Annual Changes of Zooplankton Communities of Different Size Fractions in Thale-Noi, Phatthalung Province

Rattanawan Inpang

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Ecology (International Program)

Prince of Songkla University

2008

Annual Changes of Zooplankton Communities of Different Size Fractions in Thale-Noi, Phatthalung Province

Rattanawan Inpang

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree

of Master of Science in Ecology (International Program)

Prince of Songkla University

2008

Thesis Title	Annual Changes of Zooplankton Communities of Different Size Fractions in Thale-Noi, Phatthalung Province
Author	Miss Rattanawan Inpang
Major Program	Ecology (International Program)

Major Advisor	**Examining Committee:**
	.....................................Chairperson
....	(Dr. Supiyanit Maiphae)
(Assoc. Prof. Dr. Pornsilp Pholpunthin)	.....................................Committee
	(Assoc. Prof. Dr. Pornsilp Pholpunthin)
Co-advisor	.....................................Committee
....	(Prof. Dr. Saowapa Angsupanich)
(Prof. Dr. Saowapa Angsupanich)	.....................................Committee
	(Dr. Supenya Chittapun)

The Graduate School, Prince of Songkla University, has approved this thesis as partial fulfillment of the requirements for the Master of Science Degree in Ecology (International Program)

....

(Assoc. Prof. Dr. Krerkchai Thongnoo)

Dean of Graduate School

ชื่อวิทยานิพนธ์ การเปลี่ยนแปลงในรอบปีของประชาคมแพลงก์ตอนสัตว์ในช่วงขนาดที่ต่างกัน ในทะเลน้อย จังหวัดพัทลุง

ผู้เขียน นางสาวรัตนวรรณ อินแพง

สาขาวิชา นิเวศวิทยา (นานาชาติ)

ปีการศึกษา 2550

บทคัดย่อ

จากการศึกษาการเปลี่ยนแปลงในรอบปีของประชาคมแพลงก์ตอนสัตว์ในช่วงขนาดที่ต่างกัน ในทะเลน้อย จังหวัดพัทลุง โดยแบ่งการศึกษาออกเป็น 3 ช่วง คือ ฤดูฝนตกน้อย (เดือนกรกฎาคม-เดือนสิงหาคม 2547) ฤดูฝนตกมาก (เดือนพฤศจิกายน-เดือนธันวาคม 2547) และ ฤดูแล้ง (เดือนมีนาคม-เดือนเมษายน 2548) จากบริเวณที่มีสภาพพื้นที่แตกต่างกัน 4 บริเวณ คือ พื้นที่ป่าพรุ บริเวณคลอง บริเวณใกล้แหล่งที่อยู่อาศัย และบริเวณกลางทะเลน้อย โดยตรวจสอบปัจจัยทางกายภาพ เคมี และชีวภาพ จำนวน 10 ปัจจัย พร้อมทั้งวิเคราะห์ชนิด และความชุกชุมของแพลงก์ตอนสัตว์ขนาดเล็ก (20-200 ไมโครเมตร) และแพลงก์ตอนสัตว์ขนาดใหญ่ (มากกว่า 200 ไมโครเมตร) ฤดูละ 2 เดือน เดือนละ 2 ครั้ง จากผลการศึกษา พบว่าประมาณ 95 เปอร์เซ็นต์ของปริมาณแพลงก์ตอนสัตว์ทั้งหมดเป็นแพลงก์ตอนสัตว์ขนาดเล็ก อย่างไรก็ตาม แพลงก์ตอนสัตว์ขนาดเล็กมีปริมาณสูงสุดใน 2 ช่วงที่ศึกษาคือ ฤดูฝนตกมาก (1.57×10^6 ตัวต่อลูกบาศก์เมตร) และฤดูแล้ง (1.36×10^6 ตัวต่อลูกบาศก์เมตร) ซึ่งพบว่าปริมาณของแพลงก์ตอนสัตว์ขนาดเล็กสูงสุดในบริเวณคลอง และต่ำสุดในบริเวณใกล้แหล่งที่อยู่อาศัย ส่วนแพลงก์ตอนสัตว์ขนาดใหญ่เกิดขึ้นอย่างเด่นชัดและมีปริมาณสูงสุดในช่วงฤดูฝนตกมาก (3.9×10^5 ตัวต่อ

ลูกบาศก์เมตร) เท่านั้น จากการศึกษาพบแพลงก์ตอนสัตว์ทั้งสิ้น 5 ไฟลัม ได้แก่ Protozoa, Rotifera, Arthropoda, Mollusca และ Chordata ซึ่งในองค์ประกอบของแพลงก์ตอนสัตว์ขนาดเล็ก พบเป็นแพลงก์ตอนสัตว์ถาวรทั้งสิ้น 7 กลุ่ม ได้แก่ Protozoa, Rotifera, Cladocera, Copepoda, copepodite copepods, juvenile ostracods และ crustacean nauplii ส่วนองค์ประกอบของแพลงก์ตอนสัตว์ขนาดใหญ่ พบแพลงก์ตอนสัตว์กลุ่มที่เป็นแพลงก์ตอนสัตว์ถาวรเหมือนในองค์ประกอบขนาดเล็ก และยังพบแพลงก์ตอนสัตว์ชั่วคราว คือ ตัวอ่อนของกุ้ง ปู หอย และปลาอีกด้วย แต่จะพบในช่วงที่มีปริมาณน้ำฝนน้อยเป็นส่วนใหญ่ ผลการศึกษาแพลงก์ตอนสัตว์ชนิดเด่นมีความแตกต่างกันตามสถานที่และเวลา ในองค์ประกอบขนาดเล็ก Protozoa *Trachelomonas* spp. และ *Peridinium* sp. เป็นแพลงก์ตอนสัตว์กลุ่มเด่นในช่วงฤดูฝนตกมากจนถึงฤดูแล้ง และ Rotifera *Polyarthra* spp. และ *Anuraeposis* spp. เป็นแพลงก์ตอนสัตว์กลุ่มเด่นในช่วงฤดูฝนตกน้อย ส่วนในองค์ประกอบขนาดใหญ่ Cladocera เป็นแพลงก์ตอนสัตว์กลุ่มเด่นในทุกบริเวณและทุกช่วงเวลาที่ศึกษา ยกเว้นบริเวณคลองและบริเวณกลางทะเลน้อย ซึ่ง Copepoda จะเพิ่มจำนวนและกลายเป็นแพลงก์ตอนสัตว์กลุ่มเด่นในช่วงที่มีปริมาณน้ำฝนน้อย สำหรับแพลงก์ตอนสัตว์ชนิดเด่นในกลุ่ม Cladocera คือ *Bosminopsis deitersi* และ *Chydorus* spp. และในกลุ่ม Copepoda คือ *Acartiella sinensis* และ *Pseudodiaptomus* sp.

จากการวิเคราะห์ข้อมูลด้วย Canonical Correspondence Analysis (CCA) สามารถจัดกลุ่มตามช่วงที่ศึกษาได้ 3 กลุ่มคือ ฤดูฝนตกน้อย พบว่า ค่าความนำไฟฟ้าและค่าพีเอชมีค่าสูง มีความสัมพันธ์ในเชิงบวกกับ Rotifera (ได้แก่สกุล *Anuraeopsis, Brachionus, Testudinella, Trichocerca* และ *Filinia*) และ Cladocera (ได้แก่สกุล *Alona, Moinodaphnia* และ *Moina*) ฤดูฝนตกมาก พบว่าความลึก และ ความโปร่งแสงมาก มีความสัมพันธ์ในเชิงบวก

กับ Protozoa (ได้แก่สกุล *Phacus, Peridinium, Lepocinclis* และ *Arcella*), Rotifera (ได้แก่สกุล *Ascomorpha, Asplanchna, Lecane* และ *Polyarthra*) และ Cladocera (ได้แก่สกุล *Bosminopsis, Diaphanosoma, Ilyocryptus* และ *Ceriodaphnia*) ส่วนในฤดูแล้ง พบว่า อุณหภูมิ ออกซิเจนที่ละลายในน้ำ ความเค็ม ปริมาณของแข็งทั้งหมด พีเอช และค่าความนำไฟฟ้าสูง มีความสัมพันธ์ในเชิงบวกกับ Protozoa (ได้แก่สกุล *Trachelomonas, Centropyxis, Euglypha* และ *Undella*), Cladocera (ได้แก่สกุล *Alona, Chydorus, Macrothrix* และ *Latonopsis*) และ Copepoda (ได้แก่สกุล *Acartia* และ *Thermocyclops*) การวิเคราะห์ความสัมพันธ์ระหว่าง คลอโรฟิลล์เอทั้งสองขนาดกับแพลงก์ตอนสัตว์ขนาดต่างๆ พบว่า Protozoa มีความสัมพันธ์ในเชิงบวกกับคลอโรฟิลล์เอขนาดน้อยกว่า 20 ไมโครเมตร ขณะที่ Cladocera (ได้แก่ *Diaphanosoma* sp.), Ostracoda (ได้แก่ *Cypricercus* sp.) และ Copepoda (ได้แก่ *Acartia* cf. *southwelli* และ *Metacyclops* sp.) มีความสัมพันธ์ในเชิงบวกกับ คลอโรฟิลล์เอขนาด 20-200 ไมโครเมตร ขณะที่กลุ่ม Rotifera มีความสัมพันธ์ในเชิงลบกับคลอโรฟิลล์เอขนาด 20-200 ไมโครเมตร

Thesis Title	Annual Changes of Zooplankton Communities of Different Size Fractions in Thale-Noi, Phatthalung Province
Author	Miss Rattanawan Inpang
Major Program	Ecology (International Program)
Academic Year	2007

ABSTRACT

Annual changes of zooplankton communities of different size fractions in Thale-Noi, Phatthalung province were investigated over three periods: the light rainy period (July, August 2004), the rainy period (November, December 2004), and the dry period (March, April 2005); and in four different zones: the peat swamp, small inlet, resident and pelagic zones. Measurements of 10 physical, chemical and biological variables, species composition, and the abundance of micro- and mesozooplankton were taken twice a month. Microzooplankton of fraction size 20-200 μm consistently dominated in the total abundance (95%). However, two seasonal microzooplankton peaks were observed: one during the rainy period (1.57×10^{6} ind.m^{-3}) and the other during the dry period (1.36×10^{6} ind.m^{-3}). The highest density of microzooplankton was found in the small inlet zone while the lowest was found in the resident zone. Mesozooplankton of fraction size >200 μm showed a clear peak (3.9×10^{5}ind.m^{-3}) in the rainy period. Zooplankton in difference size fractions was composed of five phyla, namely Protozoa, Rotifera, Arthropoda, Mollusca and Chordata. Seven groups of zooplankton occurred in the microzooplankton

composition, namely Protozoa, Rotifera, Cladocera, Copepoda, crustacean nauplii, juvenile ostracods and copepodite copepods. The mesozooplankton composition, besides containing holoplanktonic groups that were found in the microzooplankton, also included some meroplanktonic groups, such as shrimp larvae, crab larvae, mollusk larvae and fish larvae which were found during the low water period. The results showed that there were spatial and temporal differences in dominance of zooplankton genera. However, the dominant microzooplankton groups in all zones were Protozoa *Trachelomonas* spp. and *Peridinium* sp., particularly during the rainy to dry periods, and Rotifera *Polyarthra* spp. and *Anuraeposis* spp. in the light rainy period. In the mesozooplankton community it was found that Cladocera was the most abundant group in all zones and during all periods, except in the small inlet and pelagic zones where Copepoda was the most abundant group during the low water period. The dominant species of Cladocera were *Bosminopsis deitersi* and *Chydorus* spp. and of Copepoda were *Acartiella sinensis* and *Pseudodiaptomus* sp.

Canonical Correspondence Analysis (CCA) ordination indicated that there are three major groupings related to the different climatic periods. The light rainy period is associated with high conductivity and pH, having a positive relationship with Rotifera (i.e., *Anuraeopsis, Brachionus, Testudinella, Trichocerca* and *Filinia*), and Cladocera (i.e., *Alona, Moinodaphnia and Moina*). The rainy period is associated with high depth and transparency, having a positive relationship with Protozoa (i.e., *Phacus, Peridinium, Lepocinclis* and *Arcella*), Rotifera (i.e., *Ascomorpha, Asplanchna, Lecane* and *Polyarthra*), and Cladocera (i.e., *Bosminopsis, Diaphanosoma, Ilyocryptus* and *Ceriodaphnia*). The dry period is associated with high temperature, DO, salinity, total solids, pH and conductivity, having a positive

relationship with Protozoa (i.e., *Trachelomonas, Centropyxis, Euglypha* and *Undella*), Cladocera (i.e., *Alona, Chydorus, Macrothrix* and *Latonopsis*) and Copepoda (i.e., *Acartia* and *Thermocyclops*). Correlation analysis showed that chl *a* of < 20 µm fraction size tends to be positively related to the abundance of Protozoa, while chl *a* of 20-200 µm fraction size was positively correlated with Cladocera (i.e., *Diaphanosoma* sp.), Ostracoda (i.e., *Cypricercus* sp.) and Copepoda (i.e., *Acartia* cf. *southwelli* and *Metacyclops* sp.) while Rotifera was negatively correlated with chl *a* of 20-200 µm fraction size.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my advisor, Assoc. Prof. Dr. Pornsilp Pholpunthin, for his support, patience, and encouragement throughout my graduate studies. His technical and editorial advice was essential to the completion of this thesis and has taught me innumerable lessons and insights in to the workings of academic research in general.

My sincere gratitude also go to my co-advisor, Prof. Dr. Saowapa Angsupanich for her worthy advice on writing previous drafts of this thesis and providing many valuable comments that improved the presentation and contents of this thesis.

I also appreciate the advice of the committee members, Dr. Supenya Chittapun and Dr. Supiyanit Maiphae, for their critical comments, which enabled me to realize the weaknesses of my thesis and make the necessary improvements according to their comments.

I would like to express special thanks to Assoc. Prof. Dr. Chutamas Satasook, Dr. Rujinard Sriwoon and Ms. Pannee Sa-addrit for their suggestions, support, interest and valuable hints.

I am grateful to Dr. Alan Gaetor and Mr. Philip Lattimore for their kind English corrections. Especially for Mr. Philip Lattimore, it is hard to imagine how they can manage to finish editing so much work in such a short time. I owe them all my sincere gratitude for their generous and timely help.

I give special and sincere thanks to the members of the Plankton Research Unit, Mr. Weeradej Meeinkuirt, Mr. Suwanit Boon-rod, Ms. Aaesoh

Tohmusor, Ms. Sopawadee Moolmek, Ms. Orathai Pongruktum, Ms. Kesarin Suankamjad and Ms. Koraon Wongkumhaeng for their help in field samplings, including hardships, a heavy work load and for their continuous encouragement. I would also like to thank Ms. Katesarin Maneenoon, Ms. Amporn Pluppleng, Mr. Nawee Noon-anun, Ms. On-urai Pongpanich, Mr. Theerapong Karnprakob, Mr. Dej Mann, Ms. Khwuntida Inpang, Ms. Jutamon Inpang, Malida Choorin and Ms. Wannapa Suwannarat for their encouraged and helped in various ways. In addition, I am grateful to all other friends and all teachers in the Department of Biology for their help and friendship over the course of this study.

Special thanks are also due to all the technical and instrumental supporters especially Mr. Sutum Mayakul and Mrs. Ratana Hirunphan for providing necessary laboratory resources throughout my study.

I am extremely thankful to the TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT T_349001 and by the financial support of the Graduate School, Prince of Songkla University, Hat Yai, Songkhla, Thailand for their financial support in the sample collections and for supporting throughout my study.

Finally, my deepest appreciation is sent to my parent, Mr. Somboon Inpang and Mrs. Ranoo Inpang, my bother, my sister, my relatives and Mr. Theerapong Karnprakob for their love and care and incessant encouragement throughout my life.

To all of you, thank you.

Rattanawan Inpang

CONTENTS

CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF ABBREVIATIONS AND SYMBOLS

et al.	=	Et. Ali (Latin), and others
fig.	=	Figure
° C	=	degree Celsius
DO	=	Dissolved Oxygen
TS	=	Total Solids
$mg.l^{-1}$	=	milligram per liter
$\mu s.cm^{-1}$	=	microsiemens per centrimeter
ppt.	=	part per thousand
chl *a*	=	Chlorophyll *a*
ind.	=	individual
St.	=	Station
CCA	=	Canonical Correspondence Analysis
ANOVA	=	Analysis of Variance
SPSS	=	Statistical Package for Social Science
μm	=	micrometer
nm	=	nanometer
mm	=	millimeter
m^2	=	square meter
m^3	=	cubic meter
ml	=	milliliter
mg	=	milligram
g	=	gram
L	=	liter

CHAPTER 1

INTRODUCTION

1. Background and Rationale

Thale-Noi, a freshwater area of Songkhla lake, is an important bird sanctuary in Southern Thailand (Tunsakul and Sirimontraporn, 1982; Pholpunthin, 1997). It contains a rich biodiversity, the resources of which enable local residents to earn a living from activities such as fishing, agriculture, handicraft and especially tourism (Leingpornpan and Leingpornpan, 2005; Tunsakul *et al.,* 1986). Because of this, Thale-Noi has been named the first Ramsar Site in Thailand (Aiumnau *et al.,* 2000). This area has complex and sensitive ecosystems, thus, it is necessary for conservation and preservation biodiversity to utilize the resources sustainably. However, due to the ongoing expansion of near-shore villages, waste water is being constantly discharged into the lake (Nookua, 2003; Tunsakul, 1983). The result is that the Thale-Noi ecosystem and its water quality are subject to continuously changing and unnatural sources (Leingpornpan and Leingpornpan, 2005). The waste water adds nutrients to the lake, which affects the aquatic community structure and may lead to the destruction of the food web in the area. Between 1988 and 2002, the fish population in Thale-Noi declined and was not enough to support the people engaged in fishing activities (Thungwa *et al.,* 2002). Moreover, this problem seriously affected the villagers' livelihood, economy, and society in general (Hembanthid, 2001). Understanding the factors involved in the control of the aquatic food web structure is key to understanding the changes in recruitment success for aquatic animals (Pedersen *et al.*, 2005).

Additionally, zooplankton communities are highly sensitive to environmental variation. Changes in their abundance, species diversity, or community composition can provide important indications of environmental change or disturbance (Branco *et al.*, 2002). They respond to low dissolved oxygen, high nutrient levels, toxic contaminants, poor food quality or abundance and predation (Kovalev *et al.*, 1999). Some species of rotifers, such as *Brachionus calyciflorus* Pallas and *Keratella tecta* (Gosse) are species indicators in waste water (Sanoamuang, 2002). Rotifers often respond quickly to environmental change because most species have short generation times (Keppeler and Hardy, 2004). Protozoa are considered a major link in the limnetic food web and perform key functions in energy flow and element cycling in freshwater ecosystems (Xu *et al.*, 2005). Additionally, most zooplankton are filter feeders; they serve to cleanse the water column of suspended matter and hence contribute significantly to the improvement of water quality (Bekleyen, 2003).

Microzooplankton have long been thought to be a major consumer of small particles unavailable to meso-and macrozooplankton (Gifford, 1991) and these organisms also act as a significant food source for a variety of invertebrate and vertebrate predators (Godhantaraman, 2001). Thus, microzooplankton are an important link in transferring pico- and nanoplankton production to higher trophic levels (Eskinazi-Sant'Anna and Bjornberg, 2006). In aquatic ecosystems, mesozooplankton are the major secondary producers which graze on phytoplankton and in turn are preyed upon by planktivorous fish and carnivorous invertebrates such as jellyfish (Uye *et al.*, 2000). The linkage between phytoplankton and zooplankton is a dynamic process controlled by several factors, including environmental and biological factors (Mageed and Heikal, 2006; Medina-Sanchez *et al.*, 1999; Shinada *et al.*, 2000) which affect the growth of each community and the interaction between them. Grazing is one of the most important factors controlling the relationship between the two communities (Abdel Aziz *et al.*, 2006; Leonard *et al.*, 2005).

Zooplankton have been intensively investigated in Thale-Noi, especially with regard to their taxonomy and spatial distribution (Pholpunthin, 1997; Segers and Pholpunthin, 1997). Few studies had provided information on seasonal changes in the abundance of zooplankton (Angsupanich, 1985; Angsupanich and Rukkhiaw, 1984). Although ecological knowledge of zooplankton in freshwaters is important for understanding the functioning of aquatic ecosystems, such knowledge is still rather scarce regarding Thale-Noi.

Therefore, in order to find out, the seasonal and spatial variations of zooplankton different size fractions in Thale-Noi, as well as the possible influence of environmental parameters on the zooplankton community. The present study proposed to examine water quality and chlorophyll *a* in Thale-Noi to explain the *factors that affect changes in the micro- and mesozooplankton communities along the* lake during the different seasons and in different habitats.

2. Literature review

2.1 What are zooplankton?

Zooplankton are small animals that float freely in the water column of lakes and oceans and whose distribution is primarily determined by water currents and mixing. The zooplankton community of most lakes comprises individuals ranging in size from a few tens of microns (Protozoa) to > 2 mm (macrozooplankton). In terms of biomass and productivity, the dominant groups of zooplankton in lakes are Crustacea and Rotifera. The zooplankton in freshwater consists primarily of protozoans (ciliates and flagellates; which range in size from a few to a few hundred micrometers), rotifers (30 μm to 1 mm), and crustaceans (copepods and cladocerans; 100 μm to 1 cm) (Lampert *et al.,* 1997). A few coelenterates, larval trematode flatworms, gastrotrich, mite, and the larval stages of certain insects and fish occasionally occur among the true zooplankton, if only for a portion of their life cycles (Wetzel, 2001). These groups have different reproductive strategies which influence the rate of population increase and hence responses to food availability. Protozoa can reproduce by simple fission, with sexual reproduction confined to relatively rare periods as a response to adverse condition, such as low temperature. Rotifers and cladocerans usually reproduce parthenogenetically, with male individuals rare and the population consisting almost entirely of cloned females during periods favorable to growth. Sexual reproduction is confined to periods of adverse conditions such as low food or low temperature and involves resting, fertilized eggs. Calanoids and cyclopoids only reproduce sexually, with females carrying external egg sacs. As a consequence, population growth in these taxa is slower (Harper, 1992).

2.2 Classification of zooplankton

The zooplankton are classified according to their habitat, depth distribution, size and duration of planktonic life (life history). On the basis of habitat, the zooplankton is classified as marine plankton or 'haliplankton', and freshwater plankton or 'limnoplankton' (Pholpunthin, 2001).

Based on size, different fractions of zooplankton have been divided into seven groups as shown in Table 1.

Table 1. The seven groups of zooplankton separated based on size.

Group	Size limits	Major organisms
1. Ultrananoplakton	< 2 µm	Free bacteria
2. Nanozooplankton	2-20 µm	Fungi, small flagellates, small diatoms
3. Microzooplankton	20-200 µm	Most phytoplankton species, foraminiferans, ciliates, rotifers, copepods nauplii
4. Mesozooplankton	200 µm-2 mm	Cladocerans, copepods, larvaceans
5. Macrozooplankton	2-20 mm	Pteropods, copepods, euphausiids, chaetognaths
6. Megalozooplankton	>20 mm	Scyphozoans, thaliaceans
7. Micronekton	20-200 mm	Cephalopod, euphausiid, sergestids, myctophids

Sources: Omori and Ikeda (1984) cited by Pholpunthin (2001).

With regard to the duration of planktonic life, zooplankton may be grouped into 'holoplankton' and 'meroplankton'. Holoplankton is comprised of organisms which are planktonic throughout their life cycle (e.g. tintinnids, cladocerans, copepods, chaetonaths and pteropods). Meroplankton is comprised of organisms which remain planktonic only for a portion of their life cycle (e.g. larvae of benthic invertebrates and fish larvae ichthyoplankton) (Santhanam and Srinivasan, 1994).

2.3 The important of zooplankton

Zooplankton, especially rotifers and cladocerans, support the economically important fish populations (Howick and Wilhm, 1984; Santhannam and Srinivasan, 1994). Rotifers are highly nutritive to planktivorous fish. Their protein supports the fast growth of fish larvae and juveniles and, as such, they are of great importance to fish farmers (Fafioye and Omoyinmi, 2006), as are several other genera of Cladocera such as *Dahpnia*, *Moina, Diaphanosoma* and *Pseudosida* that are currently used in aquaculture (Maiphae, 2005). Zooplankton acts as the major mode of energy transfer between phytoplankton and the fish (Howick and Wilhm, 1984; Pedersen *et al.*, 2005). Zooplankton play a pivotal role in aquatic food webs because they are an important food source for fish and invertebrate predators (Zhensheng *et al.*, 2006). Because of their small size and high metabolic rate, protozoa play a substantial role in nutrient regeneration in the water column. Protozoa have been considered a major link in the limnetic food web and perform key functions in energy flow and element cycling in freshwater ecosystems (Xu *et al.*, 2005). Additionally, certain species of zooplankton are usually considered to be useful indicators of water quality, trophic status and pollution (Michaloudi *et al.*, 1997). Moreover, zooplankton, especially *Brachionus calyciflorus* and *B. plicatilis*, have been employed as test organisms for toxicological studies (Chittapun, 2003). Recently, cyclopoid copepods have been used for the purpose of bio-controlling the larvae of mosquitoes to reduce the use of chemical compounds (Wansuang and Sanoamuang, 2006).

2.4 The trophic cascade in the lake

The ecological role of an organism is largely determined by its position and significance in the food web. Decisive characteristics are body size, food spectrum and feeding type (Harris *et al.*, 2000). Trophic cascade theory holds that each trophic level in the food web is inversely and directly related to trophic levels above and below it. For example, if the abundance of large piscivorous fish is increased in a lake, the abundance of the zooplanktivorous fish on which they prey should decrease; the abundance of large herbivorous zooplankton should increase; and the phytoplankton biomass should decrease (Brett and Goldman, 1996). Recent studies in an oligotrophic Andean lake have shown that the large cladoceran *D. middendorffiana* exhibited a strong top down impact on different levels of the microbial food web. *Daphnia* was able to depress the nanoflagellates, ciliates and autotrophic picoplankton (Modenutti *et al.,* 2003). Havens (2002) pointed out that a simple conceptual model, based on zooplankton research in Southern Florida, indicated that while phytoplankton biomass is controlled by nutrients, zooplankton biomass is primarily controlled by the productivity of bacteria. In a system of this type it might be optimal to predict macrozooplankton biomass based on the combined biomass of phytoplankton and bacterioplankton.

2.5 Seasonal succession in zooplankton

The pattern of succession in lakes can be observed in the seasonal changes in the biomass, species composition and abundance of the plankton (Calbet *et al.*, 2001; Lampert *et al.*, 1997). There is also evidence of a seasonal pattern related to external factors (e.g. temperature) and sudden influences (e.g. rain and, indirectly, Mistral wind), which modify the succession of the plankton communities (Jamet *et al.*, 2005). In addition, comprehensive descriptions of temporal cycles of the biological communities and of the abiotic environment are fundamental to understanding the overall range of this variability (Mazzocchi and Ribera d'Alcala, 1995). However, recent studies have shown that changes in biomass or the production of autotrophic food seem to play a small role in determining the seasonal succession of planktonic metazoans. Further, it has been suggested other factors, such as salinity and temperature, and possibly also food size-spectra, may be more important in determining the seasonality of the zooplankton species composition (Calbet *et al.*, 2001). Equilibrium models assume that population densities are food limited and follow the fluctuations of their resources. However, such assumptions always yield outcomes that predict the exclusion of specific species. For example, the succession of small cladocerans in August was accompanied by a reduction in edible algae due to grazing (Eckert and Walz, 1998).

Figure 1 gives an example of the model of seasonal succession among zooplankton in eutrophic and oligotrophic lakes in the temperate region. In eutrophic lakes, a spring maximum of small phytoplankton algae is followed by a dominantly persisting summer maximum of large, grazing-resistant algae and cyanobacteria. These common phytoplankton maxima of eutrophic lakes are often separated by the "clear water phase," a very short-lived period when large zooplankton graze on phytoplankton voraciously to bring on conditions of acute food limitation and are then rapidly replaced by smaller zooplankton species. The phytoplankton "clear water phase" may persist somewhat longer into the summer, depending on the effectiveness of the grazing of the smaller zooplankton species and nutrient loading, particularly of phosphorus. The collective primary productivity of phytoplankton, however, particularly with regard to smaller species with higher reproductive rates and less biogenic "turbidity", is generally very high during the summer period. In oligotrophic lakes, the phytoplankton-zooplankton successional process is similar although highly muted and slower (Fig. 1) (Wetzel, 2001).

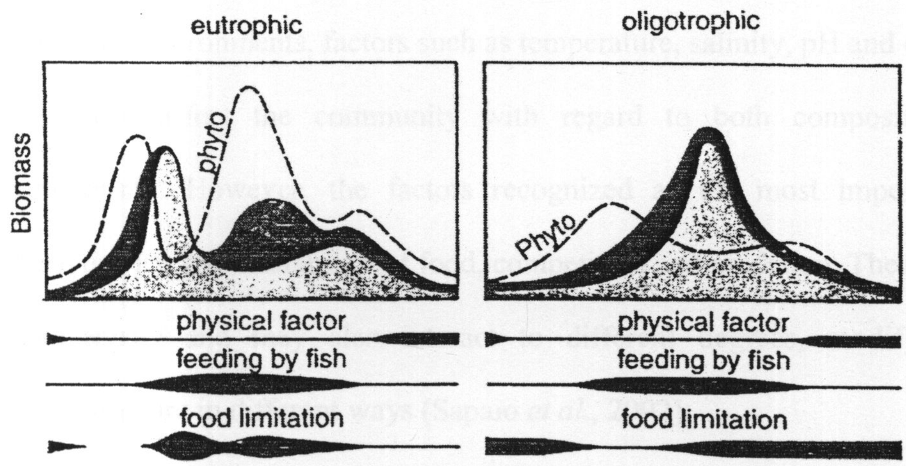


Figure 1. General model of seasonal succession of zooplankton in typical thermally stratified eutrophic (left) and oligotrophic (right) lakes of the temperate region. Phytoplankon: dashed line. Zooplankton: small species, dark shading; large species, lighter shading. Black lower bar indicates the relative intensity seasonal of factors noted (Wetzel, 2001).

2.6 Environmental variables influencing zooplankton communities

The environment in which an organism lives is never constant; it changes, for example, with the time of year. Also, within the life cycle of a species, the environmental pressures and the tolerances of the organism can change (Lampert *et al.,* 1997). The presence and success of an organism or group of organisms depend on a combination of conditions. Any condition that approximates or exceeds the limits of tolerance is said to be a limiting condition or limiting factor (Keppeler and Hardy, 2004). Species composition, abundance and distribution of zooplankton communities can be influenced by a number of physical, chemical and biological factors (Branco *et al.*, 2002; David *et al.,* 2005; Sapaio *et al.*, 2002). These factors can directly or indirectly influence the reproduction and survival of organisms (Espindola *et al.*, 2000). In natural environments, factors such as temperature, salinity, pH and electrical conductivity can affect the community with regard to both composition and population density. However, the factors recognized as the most important are temperature, quality and availability of food, competition and predation. These factors act simultaneously and may also interact to different degrees, modifying the zooplankton structure in different ways (Sapaio *et al.*, 2002).

Temperature and oxygen concentration are the key factors in restricting zooplankton occurrence (Yildiz *et al.,* 2007). Moreover, temperature is also important within the lethal limits, since it regulates the speed of the chemical, and ultimately, therefore, the biochemical and physiological processes. Some aquatic animals have blood pigment hemoglobin that has a high affinity for oxygen and enables the animals to live in habitats with extremely low oxygen concentrations (Lampert *et al.,* 1997). pH is related to many other variables in freshwaters that are correlated with zooplankton distribution and it is known that rotifers exhibit a very wide range of pH and turbidity tolerance (Berzins and Pejler, 1987). Total dissolved salt and electrical conductivity are important factors affecting zooplankton distribution in Lake Marmara (Yildiz *et al.*, 2007). Quality and quantity of food can alter species composition as well as the abundance of the species. In the study of rotifers *Brachionus angularis*, it was observed that food concentrations caused significant effects on population growth rate, body size and egg size in this species when *Chlorella pyrenoidosa* was used as food (Keppeler and Hardy, 2004). The degree of predation greatly affects the diversity of population of the species being preyed upon. Moderate predation often reduces the density of dominant species, thereby providing less competitive species with increased opportunities to utilize space and resources (Keppeler and Hardy, 2004).

