *Hanguana malayana* (Jack.) Merr., which is morphologically homogeneous, is nevertheless associated with a relatively highly diverse sessile rotifer community.

CHAPTER 5

CONCLUSIONS

5.1 Conclusions drawn from study of diversity of sessile rotifers in Thale Noi Lake

One obvious outcome from the present study is that knowledge of biodiversity of sessile rotifers in Thailand has been scant. Even the present alpha-diversity study was conducted in a single lake, the knowledge of sessile rotifers in Thailand increased significantly as twenty-seven species are newly added to Thai fauna. Moreover, the results pointed out not only to the fact that a study on the biodiversity of these microinvertebrates in Thailand is important to understand the diversity of natural resources within our country, but also to the biological importance of Thale Noi Lake as an academic interest and a valuable conserved area because several new taxa including *Melicerta coloniensis* Colledge, *Acyclus* sp., *Collotheca* sp., and *Ptygura* sp.1 are proposed, and nearly a half of members of the group are recorded from the lake.

5.2 Contribution to the pool of knowledge

5.2.1 On Taxonomy and Biodiversity

The present study confirmed the hidden diversity of sessile rotifers, and contributed to knowledge of biodiversity of these animals at global, regional, and especially faunal richness in Thailand. The study also unraveled habitat diversity which is here referred to as species of inhabiting aquatic plants. Besides proposing new taxa and a new combination that provokes taxonomy in the group, critical taxonomic remarks in many of them are vital to future taxonomic study of these rotifers.

5.2.2 On Biogeography

The present result supported the idea of absolutely long distant dispersal in microorganisms in the light of cosmopolitanism point of view which on grounds of the relatively high ratio of local/global diversity of the observed sessile rotifers. Moreover, this study proposed the case study of misidentification impact the geographic distribution of the rotifer species, and as a result, supported the fauna species, *Octotrocha speciosa* Thorpe, for the affinity of Oriental region or indeed so far as China, Cambodia, Vietnam (Meksuwan and Segers, personal observation) and Thailand.

5.2.3 On Ecology

Based just only on species occurrence, the present observation supported the principle of habitat preference for one species, *Ptygura beauchampi* Edmondson, 1940, on *Utricularia* spp., and supported the view that the structures of inhabiting plants influence species richness of sessile rotifers. Moreover, the importance of temporal and spatial observations to represent the faunal diversity within the lake was strongly recommended.

5.2.4 Contribution to conservation biology

In view of the proposition of new species that constitute Thale Noi Lake as their type locality and the fact that relatively high richness of sessile rotifers inhabit here, the present results demonstrated the biological importance of Thale Noi Lake and Thale Noi Non-Hunting Area Wetland, and provided the data to support the main thrust of the Office of Environmental Policy and Planning in an appeal to Ramsar Convention to broaden the wetland area. In addition, the data of species richness and composition may be used for monitoring the ecosystem in Thale Noi Lake and the wetland where diverse and seemingly uncontrollable activities from nearby areas have been expanded to a worrying extent.

BIBLIOGRAPHY

Angsupanich, S. 1985. Zooplankton community of Thale-noi, Songkhla lake. *Fisheries Gazette*. 38(6): 465-476.

Angsupanich, S. and Rukkheaw, S. 1984. Distribution of Rotifera in Thale-noi, Songkhla lake. *Songklanakarin J. Sci. Technol*. 6(4): 363-368. (in Thai).

Arora, J. and Mehra, N. K. 2003. Seasonal dynamics of rotifers in relation to physical and chemical conditions of the river Yamuna (Delhi), India. *Hydrobiologia*. 491: 101-109.

Artharamas, C. 1984. *The Survey of Aquatic Macrophytes in Thale-Noi*. Department of Biology, Faculty of Science, Prince of Songkla University.

Balian, E. V., Segers, H., Lévêque, C. and Martens, K. 2008. An introduction to the Freshwater Animal Diversity Assessment (FADA) project. *Hydrobiologia*. 595: 3-8.

Bērziņš, B. and Pejler, B. 1987. Rotifer occurrence in relation to pH. *Hydrobiologia*. 147: 107-116.

Bioton, D. T., Freeland, J. R., and Okamura, B. 2001. Dispersal in freshwater invertebrates. *Annu. Rev. Ecol. Syst*. 32: 159-181.

Boonsom, J. 1984. The Freshwater zooplankton of Thailand (Rotifera and Crustacea). *Hydrobiologia*. 113, 223-229.

Chayamarit, K. 2005. PONTEDERIACEAE. In: Santisuk, T. and Larsen, K. (Eds), *Flora of Thailand*, vol. 9, part 1, Prachachon Co. Ltd., Bangkok, Thailand, pp 51-57.

Chittapun, S. 2004. *Human Impact on Rotifera Communities of Coastal Peat Swamps in Phuket Province, Southern Thailand*. Ph. D. Thesis, Prince of Songkla University, Songkhla, Thailand.

Chittapun, S. and Pholpunthin, P. 2001. The rotifer fauna of peat-swamps in southern Thailand. *Hydrobiologia*. 446/447: 255-259.

Chittapun, S., Pholpunthin, P. and Segers, H. 2007. Diversity of rotifer fauna from five coastal peat swamps on Phuket island, southern Thailand. *ScienceAsia*. 33: 383-387.

Colledge, W. R. 1918. Notes on a new rotifer *Melicerta coloniensis*. *Proc. Roy. Soc. Queensland*. 30: 171-175.

Connor, E. F. and McCoy, E. D. 2001. Species-area relationships. *In: Encyclopedia of biodiversity*, Academic Press, San Diego, Vol. 5, pp 397-411.

De Meester, L., Gomez, A., Okamura, B. and Schwenk, K. 2002. The monopolization hypothesis and the dispersal-gene flow paradox in aquatic organisms. *Acta Oecol*. 23: 121-135.

De Paggi, S. J. and Koste, W. 1988. Rotifera from Saladillo river basin (Santa Fe province, Argentina). *Hydrobiologia*. 157: 13-20.

De Ridder, M. 1989. Rotifers from Western Sudan. *Hydrobiologia*. 179: 205-209.

De Smet, W. H. 1998. Preparation of rotifer trophi for light and scanning electron microscopy. *Hydrobiologia*. 387/388: 117-121.

Duggan, I. C. 2001. The ecology of periphytic rotifers. *Hydrobiologia*. 446/447: 139-148.

Dumont, H. J. 1983. Biogeography of rotifers. *Hydrobiologia*. 104: 19-30.

Edmondson, W. T. 1940. The sessile Rotatoria of Wisconsin. *T. Am. Microsc. Soc*. 59(4): 433-459.

Edmondson, W. T. 1944. Ecological studies of sessile Rotatoria, part I: factors affecting distribution. *Ecol. Monogr*. 14(1): 31-66.

Edmondson, W. T. 1945. Ecological studies of sessile Rotatoria, part II: dynamics of populations and social structures. *Ecol. Monogr*. 15(2): 141-172.

Edmondson, W. T. 1939. New species of Rotatoria, with notes on heterogonic growth. *Transactions of the American Microscopical Society*. 58(4): 459-472.

Edmondson, W. T. 1949. A formula key to the rotatarian genus *Ptygura*. *Transactions of the American Microscopical Society*. 68(2): 127-135.

Fenchel, T. and Finlay, B. J. 2004. The ubiquity of small species: Patterns of local and global diversity. *Bioscience*. 54(8): 777-784.

Fernando, C. H. and Zankai, N. P. 1981. The Rotifera of Malaysia and Singapore with remarks on some species. *Hydrobiologia*. 78: 205-219.

Finlay, B. J. 2002. Global dispersal of free-living microbial eukaryote species. *Science*. 269: 1061-1063.

Foissner, W. 2006. Biogeography and dispersal of micro-organisms: A review emphasizing protists. *Acta Protozool*. 45: 111-136.

Gómez, A. and Snell, T. W. 1996. Sibling species and cryptic speciation in the *Brachionus plicatilis* complex (Rotifera). *J. Evol. Biol*. 9: 953-964.

Groom, M. J., Meffe, G. K. and Carrol, C. R. 2006. *Principles of conservation biology*, 3^{rd} ed. Sinauer Associates: USA.

Harring, H. K. 1913. *Synopsis of the Rotatoria*. Smithsonian Institution. United States National Museum, Bulletin. 81: 1-226.

Haynes, R. R. 2001a. HYDROCHARITACEAE. In: Santisuk, T. and Larsen, K. (Eds), *Flora of Thailand*, vol. 7, part 3, Prachachon Co. Ltd., Bangkok, Thailand, pp 365-382.

Haynes, R. R. 2001b. POTAMOGETONACEAE. In: Santisuk, T. and Larsen, K. (Eds), *Flora of Thailand*, vol. 7, part 3, Prachachon Co. Ltd., Bangkok, Thailand, pp 387-390.

Hessen, D. O. and Walseng, B. 2008. The rarity concept and the commonness of rarity in freshwater zooplankton. *Freshwater Biol*. 53: 2026-2035.

Hudson, C. T. and Gosse P. H. 1886. *The Rotifera; or Wheel-animalcules*, the first volume. Longmans, Green & Co.: London.

Hudson, C. T. and Gosse P. H. 1889. *The Rotifera; or Wheel-animalcules*, the supplement. Longmans, Green & Co.: London.

Inpang, R. 2008. *Annual Changes of Zooplankton Communities of Different Size Fractions in Thale-Noi, Phatthalung Province*. Master of Science Thesis, Prince of Songkla University, Songkhla, Thailand.

International Commission on Zoological Nomenclature. 1999. *International Code of Zoological Nomenclature*, 4^{th} ed (English text). The International Trust for Zoological Nomenclature: London.

Jenkins *et al*. 2007. Does size matter for dispersal distance? *Global Ecol. Biogeogr*. 16: 415-425.

Koste, W. 1975. Über den Rotatorienbestand einter Mikrobiozönose in einem tropische aquatischen Saumbiotop, der *Eichornia crassipes*-Zone im litoral des Bung-Borapet, einem Stausee in Zentralthailand. *Gewässer und Abwässer*. 57/58: 43-58.

Koste, W. 1978. *Rotatoria*. Die Rädertiere Mitteleuropas. Borntraeger, Berlin, Stuttgart.

Krebs, C. J. 2009. *Ecology: the experimental analysis of distribution and abundance*, 6th ed. Pearson Benjamin Cummings: USA.

Kuczyn´ska-Kippen, N. 2007. Habitat choice in rotifer communities of three shallow lakes: impact of macrophyte substratum and season. *Hydrobiologia*. 593: 27-37.

Lachance, M.-A. 2004. Here and there or everywhere? *Bioscience*. 54: 884.

Larsen, K. 1972. HANGUANACEAE. In: Smitinand, T. and Larsen, K. (Eds), *Flora of Thailand*, vol. 2, The TISTR Press, Bangkok, Thailand, pp 164-166.

Leingpornpan, S. and Leingporpan, S. 2005a. *A study on aquatic plants and their distribution mapping in Thale Noi Lake* (research report). Thaksin University. pp 1-14. (in Thai).

Leingpornpan, S. and Leingporpan, S. 2005b. A study on aquatic plants and their distribution mapping in Thale Noi Lake. *Thaksin. J.* 8(2): 24-43.

Lomolino, M. V., Riddle, B, R., and Brown, J. H. 2006. *Biogeography*, 3rd ed. Sinauer Associates. USA.

Magurran, A. E. 2004. *Measuring Biological Diversity*. Blackwell Publishing: Oxford.

Maxwell, J. F. 1985. Taxonomic revision of *Utricularia* L. (Lentibulariaceae) in Thailand. Songklanakarin J. Sci. Technol. 7(4): 409-424.

Mayr, E. 1999. *Systematics and the origin of species from the viewpoint of a zoologist*. Harvard University Press: USA.

Minelli, A. 1993. *Biological systematics: the state of the art*. Chapman & Hall: London.

Molles, M. C. Jr. 2010. *Ecology: concepts and applications*, 5th ed. McGraw-Hill: New York.

Nielsen, I. C. 1985. LEGUMINOSAE-MIMOSOIDEAE. In: Smitinand, T. and Larsen, K. (Eds), *Flora of Thailand*, vol. 4, part 2, The TISTR Press, Bangkok, Thailand, pp 131-222.

Office of Environmental Policy and Planning. 2000. *Biodiversity of Thale-Noi Wetland*. Ministry of Science, Technology and Environment: Bangkok. (in Thai).

Penard, E. 1914. A propos de Rotifères. *Rev. Suisse. De Zool*. 22(1): 1-26.

Pejler, B and Bērziņš, B. 1993. On relation to substrate in sessile rotifers. *Hydrobiologia*. 259: 121-124.

Pholpunthin, P. 1997. Freshwater zooplankton (Rotifera, Cladocera and Copepoda) from Thale-noi, South Thailand. *J. Sci. Soc.* 23: 23-34.

Pholpunthin, P. and Chittapun, S. 1998. Freshwater Rotifera of the genus *Lecane* from Songkhla Province, southern Thailand. *Hydrobiologia*. 387/388: 23-26.

Pollard, A. I., Gonzalez, M. J., Vanni, M. J. and Headworth, J. L., 1998. Effects of turbidity and biotic factors on the rotifer community in an Ohio reservoir. *Hydrobiologia*. 387/388: 215-223.

Pourriot, R. 1996. Rotifers from Petit Saut reservoir (French Guyana), with the description of a new taxon. *Hydrobiologia*. 331: 43-52.

Sanoamuang, L. 1998. Rotifera of some freshwater habitats in the floodplain of the River Nan, northern Thailand. *Hydrobiologia*. 387/388: 27-33.