2.7 A study of zooplankton communities in freshwater environments

Many studies have dealt with changes in zooplankton communities in temperate, subtropical and tropical zones (Table 2). Most studies of zooplankton communities have been carried out in temperate and subtropical zones, especially in the European region. However, studies of seasonal zooplankton change in the tropical zone have increased recently. Studies in several European countries, such as Norway, Germany and Denmark, have been conducted in freshwater lakes. Hessen and Lydersen (1996) and Primicerio (2000) gave accounts of seasonal changes in species composition in Norway. Eckert and Walz (1998) dealt with zooplankton succession in the shallow Müggelsee, Germany. Yakovlev (2001) detailed the spatial and temporal distribution of fish and zooplankton in a shallow lake in Denmark. The results of these studies showed that the dominant zooplankton was a similar group (rotifers, cladocerans) but a different species (Table 2). In New Zealand, Burns and Mitchell (1980) and James *et al.* (2001), observed seasonal changes in zooplankton communities. Calanoid copepod *Boeckella* was the dominant genus in both studies. In the subtropical region, abundance and seasonal fluctuation of zooplankton have been published by Maria-Heleni *et al.* (2000), Bonacila and Pasteris (2001), Ferrara *et al.* (2002), Manca and Comoli (2006) and Yildiz *et el.* (2007). In the tropical region, such studies conducted in Brazil have examined the distribution, composition and abundance of zooplankton in diverse habitats, such as in seven reservoirs of the Paranapanema River (Sampaio *et al.,* 2002), the Tucurui Reservoir (Espindola *et al.,* 2000), Ponte Nova and Guarapiranga Reservoirs (Sendacz *et al.*, 2006), Furnas Reservoir, Ibirite Reservoir and Pampulha Reservoir (Pinto-Coelho *et al.*, 2005b), Lake Souza Lima and Lake Parque Atalalia (Neves *et al.,* 2003), and Lake Lago Amapà (Keppeler and Hardy, 2004). In these studies, one group of Rotifera was dominant over the other groups, but the dominant genera *Synchaeta*, *Collotheca*, *Keratella*, *Polyarthra*, *Brachionus*, *Filinia*, *Ptygura*, *Conochilus,* differed in different habitats. In general, these genera are similar to those that have been studied in other tropical areas. Other investigations of zooplankton in tropical regions are as follows: Mengestou and Fernando (1991), Torres-Orozco and Zanatta (1998), Mageed and Heikal (2006) (Table 2).

2.8 A study of zooplankton in Thailand

The study of freshwater zooplankton in Thailand has increased recently. Most studies have concentrated on a specific aspect (species taxonomy and their distribution) of zooplankton communities in various water bodies, covering many provinces (Boonsom, 1984; Pholpunthin, 1997; Pipatcharoenchai, 2001; Wansuang and Sanoamuang, 2006). Large groups of zooplanktonic organisms are now known for the Rotifera, Cladocera and Copepoda. Minor zooplanktonic groups like Protozoa and Ostracoda are still poorly known systematically. The studies have often been limited to specific populations or groups, e.g., protozoan by Charubhun and Charubhun (2000), rotifers by Sergers and Pholpunthin (1997), Pholpunthin and Chittapun (1998), Sanoamuang and Savatenalinton (2001), Chittapun (2003), Chittapun *et al.* (2003), Savatenalinton and Segers (2005), cladocerans and copepods by Sa-ardrit (2002), Maiphae *et al.* (2004), Maiphae (2005), Maiphae *et al.* (2005), Sa-ardrit and Beamish (2005) and Sanoamuang and Faitakum (2005). As a result of these studies in all the parts of the country, the taxonomic knowledge of zooplankton has changed recently due to newcomers.

A few studies have investigated temporal variations (mainly diurnal and seasonal), spatial variations (both horizontal and vertical), and the distribution of zooplankton communities or species in diverse habitats (freshwater: Angsupanich and Rukkhiaw, 1984; Angsupanich, 1985; Chaiubol, 1998; Jithlang and Wongrat, 2004, brackish water: Ouppabullung and Angsupanich, 1995; Angsupanich, 1998; Chaleoisak, 2000; Charoenpol, 2003) (Table 3). In the bulk of these studies, abundance and species composition of zooplankton were seasonally different and related to environmental factors (e.g. precipitation, freshwater runoff, salinity, pH, dissolved oxygen, conductivity, transparency, etc.). Moreover, in most investigations, Protozoa and Rotifera were the most dominant groups in the community (Table 3).

In Thale-Noi lake, research has been conducted on the ecology of the zooplankton community. Angsupanich and Rukkhiaw (1984) studied the distribution of Rotifera in Thale-Noi between April 1982 and March 1983. Zooplankton samples were collected by both horizontal hauls and vertical hauls from five stations. The results indicated that rotifer density showed no significant differences between stations or seasons. Later in 1985, Angsupanich investigated the zooplankton communities in Thale-Noi. Comparison studies on composition and density of zooplankton between stations and seasons were carried out. Six major groups occurred in the community, namely protozoans, rotifers, nauplii, copepods, cladocerans, and ostracods. Of these, the rotifers were the most abundant. However, zooplankton density showed significant differences between station and season and it was suggested that dissolved oxygen content was the main environmental factor determining rotifer density. Pholpunthin (1997) studied the freshwater zooplankton (Rotifera, Cladocera, and Copepoda) in Thale-Noi, Southern Thailand. The study focused on taxonomy using samples collected from nine localities. He found 106 species of Rotifera, 17 species of Cladocera and three species of Copepoda and went on to describe 20 species of rotifers, seven species of cladocerans and two species of copepods which were new to Thailand. Later, Segers and Pholpunthin (1997) published an article on new and rare Rotifera from Thale-Noi Lake, Phatthalung Province, Thailand, with a note on the taxonomy of *Cephalodella* (Notommatidae). They found two new species of rotifer and 14 rotifer species that were recorded for the first time in Thailand. These results suggest that the Thale-Noi ecosystem has a special and specific zooplankton community, which includes rotifer, cladoceran and copepod species. Thus the study of changes in this zooplankton community is important for understanding the functioning of the lake.

Table 2. Studies of zooplankton communities in freshwater environments.

Regions	**Area**	**Total zooplankton group**	**The dominant zooplankton group**	**Net mesh size**	**Source**
Temperate	Lake Skjervatjern, Norway	Rotifers, Cladocerans and Copepods	Cladocerans: *Holopedium gibberum, Bosmina longisina* and *Diaphanosoma brachyurum*	45 µm	Hessen and Lydersen (1996)
	Lake Takvatn, Norway	Rotifers, Cladocerans, Copepods and Copepod nauplii	Nauplii of *Cyclops scutifer* Sars and *Eudiaptomus graciloides* ; Rotifers: *Keratella cochlearis*, *Conochilus unicornis* *Rousslet, Polyarthra* sp. and *Kellicottia longispina* (Kellicot)	50 µm	Primicerio (2000)
	Lake Muggelsee, Germany	Rotifers, Cladocerans and Copepods	Rotifers: *Keratella cochlearis, Synchaeta oblonga* and *K. quadrata*	30 µm	Eckert and Walz (1998)
	Lake Hanebjerg, Denmark	Cladocerans and Copepods	Cyclopoid copepods	45 µm	Romare *et al.* (2003)
	Lake Coleridge, New Zealand	Rotifers, Copepods and Copepod nauplii	Calanoid copepod: *Boeckella hamata*	55 µm	James *et al.* (2001)
	Lake Hayes and Lake Johnson, New Zealand	Rotifers, Cladocerans and Copepods	Cladocerans: *Ceriodaphnia dubia* Richard; Calaniod copepod: *Boeckella dilatata* Sars	77 µm	Burns and Mitchell (1980)

Table 2. Continued.

Regions	Area	Total zooplankton group	The dominant zooplankton group	Net mesh size	Source
Subtropical	Aliakmon river, Greece	Rotifers, Cladocerans, Copepods and Mollusca larvae	Rotifers and Mollusca larvae of *Dreissena polymorpha* Pal.	35 µm	Maria-Heleni *et al.* (2000)
	Lake Orta, Italy	Rotifers, Cladocerans, Copepods and Mollusca larvae	Rotifers: *Keratella quadrata, Brachionus urceolaris* and *Polyarthra dolycoptera-vulgaris*	76 µm	Bonacila and Pasteris (2001)
	Lake Bracciano, Italy	Rotifers, Cladocerans and Copepods	Copepods: *Eudiaptomus padanus etruscus*	80 µm	Ferrara *et al.* (2002)
	Lago Paione Superiore, Italy	Rotifers, Cladocerans, Copepods and Nauplii	Cladocerans: *Daphnia longispina*; Copepods: *Cyclops abyssorum tatricus*	200 µm	Manca and Comoli (2006)
	Lake Marmara, Turkey	Rotifers, Cladocerans and Copepods	Rotifers: *Keratella* spp., *Polyarthra* spp. and *Brachionus* spp.; Cladocerans: *Bosmina longirostris*	55 µm	Yildiz *et el.* (2007)

Table 2. Continued.

Regions	Area	Total zooplankton group	The dominant zooplankton group	Net mesh size	Source
Temperate	Ontario Coldwater lakes, Canada	Cladocerans and Copepods	Cyclopoid copepods	53 µm	Pinto-Coelho *et al.* (2005b)
Temperate	SFM lakes, Canada		Cyclopoid copepods	53 µm	
Temperate	TROLS lakes, Canada		Cyclopoid copepods	53 µm	
Subtropical	Florida lakes, USA		Cladocerans	150 µm	
Tropical	Volta Grande reservoir, Brazil		Cladocerans	90 µm	
Tropical	Furnas reservoir, Brazil		Cyclopoid copepods	90 µm	
Tropical	Ibirite reservoir, Brazil		Cyclopoid copepods	90 µm	
Tropical	Pampulha reservoir, Brazil		Cyclopoid copepods	90 µm	
Tropical	Tucurui reservoir, Brazil	Rotifers, Cladocerans, Copepods, Turbellaria, Ostracoda and Chaoborus	Copepods: *Thermocyclops minutus* and *Notodiaptomus henseni*; Cladocerans: *Ceriodaphnia cornuta* and *Bosminopsis deitersi*	68 µm	Espindola *et al.* (2000)

Table 2. Continued.

Regions	Area	Total zooplankton group	The dominant zooplankton group	Net mesh size	Source
Tropical	Jurumirim Reservoir, Brazil	Rotifers, Cladocerans and Copepods	Rotifers: *Synchaeta* sp.	68 µm	Sampaio *et al.* (2002)
	Piraju Reservoir, Brazil		Rotifers		
	Xavantes Reservoir, Brazil		Rotifers; Cladocerans		
	Salto Grande Reservoir, Brazil		Rotifers		
	Rio Pari Reservoir, Brazil		Rotifers; Cladocerans		
	Capivara Reservoir, Brazil		Rotifers; Cyclopoid copepods		
	Rio Novo Reservoir, Brazil		Rotifers: *Collotheca* sp. ; Cyclopoid copepods: *Thermocyclops*		
Tropical	Lake Souza Lima, Brazil	Rotifers, Cladocerans and Copepods	Rotifers: *Keratella americana* and *K. cochlearis*; Cladocerans: Diaphanosoma fluviatile and *Moina minuta*	68 µm	Neves *et al.* (2003)
	Lake Parque Atalaia, Brazil		Rotifers: *Polyarthra vulgaris* and *Brachionus angularis* Cladocerans: Diaphanosoma fluviatile and *Moina minuta*		

Table 2. Continued.

Regions	Area	Total zooplankton group	The dominant zooplankton group	Net mesh size	Source
Tropical	Lake Awasa, Ethiopia	Cladocerans and Copepods	Cladocerans: *Diaphanosoma excisum* Sars and *Alona diaphana* Sars; Copepods: *Mesocyclops aequatorialis similes* and *Thermocyclops consimilis*	64 µm	Mengestou and Fernando (1991)
	Lake Catemaco, Mexico	Protozoans, Rotifers, Ostracods, Cladocerans, Copepods, Fish larvae and Insect larvae	Rotifers: *Brachionus havanaensis* and *Conochilus unicornis*; Calanoid and Cyclopoid nauplii	100 µm	Torres-Orozco and Zanatta (1998)
	Lake Nasser, Egypt	Rotifers, Cladocerans and Copepods	Copepods: *Thermocyclops neglectus* (Sar) and *T. galebi* ; Cladocerans: *Ceriodaphnia reticulate* and *Diaphanosoma excisum*	55 µm	Mageed and Heikal (2006)
	Lake Lago Amapà, Brazil	Rotifers, Cladocerans, Copepods, Copepod naupii and Chaoborus	Rotifers: *Keratella cochlearis, Filinia longiseta, F. terminalis* and *Brachionus calicyflorus*	55 µm	Keppeler and Hardy (2006)
	Ponte Nova reservoir, Brazil Guarapiranga reservoir, Brazil	Rotifers, Cladocerans and Copepods	Rotifers: *Polyarthra vulgaris, Ptygura libera, Conochilus unicornis* and *Collotheca ornate* Rotifers: *P. vulgaris, Synchaeta oblonga* and *Keratella cochlearis*	40 µm	Sandacz *et al.* (2006)

Table 3. Zooplankton groups or phyla reported as numerically dominant in the water body, Thailand.

	Protozoa	Rhynchoceala	Cnidaria	Rotifera	Coelenterata	Ctenophora	Nematoda	Bryozoa	Chaetognatha	Annelida	Arthropoda	Mollusca	Echinndermata	Chordata	
Freshwater															
Thale-Noi	■			■ *							■				Angsupanich, 1995
Ang Kaew Reservoir	■			■ *							■				Chaiubol, 1998
Pasak Jolasid Reservoir	■		■	■ *							■				Jithlang and Wongrat, 2004
Brackish water															
Phawong Canal	■ *	■		■	■	■	■	■	■	■	■	■	■	■	Ouppabullung and Angsupanich, 1995
Thale Sap Songkhla	■ *			■	■	■	■	■	■	■	■	■	■	■	Angsupanich, 1997
Tha-Chin River	■ *			■							■				Chaleoisak, 2000
Bangpakong River	■ *			■						■	■	■			Charoenpol, 2003

Note: ■ present in the community   * dominant group of community

□ absent in the community

3. Research questions

1. How do the zooplankton communities of different size fractions change annually in Thale-Noi?
2. What are the possible factors affecting the changes of zooplankton of different size fractions in Thale-Noi?

4. Hypothesis

1. Seasonal and spatial variations and environmental parameters influence changes in zooplankton communities
2. Food availability influences changes in zooplankton communities

5. Objectives

1. To investigate the seasonal and spatial variations of zooplankton communities of different size fractions in Thale-Noi
2. To investigate the effects of certain environmental factors on change of zooplankton communities of different size fractions in Thale-Noi

CHAPTER 2

MATERIALS AND METHODS

1. Study area

Thale-Noi, a shallow roundish lake, is located at the northernmost end of the overall Songkhla lake system in Phatthalung Province, Southern Thailand (Buapetch, 2002) between latitude 7° 45′ N to 7° 55′ N and longitude 100° 05′ E to 100° 15′ E (Pholpunthin, 1997). It covers an area of 30 km^2, has a shoreline of about 20 km, and contains about 32 M m^3 of water (Kuwabara, 1995). Thale-Noi is one of the few surviving intact freshwater wetland ecosystems in Thailand. It comprises several distinct topological areas: swamp forest, lake, moist evergreen forest and agricultural lands (Storer, 1977). All of these areas are important feeding sites for bird and wildlife species including aquatic animals, phytoplankton and zooplankton. Thale-Noi is an important waterfowl reserve in Southern Thailand (Leingpornpan and Leingpornpan, 2005). More than 187 species of waterfowl, including both migratory and indigenous birds, make their home at Thale-Noi. Thale-Noi has been named the first world wetland site in Thailand and there are aims to preserve the sustainable ecology of the area (Aiumnau *et al.*, 2000). The principal inflow to the lake is the runoff from the steep forested slopes of the Banthad Mountains to the west. Outflow is via the Klong Nang Riam, Klong Ban Glang and Klong Yuan canals into Thale Luang, Lake Songkhla. The lake is rather shallow with a mean depth of 1.2m but water levels can fluctuate up to one meter, typically reaching their lowest level in

August. The lake is normally fresh to slightly saline (1.48 ppt). The salinity may rise during the driest months (to 3.5 ppt) when saline water from Lake Songkhla may intrude. The pH varies spatially and seasonally from 1.2 - 8.1 (average 4.4). The northern end (near the *Melaleuca* swamp forest) is more acidic than the south. Acidity increases during the rainy season from the leaching of acidic humus. The climate is tropical monsoon with an average annual rainfall of 2,208 mm, and the mean pan evaporation rate is 1,753 mm (Aiumnau *et al.,* 2000).

Twelve plankton sampling stations were selected for this study (Fig. 2 and 3). These stations were representative of four different habitats in Thale-Noi: a peat swamp zone (1, 2, 3), a small inlet zone (4, 5, 6), a resident zone (7, 8, 9) and a pelagic zone (10, 11, 12). The decision where to site the selection zones was based on a preliminary survey and information from previous studies (Angsupanich, 1985; Nookua, 2003). Data from the preliminary survey in the Thale-Noi area indicated diverse microhabitats of waterbodies, including swamp forest, *Melaleuca* forests, moist evergreen forest and agricultural lands. Therefore, twelve stations were designed to cover areas of all zooplankton sampling. Site locations were determined by using an electronic global positioning system (GPS).

2. Climate and monsoon system

Thale-Noi's climate is strongly influenced by the tropical monsoon system (Table 4); the northeast monsoon (November to April) and the southwest monsoon (May to October) (Colborm, 1975 cited by Suphakason, 1992). In addition, three principal seasons characterize the climatic periods: the light rainy period from late April to August, the rainy period from August to December, and the dry period from January to April (Hembanthid, 2001). Monthly average precipitation levels recorded for the period 1991-1995 in the Thale-Noi area at Banpraw village, Parpayom District, ranged from 54.3 mm in January to 645.4 mm in November, with an overall monthly average of 193.3 mm (Thungwa *et al.*, 1990 cited by Hembanthid, 2001). In the present study, decisions regarding the selection of sampling periods were determined by the precipitation pattern from ten years ago and the monsoon system. The data on the precipitation of Thale-Noi lake during the present study (2004-2005) was obtained from areas in the Khuan-Kanun District, Phatthalung Province (Fig. 4).

Table 4. The monsoon system pattern in the Thale-Noi area.

Period	**Monsoon system**
January – February	The northeast monsoon
March – April	The end of the northeast monsoon and a period of changing wind direction.
May – June	The beginning of the southwest monsoon
July – August	The southwest monsoon
September – October	The end of the southwest monsoon and a period of changing wind direction.
November – December	A period of changing wind direction and the beginning of the northeast monsoon

Source: Colborm (1975) cited by Suphakason (1992).

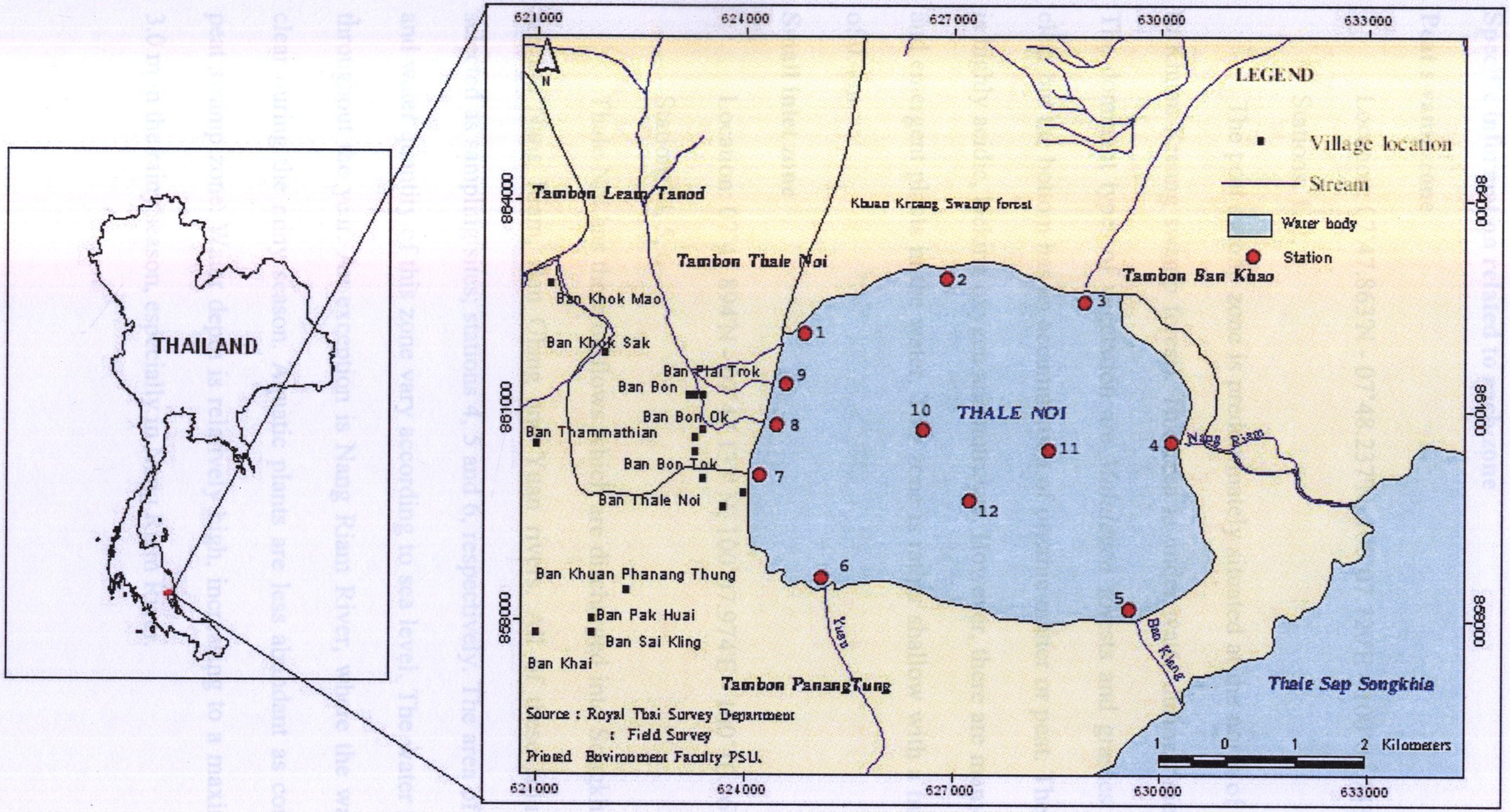


Figure 2. Study area and sampling stations in Thale-Noi, Phatthalung Province.

Specific information related to each zone

Peat swamp zone

Location: 07°47.863'N - 07°48.237'N, 100°07.720'E - 100°09.743'E

Stations: 1, 2, 3

The peat swamp zone is predominately situated at the north of the lake (next to Khuan Kreang swamp forest). This area is under water during times of flooding. The dominant types of vegetation are *Malaleuca* forests and grasses. The water is clear but the bottom has an accumulation of organic matter or peat. The water quality is highly acidic, lacking oxygen and nutrients. However, there are many lotus flowers and emergent plants in the water. This zone is rather shallow with a minimum depth of 0.4 m.

Small inlet zone

Location: 07°45.894'N - 07°47.133' N, 100°07.974'E - 100°10.569'E

Stations: 4, 5, 6

Thale-Noi has three outflows which are discharged into Songkhla Lake. They are the Nang Riam, Ban Glang and Yuan rivers. All of these small inlets were selected as sampling sites; stations 4, 5 and 6, respectively. The area of surface water and water quantity of this zone vary according to sea level. The water is quite turbid throughout the year. An exception is Nang Riam River, where the water is usually clear during the rainy season. Aquatic plants are less abundant as compared to the peat swamp zone. Water depth is relatively high, increasing to a maximum value of 3.0 m in the rainy season, especially in Nang Riam River.

Resident zone

Location: 07°46.483'N - 07°47.328'N, 100°07.645'E - 100°07.685'E

Stations: 7, 8, 9

The resident zone is located close to fish pens and the human resident area along the shore, situated on the western side of Thale-Noi. The dominant vegetation is submerged plants such as *Hydrilla verticillata*, *Ceratophyllum demersum* followed by floating plants such as lotuses. These act as food sources for fish and small aquatic animals. However, they can also adversely affect water quality by reducing the amount of dissolved oxygen concentration in the water.

Pelagic zone

Location: (07°46.625'N- 07°47.043'N, 100°08.369'E- 100°09.412'E)

Stations: 10, 11, 12

The pelagic zone is located in the middle of Thale-Noi where dense submerged vegetation covers the lake bottom. *Hydrilla verticillata* and *Utricularia flexussa* are the dominant species. The water color is brown and the bottom is covered with a thick detritus layer showing high biological production. The water transparency in this zone is increased when the submerged vegetation is dense. The amount of floating plants is very low; probably due to the effect of wind and wave actions. This zone is reliant on flood conditions.

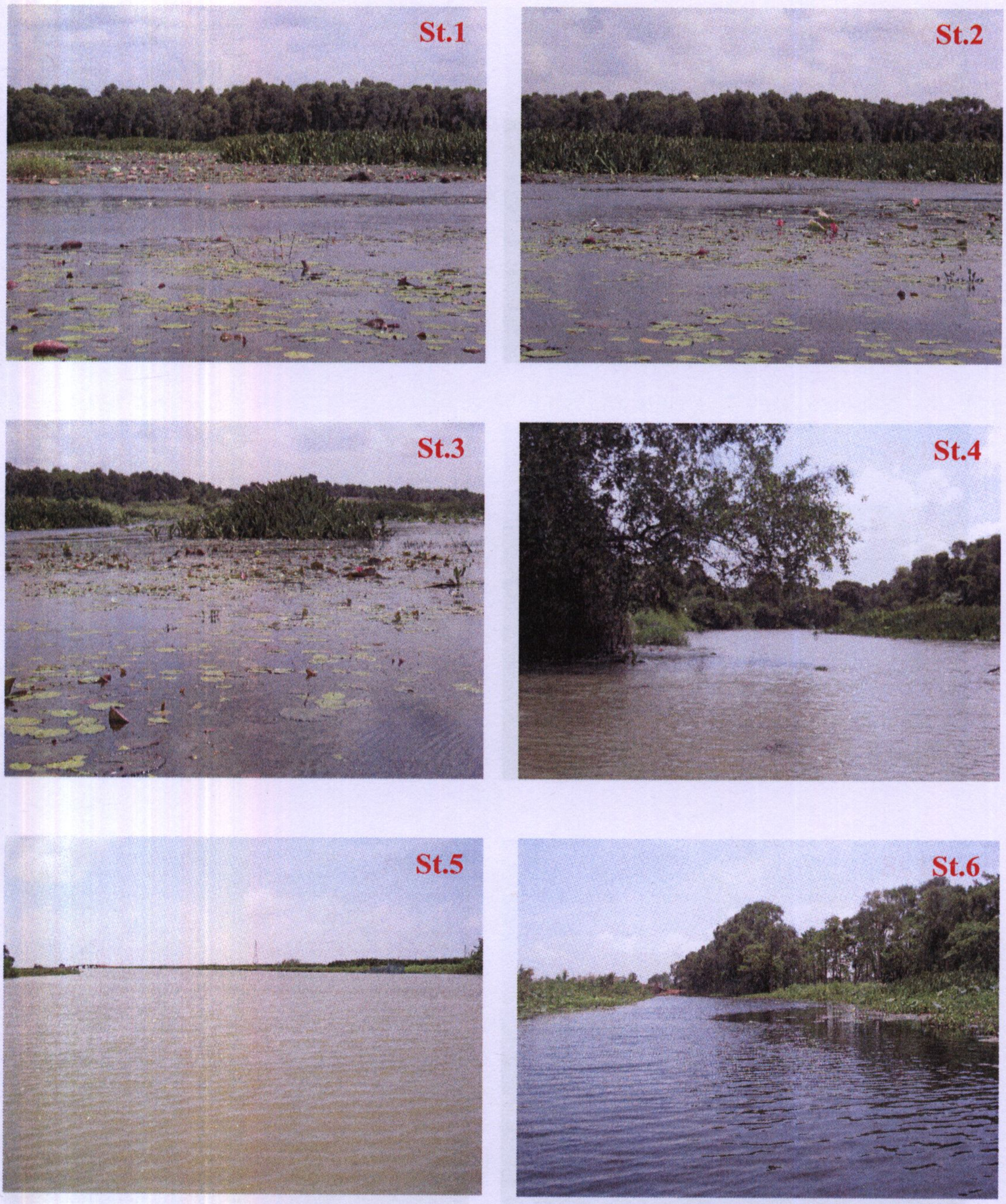


Figure 3. Sampling stations in Thale-Noi lake: Stations 1-3, Peat swamp zone; Stations 4-6, Small inlet zone.

Figure 3. Continued. Stations 7-9, Resident zone; Stations 10-12, Pelagic zone.

3. Methodology

3.1 Zooplankton sampling and analysis

Quantitative zooplankton samples from each station were taken using two different sampling methods. The first was a horizontal towing using a 200 μm plankton net fitted with a flow meter towed by a low speed boat for three minutes. The second was a filtration of 20-50 liters of water through a 20 μm plankton net. The zooplankton samples were immediately preserved in a 5% formaldehyde solution and brought to the laboratory for further analysis. Zooplankton sampling was conducted twice a month in three bimonthly periods, comprising the moderate-water phase (light rainy period) in July and August 2004, the high-water phase (rainy period) in November and December 2004, and the low-water phase (dry period) in March and April 2005.

In the laboratory, the 20 μm net samples were separated into two nominal size fractions: 20-200 μm (microzooplankton), and > 200 μm (mesozooplankton) by filtering plankton samples through a 200 μm sieve. Between 50% and 100% of all specimens, from the two sampling methods, were counted and identified to genus or species levels using Olympus CH-2 Compound and Olympus SZ-40 Stereo microscopes. Zooplankton identification was based on information from the following experts: Koste (1978), Theodore *et al.* (1979), Idris (1982), Smirnov (1992), Korovchinsky (1992), Segers (1995-1996), Wongrat (2000), Sanoamuang (2002) and Maiphae (2005). Quantitative analysis of protozoans and rotifers was performed in a Sedgwick-Rafter Counting Cell, counting between three and five slides (depending on abundance) in order to determine the density and relative abundance of all species. Crustacean zooplankton were counted in reticulated acrylic chambers in sub samples varying from 10 ml to the entire concentrated sample (30 ml), depending on the concentrations of organisms. Some species of rotifers were put on slides and mastex preparations with sodium-hypochlorite were made whenever necessary so that specimens could be examined under a compound microscope. Some specimens, such as cladocerans, ostracods and copepods, were placed on slides with a drop of glycerin, dissected using a stereo microscope, and examined under a compound microscope. The identification uses not only the outer morphological characteristics but also, in most cases, a more detailed examination of the inner characteristics. Thus, the dissection method for cladocerans, ostracods and copepods followed that described by Maiphae (2005), Wongrat (2000) and Sanoamuang (2002), respectively.

3.2 Water sampling and analysis

At each station, depth, transparency, conductivity, temperature, salinity and pH were measured *in situ*. Water depth was determined using a tape measure and transparency was determined using a Secchi disc. Additionally, temperature, conductivity and salinity were automatically measured using a YSI 30 model 30/10 FT, and pH was determined using a YSI60 model 60/10 FT. One liter samples of water were collected using polyethylene bottles. All samples were stored in ice boxes during transportation to the laboratory for chlorophyll *a*, total solid and dissolved oxygen (DO) concentration analysis.

Water samples were analyzed for total solids, dissolved oxygen and chlorophyll *a* in laboratory conditions following the Standard Method (APHA, AWWA, and WEF, 1998). Size-fraction of the chlorophyll *a* was analyzed. 250 ml water samples were filtrated through 200 μm mesh nets to eliminate zooplankton. The filtrated water was then poured sequentially through 20 μm mesh nets. The residual on the 20 μm net was re-suspended in distilled water and analyzed for chlorophyll *a* fraction size of 20-200 μm. The samples that passed through the 20 μm mesh net were analyzed for chlorophyll *a* size fractions of < 20 μm. The two size-fractions of chlorophyll *a* were filtered through Whatman GF/C glass fiber filters and the filters were kept deep frozen for later analyses. Pigments were extracted in 90 % acetone. Absorbances of the extracts were measured at 750, 664, 647 and 630 nm with a spectrophotometer.

3.3 Data analysis

3.3.1 Calculation: The total number of zooplankton in the water sample

Density of organisms was calculated from the volume of water filtered and the size of each sub sample, and expressed as numbers of individuals per cubic meter. The total number of zooplankton present in a cubic meter of water sample from the Sedgwick-Rafter Counting Cell can be calculated using the following formula:

$$N = n \times v \frac{(1000)}{V}$$

where N : total number of zooplankters per cubic meter of water filtered;

n : average number of zooplankters in 1 ml of plankton sample;

v : volume of plankton concentrate (ml);

V : volume of total water filtered (l).

For the horizontal net (200 μm), the sample can be determined as follows:

$$T = N/V$$

Where T : total number of zooplankters per cubic meter of water filtered;

N : number of zooplankton in the concentrate plankton sample (individual);

V : total volume of water actually filtered by the net (m^3).

The volume of water filtered during a tow (V) can also be calculated using the following procedure:

$$V = a \times m \times n$$

Where a : the area (m^2) of the mouth of the net (the present study, πr^2 = 3.14x0.18x0.18 = 0.1 m);

m : the towing distance (m) per one flowmeter revolution in the calibration (the present study, m = 0.029 m);

n : the number of flowmeter revolutions.