Sanoamuang, L. 2007. The rotifer communities of temporary waters in northeast Thailand. *KKU Res. J.* 12(3): 203-209.

Sarma, S. S. S. and Manuel, E-G. 1998. Rotifer diversity in a central Mexican pond. *Hydrobiologia*. 387/388: 47-54.

Savatenalinton, S. and Segers, H. 2005. Rotifers from Kalasin province, northeast Thailand, with notes on new and rare species. *Zool. Stud.* 44(3): 361-367.

Schröder, T. and Walsh, E. J. 2007. Cryptic speciation in the cosmopolitan *Epiphanes senta* complex (Monogononta, Rotifera) with the description of new species. *Hydrobiologia*. 593: 129-140.

Seepen, S. 1999. *Aquatic plants in Thailand*. Amarin Printing & Publishing Public Co. Ltd.: Bangkok. (in Thai).

Segers, H. 1993. Rotifera of some lakes in the floodplain of the River Niger (Imo State, Nigeria): I. new species and other taxonomic considerations. *Hydrobiologia*. 250: 39-61.

Seger, H. 1997. Contribution to a revision of *Floscularia* Cuvier, 1798 (Rotifera: Monogononta): notes on some Neotropical taxa. *Hydrobiologia*. 354: 165-175.

Segers, H. 2001. Zoogeography of the Southeast Asian Rotifera. *Hydrobiologia*. 446/447: 233-246.

Segers, H. 2002. The nomenclature of the Rotifera: annotated checklist of valid family- and genus-group names. *J. Nat. Hist.* 36: 631-640.

Segers, H. 2007. Annotated checklist of the rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. *Zootaxa*. 1564: 1-104.

Segers, H. 2008. Global diversity of rotifers (Rotifera) in freshwater. *Hydrobiologia*. 595: 49-59.

Segers, H., Kotethip, W. and Sanoamuang, L. 2004. Biodiversity of freshwater microfauna in the floodplain of the River Mun, northeast Thailand: the Rotifera monogononta. *Hydrobiologia*. 515: 1-9.

Segers, H. and Pholpunthin, P. 1997. New and rare Rotifera from Thale-noi lake, Phatthalung Province, Thailand, with a note on the taxonomy of Cephalodella (Notammatidae). *Annls Limnol.* 33(1): 13-21.

Segers, H. and Shiel, R. 2008. Diversity of cryptic Metazoa in Australian freshwaters: a new genus and two new species of sessile rotifer (Rotifera, Monogononta, Gnesiotrocha, Flosculariidae). *Zootaxa*. 1750: 19-31.

Segers, H. and De Smet, W. H. 2008. Diversity and endemism in Rotifera: a review, and *Keratella* Bory de St Vincent. *Biodivers*. *Conserv*. 17: 303-316.

Segers, H., Meksuwan, P. and Sanoamuang, L. 2010. New records of sessile rotifers (Rotifera: Flosculariacea, Collothecacea) from Southeast Asia. *Belg. J. Zool*. 140(2): 235-240.

Sharma, B. K. 2005. Rotifer communities of floodplain lakes of the Brahmaputra basin of lower Assam (N. E. India): biodiversity, distribution and ecology. *Hydrobiologia*. 533: 209-221.

Sharma, B. K. and Sharma, S. 2001. Biodiversity of Rotifera in some tropical floodplain lakes of the Brahmaputra river basin, Assam (N. E. India). *Hydrobiologia*. 446/447: 305-313.

Shephard, J. 1899. A new rotifer, *Lacinularia striolata*, with note on *L. pedunculata*. *Proceeding of the Royal Society of Victoria*. 20-35.

Simpson, D. A. and Koyama, T. 1998. CYPERACEAE. In: Santisuk, T. and Larsen, K. (Eds), *Flora of Thailand*, vol. 6, part 4, Diamond Printing Co. Ltd., Bangkok, Thailand, pp 247-485.

Smitinand, T. 2001. *Thai plant names* (revised edition). The Forest Herbarium, Royal Forest Department. Prachachon Co. Ltd., Bangkok, Thailand. (in Thai).

Statistical Analysis Software. 2008. JMP® 8.0 trial version. SAS Institute Inc.: USA.

Teeramaethee, J., Trevanich, A. and Sanoamuang, L. 2006. Biodiversity and abundance of rotifers in Bueng Boraphet, Nakhon Sawan province, Thailand. *KKU Res. J.* 11(3): 191-202. (in Thai).

Vidrine, M. F., McLaughlin, R. E. and Willis, O. R. 1985. Free-swimming colonial rotifers (Monogononta: Flosculariacea: Flosculariidae) in southwestern Louisiana rice fields. *Freshwat. Invertebr. Biol.* 4(4): 187-193.

Wallace, R. L. 1978. Substrate selection by larvae of the sessile rotifer *Ptygura beauchampi*. *Ecology*. 59(2): 221-227.

Wallace, R. L. 1980. Ecology of sessile rotifers. *Hydrobiologia*. 73: 181-193.

Wallace, R. L. 1987. Coloniality in the phylum Rotifera. *Hydrobiologia*. 147: 141-155.

Wallace, R. L. 2002. Rotifer: exquisite metazoans. *Integ. and Comp. Biol*. 42: 660-667.

Wallace, R. L. and Edmondson, W. T. 1986. Mechanism and adaptive significance of substrate selection by a sessile rotifer. *Ecology*. 67(2): 314-323.

Wallace, R. L., Snell, T. W., Ricci, C. and Nogrady, T. 2006. *Rotifera vol 1: Biology, Ecology and Systematics*. In: *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World*, 23. Segers, H. and Dumont, H.J.F. (Eds). Kenobi productions, Ghent, Belgium and Backhuys Academic Publishing, The Hague, The Netherlands.

Western, G. 1891. Notes on rotifers: a free-swimming variety of *Lacinularia* and a new rotifer found at Guildford. *Journ. Q.M.C.* 254-258.

Winston, J. E. 1999. *Describing species: practical taxonomic procedure for biologists*. Columbia University Press: New York.

APPENDIX

Appendix I. Composition and distribution of sessile rotifers on the aquatic plant species (for sessile taxa) and the sampling stations (for planktonic colonial taxa) (* = underrepresented species).

The aquatic plants / **Sessile rotifers**	**EO**	**HM**	**NN**	**NO**	**LA**	**HA**	**EC**	**SC**	**NI**	**NL**	**CD**	**HV**	**PM**	**UA**	**US**
1. *Acyclus inquietus* Leidy	-	-	-	+	+	+	+	-	-	-	-	-	-	+	-
2. *Acyclus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
3. *Beauchampia crucigera* (Dutrochet)	-	+	-	+	+	+	+	-	-	-	+	-	-	+	-
4. *Collotheca algicola* (Hudson)	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
5. *C. ambigua* (Hudson)	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+
6. *C. campanulata* (Dobie)	-	-	-	+	-	-	+	+	-	-	-	-	-	-	+
7. *C. campanulata* var. *longicaudata* (Hudson)	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
8. *C. heptabrachiata* (Schoch)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
9. *C. ornata* (Ehrenberg)	-	-	+	+	+	+	+	-	-	+	-	-	-	+	+
10. *C. stephanochaeta* Edmondson	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-
11. *C. tenuilobata* (Anderson)	-	+	-	+	+	+	+	+	-	-	-	-	-	+	+
12. *C. trilobata* (Collins)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
13. *Collotheca* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
14. *Conochilus (Conochilus) hippocrepis* (Schrank)	Planktonic colonial species: TN 2														
15. *Floscularia armata* Segers	-	-	-	+	+	+	+	-	-	-	-	-	-	+	+
16. *F. bifida* Segers	-	+	-	+	+	-	+	-	-	-	+	+	-	+	+

Appendix I. (Continued)

Sessile rotifers / The aquatic plants	EO	HM	NN	NO	LA	HA	EC	SC	NI	NL	CD	HV	PM	UA	US
17. *Floscularia conifera* (Hudson)	-	+	+	+	+	+	+	-	-	+	-	+	-	+	+
18. *F. pedunculata* (Joliet)	-	+	+	+	+	-	+	-	-	-	+	-	-	-	-
19. *F. ringens* (Linnaeus)	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-
20. *F. wallacei* Segers & Shiel	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
21. *Lacinularia flosculosa* (Muller)	-	+	-	+	+	+	+	-	-	-	-	+	-	+	-
22. *L.* cf. *pedunculata* Hudson	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
23. *Limnias ceratophylli* Schrank	-	+	+	+	+	-	+	-	+	+	-	+	+	-	+
24. *L. melicerta* Weisse	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-
25. *Melicerta coloniensis* Colledge	-	+	-	+	+	-	+	-	-	+	-	+	-	+	-
26. *Octoctrocha speciosa* Thorpe	-	-	-	+	+	+	+	-	-	-	-	-	+	+	+
27. *Pentatrocha gigantea* Segers & Shiel	-	-	-	-	+	-	+	-	-	-	-	-	-	+	-
28. *Ptygura agassizi* Edmondson*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
39. *P. barbata* Edmondson	+	+	+	+	+	+	+	+	-	+	-	+	-	+	+
30. *P. beauchampi* Edmondson	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
31. *P. crystallina* (Ehrenberg)	-	-	-	+	+	+	+	-	-	-	-	+	-	+	+
32. *P. ctenoida* Koste & Tobias*	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-
33. *P. elsteri* Koste*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-

Appendix I. (Continued)

The aquatic plants / Sessile rotifers	EO	HM	NN	NO	LA	HA	EC	SC	NI	NL	CD	HV	PM	UA	US
34. *Ptygura furcillata* (Kellicott)*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
35. *P. longicornis* (Davis)	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-
36. *P. mucicola* (Kellicott)*	-	-	-	+	-	+	+	-	-	-	+	-	-	-	+
37. *P. noodti* (Koste)	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-
38. *P. pedunculata* Edmondson	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-
39. *P. tacita* Edmondson	-	-	-	+	+	+	+	-	-	-	-	-	-	+	+
40. *P. wilsonii* (Anderson & Shephard)*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
41. *Ptygura* sp.1	-	-	-	+	-	+	+	-	-	-	-	+	-	-	+
42. *Ptygura* sp.2	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+
43. *Sinantherina semibullata* (Thorpe)	Planktonic colonial species: TN 2, 3, 5, 6														
44. *S. socialis* (Linnaeus)	-	-	-	+	+	+	+	-	-	-	+	+	-	+	+
45. *S. spinosa* (Thorpe)	Planktonic colonial species: TN 2, 5, 6														
46. *Stephanoceros fimbriatus* (Goldfusz)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
47. *S. fimbriatus millsii* (Kellicott)	-	+	-	-	+	-	-	-	-	-	-	-	-	+	-

Appendix II. Frequency of occurrence (%) and commonness and rarity (%) of the sessile rotifers.

No.	**Sessile rotifers**	**% occurrence (n = 66)**	**Commonness & Rarity**
1.	*Limnias melicerta* Weisse	56.06	100
2.	*Ptygura barbata* Edmondson	46.97	83.79
3.	*Ptygura crystallina* (Ehrenberg)	34.85	62.17
4.	*Floscularia conifera* (Hudson)	30.30	54.05
5.	*Lacinularia flosculosa* (Muller)	25.76	45.95
6.	*Limnias ceratophylli* Schrank	24.24	43.24
7.	*Sinantherina socialis* (Linnaeus)	24.24	43.24
8.	*Floscularia pedunculata* (Joliet)	22.73	40.55
9.	*Octoctrocha speciosa* Thorpe	18.18	32.43
10.	*Floscularia bifida* Segers	16.67	29.74
11.	*Beauchampia crucigera* (Dutrochet)	15.15	27.02
12.	*Ptygura tacita* Edmondson	15.15	27.02
13.	*Collotheca tenuilobata* (Anderson)	13.64	24.33
14.	*Floscularia ringens* (Linnaeus)	13.64	24.33
15.	*Floscularia armata* Segers	12.12	21.62
16.	*Melicerta coloniensis* Colledge	12.12	21.62
17.	*Collotheca ornata* (Ehrenberg)	10.61	18.93
18.	*Collotheca campanulata* (Dobie)	9.09	16.21
19.	*Ptygura* sp.1	7.58	13.52
20.	*Acyclus inquietus* Leidy	6.06	10.81
21.	*Collotheca ambigua* (Hudson)	4.55	8.12
22.	*Ptygura longicornis* (Davis)	4.55	8.12
23.	*Ptygura pedunculata* Edmondson	4.55	8.12
24.	*Ptygura beauchampi* Edmondson	3.03	5.40
25.	*Acyclus* sp.	1.52	2.71
26.	*Collotheca heptabrachiata* (Schoch)	1.52	2.71
27.	*Collotheca stephanochaeta* Edmondson	1.52	2.71
28.	*Floscularia wallacei* Segers & Shiel	1.52	2.71
29.	*Lacinularia* cf. *pedunculata* Hudson	1.52	2.71
30.	*Ptygura* sp.2	1.52	2.71
31.	*Pentatrocha gigantea* Segers & Shiel	1.52	2.71
32.	*Stephanoceros fimbriatus* (Goldfusz)	1.52	2.71

Appendix III. Frequency of occurrence (%) of the sessile rotifers observed in rainy and dry period.