3.3.2 Zooplankton community

Spatial and temporal variations of zooplankton density and environmental parameters were analyzed using an analysis of variance (ANOVA). Period of sampling and zone were treated as fixed factors. Abundance was transformed to log (x+1) to normalize the variance.

3.3.3 Environmental variables

Environmental data including temperature, pH, dissolved oxygen (DO), salinity, conductivity, total solid, depth, transparency, chlorophyll *a* fraction size of <20 μm and chlorophyll *a* fraction size of 20-200 μm (which were used without transformation) were analyzed using the multivariate test SPSS for Windows.

3.3.4 The influence of environmental variables on the zooplankton community

The correlation between the abundance of each zooplankton genus and environmental factors was investigated at each zone and during each period by Canonical Correspondence Analysis (CCA), incorporating the unimodal response of a species to environmental variables. Linear combinations of environmental variables were selected to provide maximum separation in species distribution. The CCA procedure produces an ordination diagram in which genera are represented by points and environmental variables by vectors. The statistical significance of the relationship between a set of environmental factors and genus composition was estimated using a Monte Carlo permutation test.

Zooplankton species data was converted to relative abundance values. To assess the homogeneity of variance, the relative abundance was transformed using log (x+1), which prevented the creation of undefined values due to having zeros in the data set. In addition, the zooplankton data was approved by distinguishing reference samples from impaired samples with downweight rare species, to be used in CCA.

Spearman rank correlations were also used to investigate the relationships between the two size fractions of chlorophyll *a* and zooplankton abundance (both zooplankton in each group and genus).

Statistical analysis details: CCA, using the PC-ORD program, version 3.2. ANOVA and Spearman correlation were employed in combination with the SPSS program, version 11.0 for Windows.

CHAPTER 3

RESULTS

3.1 Environmental variables

Precipitation

Thale-Noi lake has a humid tropical climate in which the seasons was essentially determined by the precipitation pattern. The annual pattern of precipitation and its average in the Khuan-Khanun district of Thale-Noi are presented in Figure 4. Three distinct periods: the light rainy period, associated with the moderate water phase (July and August 2004), the rainy period, associated with the highest water phase (November and December 2004) and the dry period, associated with the lowest water phase (March and April 2005) were used for the present study. The average precipitation ranged from 0 mm (non detection) to 69 mm. The result of precipitation measurement during the year long study was not as expected. Instead of the dry period having the lowest precipitation value, the lowest value was found to be in the light rainy period. However, the highest value was found in the rainy period which concurs with this sampling period sets. Because the precipitation falls on a small watershed basin, the precipitation also determines the hydrological regime of the canals that connect to the Songkhla Lake. Accordingly, the light rainy and dry periods correspond to the low water period while the rainy period is associated with the flood period of the lake.

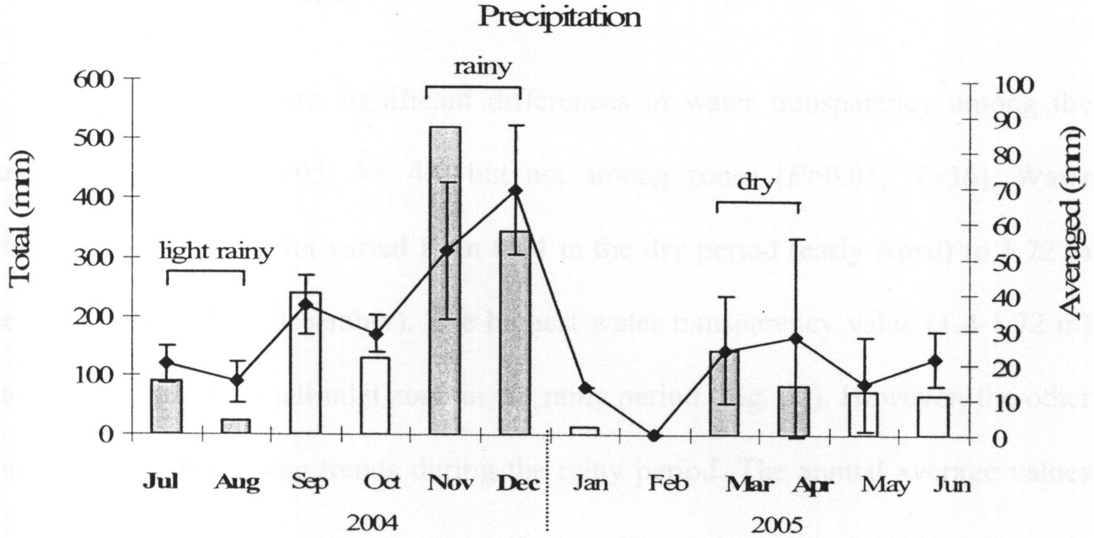


Figure 4. Annual pattern of total precipitation (histogram) and average monthly precipitation (solid line) at Khuan-Khanun District during July 2004 to June 2005. The fill histogram indicates the sampling periods for this work.

Source: Khuan-Khanun District Office.

Depth

There were significant differences in water depth among the sampling periods (*P*<0.05, *N*= 48) and zones (*P*<0.05, *N*=36). The mean water depth of Thale-Noi ranged from 0.7 to 2.3 m (Fig. 5a). The highest value of water depth was recorded in the rainy period (early November) while the lowest value was found in the light rainy period (early July). The small inlet zone shows a higher value (ranged from 1.2 to 2.2 m, $\bar{x}$ = 1.76±0.43 m) than those at other zones throughout the study, followed by the pelagic zone (ranged from 0.8 to 2 m, $\bar{x}$ = 1.38±0.47 m), the resident zone (ranged from 0.7 to 1.8 m, $\bar{x}$ = 1.23±0.41 m) and the peat swamp zone (ranged from 0.7 to 1.7 m, $\bar{x}$ = 1.1±0.4 m), respectively.

Transparency

There were significant differences in water transparency among the sampling periods ($P<0.05$, $N= 48$) but not among zones ($P>0.05$, $N=36$). Water transparency at Thale-Noi varied from 0.44 in the dry period (early April) to 1.72 in the rainy period (late December). The highest water transparency value (1.4-1.72 m) was observed in the small inlet zone in the rainy period (Fig. 5b). However, the other zones showed decreasing trends during the rainy period. The annual average values ranged from 0.6 to 1.5 m ($\bar{x}$ = 0.97±0.2 m) at the pelagic zone, from 0.4 to 1.72 m ($\bar{x}$= 0.94±0.5 m) at the small inlet zone, from 0.4 to 1.3 m ($\bar{x}$= 0.88±0.2 m) at the resident zone and from 0.4 to 1.2 m ($\bar{x}$ = 0.75±0.2 m) at the peat swamp zone, respectively.

pH

There were significant differences in water pH among the sampling periods ($P<0.05$, $N= 48$) and zones ($P<0.05$, $N=36$). pH values during the study varied between 5.0 and 9.1. Higher values of water pH were found in the light rainy period (ranged from 6.2 to 9.1) and the dry periods (ranged from 5.0 to 8.6) compared to that in the rainy period (ranged from 5.6 to 7.8) (Fig. 5c). pH values showed similar trends in all zones, however, pH values at the peat swamp zone were lower than those at other zones throughout this study. During the rainy period, pH values decreased to 5.6 at the small inlet zone. The mean water pH value was highest at the pelagic zone ($\bar{x}$ = 7.5±0.9) followed by the resident zone ($\bar{x}$ = 7.4±0.5), the small inlet zone ($\bar{x}$ = 7.0±0.8) and the peat swamp zone ($\bar{x}$ = 5.8±0.8).

Total solid

Total solid varied widely, with the maximum value (1,691.4 $mg.l^{-1}$) being observed in early November while the minimum value (59.4 $mg.l^{-1}$) was observed in late December. There were significant differences in total solid among the sampling periods ($P<0.05$, $N=48$) and zones ($P<0.05$, $N=36$). The total solid value of all zones in the light rainy period showed similar patterns in the dry period, but different patterns in the rainy period (Fig. 5d). The highest value of total solid was measured at the small inlet zone (ranged from 113.9 to 1691.4 $mg.l^{-1}$, $\bar{x}$ = 880.9±493.8 $mg.l^{-1}$), followed by the resident zone (ranged from 62.4 to 896.4 $mg.l^{-1}$, $\bar{x}$ = 456.7±244.9 $mg.l^{-1}$), the pelagic zone (ranged from 59.4 to 887.8 $mg.l^{-1}$, $\bar{x}$ = 435.2±262.3 $mg.l^{-1}$) and the peat swamp zone (ranged from 122.6 to 626.7 $mg.l^{-1}$, $\bar{x}$ = 303.5±147.2 $mg.l^{-1}$), respectively.

Water temperature

There were significant differences in water temperature among the sampling periods ($P<0.05$, $N=48$) but not among zones ($P>0.05$, $N=36$). Water temperature fluctuated in the range of 26.6 °C (early December) in the rainy period to 32.8 °C (late April) in the dry period. The patterns of seasonal change in water temperature were similar at all zones (Fig. 5e). In the light rainy period, the water temperature ranged from 27.3 to 31.8 °C ($\bar{x}$= 29.5±1.2 °C), with the maximum value observed at the peat swamp zone. In the rainy period, the water temperature was lower (ranged from 26.6 to 30.0 °C, $\bar{x}$= 28.3±1.1 °C), with the minimum values recorded at the resident and pelagic zones. In contrast, during the dry period, there were higher values of water temperature (between 28.5 and 32.8 °C, $\bar{x}$ = 30.6±1.2 °C), an increasing trend shown at all zones.

Salinity

Salinity changes are generally low. Salinity was between 0 and 1.4 ppt, the lowest salinity value was recorded in the rainy period while the highest value was recorded in the dry period (Fig. 5f). There were significant differences in water salinity among the sampling periods (P<0.05, N= 48) and zones (P<0.05, N=36). At the small inlet zone, salinity varied widely and showed a higher value than those at other zones throughout this work (ranged from 0.4 to 1.4, $\bar{x}$ = 0.8±0.4 ppt). For the other zones, salinity values in the light rainy and rainy periods were slightly lower; however, the salinity showed an increasing trend in the dry period. The mean of water salinity was 0.36±0.2 ppt, recorded at the resident zone, 0.35±0.2 ppt at the pelagic zone and 0.2±0.1 ppt at the peat swamp zone.

Water conductivity

Water conductivity varied widely. The maximum value (2,572 $\mu s.cm^{-1}$) was observed in late December and the minimum value (54.6 $\mu s.cm^{-1}$) in early November (Fig. 5g). There were significant differences in water conductivity among the sampling periods (P<0.05, N= 48) and zones (P<0.05, N=36). During the light rainy period, the water conductivity ranged between 427.8 and 2,197.3 $\mu s.cm^{-1}$, with a mean value of 899.0±524 $\mu s.cm^{-1}$. In the rainy period, the water conductivity showed a decreasing trends at all zones, ranging between 54.6 and 2,572 $\mu s.cm^{-1}$, with a mean value of 490.6±663 $\mu s.cm^{-1}$. For the dry period, the water conductivity was higher than that in the other sampling periods, it ranged between 250.2 and 2570.7 $\mu s.cm^{-1}$, and the mean value was 1,212.5±605 $\mu s.cm^{-1}$. The greatest water conductivity was recorded at the small inlet zone ($\bar{x}$= 1,477.8±827.9 $\mu s.cm^{-1}$) in all sampling periods. However, water conductivity varied slightly among other zones.

Dissolved oxygen

Throughout this study, dissolved oxygen concentrations varied between 0.87 and 9.1 $mg.l^{-1}$, $\bar{x}$=3.4±2.1 $mg.l^{-1}$. The highest dissolved oxygen was recorded in the dry period (ranged from 2.8 to 9.1 $mg.l^{-1}$), followed by the rainy period (ranged between 1.4 and 3.7 $mg.l^{-1}$) and the light rainy period (ranged between 0.87 and 2.3 $mg.l^{-1}$, respectively (Fig. 5h). Although dissolved oxygen concentrations peaked at the resident zone, slight variations were observed between zones. On the other hand, there were significant differences in dissolved oxygen among the sampling periods (P<0.05, N= 48) and zones (P<0.05, N=36). The highest mean value of dissolved oxygen was at the resident zone (3.9±2.6 $mg.l^{-1}$), followed by the pelagic zone (3.8±2.3 $mg.l^{-1}$), the small inlet zone (3.1±2.0 $mg.l^{-1}$) and the peat swamp zone (2.9±1.7 $mg.l^{-1}$).

Chlorophyll *a* fraction of < 20 µm (Pico-nanophytoplankton)

Chlorophyll *a* size fractions of < 20 µm fluctuated in range between 306.0 (early August) and 13,204 $mg.m^{-3}$ (late August), with an average of 3,138.5±2,847 $mg.m^{-3}$. There were no distinct differences in pico-nanophytoplankton among the sampling periods. Pico-nanophytoplankton concentration ranged from 306.0 to 13,204 $mg.m^{-3}$ in the light rainy period, from 745.8 to 10,125.9 $mg.m^{-3}$ in the rainy period, and from 600.7 to 7,974.8 mg.m^{-3} in the dry period. There were no clear spatial patterns in pico-nanophytoplankton concentrations within the area of investigation (Fig. 5i). The highest pico-nanophytoplankton concentrations were found at the small inlet zone (13,203.7 mg.m^{-3}), followed by the pelagic zone (12,303.7 mg.m^{-3}), the resident zone (7,422.4 mg.m^{-3}) and the peat swamp zone (3,916.4 mg. m^{-3}).

Chlorophyll *a* fraction of 20-200 μm (Microphytoplankton)

Chlorophyll *a* size fraction of 20-200 μm concentration during the study ranged between 134.9 and 10,604.1 mg.m^{-3}. The highest concentration was observed during the rainy period and the lowest during the dry period (Fig. 5j). Total microphytoplankton during the light rainy period varied from 360.4 to 6,436.5 mg.m^{-3}, between 740.2 and 10,604.1 mg.m^{-3} in the rainy period, and between 134.9 and 7,083.9 mg.m^{-3} during the dry period. The total microphytoplankton was higher at the resident zone (between 134.9 and 10,604.1mg.m^{-3}) than that at other zones, followed by at the small inlet zone (between 796.8 and 7,083.9 mg.m^{-3}), the peat swamp zone (between 360.4 and 6,436.5mg.m^{-3}) and the pelagic zone (between 504 and 3,024.1 mg.m^{-3}). Moreover, there were no significant differences between the sampling periods (P>0.05, N= 48) and zones (P>0.05, N=36).

Throughout the study, total chlorophyll *a* was dominated by the chlorophyll *a* size fraction of < 20 μm, which comprised between 43% and 82% of the total chlorophyll *a*. An exception was recorded during early July when chlorophyll *a* fraction of size 20-200 μm dominated the overall concentration (Fig. 6). There were significant differences among size fractions of chlorophyll *a* (P<0.05) during any of sampling period.

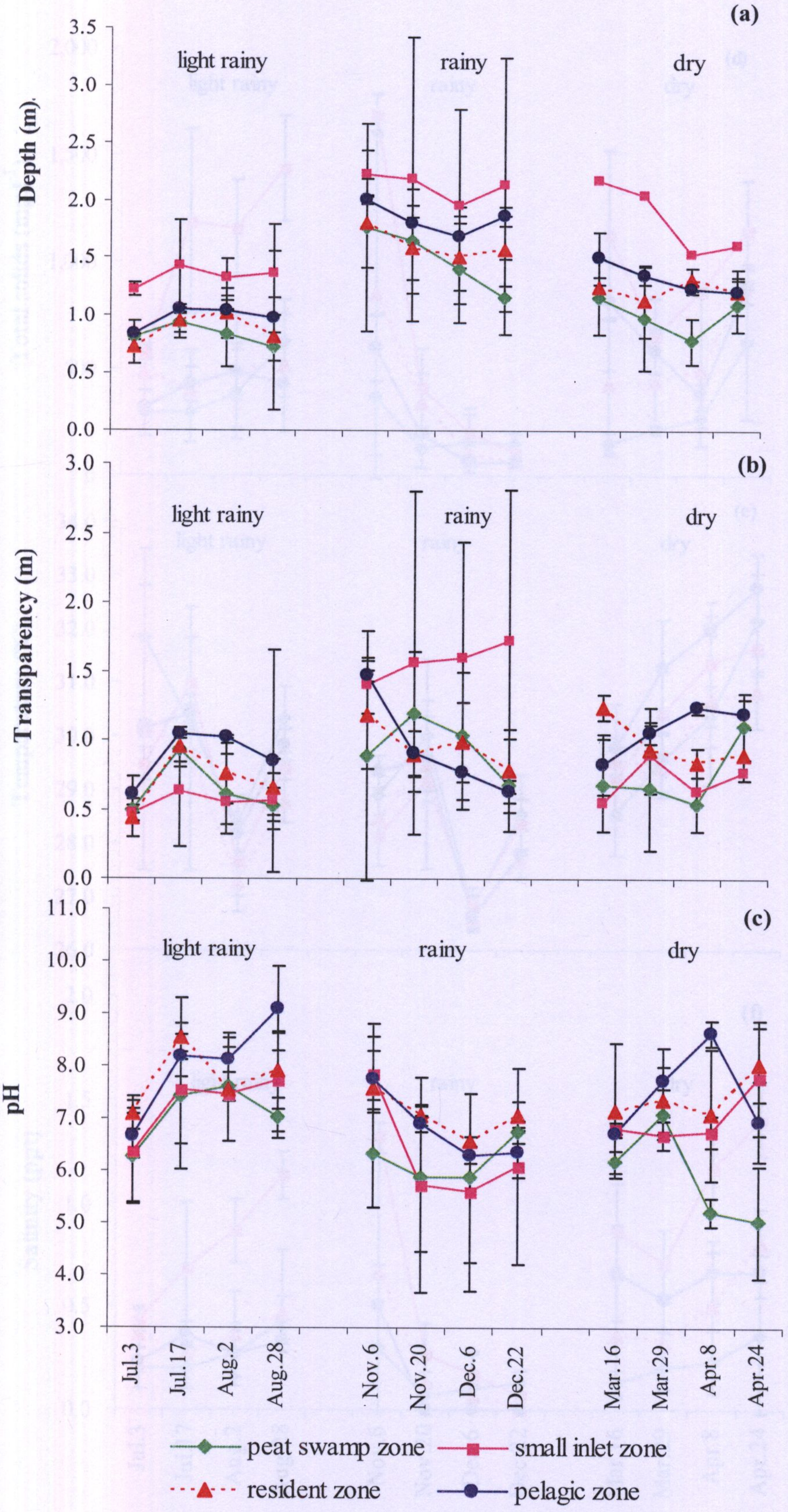


Figure 5. Environmental variables in Thale- Noi during July 2004 to April 2005, (a; Depth, b; Transparency and c; pH).

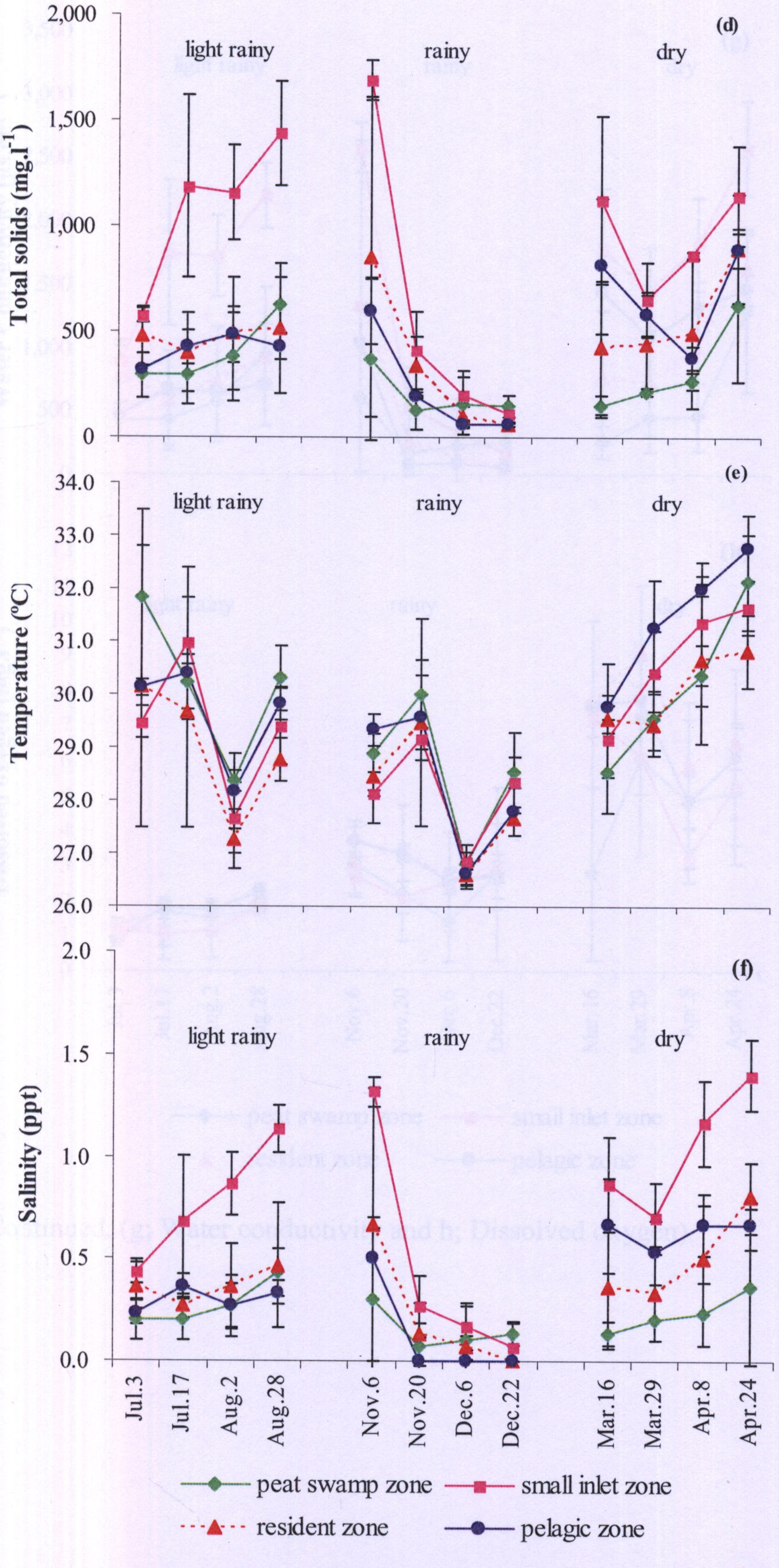


Figure 5. Continued. (d; Total solid, e; Water temperature and f; Salinity).

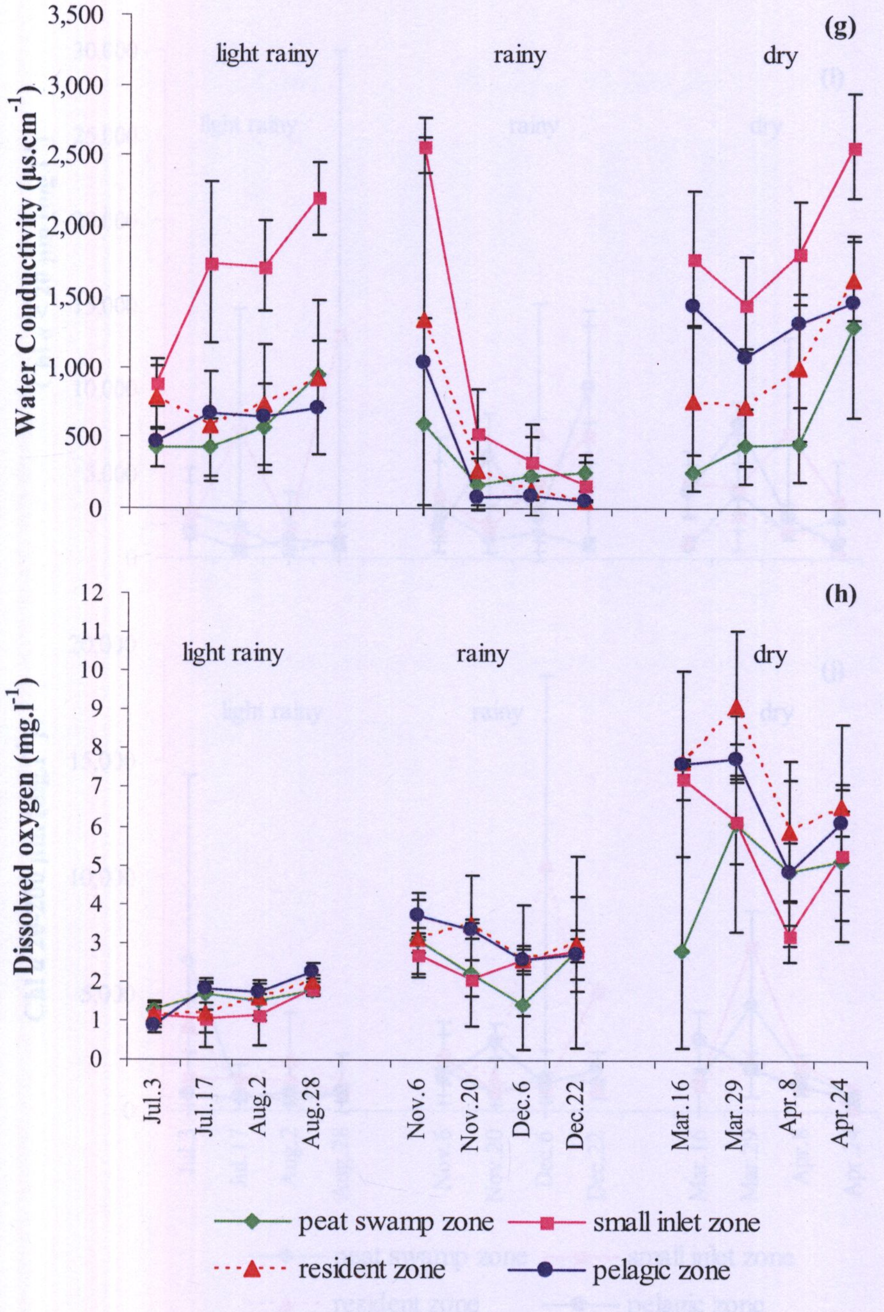


Figure 5. Continued. (g; Water conductivity and h; Dissolved oxygen).

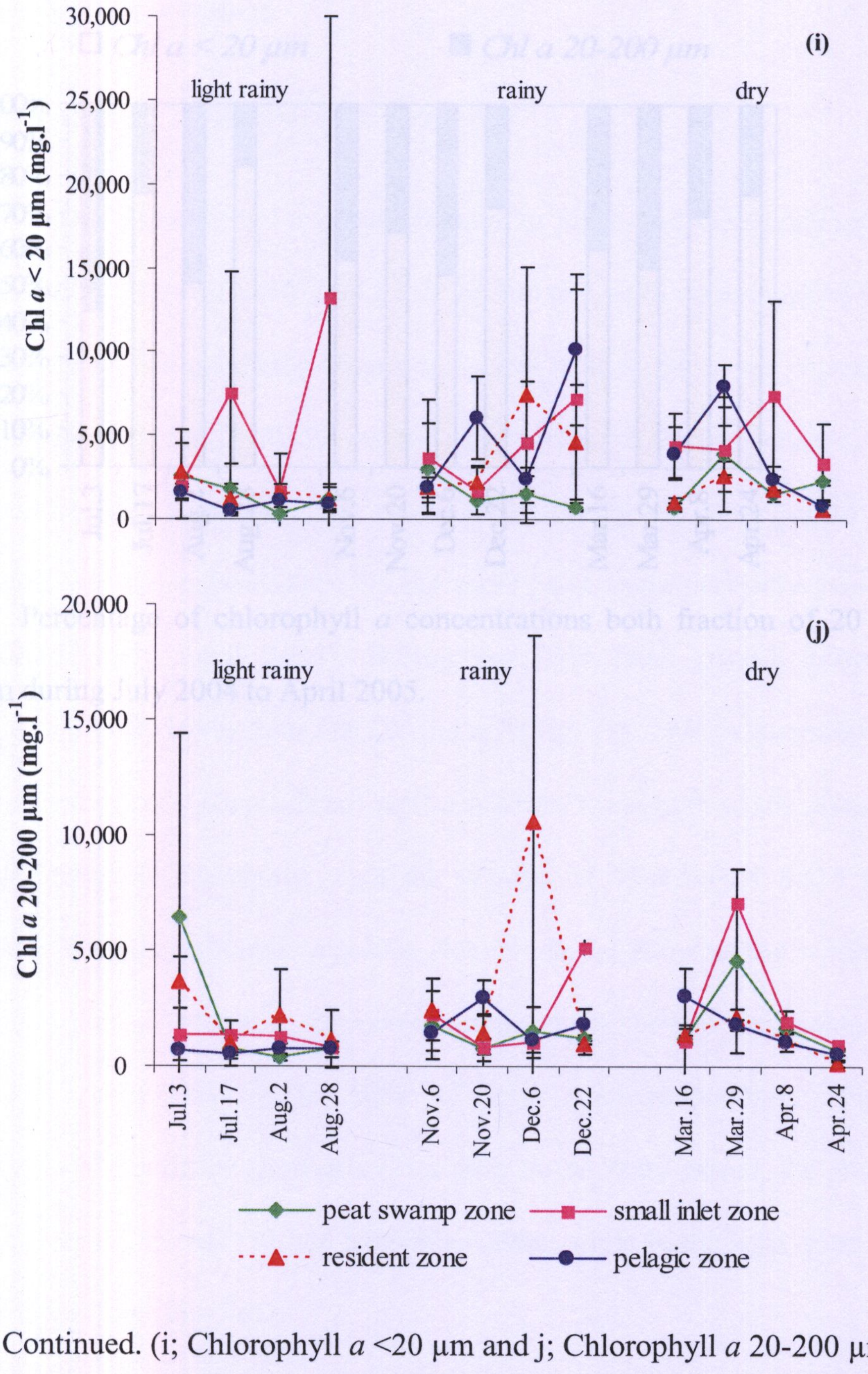


Figure 5. Continued. (i; Chlorophyll *a* <20 μm and j; Chlorophyll *a* 20-200 μm).

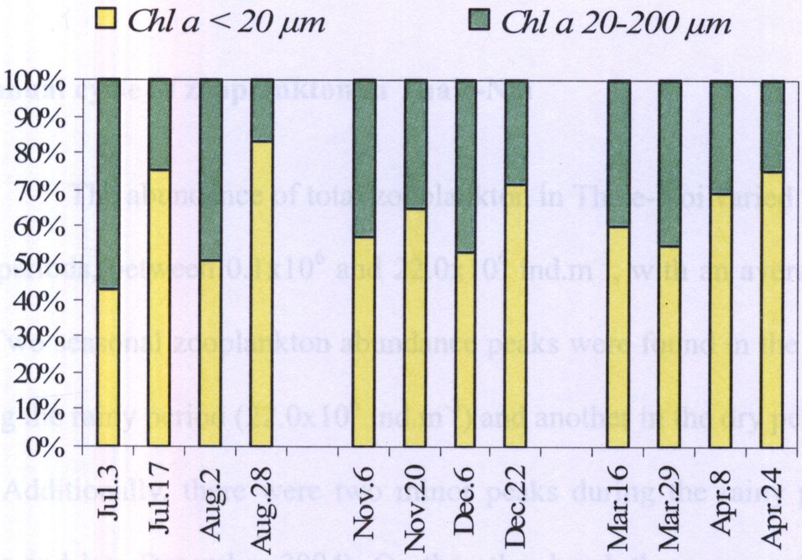


Figure 6. Percentage of chlorophyll *a* concentrations both fraction of 20 μm and 20-200 μm during July 2004 to April 2005.

3.2 Zooplankton communities

3. 2.1 Annual cycle of zooplankton in Thale-Noi

The abundance of total zooplankton in Thale-Noi varied markedly with seasonal periods, between $0.1x10^6$ and $22.0x10^6$ ind.m^{-3}, with an average of $7.9x10^6$ ind.m^{-3}. Two seasonal zooplankton abundance peaks were found in the present study: one during the rainy period ($22.0x10^6$ ind.m^{-3}) and another in the dry period ($16.4x10^6$ ind.m^{-3}). Additionally, there were two minor peaks during the rainy period (in late November and late December 2004). On the other hand, there was only one peak in the dry period (early April 2005). During the light rainy period, zooplankton abundance was usually lower than $5.0x10^6$ ind.m^{-3} (Fig. 7a). The zooplankton 20-200 µm size categories (microzooplankton) represented the main bulk of the zooplankton community throughout the study, with an average of 95.4 % (6.4 S.D.) of total zooplankton abundance. Microzooplankton dominated the zooplankton communities in all sampling periods except in the rainy period, which showed decreasing values, but they still comprised up to 80% of total microzooplankton (Fig. 7b). Mesozooplankton abundance showed a clear peak in the rainy period, the abundance was highest ($3.2x10^6$ ind.m^{-3}) in late November 2004, while in the light rainy and the dry periods it was low (Fig. 7c).

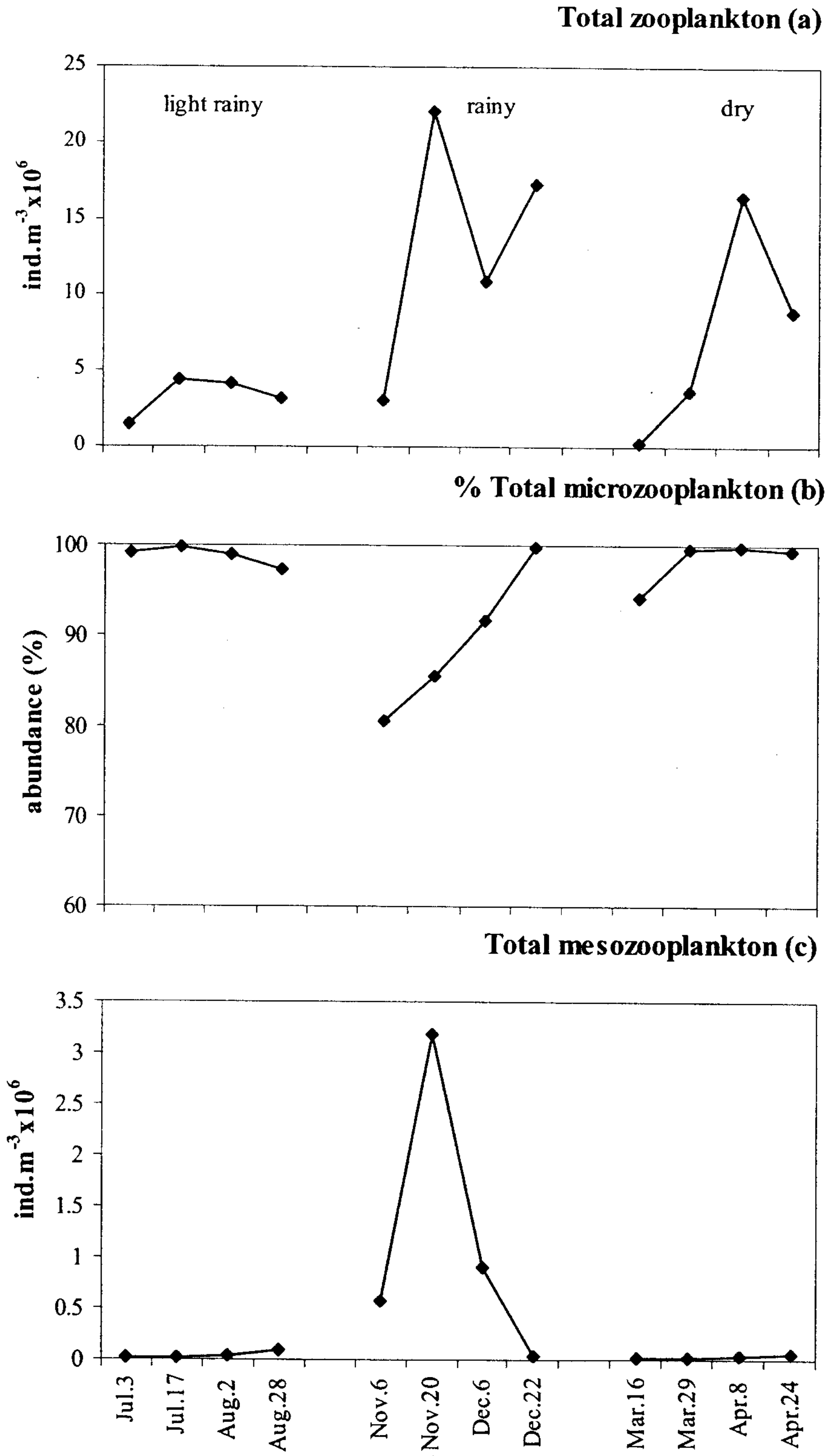


Figure 7. (a) Annual pattern of abundance of total zooplankton (20-200 μm+ > 200 μm). (b) Percentage (in abundance) of the zooplankton community represented by microzooplankton (20-200 μm). (c) Annual cycle in total abundance of mesozooplankton (>200 μm). July 2004 - April, 2005.

3.2.2 Species composition and diversity

Microzooplankton

Throughout the year, the microzooplankton community was composed of 22 genera of Protozoa (31%), 32 genera of Rotifera (46%), 13 genera of Cladocera (19%) and 3 genera of Copepoda (4%). Larvae and juvenile forms such as Ostracod juvenile, Crustracean nauplii and copepodite of Copepoda were also found (Fig. 8, 9 and Table 5). The total number of genera varied from 55, at the small inlet and the pelagic zones, up to 62, at the peat swamp and the resident zones (Fig. 10). The largest number of genera (60 genera) was found in the rainy period (November and December) in 2004, with 21 genera of Protozoa, 29 genera of Rotifera, 7 genera of Cladocera and 3 genera of Copepoda while the lowest number of genera (50 genera) occurred in the dry period (March and April) in 2005, with 21 genera of Protozoa, 21 genera of Rotifera, 7 genera of Cladocera and 1 genera of Copepoda (Fig. 11). Rotifera was the most diverse microzooplankton at all zones and in all seasonal periods of the present study.

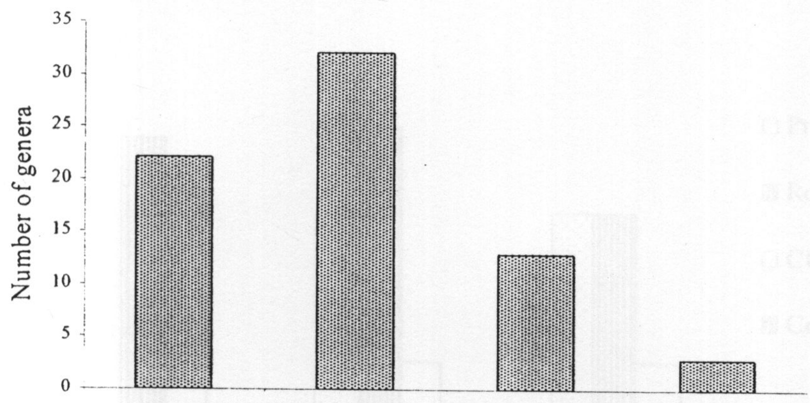


Figure 8. Number of genera of microzooplankton in Thale-Noi, during July 2004 to April 2005.

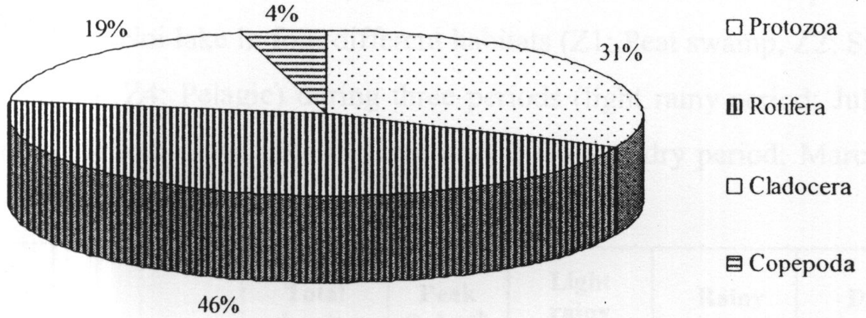


Figure 9. Percentage number of genera of microzooplankton in Thale-Noi, during July 2004 to April 2005.

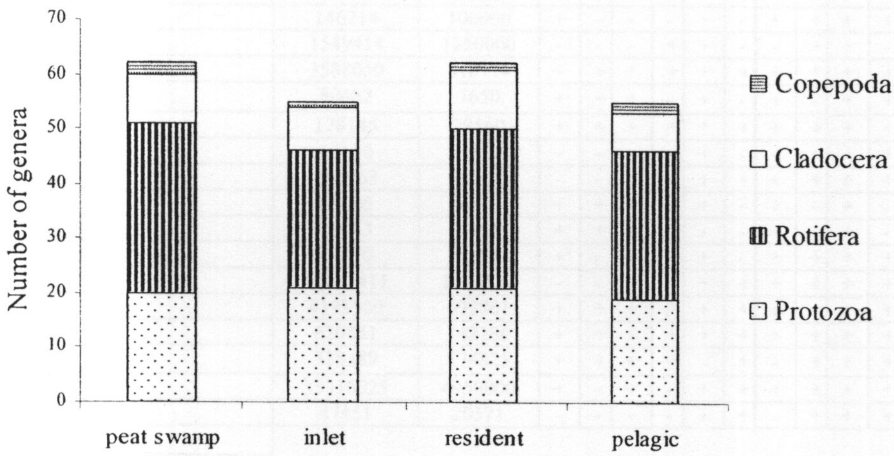


Figure 10. Comparing the number of genera of microzooplankton in each zone.

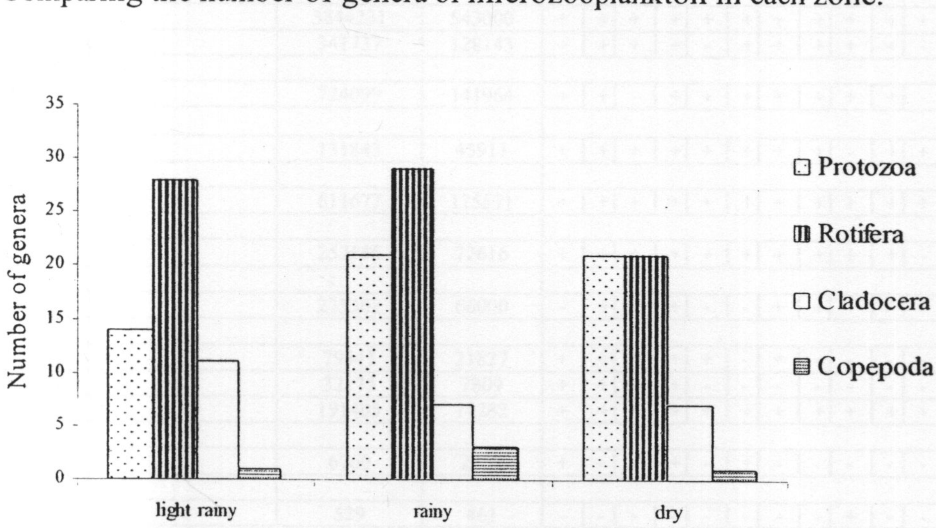


Figure 11. Comparing the number of genera of microzooplankton in each period.

Table 5. Taxonomic composition, density, peak and occurrence of microzooplankton community from Thale-Noi lake in four different habitats (Z1; Peat swamp, Z2; Small inlet, Z3; Resident and Z4; Pelagic) during three periods (light rainy period; July to August 2004, rainy period; November to December 2004 and dry period; March to April 2005). + = present and - = absent in the waterbody.

Taxa	Total density (ind.m^{-3})	Peak (ind.m^{-3})	Light rainy				Rainy				Dry			
			Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4
Phylum Protozoa														
Genus *Actinophrys*	10463	5250	-	-	-	-	-	+	+	-	-	-	-	-
Arcella	274921	42857	+	-	-	-	+	+	+	+	+	+	+	+
Centropyxis	210150	27429	+	+	+	+	+	+	+	+	+	+	+	+
Ceratium	67	67	-	-	-	-	-	-	-	-	-	-	-	+
Codonella	24598	11400	-	-	-	-	+	-	-	-	+	+	+	-
Coleps	99473	22200	+	-	+	-	+	-	-	-	+	+	+	+
Diffugia	146214	100000	+	-	-	-	+	-	+	+	+	+	+	+
Dinobryon	1549414	1250000	-	-	-	+	+	-	-	+	+	-	-	+
Euglena	3588050	310714	+	+	+	+	+	+	+	+	+	+	+	+
Euglyphra	80482	7650	+	+	+	-	+	-	+	-	+	+	+	+
Halteria	178145	28560	+	+	+	+	+	+	+	+	+	+	+	+
Holophrya	60136	48000	-	-	-	-	+	-	-	+	+	+	+	+
Lepocinclis	368963	114793	-	-	-	-	+	+	+	+	+	+	+	+
Loxodes	45636	8571	+	+	+	+	+	-	+	-	+	-	-	-
Paramecium	15643	4003	+	+	+	+	-	-	+	-	+	-	-	-
Peranema	40170	8571	+	-	+	+	+	-	+	+	+	+	+	+
Peridinium	10231411	1343232	-	-	-	-	+	+	+	+	+	+	+	+
Phacus	4193500	692861	+	+	+	+	+	+	+	+	+	+	+	+
Stentor	620831	142286	+	+	+	+	+	+	+	+	+	+	+	+
Tintinopsis	328389	174825	+	+	+	+	-	+	-	+	+	+	+	+
Trachelomonas	33316025	4950000	+	-	+	-	+	+	+	+	+	+	+	+
Undella	47451	20571	-	-	-	-	+	+	-	+	+	+	+	+
Phylum Rotifera														
Genus *Anuraeopsis*														
A. coelata (De Beauchamp)	46435	723	+	+	-	+	+	+	+	+	-	-	-	-
A. fissa (Gosse)	3844231	543000	+	+	+	+	+	+	+	+	+	+	+	+
A. navicula (Rousselet)	341737	128143	+	+	+	+	-	+	+	+	+	+	-	+
Genus *Ascomorpha*														
Ascomorpha spp.	724099	141964	+	+	-	+	+	+	+	+	+	+	-	+
Genus *Asplanchna*														
Asplanchna sp.	131843	45911	+	+	+	+	+	+	+	+	-	+	+	+
Genus *Brachionus*														
Brachionus spp.	611677	125571	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Cephalodella*														
Cephalodella spp.	257555	72616	+	+	+	+	+	+	+	+	+	+	-	-
Genus *Collotheca*														
Collotheca spp.	225302	66000	-	+	+	+	-	-	+	+	+	-	-	+
Genus *Colurella*														
C. obtusa (Gosse)	79541	21827	+	+	+	+	+	-	+	-	-	-	-	-
C. sulcata (stenroos)	32273	7809	+	+	+	+	-	-	-	-	-	-	-	-
C. spp.	191405	14282	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Dicranophorus*														
Dicranophorus spp.	6760	2250	+	-	-	+	-	+	-	-	-	-	-	-
Genus *Dicranophoroides*														
Dicranophoroides sp.	529	461	-	-	-	-	-	-	-	-	+	-	-	+
Genus *Dipleuchlanis*														
Dipleuchlanis propatula (Gosse)	2243	1200	-	-	-	-	+	-	-	-	+	-	+	-
Genus *Euchlanis*														
Euchlanis dilatata Ehrenberg	76261	375000	+	+	+	+	+	+	+	+	+	+	+	+

Table 5. Continued.

Taxa	Total density (ind.m^{-3})	Peak (ind.m^{-3})	Light rainy				Rainy				Dry			
			Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4
Genus *Filinia*														
Filinia spp.	221925	91286	+	+	+	+	+	+	+	+	-	+	-	+
Genus *Floscularia*														
Floscularia sp.	1936	1500	-	-	-	-	-	-	-	-	+	+	-	+
Genus *Hexathra*														
Hexathra spp.	704179	339806	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Keratella*														
Keratella spp.	5881884	4813714	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Lecane*														
L. aculeata (Jakubski)	3003	2000	+	-	-	+	-	-	-	-	+	-	-	-
L. batillifer (Murray)	44715	28575	+	+	+	+	-	-	-	-	-	-	-	-
L. bifurca (Bryce)	8547	2500	-	+	+	+	+	+	+	+	-	-	-	-
L. bulla (Gosse)	351007	72535	+	+	+	+	+	+	+	+	+	+	+	+
L. clara (Bryce)	33429	7864	+	+	+	+	+	+	-	+	+	+	-	-
L. closterocerca (Schmarda)	105457	1442	+	+	+	+	+	+	+	+	+	+	+	+
L. crepida Harring	18898	3568	+	-	+	-	+	+	+	+	+	-	+	-
L. curvicornis (Murray)	25204	7286	+	-	+	-	+	+	-	+	+	-	+	-
L. furcata (Murray)	43425	7077	+	+	+	+	+	+	+	+	+	+	+	+
L. hamata (Stokes)	32338	12040	+	+	+	+	+	+	+	+	+	-	+	+
L. hornemanni (Ehrenberg)	11054	2775	+	+	+	-	+	+	+	+	+	+	-	-
L. inermis (Bryce)	84120	14571	+	+	+	+	+	+	+	+	+	+	+	-
L. leontina (Turner)	9997	1907	-	-	+	+	+	+	+	+	+	+	+	-
L. ludwigi (Eckstein)	5636	3000	-	+	+	+	-	-	-	-	-	-	-	-
L .luna (O.F. Müller)	4421	860	+	+	+	+	-	+	-	-	-	-	-	-
L. lunaris (Ehrenberg)	33376	8571	+	+	+	+	-	+	+	+	+	+	+	+
L. minuta Segers	7348	2571	+	+	+	+	+	-	+	+	-	-	-	-
L. monostyla (Daday)	3419	1714	+	-	-	+	+	+	-	-	+	-	-	-
L. nana (Murray)	13865	2863	+	+	-	+	-	+	-	+	+	+	-	-
L. obtusa (Murray)	40364	9000	+	+	+	+	-	+	+	+	+	+	-	-
L. papuana (Murray)	14644	7146	+	+	+	+	+	+	-	-	+	-	+	-
L. pertica Harring & Myers	6207	2301	-	-	-	+	+	-	-	-	+	-	-	-
L. quadridentata (Ehrenberg)	18162	7329	+	+	+	+	-	-	-	+	+	-	+	-
L. signifera (Jennings)	9226	5571	+	-	+	+	-	-	-	-	+	-	+	-
L. sympoda Hauer	214	214	+	-	-	-	-	-	-	-	-	-	-	-
L. undulata Hauer	31721	6515	+	-	+	+	+	+	+	+	+	+	-	+
L. unguitata (Fadeev)	43137	25800	+	+	+	+	+	+	+	+	+	+	+	-
L. ungulata (Gosse)	3540	1315	-	+	-	+	+	+	-	+	+	-	-	-
Genus *Lepadella*														
L. heterostyla Murray	8513	3578	+	-	+	-	-	+	-	-	-	-	+	-
L. spp.	360553	78429	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Macrochaetus*														
M. sericus (Thorpe)	11611	2621	+	+	+	+	-	-	-	-	-	-	-	-
Genus *Monommata*														
Monommata spp.	26299	4800	+	+	+	+	+	+	+	+	+	-	-	-
Genus *Mytilina*														
M. compressa (Gosse)	11132	4286	+	+	+	-	+	-	-	-	-	-	+	-
Genus *Notommata*														
Notommata sp.	4363	1900	-	-	+	-	+	-	+	+	-	-	-	-
Genus *Plationus*														
P. patulus (O.F. Müller)	35470	12294	-	-	+	-	-	+	+	+	+	+	+	+
Genus *Platyias*														
P. quadricornis (Ehrenberg)	3585	2571	-	-	+	-	-	-	-	+	-	-	+	-
Genus *Polyarthra*														
Polyarthra spp.	10038490	970971	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Proales*														
Proales spp.	927615	207429	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Ptygura*														
Ptygura sp.	14199	9994	+	-	-	+	+	-	+	-	-	-	-	-

Table 5. Continued.

Taxa	Total density (ind.m^{-3})	Peak (ind.m^{-3})	Light rainy				Rainy				Dry			
			Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4
Genus *Scaridium*														
Scaridium spp.	5074	4025	+	-	+	-	+	-	-	-	-	-	-	-
Genus *Squatinella*														
S. lamellaris (O.F. Müller)	907	479	+	-	+	-	-	-	-	-	-	-	-	-
Genus *Synchaeta*														
Synchaeta sp.	22344	20000	-	-	-	-	-	+	+	+	+	-	-	-
Genus *Testudinella*														
Testudinella spp.	74534	10714	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Trichocerca*														
Trichocerca spp.	2161372	260370	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Trichotria*														
T. tetractis (Ehrenberg)	8441	3429	+	-	-	+	-	-	+	+	+	-	-	-
*Bdelloid group	403640	41143	+	+	+	+	+	-	+	+	-	-	-	-
Phylum Arthropoda														
Ostracoda														
Ostracod juvenile	119094	25149	+	+	+	+	+	+	+	+	+	+	+	+
Cladocera														
Genus *Alona*														
A. monacantha Stingelin	429	429	-	-	+	-	-	-	-	-	-	-	-	-
A. rectangula Sars	287	287	-	-	+	-	-	-	-	-	-	-	-	-
A. sarasinorum Stingelin	43	43	-	-	+	-	-	-	-	-	-	-	-	-
A. verrucosa Sars	7582	2000	+	-	+	+	+	+	-	+	-	-	+	+
A. spp.	5943	5000	-	-	-	-	-	-	-	-	-	+	+	-
Genus *Alonella*														
A. excisa (Fischer)	43	43	+	-	-	-	-	-	-	-	-	-	-	-
Genus *Bosminopsis*														
B. deitersi Richard	293765	28286	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Ceriodaphnia*														
C. cornuta Sars	974	717	-	-	-	-	+	+	+	-	-	-	-	-
Genus *Chydorus*														
C. eurynotus Sars	3514	790	+	+	+	+	-	-	-	-	-	+	+	+
C. parvus Daday	357	357	-	-	+	-	-	-	-	-	-	-	-	-
C. pubescens Sars	3151	2000	+	-	-	-	-	-	-	-	+	-	+	-
C. reticulatus Daday	3141	2057	-	-	-	-	+	-	-	+	-	-	+	-
C. ventricosus Daday	644	357	-	+	+	-	-	-	-	-	-	-	-	-
Genus *Dunhevedia*														
D. crassa King	6173	2400	-	+	+	-	-	-	+	-	-	+	+	-
Genus *Ephemeroporus*														
Ephemeroporus spp.	53747	9200	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Karualona*														
K iberica Dumont & Silva- Briano	6988	2713	-	+	-	-	-	+	+	-	-	+	+	-
Genus *Latonopsis*														
L. australis Sars	86	86	-	-	+	-	-	-	-	-	-	-	-	-
Genus *Macrothrix*														
M. spinosa King	514	429	-	-	+	+	-	-	-	-	-	-	-	-
M. triserialis Brady	2259	1580	+	-	+	-	-	-	-	-	-	+	+	-
Genus *Moina*														
M. micrura Kurz	786	643	-	-	-	-	+	-	-	+	-	-	-	-
Genus *Moinodaphnia*														
M. macleayi King	236	236	-	-	+	-	-	-	-	-	-	-	-	-
Genus *Notoalona*														
N. globulosa (Daday)	357	357	-	-	+	-	-	-	-	-	-	-	-	-
Calanoid Copepoda														
Genus *Neodiaptomus*														
N. yangtsekiangensis Mashiko	2571	2571	-	-	-	-	-	-	-	+	-	-	-	-
Calanoid copepodites	7149	3570	+	+	+	+	+	-	+	+	+	+	-	+

Table 5. Continued.

Taxa	Total density (ind.m^{-3})	Peak (ind.m^{-3})	Light rainy				Rainy				Dry			
			Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4
Cyclopoid Copepoda														
Genus *Mesocyclops*	2891	857	-	-	+	-	+	-	-	+	+	+	-	-
Metacyclops	214	214	-	-	-	-	+	-	-	-	-	-	-	-
Cyclopoid copepodites	170635	25714	+	+	+	+	+	+	+	+	+	+	+	+
Harpacticoid Copepoda														
Harpacticoid copepodites	8	3	-	-	-	-	-	-	+	+	-	+	+	+
Crustacean nauplii	5738895	324107	+	+	+	+	+	+	+	+	+	+	+	+

Mesozooplankton

The mesozooplankton community was composed of three genera of Protozoa (6%), two genera of Rotifera (4%), 28 genera of Cladocera (61%), three genera of Ostracoda (6%) and 11 genera of Copepoda (23%). Juvenile forms such as, copepodite of Copepoda and other invertebrates such as Shrimp larvae, Gastopod larvae, Bivalve larvae, Crab larvae and Fish larvae were also found (Fig. 12, 13 and Table 6). The total number of genera varied from 36, at the pelagic zone, up to 41, at the peat swamp and the resident zones, while at the small inlet zone 39 genera of mesozooplankton were found (Fig. 14). The largest number of genera was found in the rainy period (November and December) in 2004, with two genera of Protozoa, two genera of Rotifera, 26 genera of Cladocera, three genera of Ostracoda and 10 genera of Copepoda while the lowest number of genera occurred in the dry period (March and April) in 2005, with one genera of Protozoa, two genera of Rotifera, 20 genera of Cladocera, three genera of Ostracoda and 10 genera of Copepoda (Fig. 15). Cladocera was the most diverse mesozooplankton community at all zones and in all seasonal periods of the present study.

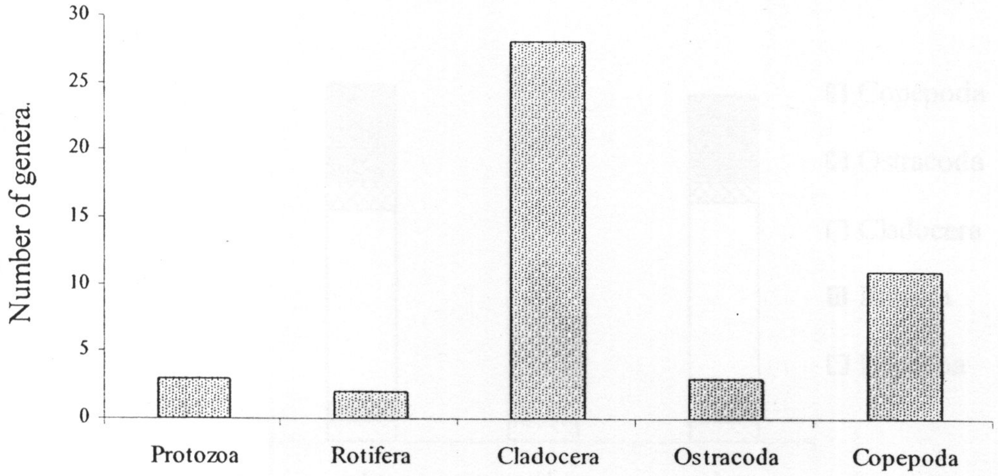


Figure 12. Number of genera of mesozooplankton in Thale-Noi, during July 2004 to April 2005.

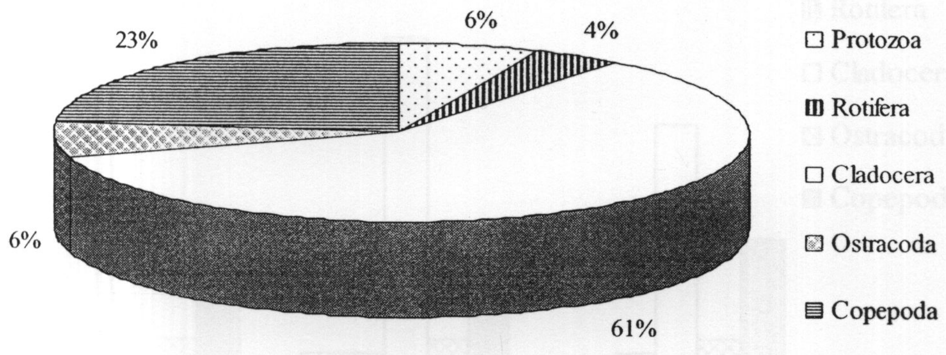


Figure 13. Percentage number of genera of mesozooplankton in Thale-Noi, during July 2004 to April 2005.

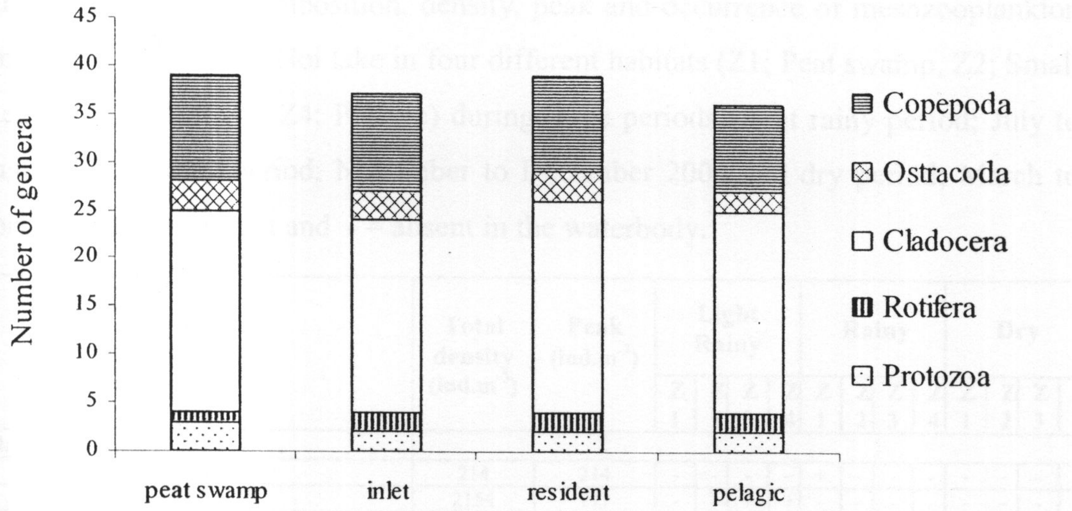


Figure 14. Comparing the number of genera of mesozooplankton in each zone.

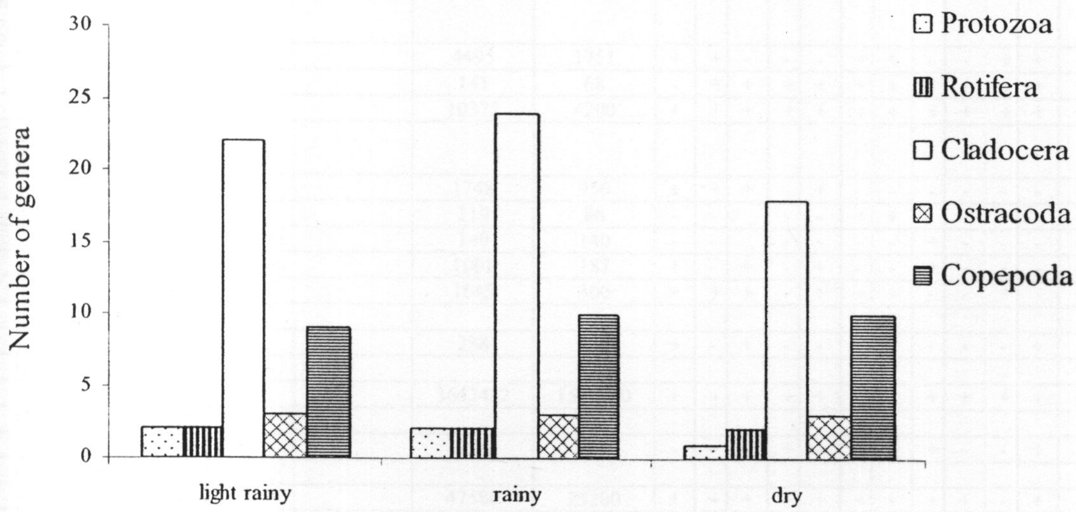


Figure 15. Comparing the number of genera of microzooplankton in each period.

Table 6. Taxonomic composition, density, peak and occurrence of mesozooplankton community from Thale-Noi lake in four different habitats (Z1; Peat swamp, Z2; Small inlet, Z3; Resident and Z4; Pelagic) during three periods (light rainy period; July to August 2004, rainy period; November to December 2004 and dry period; March to April 2005). + = present and - = absent in the waterbody.