Rainy period	**% occurrence (33 samples)**	**Dry period**	**% occurrence (33 samples)**
Limnias melicerta Weisse	54.55	*Limnias melicerta* Weisse	57.58
Ptygura crystallina (Ehrenberg)	42.42	*Ptygura barbata* Edmondson	54.55
Ptygura barbata Edmondson	39.39	*Floscularia conifera* (Hudson)	30.30
Floscularia conifera (Hudson)	30.30	*Limnias ceratophylli* Schrank	30.30
Sinantherina socialis (Linnaeus)	27.27	*Lacinularia flosculosa* (Muller)	27.27
Collotheca tenuilobata (Anderson)	24.24	*Ptygura crystallina* (Ehrenberg)	27.27
Floscularia pedunculata (Joliet)	24.24	*Ptygura tacita* Edmondson	24.24
Floscularia bifida Segers	24.24	*Floscularia pedunculata* (Joliet)	21.21
Lacinularia flosculosa (Muller)	24.24	*Sinantherina socialis* (Linnaeus)	21.21
Beauchampia crucigera (Dutrochet)	21.21	*Octoctrocha speciosa* Thorpe	18.18
Melicerta coloniensis Colledge	21.21	*Collotheca ornata* (Ehrenberg)	15.15
Limnias ceratophylli Schrank	18.18	*Floscularia armata* Segers	12.12
Octoctrocha speciosa Thorpe	18.18	*Floscularia ringens* (Linnaeus)	12.12
Collotheca campanulata (Dobie)	15.15	*Ptygura* sp.1	12.12
Floscularia ringens (Linnaeus)	15.15	*Beauchampia crucigera* (Dutrochet)	9.09
Floscularia armata Segers	12.12	*Floscularia bifida* Segers	9.09
Acyclus inquietus Leidy	6.06	*Acyclus inquietus* Leidy	6.06
Collotheca ornata (Ehrenberg)	6.06	*Ptygura pedunculata* Edmondson	6.06
Ptygura longicornis (Davis)	6.06	*Collotheca campanulata* (Dobie)	3.03
Ptygura tacita Edmondson	6.06	*Collotheca tenuilobata* (Anderson)	3.03
Ptygura pedunculata Edmondson	3.03	*Melicerta coloniensis* Colledge	3.03
Ptygura sp.1	3.03	*Ptygura longicornis* (Davis)	3.03

Appendix IV. Environmental variables that were significantly different among sampling stations in each sampling period. Stations not connected by same letter are significantly different.

Rainy period

pH

Stations				Mean
1	A			43.482867
9	A	B		39.662067
2	A	B	C	32.471533
3	A	B	C	30.994467
4	A	B	C	29.833900
5	A	B	C	25.076967
7	A	B	C	19.181533
8		B	C	16.331833
6			C	10.984200

Conductivity

Stations					Mean
3	A				0.04655372
1	A	B			0.03862410
2	A	B	C		0.03557024
4	A	B	C	D	0.02400145
9	A	B	C	D	0.02322342
5		B	C	D	0.01442379
6		B	C	D	0.01181771
8			C	D	0.01055241
7				D	0.00152740

Dry period

pH

Stations			Mean
5	A		0.16738885
3	A		0.16625862
4	A		0.16570017
2	A		0.16439020
6	A		0.16263734
7	A	B	0.15364434
8	A	B	0.14892888
9	A	B	0.13527026
1		B	0.11346324

Salinity

Stations			Mean
9	A		0.09333333
1	A	B	0.07000000
8	A	B	0.06000000
2	A	B	0.05333333
3	A	B	0.04000000
4	A	B	0.03333333
7	A	B	0.03333333
5	A	B	0.03000000
6		B	0.01000000

PHOTOGRAPHIC PLATES

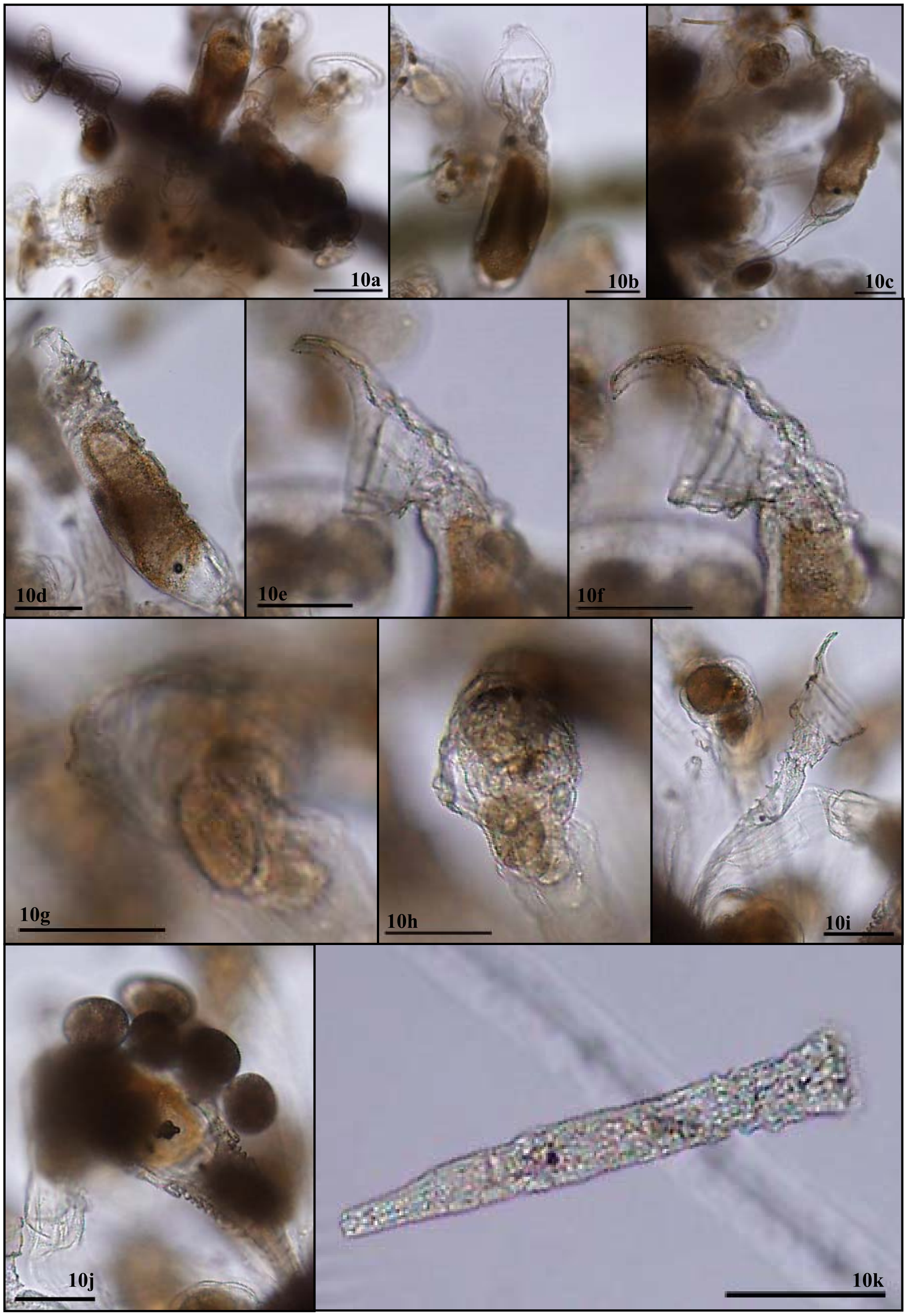

Plate 10. *Acyclus inquietus* Leidy, 1882: 10a: females on a colony of *Sinantherina socialis* (Linnaeus); 10b: a female in dorsal view; 10c: a female in lateral view; 10d: a behavior; 10e-10f: corona in lateral view; 10g-10h: the animal was swallowing an adult female in the colony; 10i: an immature animal; 10j: their eggs; 10k: a larva. Scale bars: 10a = 200 μm, 10b-10k = 100 μm.

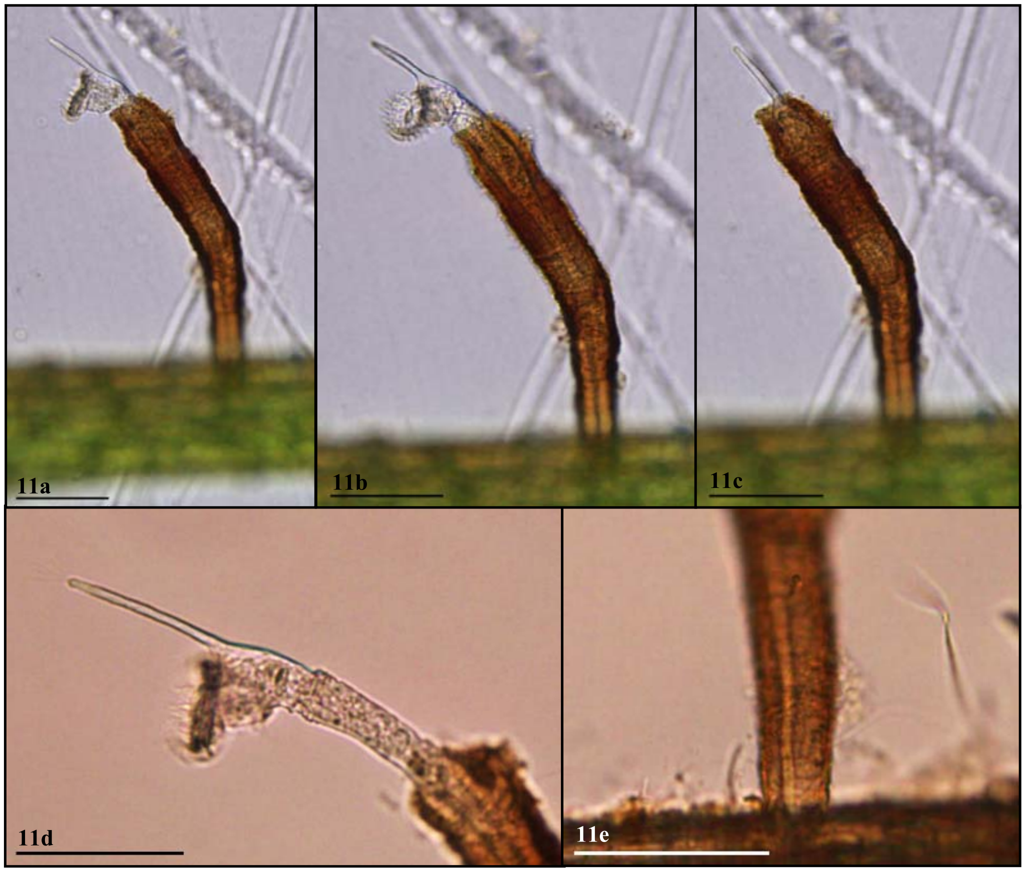

Plate 11. *Beauchampia crucigera* (Dutrochet, 1812): 11a: a female in lateral view; 11b: a female in ventral-lateral view; 11c: contracted animal; 11d: corona and dorsal antennae in lateral view; 11e: their foot. Scale bars: 11a-11e = 100 µm.

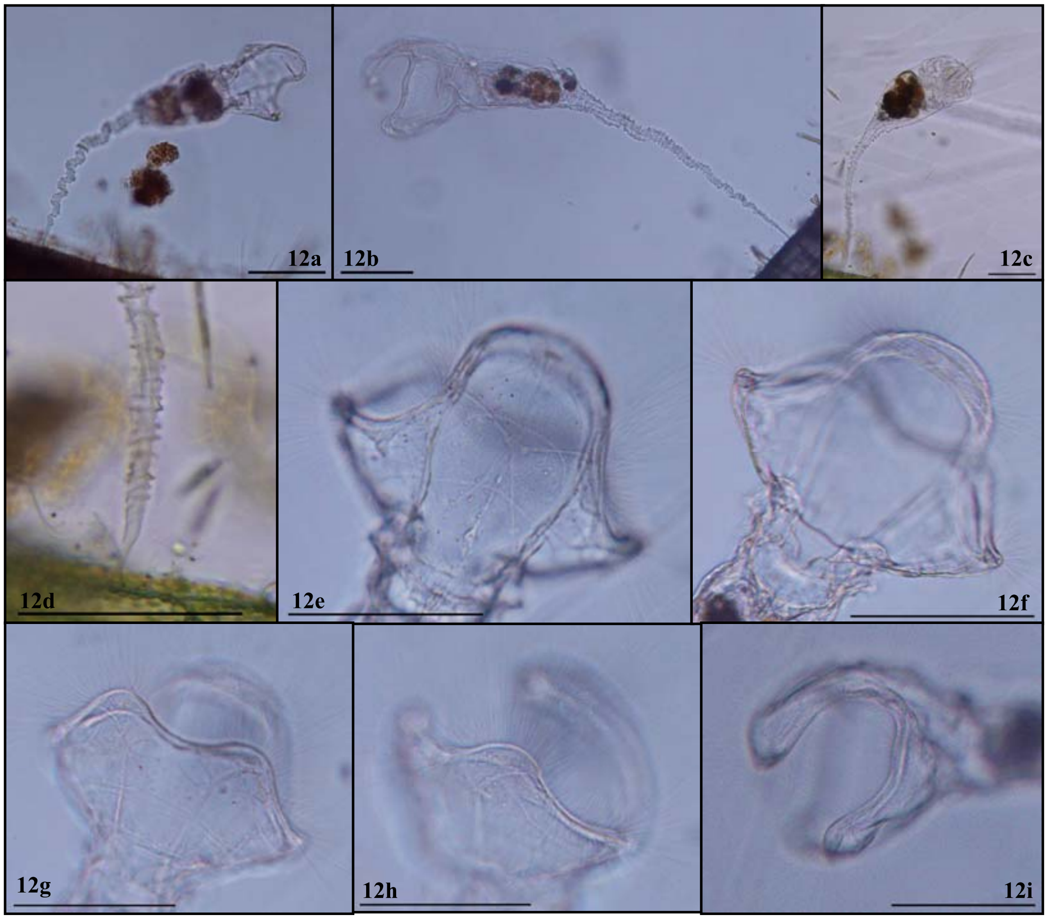

Plate 12. *Collotheca campanulata* (Dobie, 1849): 12a-12b: a female in different views; 12c: contracted animal; 12d: their foot and attached stalk; 12e-12i: corona in different views. Scale bars: 12a-12i = 100 µm.

Plate 13. *Collotheca campanulata* var. *longicaudata* (Hudson, 1883): 13a: a female; 13b-13c: corona in different views; 13d: contracted animal; 13e-13f: their foot. Scale bars: 13a-13f = 100 µm.

Plate 14. *Collotheca heptabrachiata* (Schoch, 1869): 14a: a female; 14b: a contracted animal; 14c: the corona point-lobes in lateral-anterior view; 14d: the corona point-lobes in anterior (top) view. Scale bars: 14a-14d = 100 µm.

Plate 15. *Collotheca ornata* (Ehrenberg, 1832): 15a-15b: females in different views; 15c: the corona in ventral-lateral view; 15d: the corona in dorsal-lateral view; 15e: a contracted animal; 15f: their egg and gelatinous case. Scale bars: 15a-15f = 100 µm.

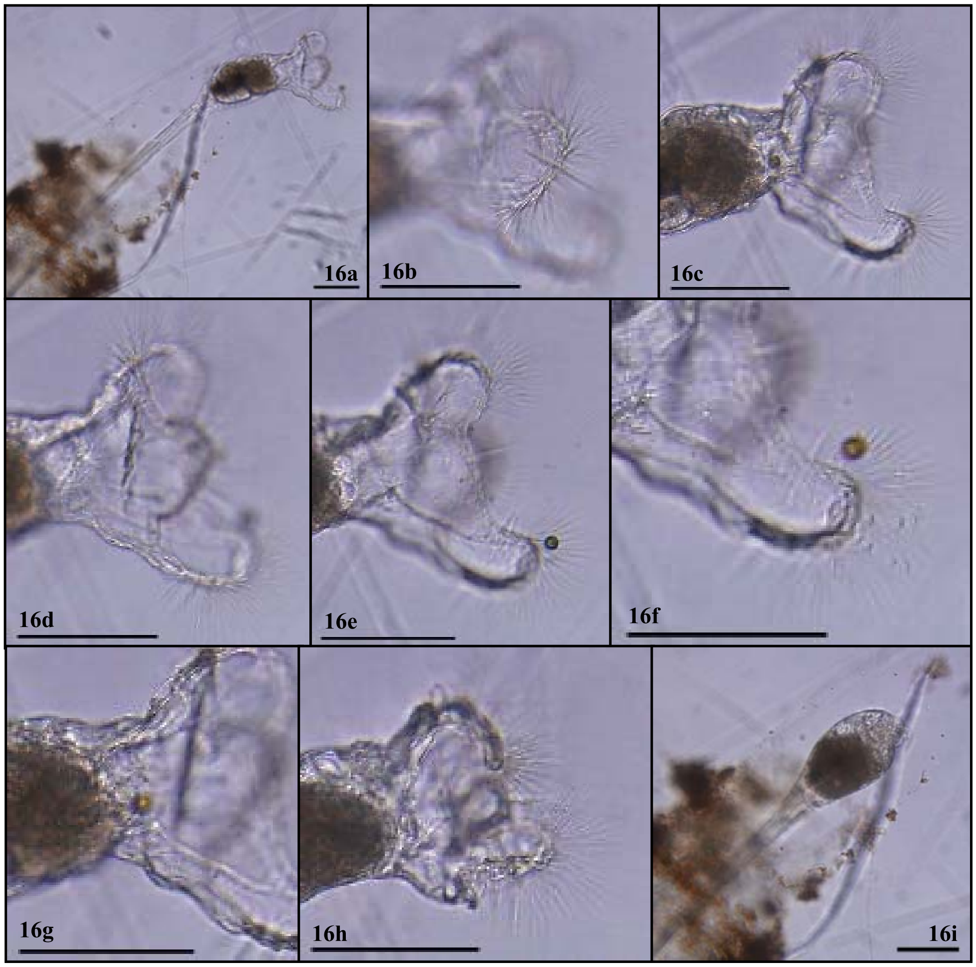

Plate 16. *Collotheca stephanochaeta* Edmondson, 1936: 16a: a female; 16b-16d: the corona lobes in different views; 16e-16g: the corona with their prey; 16h: incomplete contracted corona; 16i: a contracted animal. Scale bars: 16a-16i = 100 µm.

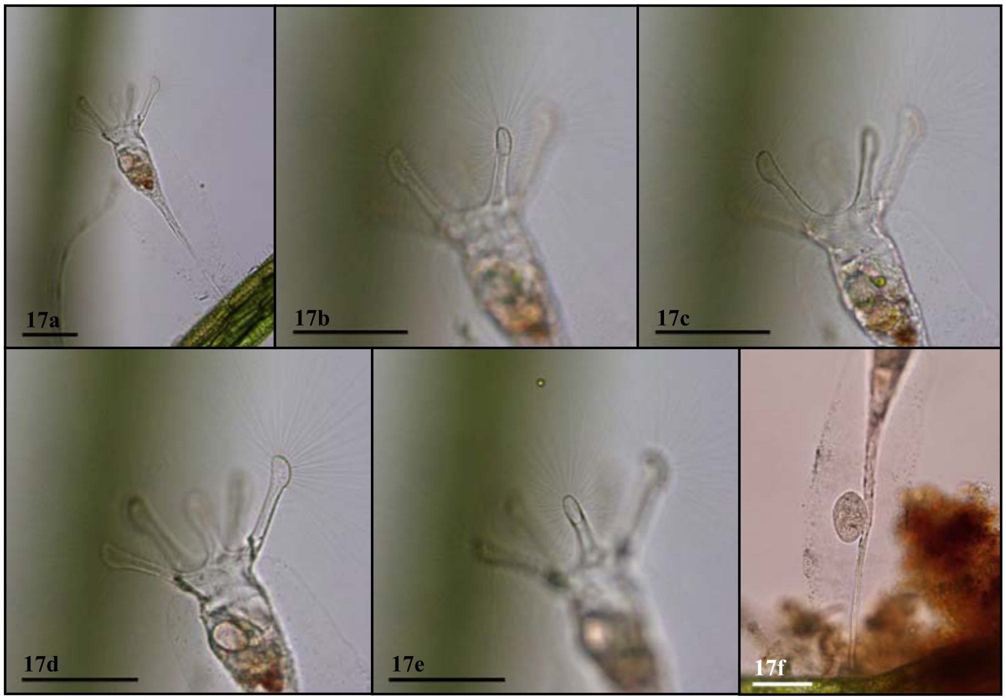

Plate 17. *Collotheca tenuilobata* (Anderson, 1889): 17a: a female; 17b-17e: the corona lobes in different views; 17f: their foot, egg, and gelatinous case. Scale bars: 17a-17f = 100 µm.

Plate 18. *Collotheca trilobata* (Collins, 1872): 18a: a female; 18b-18e: the corona lobes in different views; 18f: some part of foot and attachment stalk. Scale bars: 18a-18f = 100 µm.

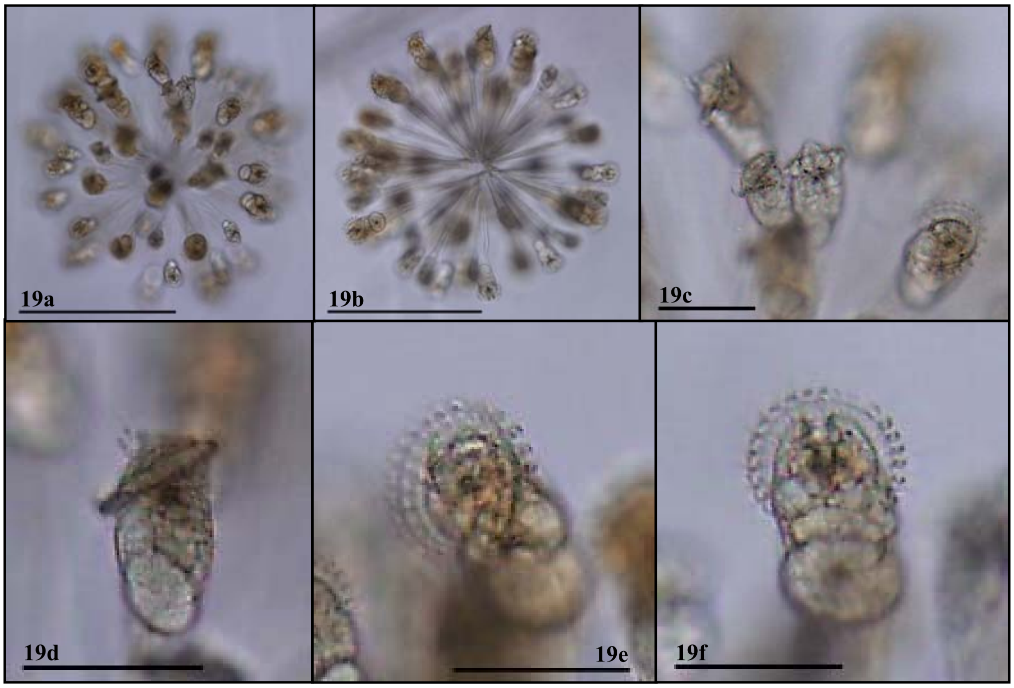

Plate 19. *Conochilus (Conochilus) hippocrepis* (Schrank, 1803): 19a-19b: a colony in different views; 19c: females on the colony; 19d: the dorsal antenna in lateral view; 19e-19f: their corona in different views. Scale bars: 19a-19b = 500 µm.; 19c-19f = 100 µm.

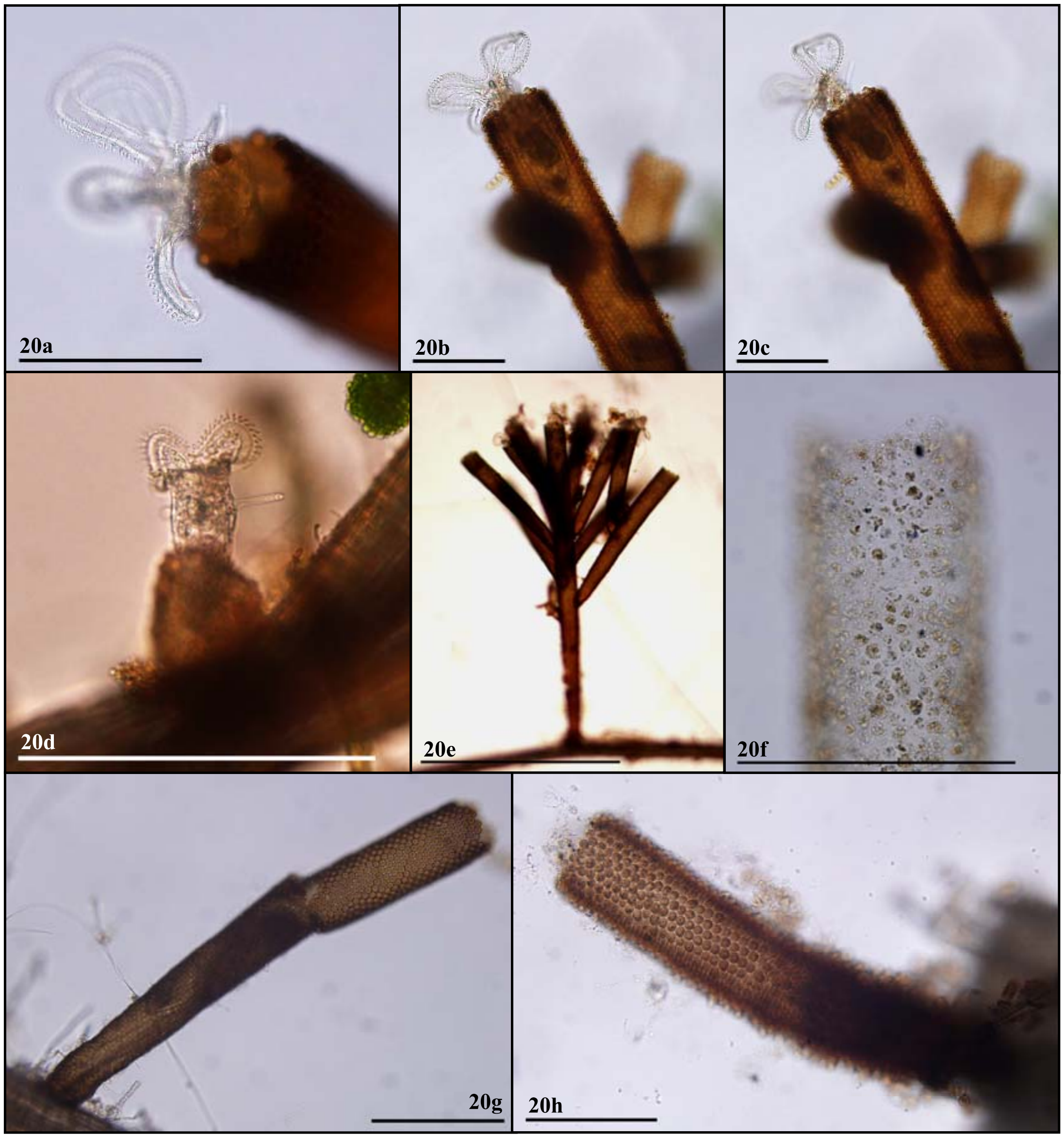

Plate 20. *Floscularia* spp.: 20a-20c: corona features in different views; 20d: a young specimen; 20e: a colony; 20f-20h: tube structures and components of different species. Scale bars: 20a-20d, 20f-20h = 200 µm.; 20e = 500 µm.