Taxa	**Total density ($ind.m^{-3}$)**	**Peak ($ind.m^{-3}$)**	**Light Rainy**				**Rainy**				**Dry**			
			Z1	**Z2**	**Z3**	**Z4**	**Z1**	**Z2**	**Z3**	**Z4**	**Z1**	**Z2**	**Z3**	**Z4**
Phylum Protozoa														
Genus *Echinoshaerium*	214	214	-	-	-	-	+	-	-	-	-	-	-	-
Epistylis	2154	771	-	+	+	+	-	-	-	-	-	-	-	-
Voticella	156770	82711	+	-	+	-	+	+	-	+	+	+	-	-
Phylum Rotifera														
Genus *Testudinella*														
Testudinella spp.	26655	18000	+	+	+	+	-	-	-	-	-	-	-	-
Genus *Trochosphaera*														
Trochosphaera sp.	5200	3827	-	+	+	+	-	-	+	-	-	-	+	-
Phylum Arthropoda														
Ostracoda														
Genus *Cypricercus*	4493	1751	+	+	-	-	-	+	+	-	-	+	+	-
Cyprinotus	141	68	-	+	+	+	+	+	+	+	+	+	+	+
Stenocypris	10372	4200	+	+	+	+	+	+	+	+	+	+	+	+
Cladocera														
Genus *Alona*														
A. affinis Leydig	1748	950	+	+	+	-	+	-	-	-	-	-	-	-
A. intermedia Sars	110	86	-	-		-	-	+	+	-	-	-	-	-
A. monacantha Stingelin	140	140	-	-		-	-	-	-	+	-	-	-	-
A. sarasinorum Stingelin	1001	187	+	-	+	-	+	-	-	+	-	-	-	-
A. verrucosa Sars	1645	300	+	+	+	-	+	+	+	-	-	+	-	+
Genus *Alonella*														
A. excisa (Fischer)	288	171	+	-	+	-	-	-	-	-	-	-	+	-
Genus *Bosminopsis*														
B. deitersi Richard	3643432	1512000	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Camptocercus*														
C. australis Sars	3099	3000	-	-	-	+	-	+	+	+	-	-	+	-
Genus *Ceriodaphnia*														
C. cornuta Sars	47580	25200	+	+	+	+	+	+	+	+	+	-	+	-
Genus *Chydorus*														
C. eurynotus Sars	10997	7500	+	+	+	+	+	+	-	+	-	+	+	+
C. parvus Daday	1125	214	-	+	+	+	-	+	-	+	+	+	+	-
C. pubescens Sars	11697	4500	+	+	+	+	-	+	+	+	+	+	+	+
C. reticulatus Daday	13819	7002	+	+	+	+	+	+	+	+	-	-	+	-
C. ventricosus Daday	7622	3000	+	+	+	+	+	-	+	-	-	-	-	-
Genus *Dadaya*														
D. macrops (Daday)	201	200	-	-	-	+	-	-	+	-	-	-	-	-
Genus *Diaphanosoma*														
Diaphanosoma spp.	67919	25200	+	+	+	+	+	+	+	+	+	+	-	-
Genus *Dunhevedia*														
D. crassa King	230565	198098	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Ephemeroporus*														
Ephemeroporus spp.	535427	10333	+	+	+	+	+	+	-	-	-	-	-	-
Genus *Euryalona*														
E. orientalis (Daday)	332	86	-	-	+	-	-	-	-	+	+	+	+	+

Table 6. Continued.

Taxa	Total density (ind.m^{-3})	Peak (ind.m^{-3})	Light Rainy				Rainy				Dry			
			Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4	Z 1	Z 2	Z 3	Z 4
Genus *Guernella*														
G. raphaelis Richard	1	1	-	-	-	-	-	-	+	-	-	-	-	-
Genus *Grimaldina*														
G. brazzai Richard	475	475	+	+	+	+	+	+	+	+	+	-	+	-
Genus *Indiaalona*														
I. macronyx	1427	375	+	-	+	-	-	-	+	-	-	+	+	-
Genus *Ilyocryptus*														
I. spinifer Herrick	9860	6000	+	-	+	-	+	+	+	+	+	+	-	+
Genus *Karualona*														
K.. iberica Dumont &Silva-Briano	4985	1751	+	+	+	-	+	+	+	+	-	+	+	+
Genus *Kurzia*														
K. longirostris (Daday)	2130	1500	-	-	-	-	-	+	-	-	-	-	-	-
Genus *Latonopsis*														
Latonopsis sp.	30642	6564	+	+	+	+	+	+	+	+	+	+	+	+
Genus *Leberis*														
L. diaphanous	4380	2438	+	-	+	-	-	-	+	-	-	+	+	-
Genus *Leydigia*														
Leydigia sp.	1450	857	+	+	+	+	-	-	-	-	-	+	-	-
Genus *Macrothrix*														
M. spinosa King	1715	429	+	-	+	-	+	-	-	+	-	-	+	-
M. triserialis Brady	10198	1249	+	+	+	+	+	+	+	+	+	+	+	+
M. spp.	2992	943	+	-	+	+	-	-	-	-	+	+	+	+
Genus *Moina*														
M. micrura Kurz	45085	21000	+	+	+	+	+	+	+	+	+	+	-	+
Genus *Moinodaphnia*														
M. macleayi (King)	4144	1751	+	+	+	+	+	+	+	-	+	-	-	-
Genus *Notoalona*														
N. globulosa (Daday)	13	13	-	+	+	-	-	+	-	+	-	-	-	-
Genus *Oxyurella*														
O. singalensis (Daday)	598	528	-	-	-	-	+	-	-	-	-	-	-	-
Genus *Pseudosida*														
Pseudosida bidentata Herrick	792	560	-	-	+	+	-	+	+	-	-	-	-	-
Genus *Scapholeberis*														
Scapholeberis kingi Sars	12067	8400	-	-	+	-	-	+	+	-	-	-	-	-
Genus *Simocephalus*														
S. serrulatus (Koch)	287	171	+	-	+	-	-	-	+	-	-	-	-	-
Calanoid Copepoda Genus *Acartia*														
A. cf. *southwelli*	821	407	-	+	-	+	-	+	-	-	-	-	-	-
Genus *Acartiella*														
A. sinensis Shen & Lee	26627	20053	+	+	+	+	-	+	+	-	+	+	+	+
Genus *Mongolodiaptomus*														
M. botulifer (Kiefer)	129	86	+	+	-	-	-	-	-	-	+	+	-	-
Genus *Neodiaptomus*														
N. yangtsekiangensis Mashiko	74342	50714	+	+	+	+	+	+	+	+	+	+	+	-
Genus *Pseudodiaptomus*														
Pseudodiaptomus sp.	1219	648	+	+	-	-	-	+	-	-	-	+	-	+
Genus *Sinocalanus*														
Sinocalanus sp.	1258	655	-	+	-	-	+	+	-	-	-	-	+	-
Calanoid copepodites	66483	7600	+	+	+	+	+	+	+	+	+	+	+	+
Cyclopoid Copepoda														
Genus *Mesocyclops*	29696	4800	+	+	+	+	+	+	+	+	+	+	+	+
Metacyclops	5534	1286	-	-	-	-	-	-	+	-	+	+	+	+
Microcyclops	47509	21000	+	+	+	+	+	+	+	+	-	+	+	+

Table 6. Continued.

Taxa	**Total density ($ind.m^{-3}$)**	**Peak ($ind.m^{-3}$)**	**Light Rainy**				**Rainy**				**Dry**			
			Z 1	**Z 2**	**Z 3**	**Z 4**	**Z 1**	**Z 2**	**Z 3**	**Z 4**	**Z 1**	**Z 2**	**Z 3**	**Z 4**
Genus *Thermocyclops*	2041	1013	+	-	+	+	+	+	+	+	+	+	+	-
Eucyclops	836	700	-	-	-	-	+	-	-	+	-	-	-	+
Cyclopoid copepodites	126888	30196	+	+	+	+	+	+	+	+	+	+	+	+
Harpacticoid Copepoda														
*Unidenified harpacticoid species	143	143	+	-	-	-	-	-	-	-	-	-	+	-
Harpacticoid copepodites	1406	642	+	+	-	-	-	+	+	+	+	+	+	+
Shrimp larvae	7807	4200	+	+	-	+	-	+	+	-	+	+	+	+
Crab larvae	86	86	+	-	-	-	-	-	-	-	-	-	-	-
Crustacean nauplii	534377	126144	+	+	+	+	+	+	+	+	+	+	+	+
Phylum Mollusca														
Gastropod larvae	466	237	+	+	+	+	-	-	-	-	-	-	+	-
Bivalve larvae	205	100	-	-	-	-	-	-	-	-	-	-	-	+
Phylum Chordata														
Fish larvae	3	2	-	+	-	-	-	-	-	-	-	-	-	-

3.2.3 Occurrence of zooplankton in Thale-Noi

Microzooplankton

Among the genera of Protozoa, *Arcella, Centropyxis, Colep, Diffugia, Euglena Euglyphra, Halteria, Loxodes, Peranema, Phacus, Stentor, Tintinnopsis, Trachelomonas* were recorded in the zooplankton communities in all sampling periods; that is, the light rainy, the rainy and the dry periods. In contrast, *Actinophrys and Ceratium* were rarely found in the lake. Other genera, *Codonella, Dinobryon, Holophrya, Lepocinclis, Peridinium* and *Undella* were found in both the rainy and the dry periods, while *Paramecium* was found in the light rainy and the dry periods (Fig. 16a).

For the genera of Rotifera, *Anuraeopsis, Ascomorpha, Asplanchna, Brachionus, Cephalodella, Collotheca, Colurella, Euchlanis, Filinia, Hexathra, Keratella, Lecane, Lepadella, Monommata, Mytilina, Notommata, Plationus, Platyias, Polyarthra, Proales, Testudinella, Trichocerca* and *Trichotria* were recorded in the zooplankton virtually throughout the sampling times, whereas *Dicranophoroides, Scaridium* and *Squatinella* were found on only one or two occasions during zooplankton sampling. There were two genera represented by seasons, the first was *Floscularia* represented in the dry period, and the second one was *Macrochaetus* which occurred in all sampling times of the light rainy period. *Dicranophorus* was found in both the light rainy and the rainy periods, while *Dipleuchlanis* and *Synchaeta* were found in both the rainy and the dry periods (Fig. 16b).

In the genera of Cladocera and Copepoda, *Alona, Bosminopsis, Chydorus, Dunhevedia, Ephemeroporus, Karualona* and *Mesocyclops* were found in all sampling periods, while *Alonella, Ceriodaphnia, Latonopsis, Moina, Moinodaphnia*, *Notoalona*, *Neodiaptomus* and *Metacyclops* were rarely found in the zooplankton communities. Although there is no genus of Cladocera or Copepoda represented by seasons, *Macrothrix* occurred in both the light rainy and the dry periods (Fig. 16c and Fig. 16d).

Mesozooplankton

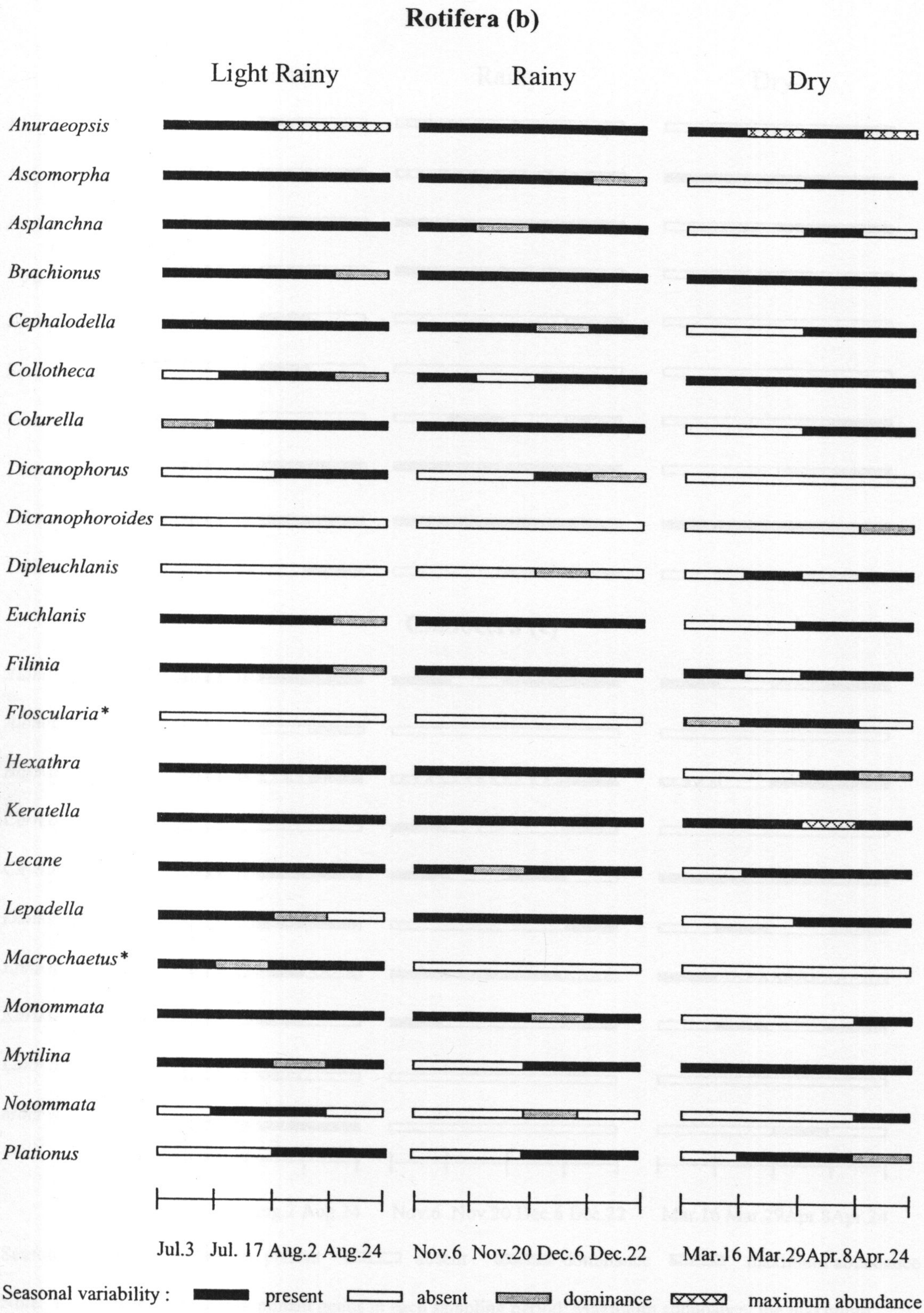
Among the genera of Protozoa, Rotifera and Ostracoda, *Voticella, Trochoshaera, Cypricercus, Cyprinotus* and *Stenocypris* were present in all sampling periods, whereas *Echinoshaerium* and *Epistylis* were rarely found in the mesozooplankton community, present only once or twice during sampling times. The genus *Testudinella* was found in both the light rainy and the dry periods (Fig. 17a, Fig. 17b and Fig. 17c).

Among the genera of Cladocera, *Alona, Alonella, Bosminopsis, Ceriodaphnia, Chydorus, Diaphanosoma, Dunhevedia, Ephemeroporus, Euryalona, Ilyocrytus, Indialona, Karualona, Kurzia, Latonopsis, Leberis, Macrothrix*, *Moina* and *Moinodaphnia* were recorded in the zooplankton virtually throughout the sampling time. In contrast, *Dadaya, Guernella, Grimaldina, Notoalona, Oxyurella* and *Scapholebersis* were rarely found in the lake. Other genera, *Camptocercus, Pseudosida*, and *Simocephalus* were found in both the early rainy and rainy periods, while *Leydigia* was found in both the light rainy and the dry periods. There was no genus of Cladocera represented by season (Fig. 17d).

Among the genera of Copepoda, *Acartia, Acartiella, Mesocyclops, Microcyclops, Neodiaptomus, Pseudodiaptomus, Sinocalanus* and *Thermocyclops* were recorded in all sampling periods, whereas, *Eucyclops* and *Mongodiaptomus* occurred only twice during all sampling times. For other genera, *Metacyclops* was found in the rainy and the dry periods (Fig. 17e). In the present study, Copepoda *Acartia* cf. *southwelli, Neodiaptomus yangtsekiangensis, Pseudodiaptomus* sp., *Sinocalanus* sp., *Mongolodiaptomus botulifer* and *Eucyclops* sp. were recorded for the first time in Thale-Noi.

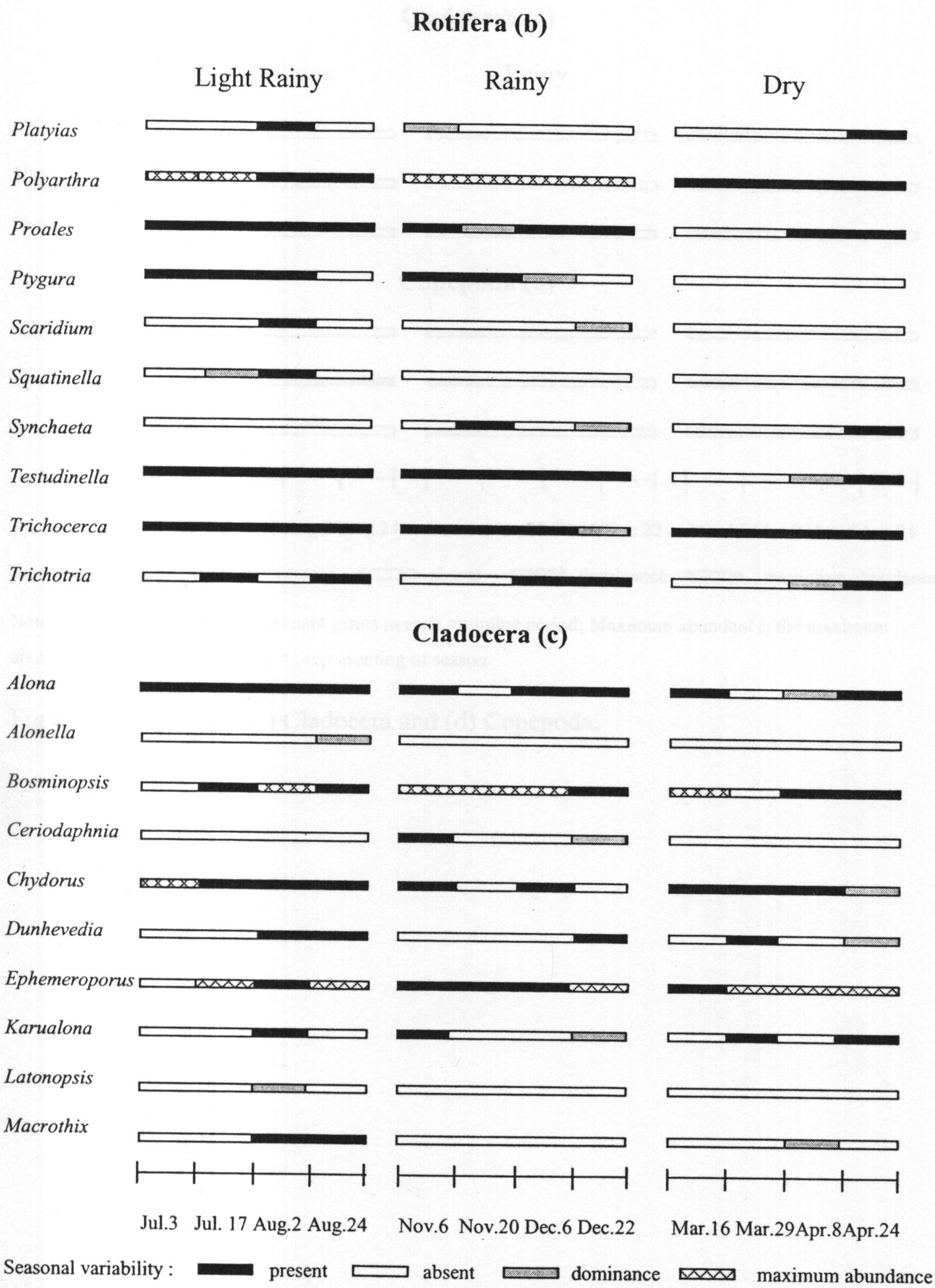
Note ; Dominance: The most dominant genus in each sampling period; Maximum abundance: the maximum abundance period of each genus

Figure16. Occurrence of microzooplankton (a) Protozoa in three sampling periods.



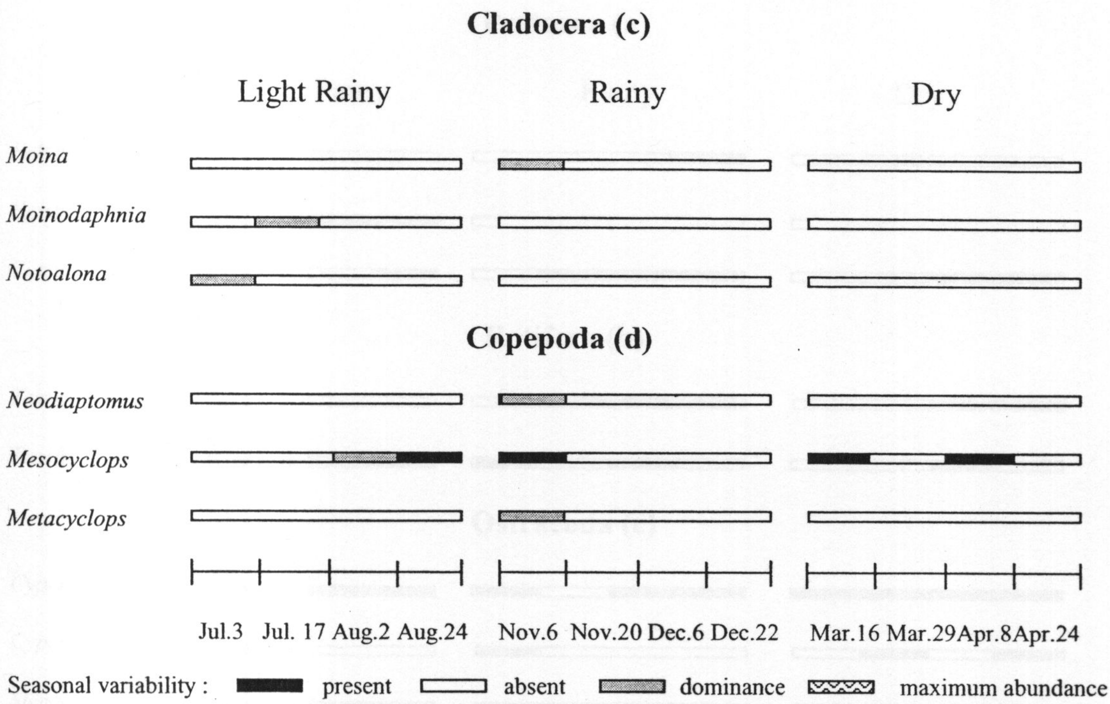
Note ; Dominance: The most dominant genus in each sampling period; Maximum abundance: the maximum abundance period of each genus; * : representing of season

Figure16. Continued. (b) Rotifera.



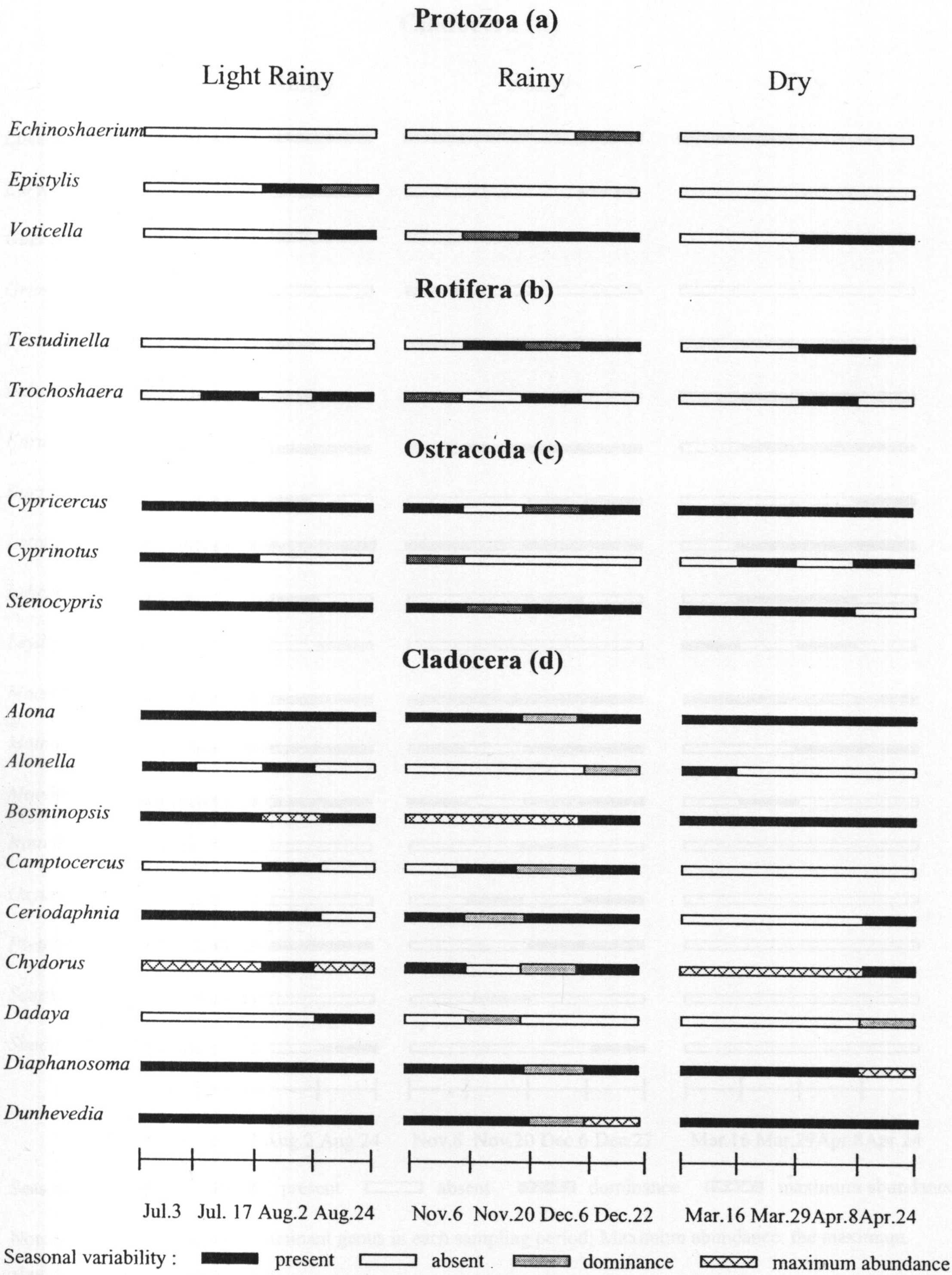
Note ; Dominance: The most dominant genus in each sampling period; Maximum abundance: the maximum abundance period of each genus

Figure16. Continued. (b) Rotifera and Cladocera (c).



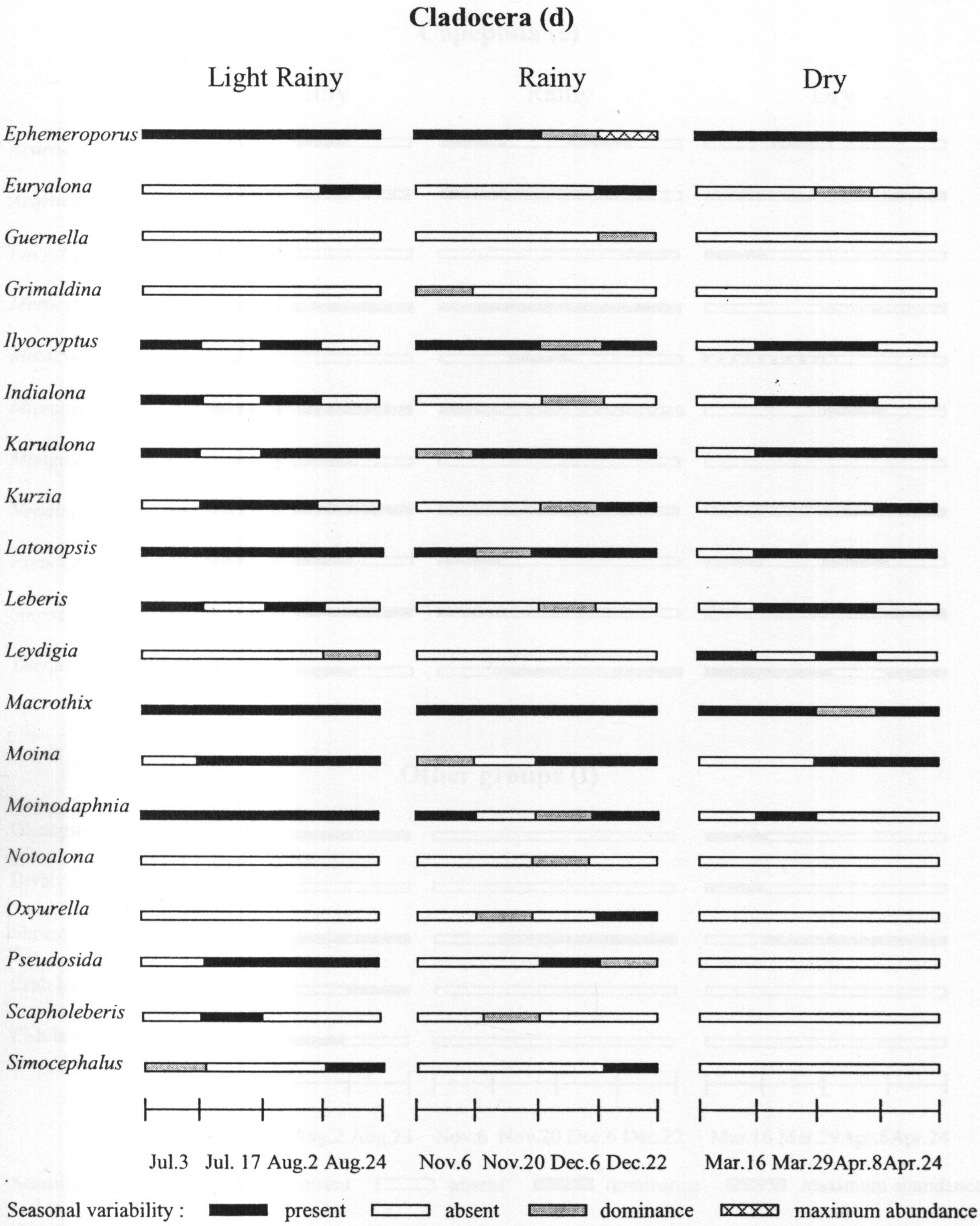
Note ; Dominance: The most dominant genus in each sampling period; Maximum abundance: the maximum abundance period of each genus; * : representing of season

Figure16. Continued. (c) Cladocera and (d) Copepoda.



Note ; Dominance: The most dominant genus in each sampling period; Maximum abundance: the maximum abundance period of each genus

Figure17. Occurrence of mesozooplankton (a) Protozoa, (b) Rotifera, (c) Ostracoda and (d) Cladocera in three sampling periods.



Note ; Dominance: The most dominant genus in each sampling period; Maximum abundance: the maximum abundance period of each genus

Figure17. Continued. (d) Cladocera.

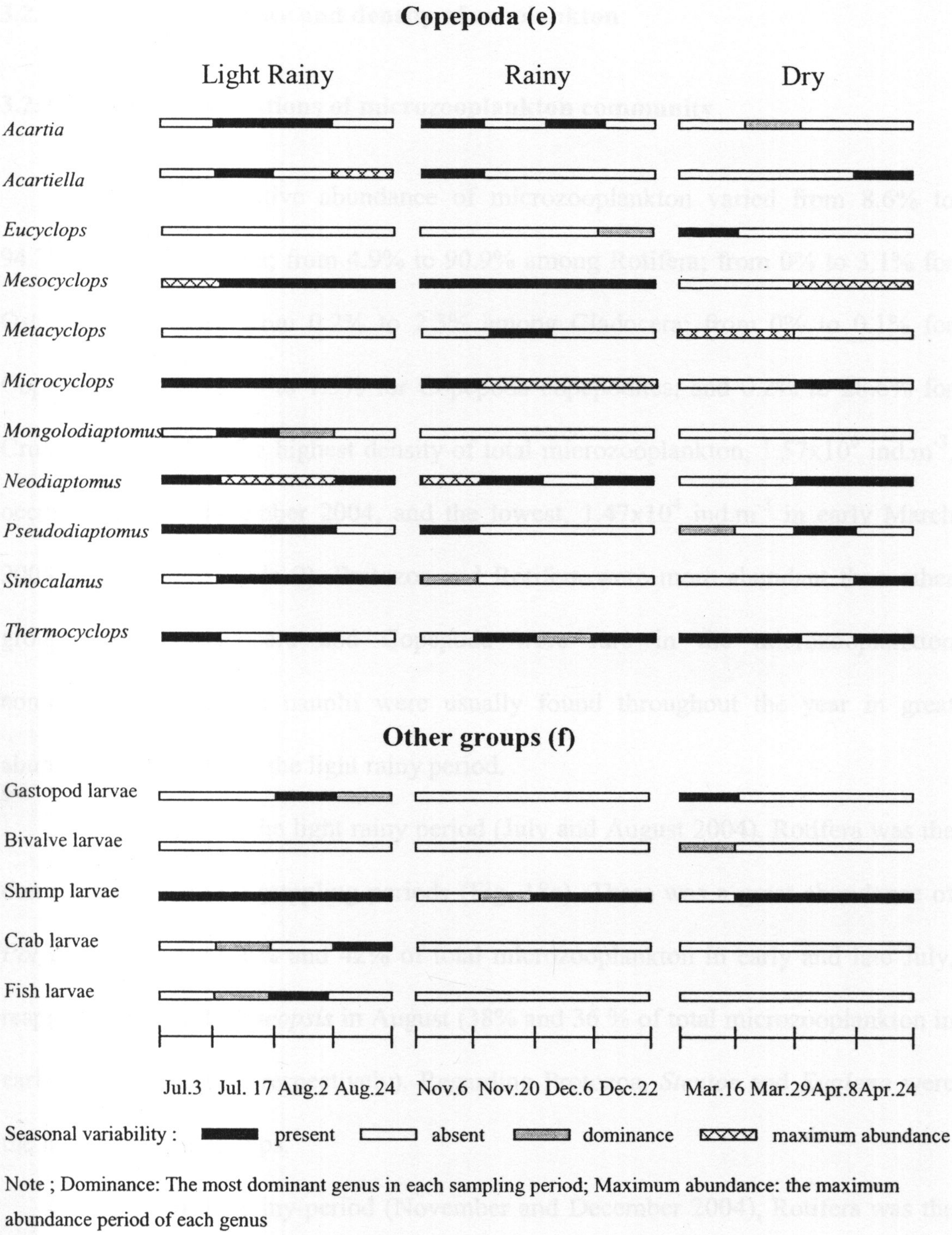


Figure17. Continued. (e) Copepoda and (f) Other groups.