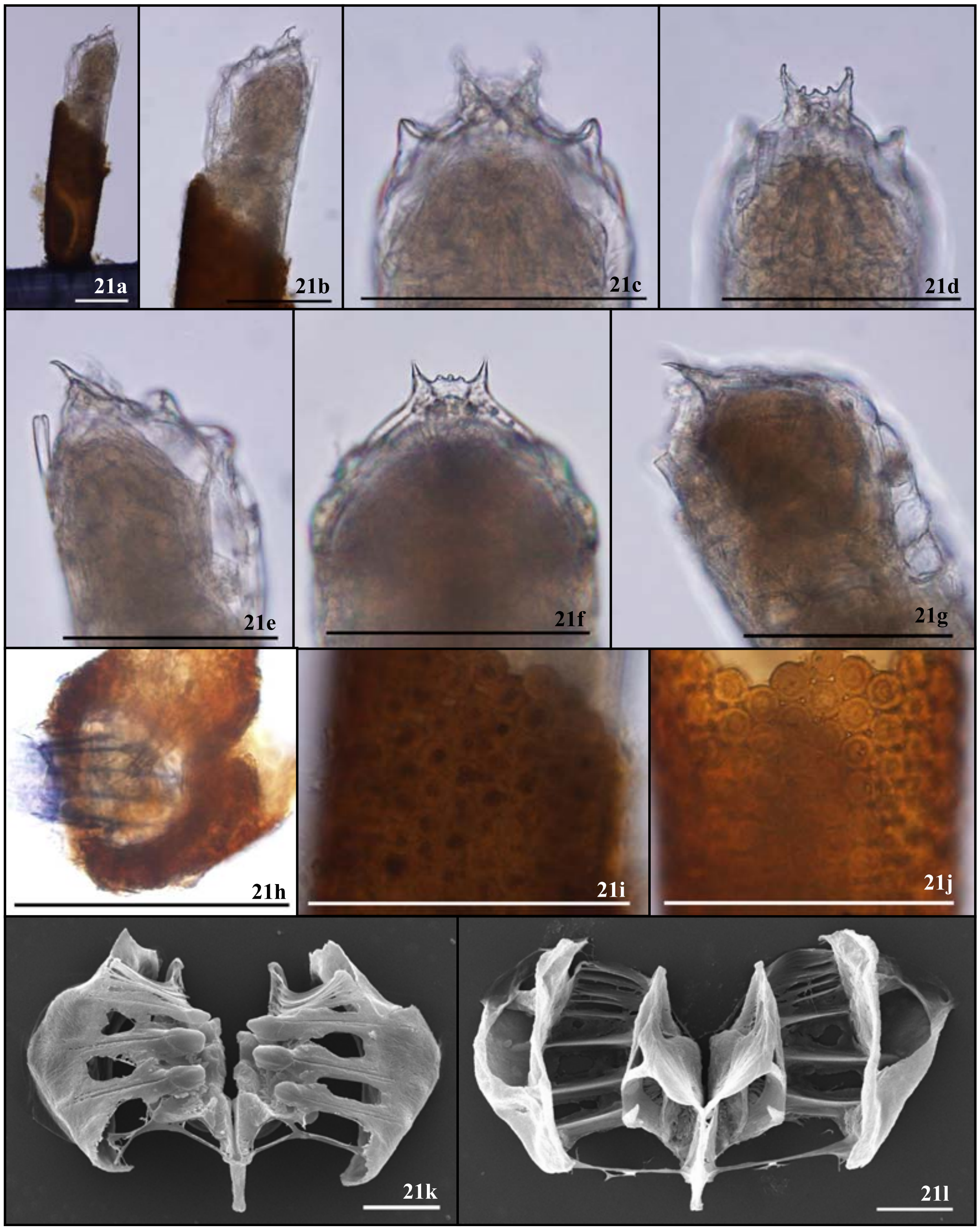

Plate 21. *Floscularia armata* Segers, 1997: 21a-21b: a contracted female; 21c: anterior plate feature in dorsal view; 21d-21e: dorsal projection feature in ventral and lateral views, respectively; 21f-21g: dorsal projection of a variant form in ventral and lateral views, respectively; 21h: attachment stalk; 21i-21j: tube feature of the typical and variant form, respectively; 21k-21l: their trophi in frontal and caudal views, respectively. Scale bars: 21a-21j = 100 µm.; 21k-21l = 10 µm.

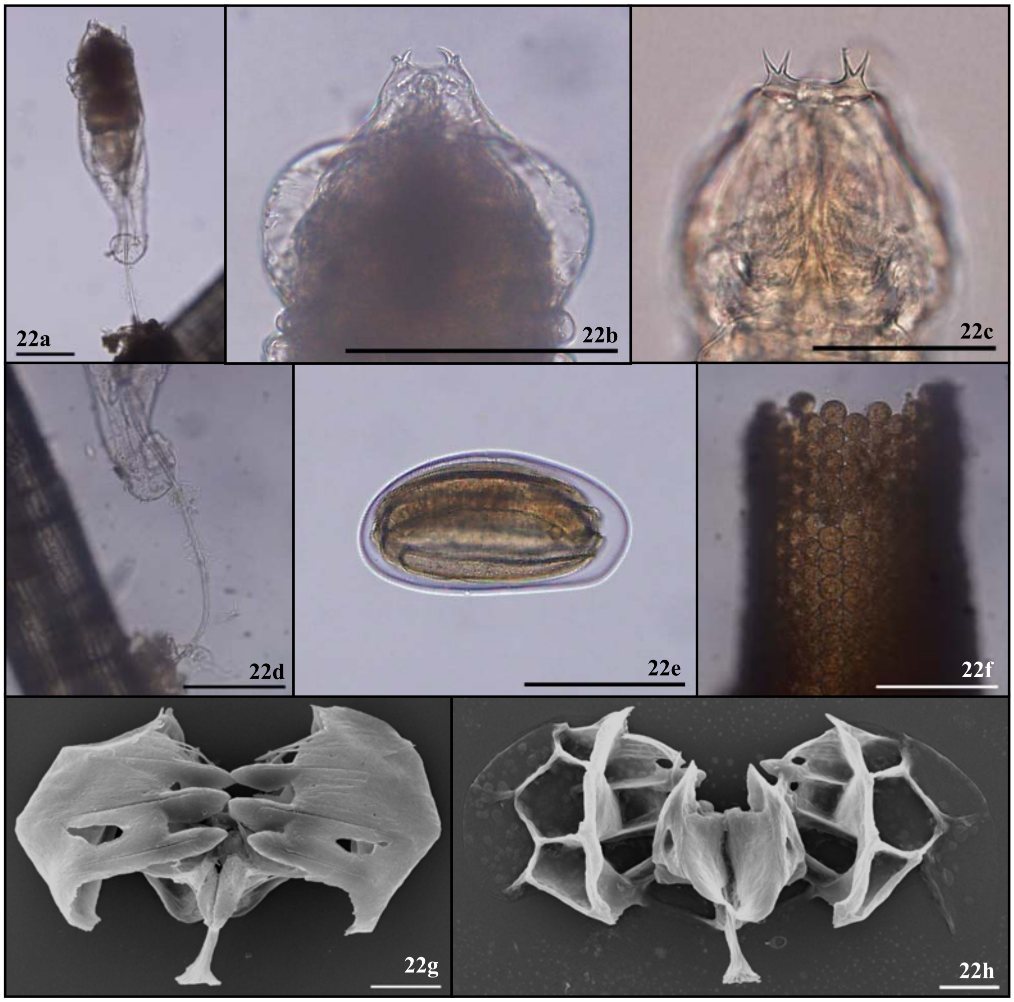

Plate 22. *Floscularia bifida* Segers, 1997: 22a: a female; 22b-22c: dorsal hook feature of different specimens; 22d: foot stalk; 22e: a resting egg; 22f: tube features; 22g-22h: their trophi in frontal, and caudal view, respectively. Scale bars: 22a-22f = 100 µm.; 22g-22h = 10 µm.

Plate 23. *Floscularia conifera* (Hudson, 1886): 23a: a female; 23b-23c: the dorsal hooks in different views; 23d: their tube feature; 23e: tube components. Scale bars: 23a, 23d = 200 µm.; 23b-23c = 50 µm.; 23e = 100 µm.

Plate 24. *Floscularia pedunculata* (Joliet, 1883): 24a-24b: contracted females; 24c-24d: dorsal hook features in ventral, and lateral view, respectively; 24e-24f: foot stalk; 24g: their trophi. Scale bars: 24a-24f = 100 µm.; 24g = 10 µm.

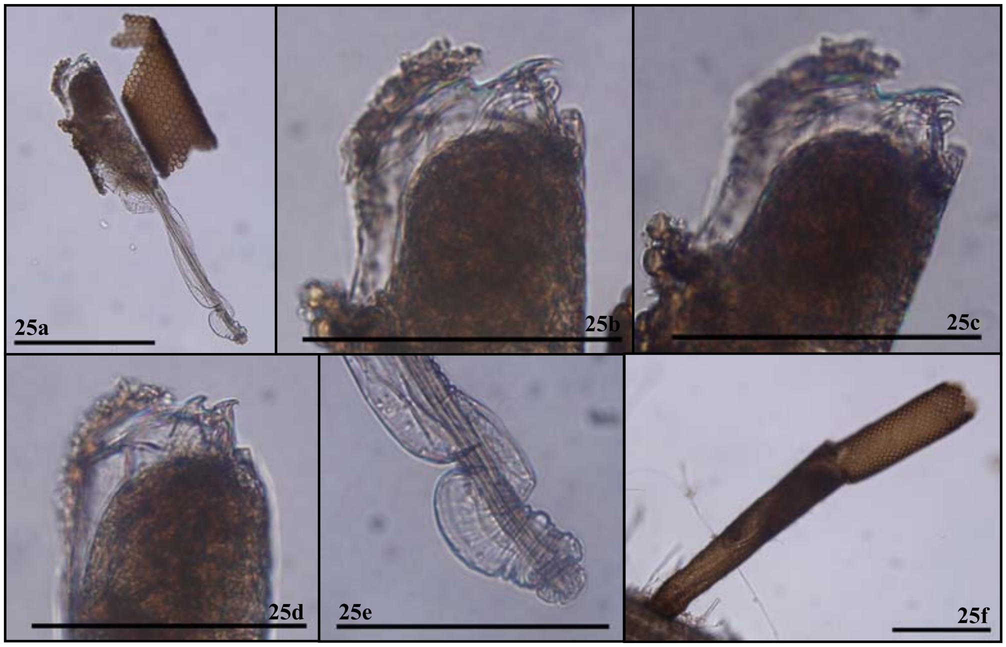

Plate 25. *Floscularia ringens* (Linnaeus, 1758): 25a: a contracted female; 25b-25d: the pair of dorsal hooks in different views; 25e: foot and attachment stalk; 25f: their tube. Scale bars: 25a, 25f = 200 µm.; 25b-25e = 100 µm.

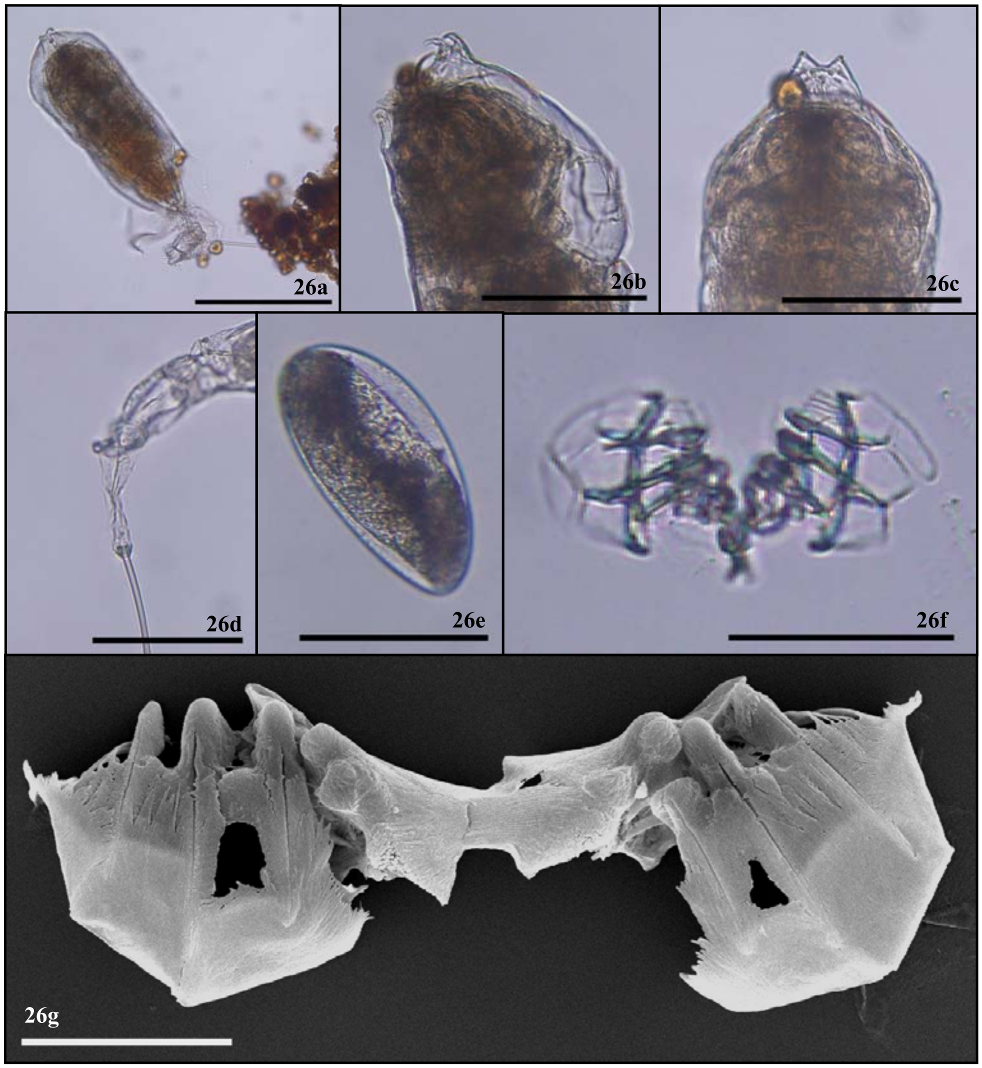

Plate 26. *Floscularia wallacei* Segers & Shiel, 2008: 26a: a contracted female; 26b-26c: the pair of dorsal hooks in different views; 26d: their foot and foot stalk; 26e: a parthenogenetic egg; 26f: light microscope photograph of their trophi; 26g: SEM photograph of their trophi. Scale bars: 26a = 200 µm.; 26b-26e = 100 µm.; 26f = 50 µm.; 26g = 20 µm.

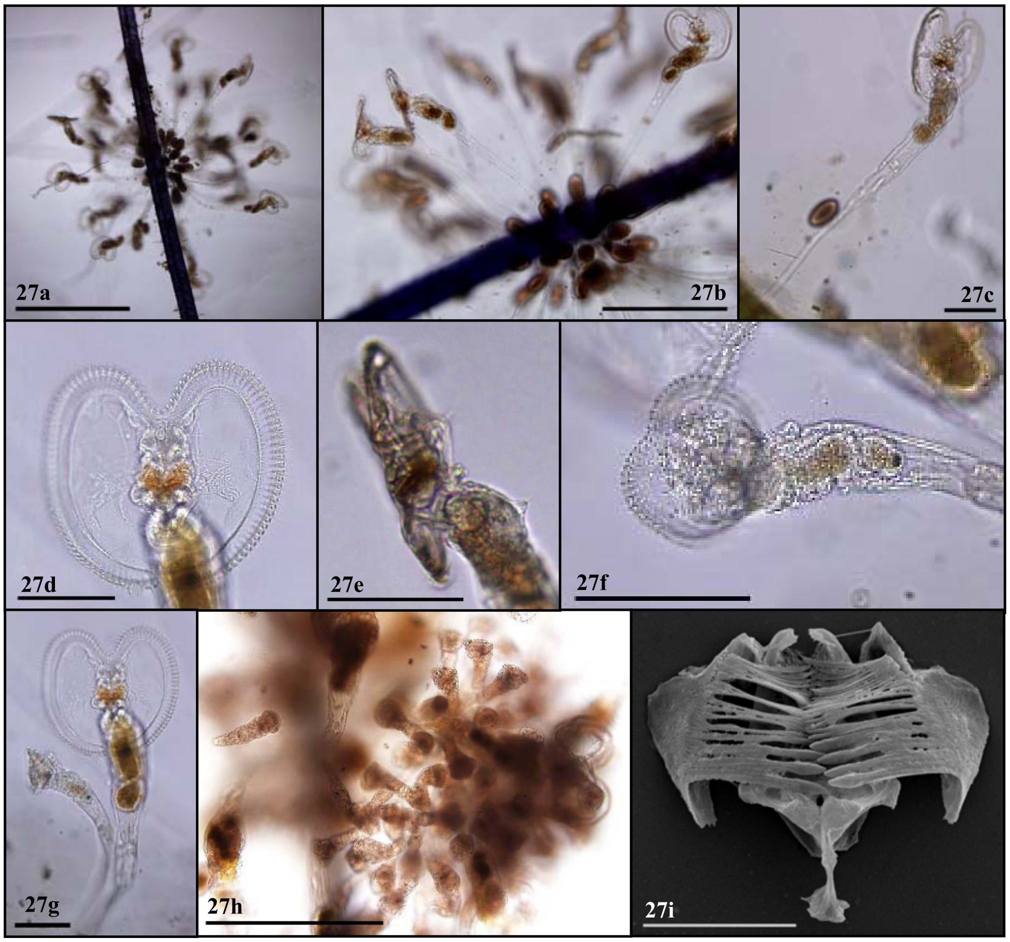

Plate 27. *Lacinularia flosculosa* (Muller, 1773): 27a-27b: a colony; 27c: a female; 27d-27e: corona features in different views; 27f-27g: an immature and a female; 27h: larvae and colony formation; 27i: SEM of trophi. Scale bars: 27a = 1 mm.; 27b, 27h = 500 µm.; 27c-27g = 100 µm.; 27i = 20 µm.

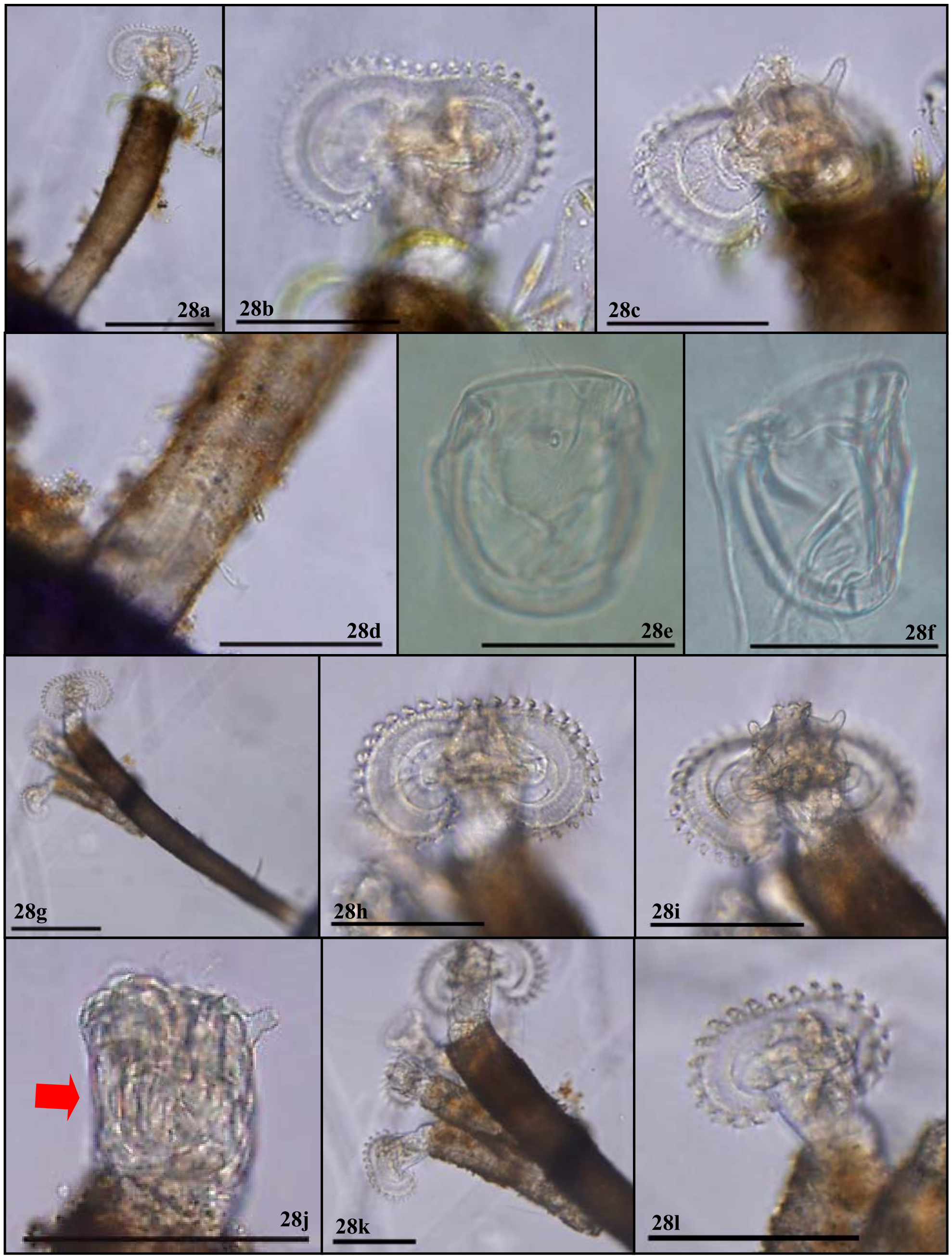

Plate 28. *Limnias ceratophylli* Schrank, 1803: 28a-28f = form1: a: a female; b: corona features; c: buccal area and lateral antenna; d: foot stalk; e-f: the dorsal plate; 28g-28l = form2: g: a colony; h: corona features; i: buccal area and lateral antenna; j: the dorsal plate (pointed); k-l: immature rotifers. Scale bars: 28a, 28g = 200 µm.; 28b-28f, 28h-28l = 100 µm.

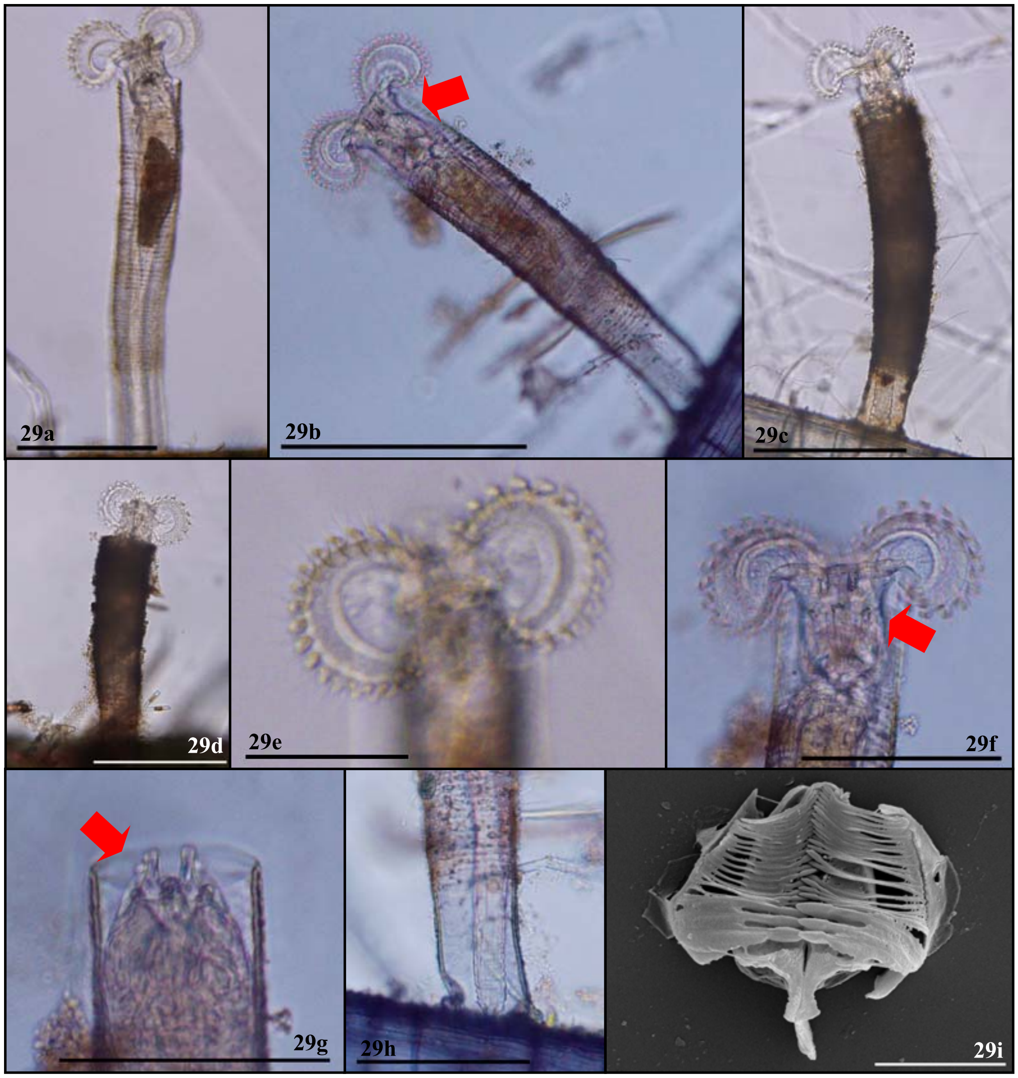

Plate 29. *Limnias melicerta* Weisse, 1848: 29a-29d: females in different transparency of their tubes, with showing of the dorsal processes (pointed); 29e: corona features; 29f-29g: the dorsal horny processes (pointed); 29h: their foot and attachment stalk; 29i: their trophi in frontal view. Scale bars: 29a-29d = 200 µm.; 29e-29h = 100 µm.; 29i = 10 µm.

Plate 30. *Octotrocha speciosa* Thorpe, 1893: 30a: a female; 30b-30e: corona features in different views: b = right dorsal-lateral, c = ventral-lateral, d = ventral, e = left dorsal-lateral; 30f: contracted specimen; 30g: their trophi. Scale bars: 30a = 500 µm.; 30b-30f = 200 µm.; 30g = 20 µm.