3.2.4 Relative abundance and density of zooplankton

3.2.4.1 Temporal variations of microzooplankton community

The relative abundance of microzooplankton varied from 8.6% to 94.3%, among Protozoa; from 4.9% to 90.9% among Rotifera; from 0% to 3.1% for Ostracoda juveniles; from 0.2% to 2.3% among Cladocera; from 0% to 0.1% for Copepoda; from 0.03% to 1.5% for Copepoda copepodites, and 0.2% to 28.6% for Crustacean nauplii. The highest density of total microzooplankton, 1.57×10^6 ind.m^{-3}, occurred in late November 2004, and the lowest, 1.47×10^4 ind.m^{-3} in early March 2005 (Fig. 18 and Table 7). Protozoa and Rotifera were more abundant than other groups, while Cladocera and Copepoda were rare in the microzooplankton community. Crustacean nauplii were usually found throughout the year in great abundance especially in the light rainy period.

During the light rainy period (July and August 2004), Rotifera was the dominant group in all sampling periods (Fig. 18a). There was a great abundance of *Polyarthra* in July (16% and 42% of total microzooplankton in early and late July, respectively) and *Anuraeopsis* in August (38% and 36 % of total microzooplankton in early and late August, respectively). Regarding Protozoa, *Stentor* and *Euglena* were the most abundant groups.

In the rainy period (November and December 2004), Rotifers was the most abundant group in early November, while Protozoa was the most abundant group in the other sampling dates; late November, early December and late December (Fig. 18b). *Polyarthra* was the most abundant genus of Rotifera (16% of total microzooplankton in early November), whereas *Trachelomonas* (46% and 47% of total microzooplankton in late November and late December, respectively) and *Peridinium* (29 % of total microzooplankton in early December) were the most abundant genera of Protozoa. High densities of microzooplankton were found in all periods.

In the dry period (March and April 2005), there was a dominance of Protozoa over the other groups during all four sampling periods (Fig. 18c). There was a great abundance of *Tintinopsis* (38% of total microzooplankton) in early March, and *Trachelomonas* in the other periods (87%, 48% and 60% of total microzooplankton in late March, early April and late April, respectively). The abundance of microzooplankton species in each sampling period was shown in table 8.

Table 7. Total density (ind.m^{-3}) and % abundance of major microzooplankton assemblages in each sampling period.

Zooplankton assemblages	**Light rainy**		**Rainy**		**Dry**	
	Total	**%**	**Total**	**%**	**Total**	**%**
Protozoa	$1.5x10^5$	14	$2.8x10^6$	70	$1.6x10^6$	67
Rotifera	$7.4x10^5$	69	$9.7x10^5$	24	$6.6x10^5$	27
Ostracoda juveniles	$6.6x10^3$	<1	$1.1x10^3$	<1	$2.1x10^3$	<1
Cladocera	$1.4x10^3$	<1	$2.6x10^4$	1	$6.0x10^4$	<1
Copepoda	$1.4x10^2$	<1	$2.6x10^2$	<1	75	<1
Copepoda copepodites	$2.7x10^3$	<1	$7.3x10^3$	<1	$4.8x10^3$	<1
Crustacean nauplii	$1.8x10^5$	17	$1.3x10^5$	5	$1.2x10^5$	5
Sum	**$1.1x10^6$**	**100**	**$4.0x10^6$**	**100**	**$2.4x10^6$**	**100**

Table 8. The most dominance of microzooplankton genera in each sampling period during July 2004 to April 2005.

Period		Microzooplankton taxa
Light rainy	- Jul.3	*Polyarthra* spp.
	- Jul.17	*Polyarthra* spp.
	- Aug.2	*Anuraeopsis* spp.
	- Aug.28	*Anuraeopsis* spp.
Rainy	- Nov.6	*Polyarthra* spp., *Euglena* spp.
	- Nov.20	*Trachelomonas* spp.
	- Dec.6	*Peridinium* sp.
	- Dec.22	*Trachelomonas* spp.
Dry	- Mar.16	*Tintinopsis* sp.
	- Mar.29	*Trachelomonas* spp.
	- Apr.8	*Trachelomonas* spp., *Keratella* spp.
	- Apr.24	*Trachelomonas* spp.

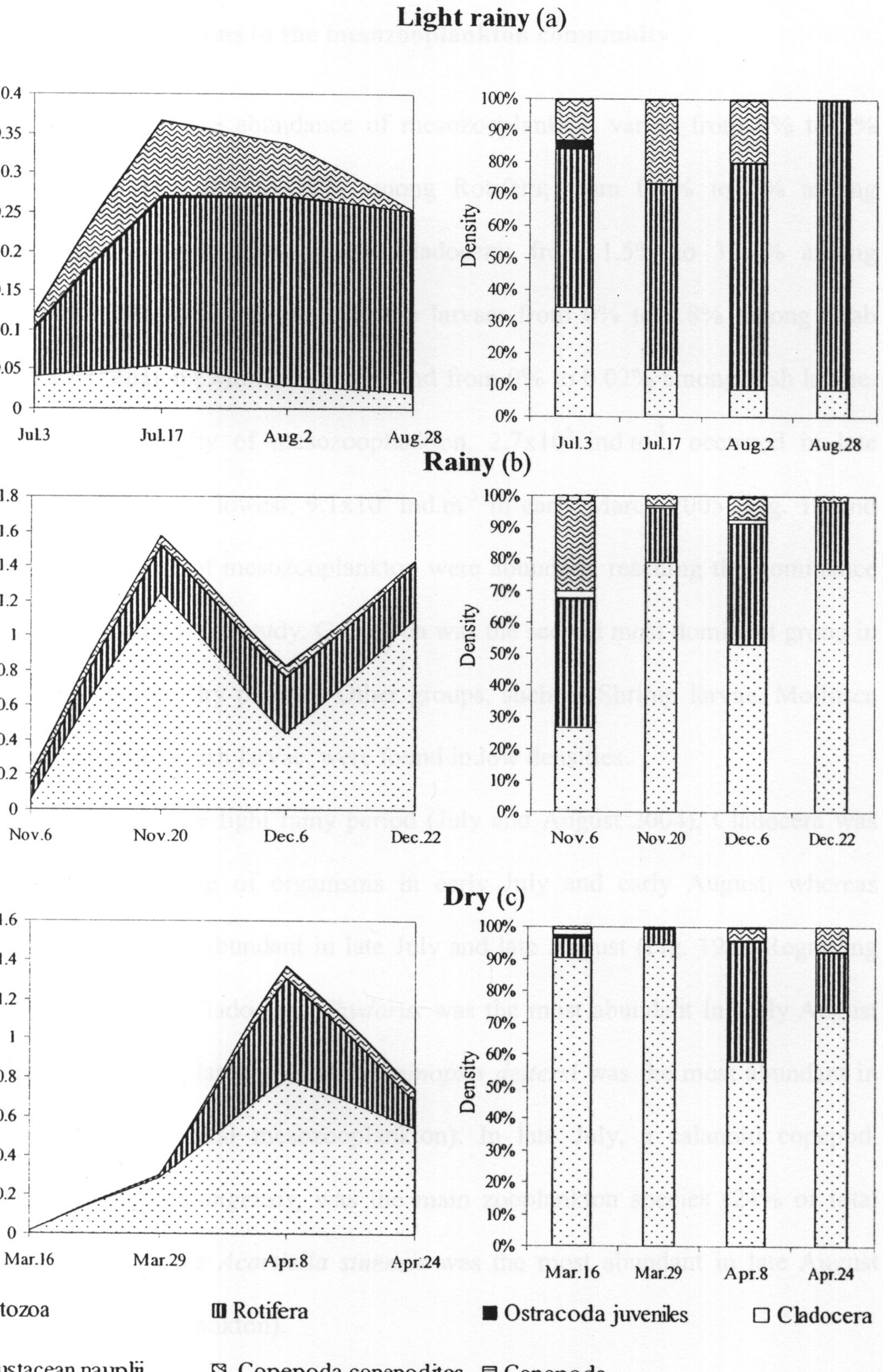


Figure 18. Changes in absolute density and relative abundance of microzooplankton in Thale- Noi during July 2004 to April 2005.

3.2.4.2 Temporal variations in the mesozooplankton community

The relative abundance of mesozooplankton varied from 0% to 7% among Protozoa; from 0% to 12% among Rotifera; from 0.1% to 5% among Ostracoda; from 19% to 82% among Cladocera; from 1.5% to 32.4% among Copepoda; from 0% to 2% among Shrimp larvae; from 0% to 0.8% among Crab larvae; 0% to 2% among Mollusca larvae and from 0% to 0.02% among Fish larvae. The highest total density of mesozooplankton, 2.7×10^{5} ind.m^{-3}, occurred in late November 2004, and the lowest, 9.1×10^{2} ind.m^{-3} in early March 2005 (Fig. 19 and Table 9). Many groups of mesozooplankton were abundant, reaching the dominance of Cladocera throughout the study. Copepoda was the second most dominant group in the light rainy and the dry periods. Other groups, such as Shrimp larvae, Mollusca larvae, Crab larvae and Fish larvae, were found in low densities.

During the light rainy period (July and August 2004), Cladocera was the most abundant group of organisms in early July and early August, whereas Copepoda was the most abundant in late July and late August (Fig. 19a). Regarding numerical densities, in Cladocera, *Chydorus* was the most abundant in early August (20% of total mesozooplankton) and *Bosminopsis deitersi* was the most abundant in late August (49% of total mesozooplankton). In late July, a calanoid copepod, *Neodiaptomus yangtsekiangensis*, was the main zooplankton species (24% of total mesozooplankton), while *Acartiella sinensis* was the most abundant in late August (33% of total mesozooplankton).

In the rainy period (November and December 2004), Cladocera was the dominant group in all sampling periods (Fig. 19b). *Bosminopsis deitersi* was dominant in three of the four sampling periods (73%, 92% and 38% of total mesozooplankton in early November, late November and early December, respectively). In late December, Cladocera, mainly *Ephemeroporus*, increased in abundance, but never reached dominance.

In the dry period, Cladocera was the most abundant group of organisms in all sampling periods (Fig. 19c). The dominant groups of Cladocera were *Chydorus* (58%, 40% and 30% of total mesozooplankton, in early March, late March and early April, respectively) and *Dunhevedia crassa* (21% of total mesozooplankton in late April). The most abundant species of mesozooplankton in each sampling period was shown in Table 10.

Table 9. Total density (ind.m^{-3}) and % abundance of major mesozooplankton assemblages in each sampling period.

Zooplankton assemblages	**Light rainy**		**Rainy**		**Dry**	
	Total	**%**	**Total**	**%**	**Total**	**%**
Protozoa	$5.2x10^2$	4	$1.2x10^4$	3	$1.9x10^2$	2
Rotifera	$3.5x10^2$	3	$2.2x10^3$	1	$1.2x10^2$	1
Ostracoda	$2.5x10^2$	2	$7.8x10^2$	<1	$2.2x10^2$	2
Cladocera	$6.1x10^3$	47	$3.5x10^5$	90	$5.8x10^3$	57
Copepoda	$3.3x10^3$	25	$1.1x10^4$	3	$1.6x10^3$	16
Copepoda copepodites	$2.4x10^3$	19	$1.1x10^4$	3	$2.0x10^3$	20
Shrimp larvae	11.7	<1	$5.2x10^2$	<1	$1.2x10^2$	<1
Crab larvae	9.4	<1	-	-	-	-
Mollusca larvae	36.4	<1	-	-	19	<1
Fish larvae	0.25	<1	-	-	-	-
Sum	**$1.3x10^4$**	**100**	**$3.9x10^5$**	**100**	**$1.0x10^4$**	**100**

Table 10. The most dominance of mesozooplankton genera in each sampling period during July 2004 to April 2005.

Period		Mesozooplankton taxa
Light rainy	- Jul.3	*Chydorus* spp.
	- Jul.17	*Neodiaptomus yangtsekiangensis*, *Chydorus* spp.
	- Aug.2	*Bosminopsis deitersi*
	- Aug.28	*Acartiella sinensis*
Rainy	- Nov.6	*Bosminopsis deitersi*
	- Nov.20	*Bosminopsis deitersi*
	- Dec.6	*Bosminopsis deitersi, Dunhevedia crassa*
	- Dec.22	*Ephemeroporus* spp.
Dry	- Mar.16	*Chydorus* spp.
	- Mar.29	*Chydorus* spp.
	- Apr.08	*Chydorus* spp.
	- Apr.24	*Dunhevedia crassa*

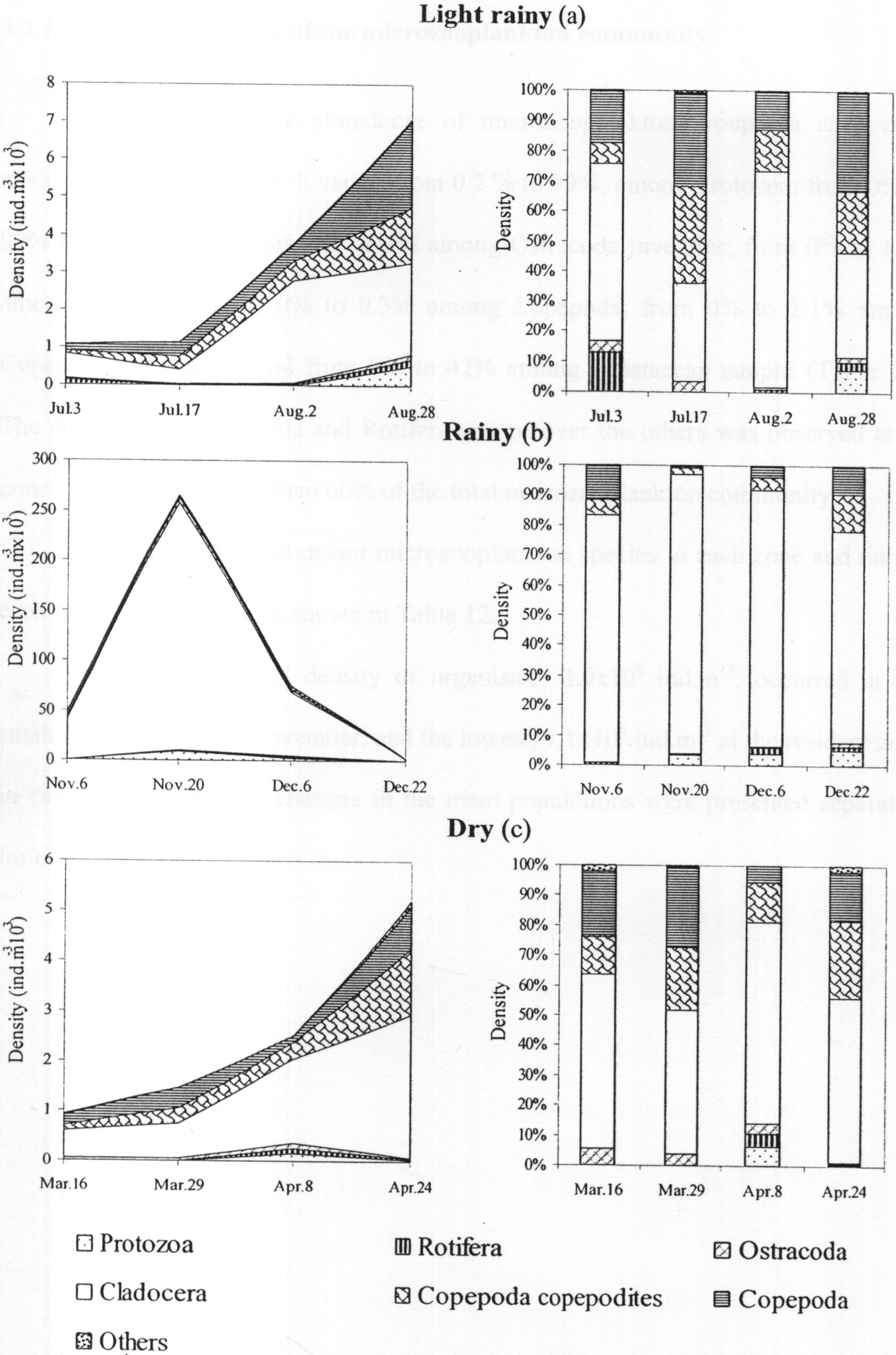


Figure 19. Changes in absolute density and relative abundance of mesozooplankton in Thale- Noi during July 2004 to April 2005.

3.2.4.3 Spatial variations of the microzooplankton community

The relative abundance of microzooplankton groups in each zone studied was quite variable. It varied from 0.2 % to 99%, among Protozoa; from 0% to 99% among Rotifera; from 0% to 7% among Ostracoda juveniles; from 0% to 14% among Cladocera; from 0% to 0.3% among Copepoda; from 0% to 2.1% among Copepoda copepodites and from 0% to 42% among Crustacean nauplii (Table 11). The dominance of Protozoa and Rotifera groups over the others was observed at all zones, representing more than 60% of the total microzooplankton community.

The most abundant microzooplankton species in each zone and during each sampling period were shown in Table 12.

The highest density of organisms, 3.0×10^{6} $ind.m^{-3}$, occurred at the small inlet zone in late November, and the lowest, 7.1×10^{3} $ind.m^{-3}$ at the resident zone in early March. Detailed changes in the main populations were presented separately for each zone, as follows:

Peat swamp zone

In the peat swamp zone, peaks in abundance of microzooplankton occurred in late November (2.0×10^6 ind.m^{-3}) and early April (1.85×10^6 ind.m^{-3}), while the abundance of microzooplankton in early March was very low ($< 0.1 \times 10^6$ ind.m^{-3}). Considering the three sampling periods, different groups alternated in dominance in each period (Fig. 20).

During the light rainy period (July to August 2004), different groups of microzooplankton alternated in dominance on each sampling date (Fig. 20a). There was a great abundance of *Stentor* sp. in early July and late August (36% and 31% of total microzooplankton, respectively), and *Polyarthra* spp. in late July and early August (51% and 32% of total microzooplankton, respectively). Regarding the Crustacean nauplii, numbers increased in abundance in late July and early August but never reached dominance.

In the rainy period (November to December 2004), Protozoa was the dominant group on all sampling dates (Fig. 20b). In November *Lepocinclis* sp. and *Peridinium* sp. occurred in higher abundances than others species (58% and 33% of total microzooplankton in early and late November, respectively). In December, *Peridinium* sp. increased in abundance, and reached dominance with individuals representing more than 70% of the total community in early December. *Dinobryon* sp. was the most abundant species in late December (38% of total microzooplankton).

In the dry period (March to April 2005), there was a dominance of Protozoa over the other groups during all four sampling dates (Fig. 20c). There was a great abundance of *Arcella* sp. (25% of total microzooplankton) in early March, and

Trachelomonas spp. reached dominance in other periods (85%, 74% and 87% of total microzooplankton in late March, early and late April, respectively).

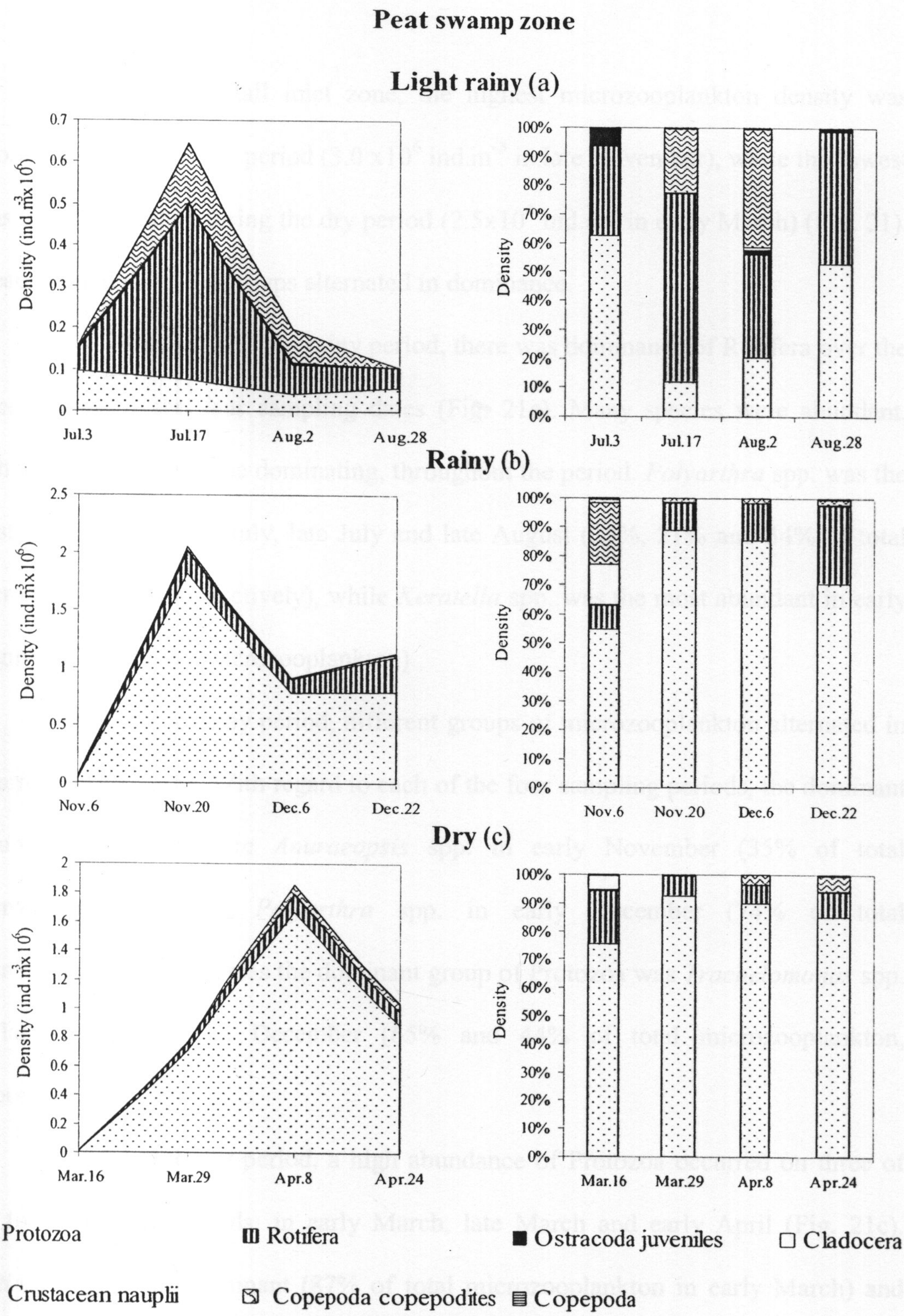


Figure 20. Changes in absolute density and relative abundance of microzooplankton in the peat swamp zone, (a) light rainy, (b) rainy and (c) dry period, during July 2004 to April 2005.

Small inlet zone

In the small inlet zone, the highest microzooplankton density was recorded during the rainy period (3.0×10^6 ind.m^{-3} in late November), while the lowest density was recorded during the dry period (2.5×10^4 ind.m^{-3} in early March) (Fig. 21). In each period different groups alternated in dominance.

During the light rainy period, there was dominance of Rotifera over the other groups on the four sampling dates (Fig. 21a). Many species were abundant, without any particular one dominating, throughout the period. *Polyarthra* spp. was the most abundant in early July, late July and late August (35%, 21% and 34% of total microzooplankton, respectively), while *Keratella* spp. was the most abundant in early August (28% of total microzooplankton).

In the rainy period, different groups of microzooplankton alternated in dominance (Fig. 21b). With regard to each of the four sampling periods, the dominant groups of Rotifera were *Anuraeopsis* spp. in early November (35% of total microzooplankton) and *Polyarthra* spp. in early December (74% of total microzooplankton), whereas the dominant group of Protozoa was *Trachelomonas* spp. in late November and December (65% and 44% of total microzooplankton, respectively).

In the dry period, a high abundance of Protozoa occurred on three of the four sampling periods: in early March, late March and early April (Fig. 21c). *Tintinopsis* sp. was dominant (87% of total microzooplankton in early March) and *Trachelomonas* spp. (89% and 42% of total microzooplankton in late March and early April, respectively). In late April, *Anuraeopsis* spp. was the most abundant group of Rotifera (43% of total microzooplankton).

Small inlet zone

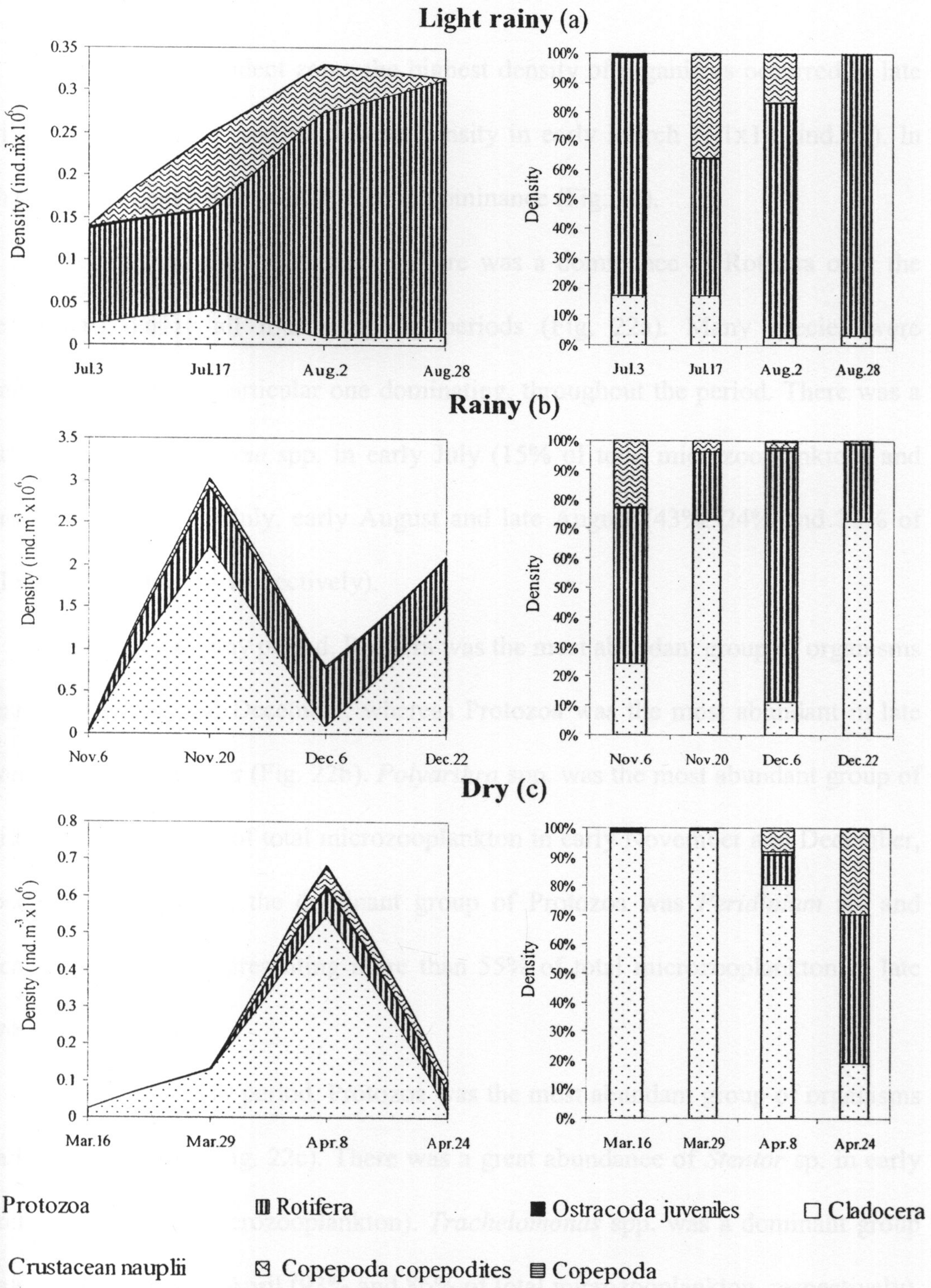


Figure 21. Changes in absolute density and relative abundance of microzooplankton in the small inlet zone, (a) light rainy, (b) rainy and (c) dry period, during July 2004 to April 2005.

Resident zone

In the resident zone, the highest density of organisms occurred in late April ($1.2x10^6$ ind.m^{-3}), and the lowest density in early March ($7.1x10^3$ ind.m^3). In each period different species alternated in dominance (Fig. 22).

In the light rainy period there was a dominance of Rotifera over the other groups during all four sampling periods (Fig. 22a). Many species were abundant, without any particular one dominating, throughout the period. There was a great abundance of *Lecane* spp. in early July (15% of total microzooplankton) and *Polyarthra* spp. in late July, early August and late August (43%, 24% and 33% of total microzooplankton, respectively).

In the rainy period, Rotifera was the most abundant group of organisms in early November and December, whereas Protozoa was the most abundant in late November and December (Fig. 22b). *Polyarthra* spp. was the most abundant group of Rotifera (36% and 27% of total microzooplankton in early November and December, respectively). Moreover, the dominant group of Protozoa was *Peridinium* sp. and *Trachelomonas* spp., representing more than 55% of total microzooplankton in late November and December.

In the dry period, Protozoa was the most abundant group of organisms on all sampling dates (Fig. 22c). There was a great abundance of *Stentor* sp. in early March (35% of total microzooplankton). *Trachelomonas* spp. was a dominant group in late March and early April (93% and 86% of total microzooplankton, respectively), while *Peridinium* sp. was the most abundant group in late April (42% of total microzooplankton).

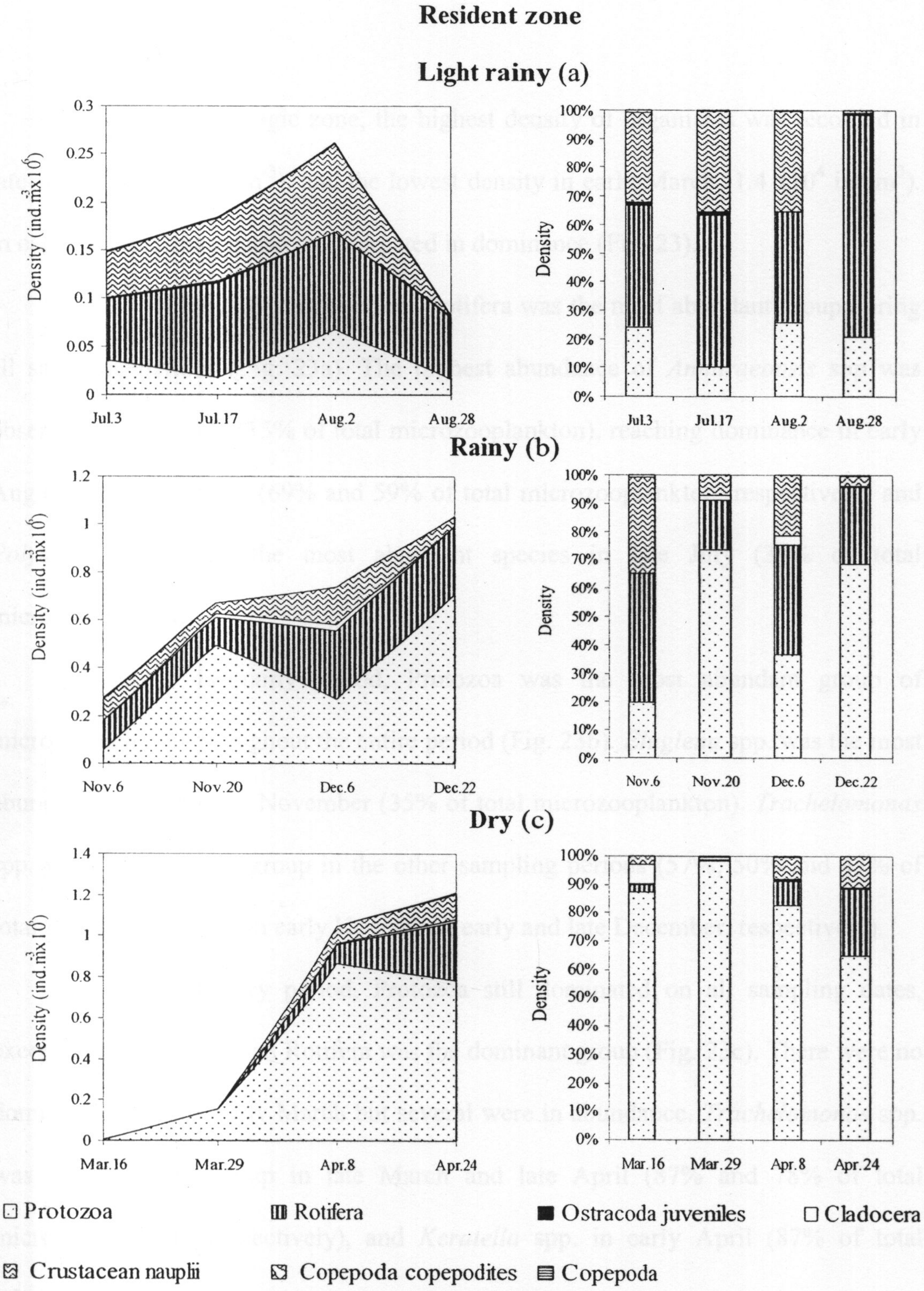


Figure 22. Changes in absolute density and relative abundance of microzooplankton in the resident zone, (a) light rainy, (b) rainy and (c) dry period, during July 2004 to April 2005.