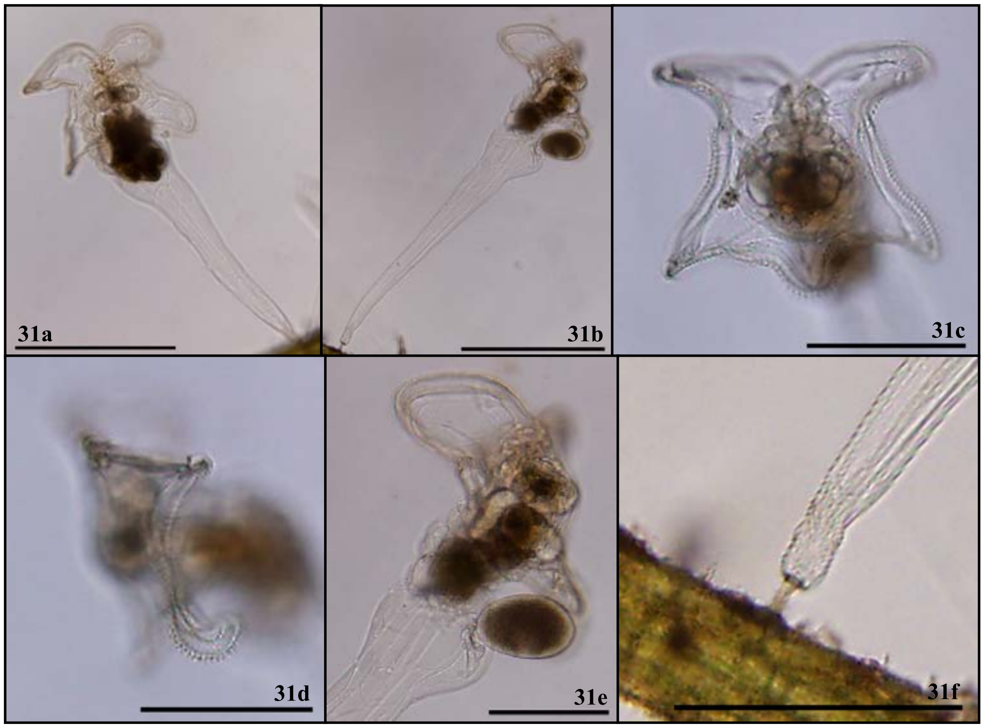

Plate 31. *Pentatrocha gigantea* Segers & Shiel, 2008: 31a-31b: females; 31c-31d: corona features in different views; 31e: oviferon and their egg; 31f: foot stalk. Scale bars: 31a-31b = 500 µm.; 31c-31f = 200 µm.

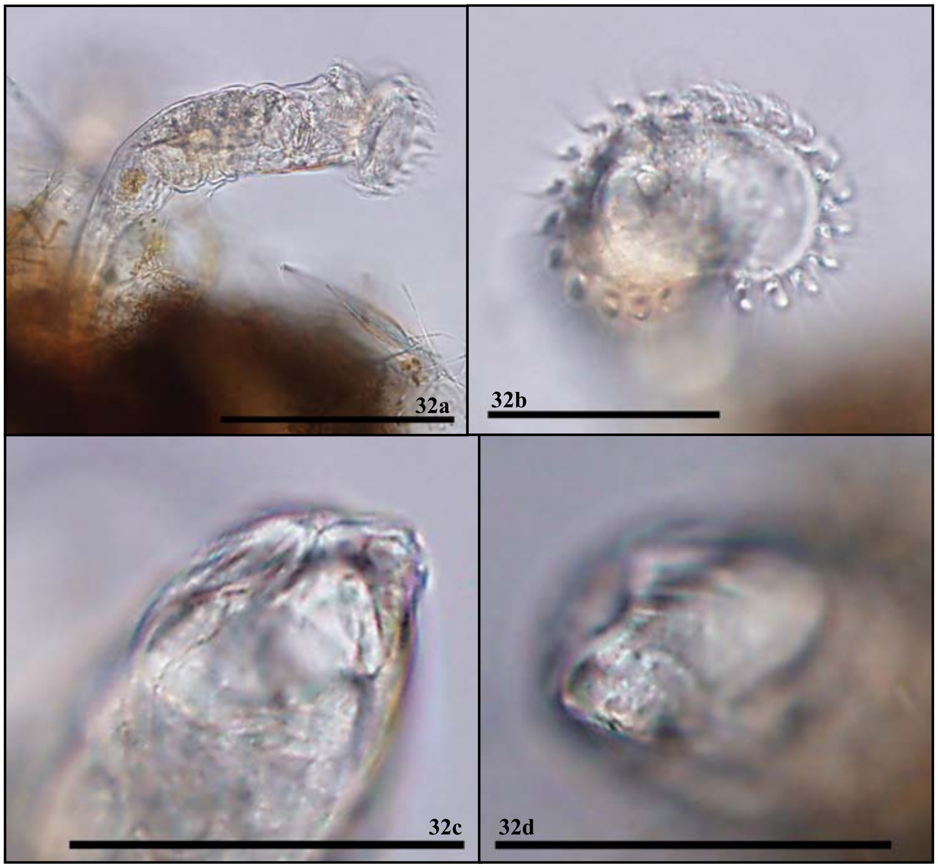

Plate 32. *Ptygura agassizi* Edmondson, 1948: 32a: a female; 32b: corona features; 32c-32d: dorsal projection in different views. Scale bars: 32a = 100 µm.; 32b-32d = 50 µm.

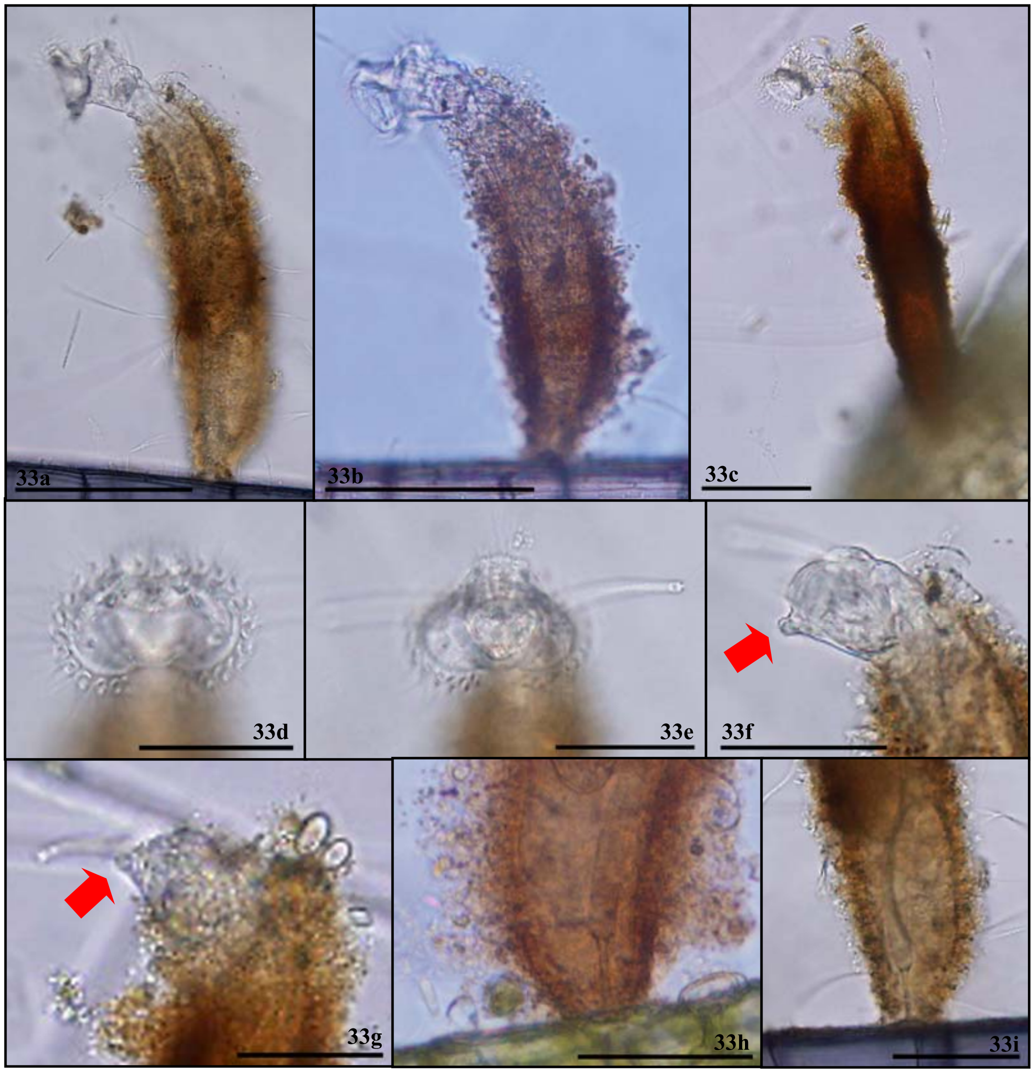

Plate 33. *Ptygura barbata* Edmondson, 1939: 33a-33c: females; 33d: corona features; 33e: buccal area features; 33f-33g: the bun-shaped process (pointed); 33h-33i: their foot stalks and eggs. Scale bars: 33a-33c = 100 µm.; 33d-33i = 50 µm.

Plate 34. *Ptygura beauchampi* Edmondson, 1940: 34a-34b: females; 34c-34e: corona features; 34f: ventral of body. Scale bars: 34a-34b = 100 µm.; 34c-34f = 50 µm.

Plate 35. *Ptygura crystallina* (Ehrenberg, 1834): 35a-35c: females; 35d-35e: corona features; 35f-35g: buccal area features; 35h: right side of body; 35i: contracted specimen. Scale bars: 35a-35c = 100 µm.; 35d-35i = 50 µm.

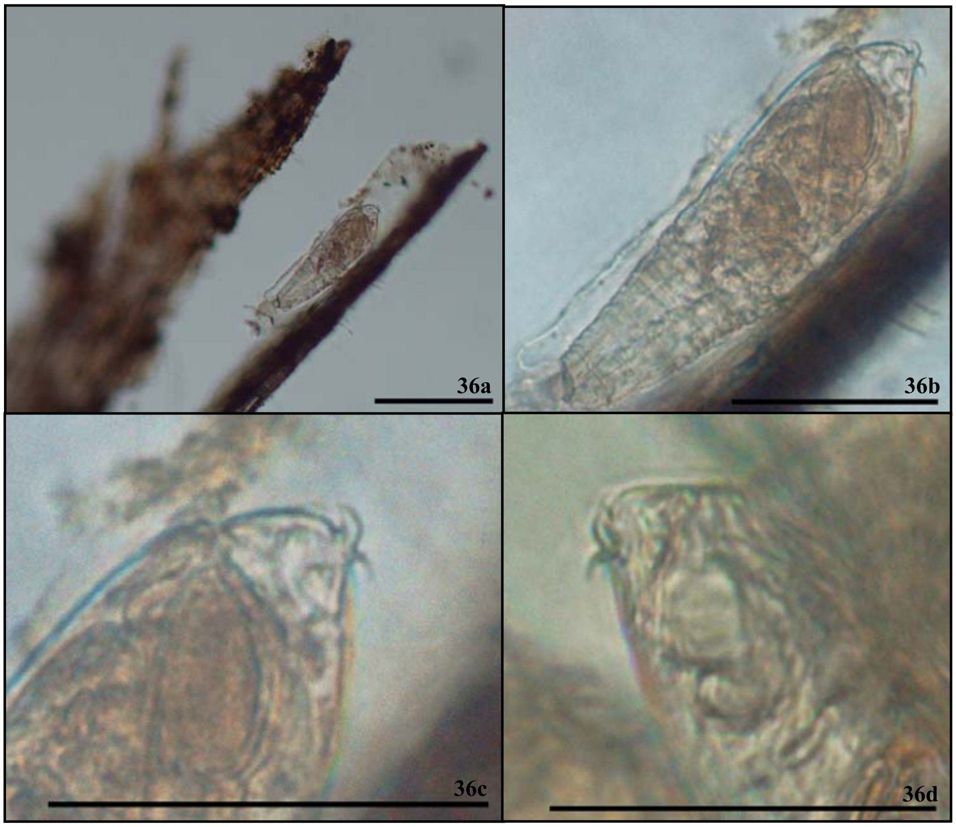

Plate 36. *Ptygura ctenoida* Koste & Tobias, 1990: 36a-36b: a female; 36c-36d: the barbed dorsal projection. Scale bars: 36a = 100 µm.; 36b-36d = 50 µm.

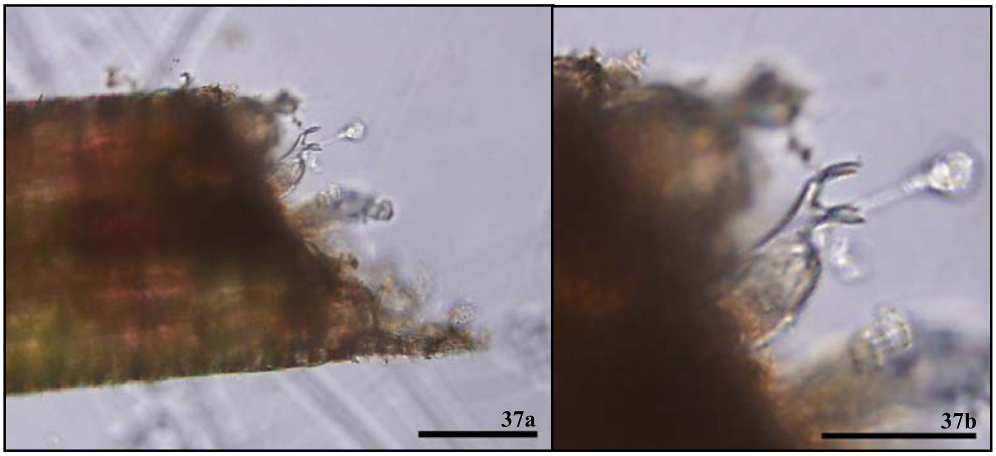

Plate 37. *Ptygura elsteri* Koste, 1972: 37a: a female within the plant opened tissue; 37b: the dorsal projections. Scale bars: 37a = 100 µm.; 37b = 50 µm.