Pelagic zone

In the pelagic zone, the highest density of organisms was recorded in late April ($1.9x10^6$ ind.m^{-3}), and the lowest density in early March ($1.4 \ x10^4$ ind.m^3). In each period different species alternated in dominance (Fig. 23).

In the light rainy period, Rotifera was the most abundant group during all sampling periods (Fig. 23a). The highest abundance of *Annuraeopsis* spp was observed in early July (15% of total microzooplankton), reaching dominance in early August and late August (69% and 59% of total microzooplankton, respectively) and *Polyarthra* spp. was the most abundant species in late July (39% of total microzooplankton).

In the rainy period, Protozoa was the most abundant group of microzooplankton throughout the entire period (Fig. 23b). *Eluglena* spp. was the most abundant group in early November (35% of total microzooplankton). *Trachelomonas* spp. was the dominant group in the other sampling periods (57%, 50% and 47% of total microzooplankton in early November, early and late December, respectively).

In the dry period, Protozoa still dominated on all sampling dates, except in early April when Rotifera was the dominant group (Fig. 23c). There were no dominant species in early March but several were in abundance. *Trachelomonas* spp. was the dominant group in late March and late April (87% and 78% of total microzooplankton, respectively), and *Keratella* spp. in early April (87% of total microzooplankton).

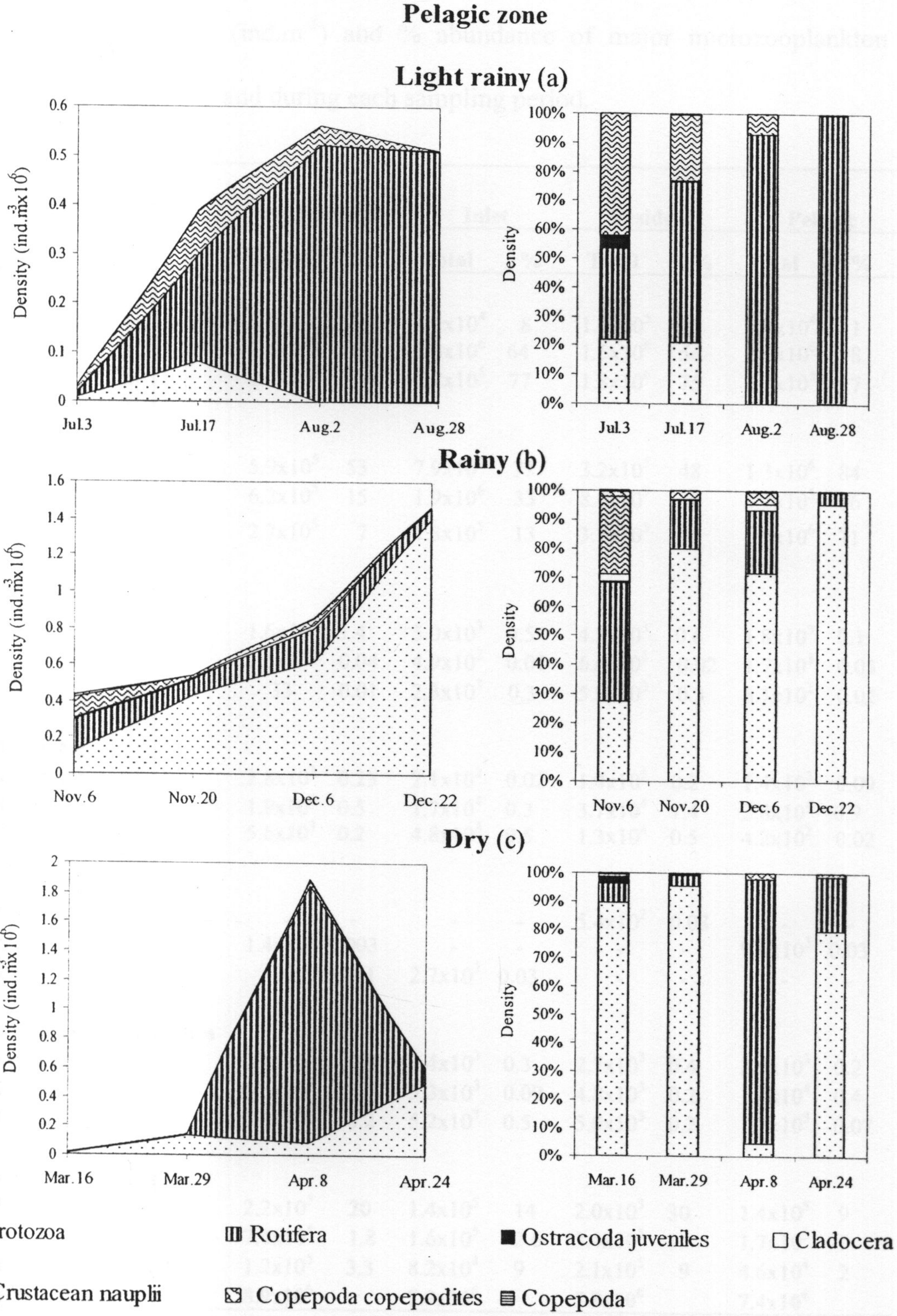


Figure 23. Changes in absolute density and relative abundance of microzooplankton in the pelagic zone, (a) light rainy, (b) rainy and (c) dry period, during July 2004 to April 2005.

Table 11. Total density (ind.m^{-3}) and % abundance of major microzooplankton assemblages in each zone and during each sampling period.

Zooplankton assemblages	**Peat swamp**		**Inlet**		**Resident**		**Pelagic**	
	Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Protozoa								
Light rainy	$2.6x10^5$	24	$8.5x10^4$	8	$1.4x10^5$	20	$9.3x10^4$	11
Rainy	$3.4x10^6$	83	$3.8x10^6$	64	$1.5x10^6$	56	$2.6x10^6$	78
Dry	$3.2x10^6$	89	$7.2x10^5$	77	$1.8x10^6$	75	$7.2x10^5$	27
Rotifera								
Light rainy	$5.9x10^5$	53	$7.9x10^5$	77	$3.2x10^5$	48	$1.3x10^6$	84
Rainy	$6.2x10^5$	15	$1.9x10^6$	33	$8.0x10^5$	30	$5.2x10^5$	16
Dry	$2.7x10^5$	7	$1.3x10^5$	13	$3.7x10^5$	15	$1.9x10^6$	71
Ostracoda juveniles								
Light rainy	$1.6x10^4$	1.4	$5.0x10^3$	0.5	$4.2x10^3$	0.6	$1.8x10^3$	0.1
Rainy	$1.5x10^3$	0.04	$4.9x10^2$	0.01	$6.6x10^2$	0.02	$1.7x10^3$	0.05
Dry	33	0.01	$2.3x10^3$	0.3	$5.9x10^3$	0.3	$5.1x10^2$	0.02
Cladocera								
Light rainy	$2.8x10^3$	0.25	$2.1x10^2$	0.02	$1.4x10^3$	0.2	$1.4x10^3$	0.09
Rainy	$1.9x10^4$	0.5	$1.7x10^4$	0.3	$3.7x10^4$	1.4	$2.8x10^4$	0.9
Dry	$5.6x10^3$	0.2	$4.8x10^3$	0.5	$1.3x10^4$	0.5	$4.2x10^2$	0.02
Copepoda								
Light rainy	-	-	-	-	$5.4x10^2$	0.08	-	-
Rainy	$1.4x10^3$	0.003	-	-	-	-	$9.0x10^3$	0.03
Dry	35	0.001	$2.7x10^2$	0.03	-	-	-	-
Copepoda copepodites								
Light rainy	$2.8x10^3$	0.3	$2.4x10^3$	0.3	$2.7x10^3$	0.4	$2.9x10^3$	0.2
Rainy	$6.3x10^3$	0.2	$5.3x10^3$	0.09	$4.8x10^3$	0.2	$1.3x10^4$	0.4
Dry	$7.3x10^3$	0.2	$5.2x10^3$	0.5	$5.0x10^3$	0.2	$1.7x10^3$	0.07
Crustacean nauplii								
Light rainy	$2.2x10^5$	20	$1.4x10^5$	14	$2.0x10^5$	30	$1.4x10^5$	9
Rainy	$7.4x10^4$	1.8	$1.6x10^5$	2.6	$3.4x10^5$	13	$1.7x10^5$	5
Dry	$1.2x10^5$	3.3	$8.2x10^4$	9	$2.1x10^5$	9	$4.6x10^4$	2
sum	**$8.9x10^6$**		**$7.9x10^6$**		**$5.8x10^6$**		**$7.4x10^6$**	

Table 12. The most dominance of microzooplankton genera in each zone during three periods of sampling in July 2004 to April 2005.

Period	Zone			
	Peat swamp	**Small inlet**	**Resident**	**Pelagic**
Light rainy				
- Jul. 3	*Stentor* sp.	*Polyarthra* spp.	*Lecane* spp.	*Stentor* sp.
- Jul.17	*Polyarthra* spp.	*Keratella* spp.	*Polyarthra* spp.	*Polyarthra* spp.
- Aug.2	*Polyarthra* spp.	*Keratella* spp.	*Polyarthra* spp.	*Anuraeopsis* spp.
- Aug.28	*Stentor* spp.	*Polyarthra* spp.	*Polyarthra* spp.	*Anuraeopsis* spp.
Rainy				
- Nov.6	*Lepocinclis* sp.	*Anuraeopsis* spp.	*Polyarthra* spp.	*Euglena* spp.
- Nov.20	*Peridinium* sp.	*Trachelomonas* spp.	*Peridinium* sp.	*Trachelomonas* spp.
- Dec. 6	*Peridinium* sp.	*Polyarthra* spp.	*Polyarthra* spp	*Trachelomonas* spp.
- Dec.22	*Dinobryon* sp.	*Trachelomonas* spp.	*Trachelomonas* spp.	*Trachelomonas* spp.
Dry				
- Mar.16	*Arcella* sp.	*Tintinopsis* sp.	*Stentor* sp.	*Trachelomonas* spp.
- Mar.29	*Trachelomonas* spp.	*Trachelomonas* spp.	*Trachelomonas* spp.	*Trachelomonas* spp.
- Apr.8	*Trachelomonas* spp.	*Trachelomonas* spp.	*Trachelomonas* spp.	*Keratella* spp.
- Apr.24	*Trachelomonas* spp.	*Anuraeopsis* spp.	*Peridinium* sp.	*Trachelomonas* spp.

3.2.4.4 Spatial variations of mesozooplankton community

The relative abundance of mesozooplankton groups in each of the zones studied was quite variable. It varied from 0 % to 23%, among Protozoa; from 0% to 40% among Rotifera; from 0% to 13% among Ostracoda; from 1.9% to 98% among Cladocera; from 0.5% to 81% among Copepoda; from 0.7% to 60% among Copepoda copepodites; from 0% to 2.3% among Shrimp larvae; from 0% to 7.5% among Crab larvae; from 0% to 0.9% among Gastopod larvae; from 0% to 11% among Bivalvia larvae and from 0% to 0.9% among Fish larvae (Table 13).

The most abundant mesozooplankton species in each zone and each sampling period were shown in Table 14.

The highest density of organisms, $6.0x10^5$ $ind.m^{-3}$, occurred at the small inlet zone in late November, and the lowest, 42 $ind.m^{-3}$ at the pelagic zone in late July. Detailed changes in the main populations are presented separately for each zone, as follows:

Peat swamp zone

In the peat swamp zone, the highest density of organisms was recorded in early November ($1.8x10^5$ ind.m^{-3}), and the lowest density in early March ($2.4x10^2$ ind.m^3). In each period different species alternated in dominance (Fig. 24).

During the light rainy period, different mesozooplankton groups and copepodites of Copepoda alternated in dominance on each sampling date. There was a great abundance of Cladocera *Alona* spp. (approximately 19% of total mesozooplankton in early July), Copepoda *Neodiaptomus yangtsekiangensis* (about 37% of total mesozooplankton in late July), and *Bosminopsis deitersi* (about 70% of total mesozooplankton in early August). In late August, there was no single constantly dominant species in this sampling period but Copepoda copepodites increased in abundance (Fig. 24a). However, Protozoa *Voticella* sp. was the most abundant group during this sampling date (19% of total mesozooplankton).

In the rainy period, a high abundance of Cladocera occurred on all sampling dates (Fig. 24b). There was a dominance of *Bosminopsis deitersi* (75% and 86% of total mesozooplankton in early and late November, respectively) and of *Chydorus* spp. (46% of total mesozooplankton in early December). In late December, there was no single constantly dominant species but *Voticella* sp. was most abundant (21% of total mesozooplankton).

In the dry period, Copepoda was the most abundant group in early and late March while Cladocera increased in early and late April (Fig. 24c). Regarding numerical density, in Copepoda, there was a great abundance of *Metacyclops* sp. (47% and 43% of total mesozooplankton in early and late March, respectively) and among the Cladocera there was an abundance of *Bosminopsis deitersi* (36% and 43% of total mesozooplankton in early and late April, respectively).

Peat swamp zone

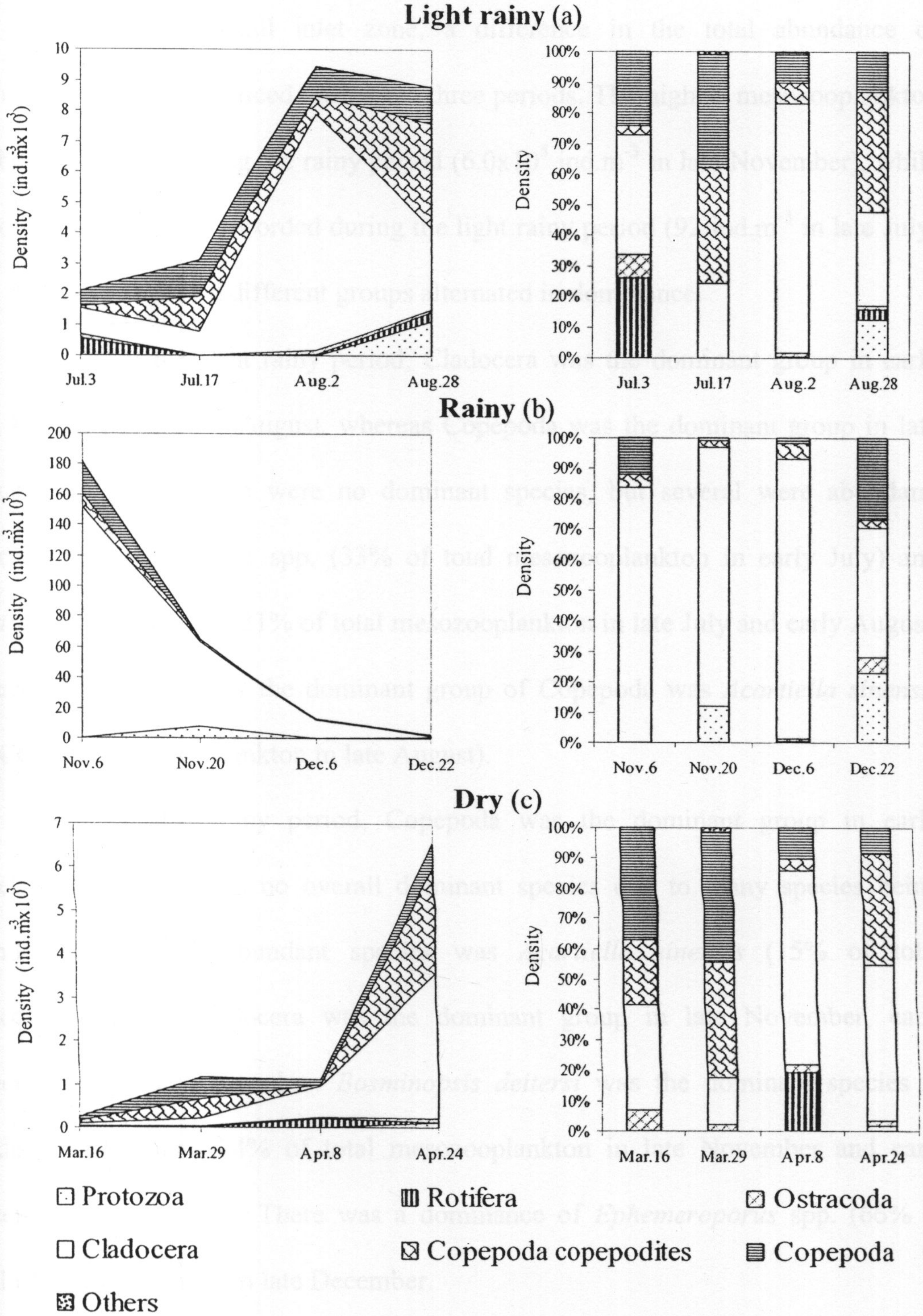


Figure 24. Changes in absolute density and relative abundance of mesozooplankton in the peat swamp zone, (a) light rainy, (b) rainy (c) dry period, during July 2004 to April 2005.

Small inlet zone

In the small inlet zone, a difference in the total abundance of mesozooplankton was noticed during the three periods. The highest mesozooplankton number was record during the rainy period (6.0×10^5 ind.m^{-3} in late November), while the lowest number was recorded during the light rainy period (92 ind.m^{-3} in late July) (Fig. 25). In each period different groups alternated in dominance.

In the light rainy period, Cladocera was the dominant group in early July, late July and early August, whereas Copepoda was the dominant group in late August (Fig. 25a). There were no dominant species, but several were abundant, especially *Ephemeroporus* spp. (33% of total mesozooplankton in early July) and *Chydorus* spp. (25% and 21% of total mesozooplankton in late July and early August, respectively). In addition, the dominant group of Copepoda was *Acartiella sinensis* (79% of total mesozooplankton in late August).

In the rainy period, Copepoda was the dominant group in early November but there was no overall dominant species due to many species being abundant. The most abundant species was *Acartiella sinensis* (15% of total mesozooplankton). Cladocera was the dominant group in late November, early December and late December. *Bosminopsis deitersi* was the dominant species of Cladocera (96% and 74% of total mesozooplankton in late November and early December, respectively). There was a dominance of *Ephemeroporus* spp. (66% of total mesozooplankton) in late December.

In the dry period, Copepoda was the most abundant group in early March, late March and late April, whereas Cladocera was the most abundant group in early April. *Pseudodiaptomus* sp. was the dominant species of Copepoda (54% of total mesozooplankton) in early March, *Metacyclops* sp. (79% of total mesozooplankton) in late March and *Mesocyclops* sp. (63% of total mesozooplankton) in late April. *Chydorus* spp. was the most abundant species of Cladocera (28% of total mesozooplankton) in early April.

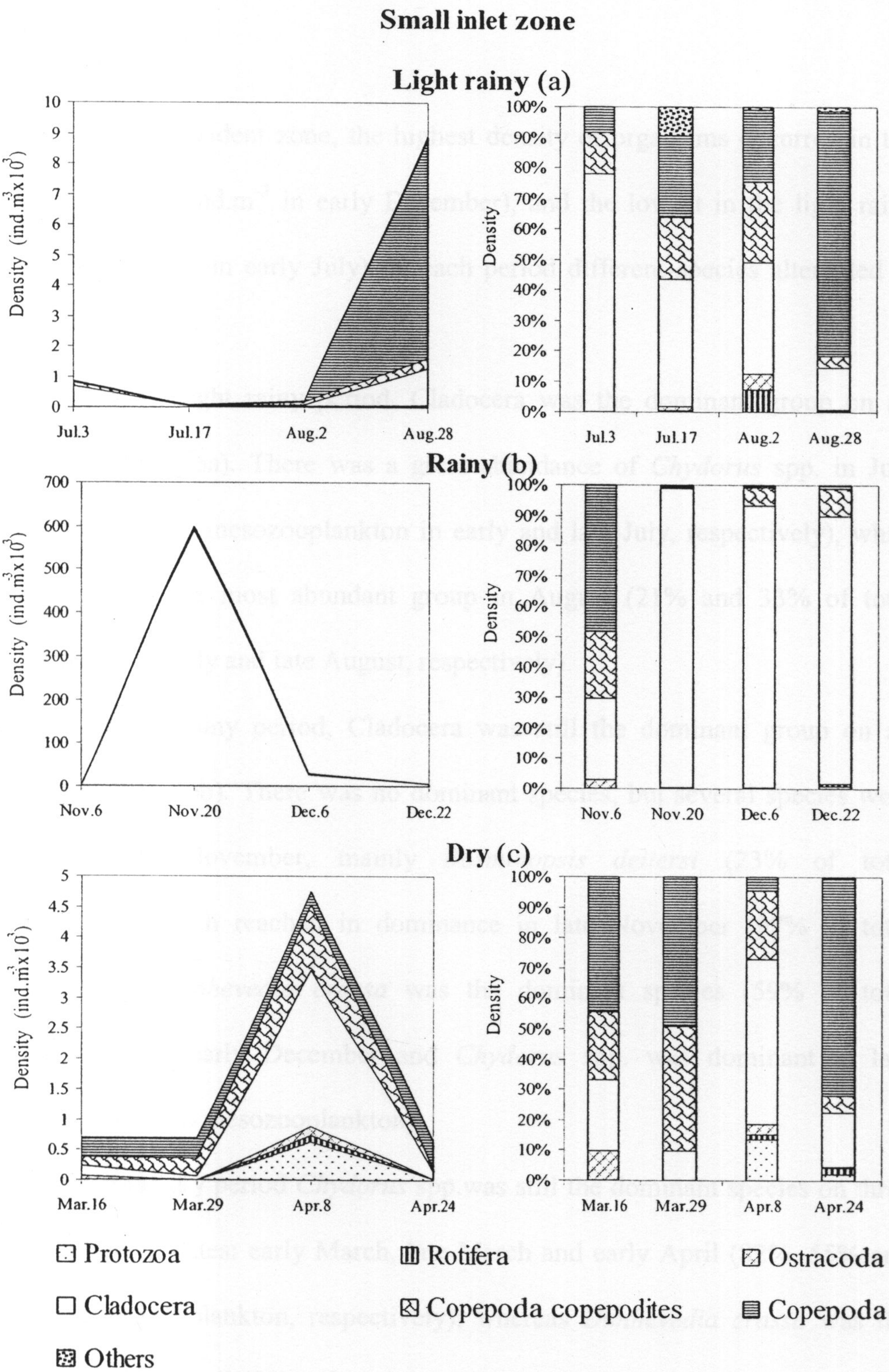


Figure 25. Changes in absolute density and relative abundance of mesozooplankton in the small inlet zone, (a) light rainy, (b) rainy (c) dry period, during July 2004 to April 2005.

Resident zone

In the resident zone, the highest density of organisms occurred in the rainy period ($1.1x10^5$ ind.m^{-3} in early December), and the lowest in the light rainy period ($1.1x10^3$ ind.m^{-3} in early July). In each period different species alternated in dominance (Fig. 26).

In the light rainy period, Cladocera was the dominant group on all sampling dates (Fig. 26a). There was a great abundance of *Chydorus* spp. in July (35% and 21% of total mesozooplankton in early and late July, respectively), while *Latonopsis* sp. was the most abundant group in August (21% and 33% of total mesozooplankton in early and late August, respectively).

In the rainy period, Cladocera was still the dominant group on all sampling dates (Fig. 26b). There was no dominant species, but several species were abundant in early November, mainly *Bosminopsis deitersi* (23% of total mesozooplankton) which reached in dominance in late November (97% of total mesozooplankton). *Dunhevedia crassa* was the dominant species (59% of total mesozooplankton) in early December and *Chydorus* spp. was dominant in late December (82% of total mesozooplankton).

In the dry period *Chydorus* spp.was still the dominant species on three of the four sampling dates: early March, late March and early April (82%, 55% and 37% of total mesozooplankton, respectively); whereas *Dunhevedia crassa* was the most abundant in late April (25% of total mesozooplankton).

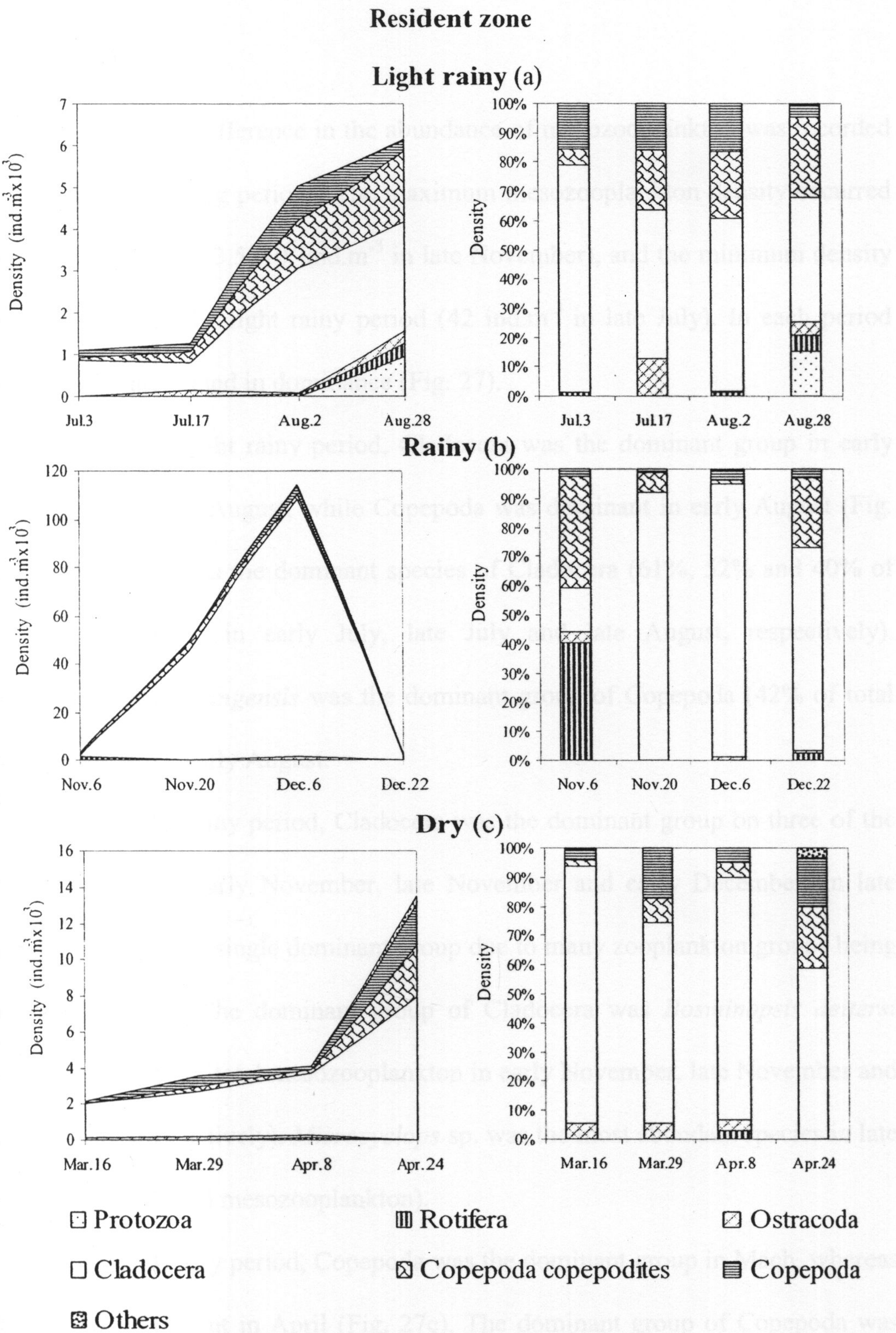


Figure 26. Changes in absolute density and relative abundance of mesozooplankton in the resident zone, (a) light rainy, (b) rainy (c) dry period, during July 2004 to April 2005.

Pelagic zone

A great difference in the abundance of mesozooplankton was recorded during the three sampling periods. The maximum mesozooplankton density occurred during the rainy period ($3.5x10^5$ ind.m^{-3} in late November), and the minimum density was recorded during the light rainy period (42 ind.m^{-3} in late July). In each period different species alternated in dominance (Fig. 27).

In the light rainy period, Cladocera was the dominant group in early July, late July and late August, while Copepoda was dominant in early August (Fig. 27a). *Chydorus* spp. was the dominant species of Cladocera (61%, 52% and 40% of total mesozooplankton in early July, late July and late August, respectively). *Nediaptomus yangtsekiangensis* was the dominant group of Copepoda (42% of total mesozooplankton) in early August.

In the rainy period, Cladocera was the dominant group on three of the four sampling dates: early November, late November and early December. In late December there was no single dominant group due to many zooplankton groups being abundant (Fig. 27b). The dominant group of Cladocera was *Bosminopsis deitersi* (62%, 86% and 61% of total mesozooplankton in early November, late November and early December, respectively). *Microcyclops* sp. was the most abundant species in late December (23% of total mesozooplankton).

In the dry period, Copepoda was the dominant group in Mach, whereas Cladocera was dominant in April (Fig. 27c). The dominant group of Copepoda was *Metacyclops* sp. (69% and 72% of total mesozooplankton in early and late March, respectively). *Bosminopsis deitersi* and *Chydorus* spp. were the abundant groups of

Cladocera (31% and 32% of total mesozooplankton in early and late April, respectively).

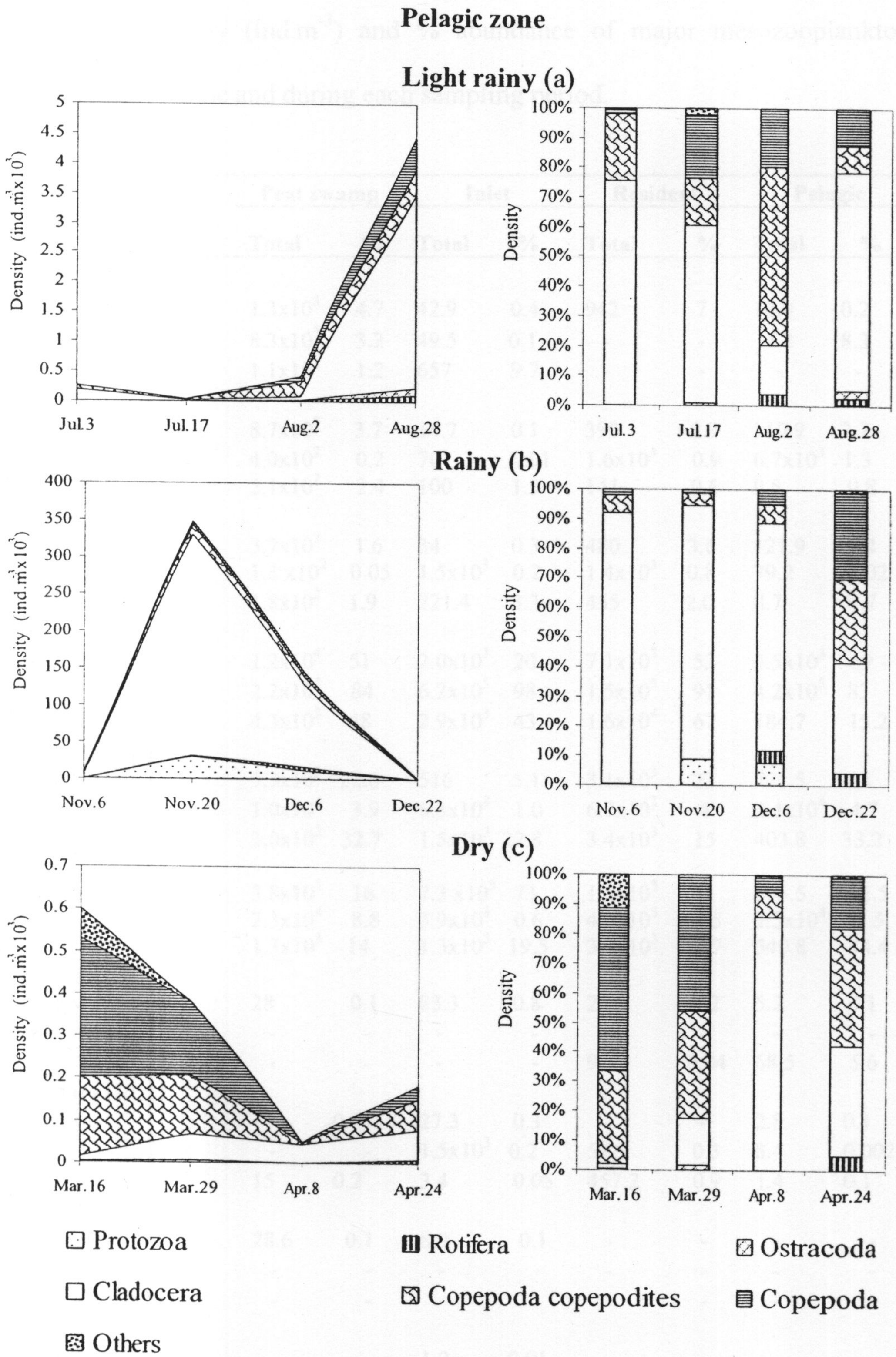


Figure 27. Changes in absolute density and relative abundance of mesozooplankton in the pelagic zone, (a) early rainy, (b) rainy (c) dry period, during July 2004 to April 2005.