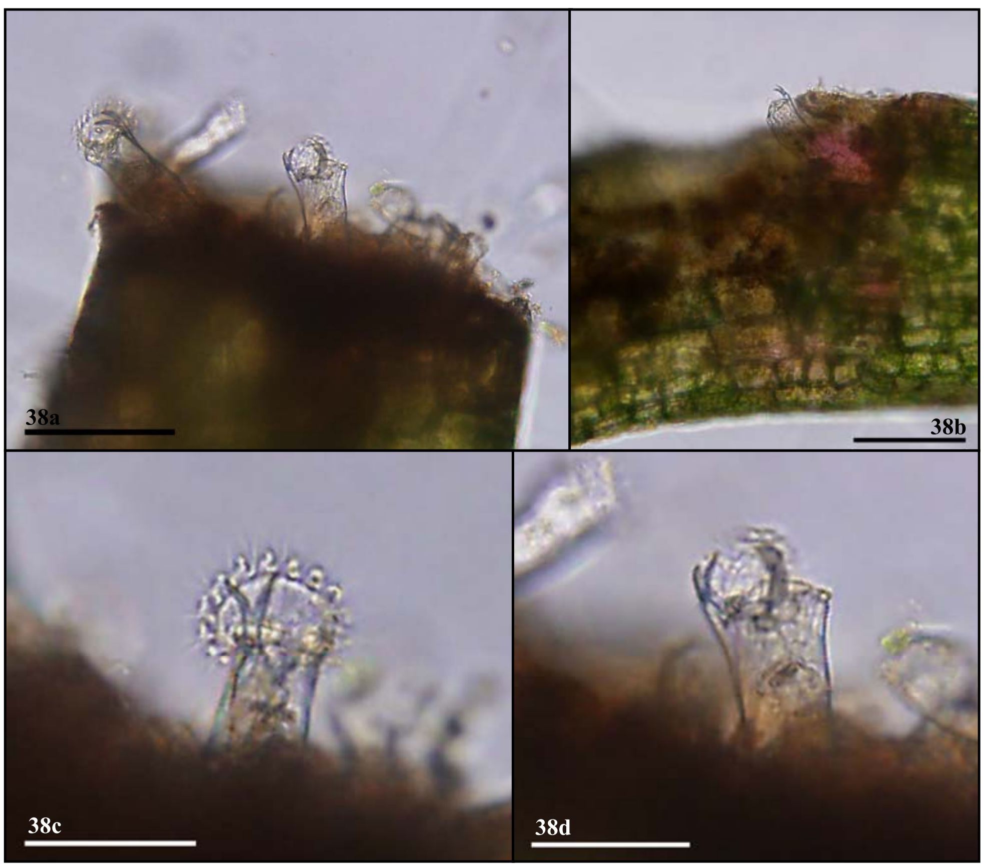

Plate 38. *Ptygura furcillata* (Kellicot, 1889): 38a-38b: females within damaged tissue of the plant; 38c-38d: the dorsal projection, corona, and buccal area features. Scale bars: 38a-38b = 100 µm.; 38c-38d = 50 µm.

Plate 39. *Ptygura longicornis* (Davis, 1867): 39a: a female; 39b-39c: corona features; 39d: contracted specimen; 39e: their foot stalk; 39f: their tube structure and egg. Scale bars: 39a = 100 µm.; 39b-39f = 50 µm.

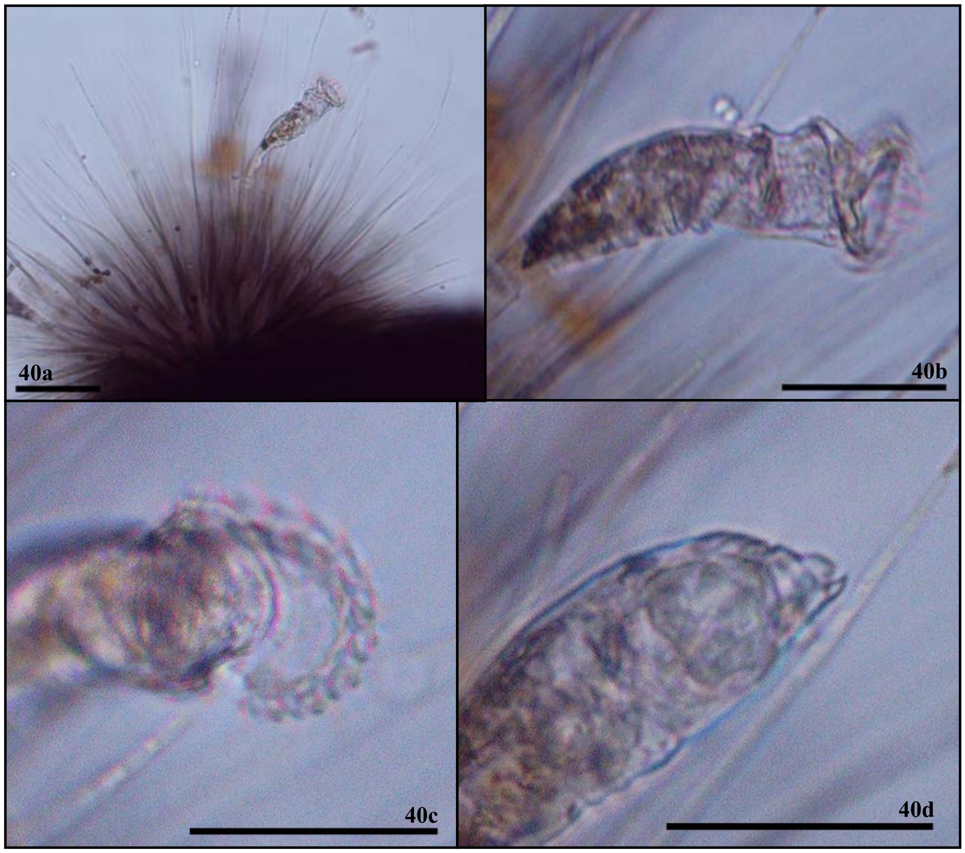

Plate 40. *Ptygura mucicola* (Kellicott, 1888): 40a: a female on colony of blue-green algae; 40b: body features; 40c: corona features and dorsal gap; 40d: the dorsal projection. Scale bars: 40a = 100 µm.; 40b-40d = 50 µm.

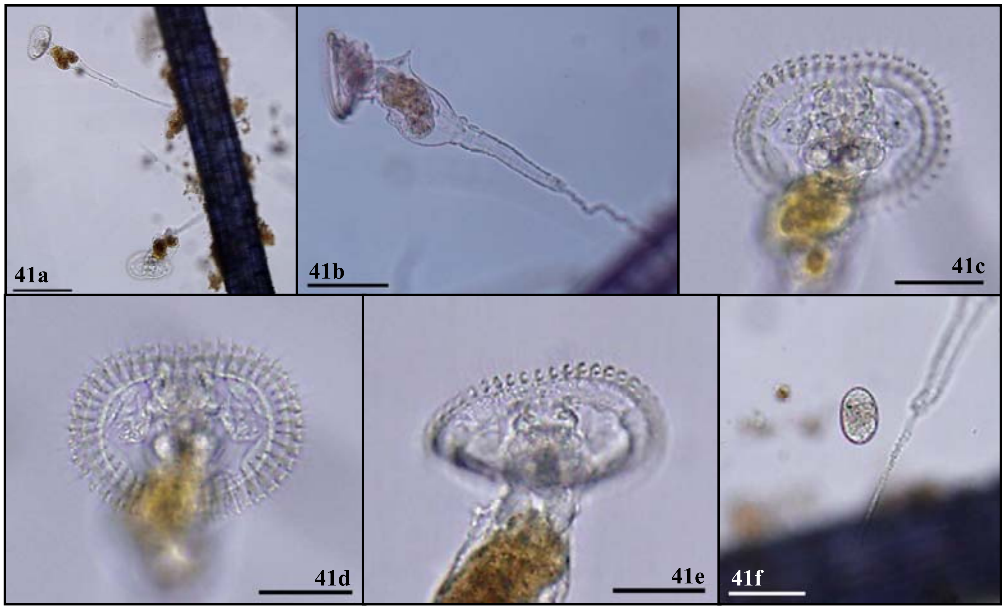

Plate 41. *Ptygura pedunculata* Edmondson, 1939: 41a: females; 41b: their body in lateral view; 41c-41e: corona and buccal area features; 41f: their egg in gelatinous case. Scale bars: 41a-41b = 100 µm.; 41c-41f = 50 µm.

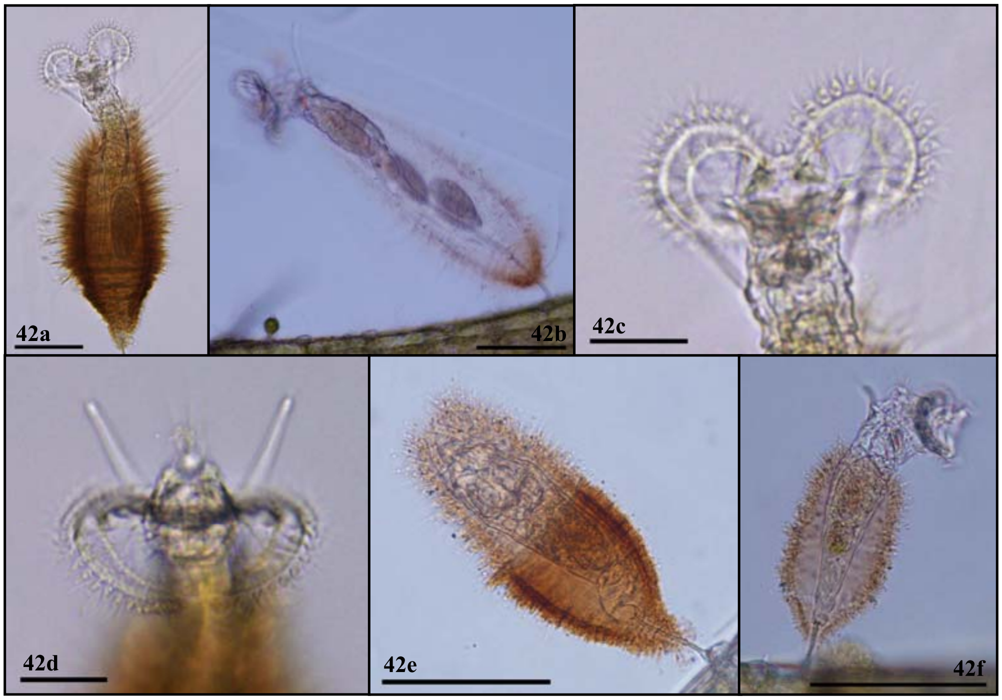

Plate 42. *Ptygura tacita* Edmondson, 1940: 42a-42b: females; 42c-42d: corona features; 42e: contracted specimen; 42f: an immature rotifer. Scale bars: 42a-42b, 42e-42f = 100 µm.; 42c-42d = 50 µm.

Plate 43. *Ptygura wilsonii* (Anderson & Shephard, 1892): 43a: a female; 43b: corona features; 43c-43d: body in lateral view and buccal area features; 43e (took from ventral side)-43f: the diagnostic processes on apical field of corona (pointed). Scale bars: 43a = 100 µm.; 43b-43f = 50 µm.

Plate 44. *Sinantherina semibullata* (Thorpe, 1893): 44a: a colony; 44b: females in colony; 44c: body features in lateral view; 44d: contracted colony. Scale bars: 44a, 44d = 500 µm.; 44b = 200 µm.; 44c = 100 µm.

Plate 45. *Sinantherina socialis* (Linnaeus, 1758): 45a: a colony; 45b: body features and their eggs in ventral-lateral view; 45c: corona feature; 45d: a contracted colony; 45e: their larva; 45f: their trophi. Scale bars: 45a, 45d = 500 µm.; 45b, 45c, 45e = 100 µm.; 45f = 10 µm.

Plate 46. *Sinantherina spinosa* (Thorpe, 1893): 46a: a colony; 46b: corona features in dorsal view; 46c: corona and ventral spines features in lateral view; 46d: a contracted female; 46e: the spines of a contracted female; 46f: their trophi. Scale bars: 46a = 500 µm.; 46b, 46d = 200 µm.; 46c, 46e = 100 µm.; 46f = 10 µm.

Plate 47. *Stephanoceros fimbriatus* (Goldfusz, 1820): 47a: a female; 47b: corona features; 47c: contracted specimen; 47d: gelatinous case features. Scale bars: 47a = 500 µm.; 47b-47d = 200 µm.

Plate 48. *Stephanoceros fimbriatus* var. *millsii* (Kellicott, 1885): 48a: a female; 48b-48c: corona features; 48d-48f: morphology features of an immature animal. Scale bars: 48a = 500 µm.; 48b-48d = 200 µm.; 48e-48f = 100 µm.

VITAE

Name Mr. Phuripong Meksuwan

Student ID 5110220057

Education Attainment

Degree	Name of Institution	Year of Graduation
Bachelor of Science (Biology)	Prince of Songkla University	2008

Scholarship Awards during Enrolment

- TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT T153007
- Research Assistant Scholarship, Faculty of Science, Prince of Songkla University