Table 13. Total density (ind.m^{-3}) and % abundance of major mesozooplankton assemblages in each zone and during each sampling period.

Zooplankton assemblages	Peat swamp		Inlet		Resident		Pelagic	
	Total	%	Total	%	Total	%	Total	%
Protozoa								
Light rainy	$1.3x10^{3}$	4.7	42.9	0.4	942	7	10.8	0.2
Rainy	$8.3x10^{3}$	3.2	49.5	0.1	-	-	4.2	8.3
Dry	$1.1x10^{2}$	1.2	657	9.7	-	-	-	-
Rotifera								
Light rainy	$8.7x10^{2}$	3.7	14.7	0.1	390	2.9	110.9	2.2
Rainy	$4.0x10^{2}$	0.2	70	0.01	$1.6x10^{3}$	0.9	$6.7x10^{3}$	1.3
Dry	$2.1x10^{2}$	2.4	100	1.5	141	0.6	9.5	0.8
Ostracoda								
Light rainy	$3.7x10^{2}$	1.6	34	0.3	480	3.6	121.9	2.4
Rainy	$1.3\ x10^{2}$	0.05	$1.5x10^{3}$	0.2	$1.4x10^{3}$	0.8	79.2	0.02
Dry	$1.8x10^{2}$	1.9	221.4	3.3	455	2.0	8.7	0.7
Cladocera								
Light rainy	$1.2x10^{4}$	51	$2.0x10^{3}$	20	$7.1x10^{3}$	52	$3.5x10^{3}$	69
Rainy	$2.2x10^{5}$	84	$6.2x10^{5}$	98	$1.5x10^{5}$	91	$4.2x10^{5}$	83
Dry	$4.3x10^{3}$	48	$2.9x10^{3}$	43	$1.6x10^{4}$	67	184.7	15.2
Copepoda copepodites								
Light rainy	$5.3x10^{3}$	22.6	516	5.1	$3.1x10^{3}$	23	721.5	14
Rainy	$1.0x10^{4}$	3.9	$6.3x10^{3}$	1.0	$6.7x10^{3}$	4	$2.4x10^{4}$	4.7
Dry	$3.0x10^{3}$	32.7	$1.5x10^{3}$	22.8	$3.4x10^{3}$	15	403.8	33.2
Copepoda								
Light rainy	$3.8x10^{3}$	16	$7.3\ x10^{3}$	73	$1.5x10^{3}$	11	645.5	12.5
Rainy	$2.3x10^{4}$	8.8	$3.9x10^{3}$	0.6	$4.3x10^{3}$	2.5	$1.3x10^{4}$	2.5
Dry	$1.3x10^{3}$	14	$1.3x10^{3}$	19.5	$3.2x10^{3}$	13.7	540.8	44.4
Mollusca larvae								
Light rainy	28	0.1	83.3	0.8	28.6	0.2	5.2	0.1
Rainy	-	-	-	-	-	-	-	-
Dry	-	-	-	-	9.5	0.04	68.5	5.6
Shrimp larvae								
Light rainy	17	0.07	27.3	0.3	-	-	2.8	0.1
Rainy	-	-	$1.5x10^{3}$	0.2	592	0.3	8.4	0.002
Dry	15	0.2	3.4	0.05	457.2	0.9	1.4	0.1
Crab larvae								
Light rainy	28.6	0.1	8.9	0.1	-	-	-	-
Rainy	-	-	-	-	-	-	-	-
Dry	-	-	-	-	-	-	-	-
Fish larvae								
Light rainy	-	-	1.0	0.01	-	-	-	-
Rainy	-	-	-	-	-	-	-	-
Dry	-	-	-	-	-	-	-	-
Sum	**$2.9x10^{5}$**		**$6.5x10^{5}$**		**$2.1x10^{5}$**		**$5.1x10^{5}$**	

Table 14. The most dominance of mesozooplankton genera in each zone during three periods of sampling between July 2004 and April 2005.

Period	**Zone**			
	Peat swamp	**Small inlet**	**Resident**	**Pelagic**
Light rainy				
- Jul. 3	*Testudinella* spp.	*Ephemeroporus* spp.	*Chydorus* spp.	*Chydorus* spp.
- Jul.17	*Neodiaptomus yangtsekiangensis*	*Chydorus* spp.	*Chydorus* spp.	*Chydorus* spp.
- Aug.2	*Bosminopsis deitersi*	*Chydorus* spp.	*Latonopsis* spp.	*Neodiaptomus yangtsekiangensis*
- Aug.28	*Voticella* sp.	*Acartiella sinensis*	*Latonopsis* spp.	*Chydorus* spp.
Rainy				
- Nov.6	*Bosminopsis deitersi*	*Acartiella senensis*	*Bosminopsis deitersi*	*Bosminopsis deitersi*
- Nov.20	*Bosminopsis deitersi*	*Bosminopsis deitersi*	*Bosminopsis deitersi*	*Bosminopsis deitersi*
- Dec. 6	*Chydorus* spp.	*Bosminopsis deitersi*	*Dunhevedia crassa*	*Bosminopsis deitersi*
- Dec.22	*Voticella* sp.	*Ephemeroporus* spp.	*Chydorus* spp.	*Microcyclops* spp.
Dry				
- Mar.16	*Metacyclops* spp.	*Pseudodiaptomus* sp.	*Chydorus* spp.	*Metacyclops* sp.
- Mar.29	*Metacyclops* spp.	*Metacyclops* sp.	*Chydorus* spp.	*Metacyclops* sp.
- Apr.8	*Bosminopsis deitersi*	*Chydorus* spp.	*Chydorus* spp.	*Bosminopsis deitersi*
- Apr.24	*Bosminopsis deitersi*	*Mesocyclops* spp.	*Dunhevedia crassa*	*Chydorus* spp.

3.3 Relationships between zooplankton densities and environmental variables

3.3.1 Microzooplankton community

Analysis of the relationship between genera and environmental factors was carried out using Canonical Correspondence Analysis (CCA), which is a kind of technique that shows non-linear relationships between species and environmental factors along with the best weights to choose for environmental variables (Maiphae, 2005). According to table 15-17, most of the variation (eigenvalue = 0.358) accounted for is in the first axis (9.4 %). Correlation between the first axis and species-environmental variables was 0.791 and there was a highly significant difference (P=0.01) with the Monte-Carlo permutation test for the first axis. The second axis (eigenvalue = 0.175) accounted for a 4.6% variation in the data set. Correlation between the second axis and species-environmental variables was 0.703 and Monte-Carlo permutation testing for the second axis was highly significant (P=0.01). The third axis (eigenvalue = 0.117) accounted for a 3.0% variation in the data set. Correlation between the third axis and species-environmental variables was 0.639 and Monte-Carlo permutation testing for the third axis was highly significant (P=0.01).

The derived CCA scores (Fig. 28) with dominant genera and environmental variable data indicated that the lake showed limnological differences between the three sampling periods. In the light rainy period the lake had high pH and conductivity whereas in the dry period it had high temperature and dissolved oxygen, and in the rainy period it had the highest transparency and depth (Fig. 28a). Although there were not clear differences among zones in Thale-Noi (Fig. 28b), the small inlet and pelagic zones, situated in the upper part of the plot, were associated with high conductivity and high pH values during the light rainy period whereas these values were more moderate in the dry period.

For CCA ordination, the genera environmental biplot (Fig. 29) showed the relationship of the genera and environmental variables within the ordination axes. The length of the arrow indicates the relative importance of the environmental variables in determining the axes. The position of the genera centers (points) along the ordination axes represents their respective optima along the environmental gradient. There was a distinct correlation between genera and their abundance and the six environmental factors, pH (r^2 = 0.72), temperature (r^2 = 0.56), transparency (r^2 = 0.55), dissolved oxygen (r^2 = 0.52), conductivity (r^2 = 0.48) and depth (r^2 = 0.41). *Peranema, Stentor, Anuraeopsis, Brachionus, Collotheca, Colurella, Euchlanis, Filinia, Hexathra, Lepadella, Macrochaetus,* and especially *Loxodes, Testudinella, Trichocerca, Proales, Mytilina* and *Alona* situated in the upper left side of the plot are associated with high pH and conductivity. *Peridinium, Ascomorpha, Asplanchna, Lecane, Polyarthra* and *Bosminopsis* situated in the lower left corner are associated with high transparency values. The other genera such as *Monommata* and *Cephalodella* were also positively influenced by this factor but at more moderate levels. *Centropyxis, Euglyphra, Halteria, Trachelomonas, Undella, Plationus Chydorus* and *Ephemeroporus* observed in the upper right side of the plot are associated with higher temperature and dissolved oxygen. The protozoan genera, such as *Phacus, Arcella* and *Lepocinclis* situated in the lower right side of the plot are associated with high depth, low conductivity and low pH.

Table 15. Canonical correspondence analysis for environmental data.

INTER-SET CORRELATIONS for 10 factors

	Variable	Correlations Axis 1	Axis 2	Axis 3
1	Temp	.114	.416	-.070
2	pH	-.395	.485	-.208
3	Conductivity	-.166	.424	.170
4	Salinity	-.137	.396	.178
5	Transparency	-.335	-.367	.019
6	Depth	.078	-.395	.002
7	DO	.293	.304	-.150
8	TS	-.239	.384	.168
9	Chl a (20-200 µm)	-.004	-.077	.147
10	chl a (< 20 µm)	.134	.068	.425

Table 16. Canonical correspondence analysis for environmental data.

AXIS SUMMARY STATISTICS
Number of canonical axes: 3
Total variance ("inertia") in the species data: 3.831

	Axis 1	Axis 2	Axis 3
Eigenvalue	.358	.175	.117
Variance in species data			
% of variance explained	9.4	4.6	3.0
Cumulative % explained	9.4	13.9	17.0
Pearson Correlation, Spp-Envt*	.791	.703	.639
Kendall (Rank) Corr., Spp-Envt	.546	.429	.284

* Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables. Set to 0.000 if axis is not canonical.

Table 17. Monte-Carlo test for genera-environmental correlations.

MONTE CARLO TEST RESULTS -- SPECIES-ENVIRONMENT CORRELATIONS

	Real data	Randomized data Monte Carlo test, 99 runs			
Axis	Spp-Envt Corr.	Mean	Minimum	Maximum	p
1	.791	.552	.420	.720	.0100
2	.703	.468	.330	.591	.0100
3	.639	.404	.307	.535	.0100

p = proportion of randomized runs with species-environment correlation greater than or equal to the observed species-environment correlation; i.e.,
p = (1 + no. permutations >= observed)/(1 + no. permutations)

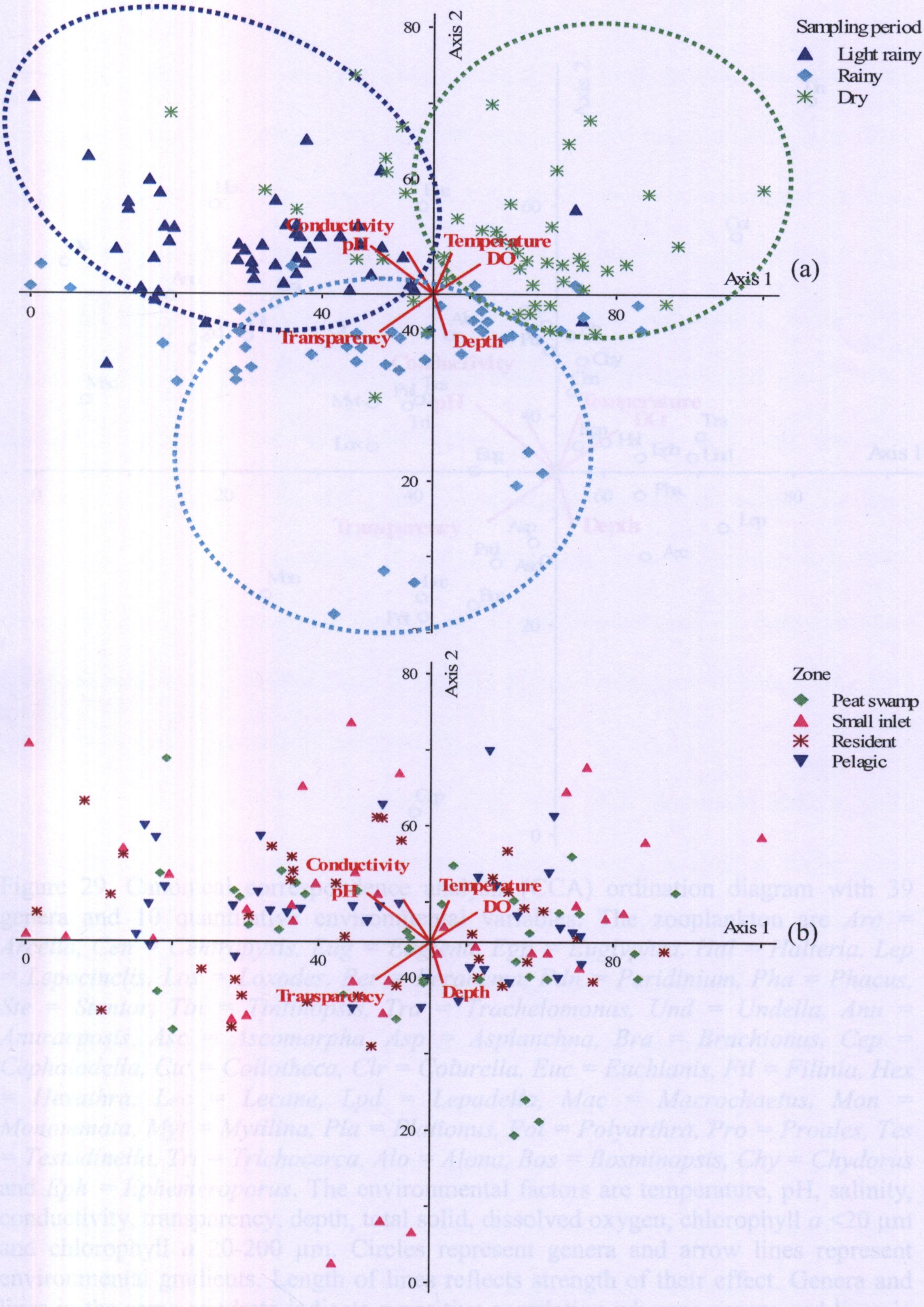


Figure 28. CCA ordination of samples and important variables of the three sampling periods (a) and four zones of Thale-Noi (b).

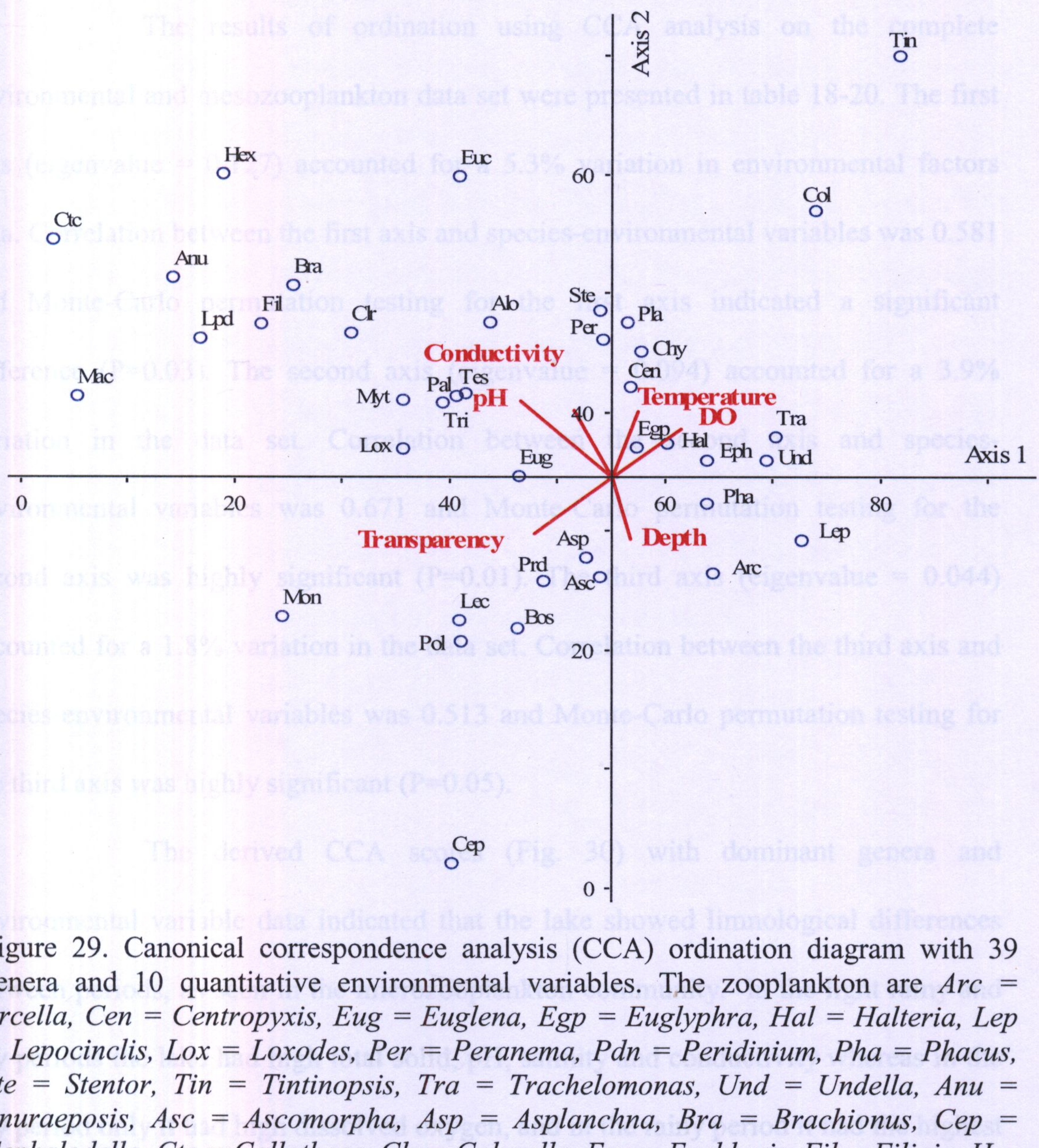


Figure 29. Canonical correspondence analysis (CCA) ordination diagram with 39 genera and 10 quantitative environmental variables. The zooplankton are *Arc = Arcella, Cen = Centropyxis, Eug = Euglena, Egp = Euglyphra, Hal = Halteria, Lep = Lepocinclis, Lox = Loxodes, Per = Peranema, Pdn = Peridinium, Pha = Phacus, Ste = Stentor, Tin = Tintinopsis, Tra = Trachelomonas, Und = Undella, Anu = Anuraeposis, Asc = Ascomorpha, Asp = Asplanchna, Bra = Brachionus, Cep = Cephalodella, Ctc = Collotheca, Clr = Colurella, Euc = Euchlanis, Fil = Filinia, Hex = Hexathra, Lec = Lecane, Lpd = Lepadella, Mac = Macrochaetus, Mon = Monommata, Myt = Mytilina, Pla = Plationus, Pol = Polyarthra, Pro = Proales, Tes = Testudinella, Tri = Trichocerca, Alo = Alona, Bos = Bosminopsis, Chy = Chydorus* and *Eph = Ephemeroporus*. The environmental factors are temperature, pH, salinity, conductivity, transparency, depth, total solid, dissolved oxygen, chlorophyll *a* <20 µm and chlorophyll *a* 20-200 µm. Circles represent genera and arrow lines represent environmental gradients. Length of lines reflects strength of their effect. Genera and lines in the same quadrate indicate a positive correlation whereas genera and lines in opposite quadrates represent a negative correlation.

3.3.2 Mesozooplankton community structure

The results of ordination using CCA analysis on the complete environmental and mesozooplankton data set were presented in table 18-20. The first axis (eigenvalue = 0.127) accounted for a 5.3% variation in environmental factors data. Correlation between the first axis and species-environmental variables was 0.581 and Monte-Carlo permutation testing for the first axis indicated a significant difference (P=0.03). The second axis (eigenvalue = 0.094) accounted for a 3.9% variation in the data set. Correlation between the second axis and species-environmental variables was 0.671 and Monte-Carlo permutation testing for the second axis was highly significant (P=0.01). The third axis (eigenvalue = 0.044) accounted for a 1.8% variation in the data set. Correlation between the third axis and species-environmental variables was 0.513 and Monte-Carlo permutation testing for the third axis was highly significant (P=0.05).

The derived CCA scores (Fig. 30) with dominant genera and environmental variable data indicated that the lake showed limnological differences between periods, as seen in the microzooplankton community. In the light rainy and dry periods the lake had high total solid, pH, salinity and conductivity whereas in the dry period only it had high dissolved oxygen, and in the rainy period it had the highest depth (Fig. 30a). However, there were no clear differences between zones (Fig. 30b).

For CCA ordination, the genera environmental biplot showed the relationship between genera and environmental variables with the ordination axes (Fig. 31). There was a distinct correlation between genera and their abundance and the six environmental factors, dissolved oxygen (r^2 = 0.84), depth (r^2 = 0.59), conductivity (r^2 = 0.51), total solid (r^2 = 0.48), salinity (r^2 = 0.47) and pH (r^2 = 0.45).

Testudinella, Moina, Moinodaphnia, Mesocyclops and *Neodiatomus* situated in the upper left corner side of the plot were positively correlated with total solid, salinity, pH and conductivity in moderate values, while *Latonopsis, Stenocypris, Alona, Chydorus, Macrothrix* and *Acartia* were observed in the upper right corner side of the plot, associated with high total solid, high salinity, high pH, high conductivity and low depth. *Bosminopsis, Ceriodaphnia, Diaphanosoma, Ilyocryptus* and *Microcyclops* situated in the lower left side of the plot were associated with high depth and low total solid, low salinity, low pH and low conductivity. *Thermocyclops* and *Karualona* were observed in the lower right side of the plot, associated with the highest dissolved oxygen. The other genera such as *Cypricercus, Euryalona and Metacyclops* were also positively influenced by this factor but at more moderate values.

Table 18. Canonical correspondence analysis for environmental data.

INTER-SET CORRELATIONS for 10 factors

Variable	Correlations Axis 1	Axis 2	Axis 3
1 Temp	.176	.227	.144
2 pH	.120	.376	-.117
3 Conductivity	.197	.385	-.276
4 Salinity	.188	.372	-.247
5 Transparency	-.068	-.069	-.187
6 Depth	-.157	-.414	-.290
7 DO	.518	-.183	-.068
8 TS	.118	.380	-.316
9 Chl a (20-200 µm)	.024	-.114	-.194
10 chl a (<20 µm)	-.002	-.148	-.126

Note: Obtain joint plots or biplots by selecting GRAPH, then requesting "Joint plots" from the GRAPH menu.

Table 19. Canonical correspondence analysis for environmental data.

AXIS SUMMARY STATISTICS
Number of canonical axes: 3
Total variance ("inertia") in the species data: 2.398

	Axis 1	Axis 2	Axis 3
Eigenvalue	.127	.094	.044
Variance in species data			
% of variance explained	5.3	3.9	1.8
Cumulative % explained	5.3	9.2	11.0
Pearson Correlation, Spp-Envt*	.581	.671	.513
Kendall (Rank) Corr., Spp-Envt	.346	.484	.316

* Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables. Set to 0.000 if axis is not canonical.

Table 20. Monte-Carlo test for species-environmental correlations.

MONTE CARLO TEST RESULTS -- SPECIES-ENVIRONMENT CORRELATIONS

	Real data	Randomized data Monte Carlo test, 99 runs			
Axis	Spp-Envt Corr.	Mean	Minimum	Maximum	p
1	.581	.463	.337	.609	.0300
2	.671	.440	.318	.586	.0100
3	.513	.420	.299	.538	.0500

p = proportion of randomized runs with species-environment correlation greater than or equal to the observed species-environment correlation; i.e.,
p = (1 + no. permutations >= observed)/(1 + no. permutations)

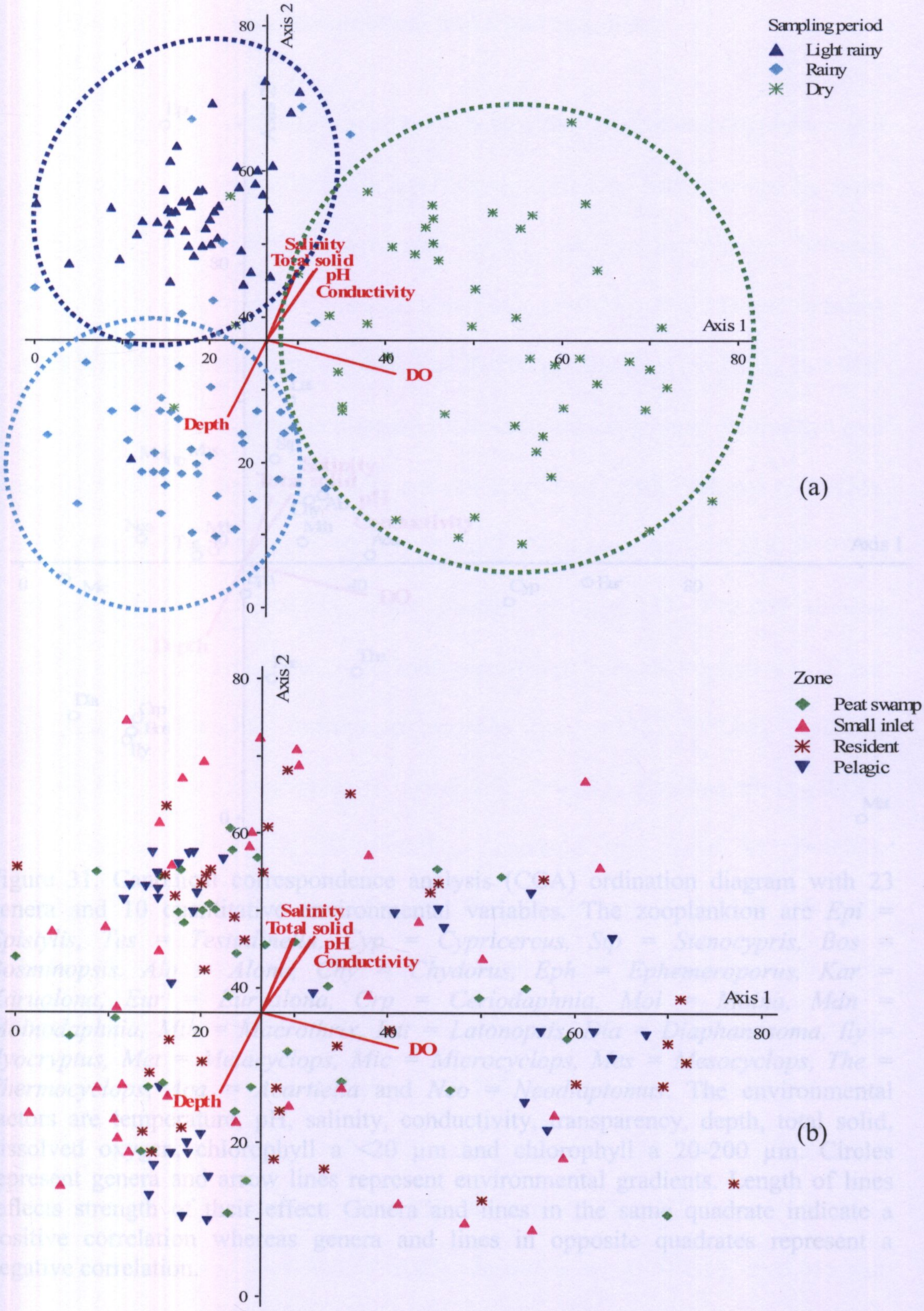


Figure 30. CCA ordination of samples and important variables of the three sampling periods (a) and four zones of Thale-Noi (b).

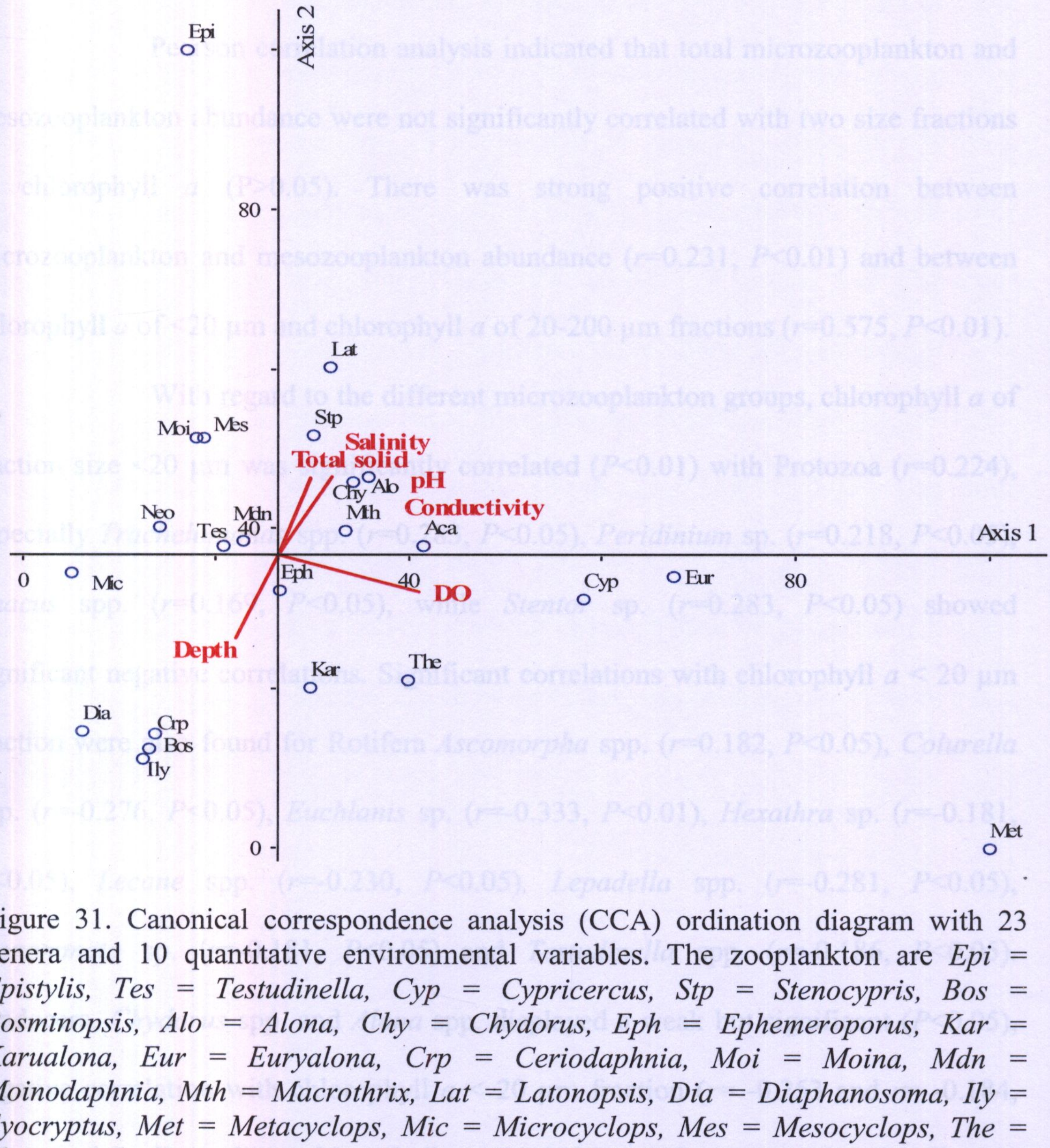


Figure 31. Canonical correspondence analysis (CCA) ordination diagram with 23 genera and 10 quantitative environmental variables. The zooplankton are *Epi* = *Epistylis, Tes* = *Testudinella, Cyp* = *Cypricercus, Stp* = *Stenocypris, Bos* = *Bosminopsis, Alo* = *Alona, Chy* = *Chydorus, Eph* = *Ephemeroporus, Kar* = *Karualona, Eur* = *Euryalona, Crp* = *Ceriodaphnia, Moi* = *Moina, Mdn* = *Moinodaphnia, Mth* = *Macrothrix, Lat* = *Latonopsis, Dia* = *Diaphanosoma, Ily* = *Ilyocryptus, Met* = *Metacyclops, Mic* = *Microcyclops, Mes* = *Mesocyclops, The* = *Thermocyclops*, *Aca* = *Acartiella* and *Neo* = *Neodiaptomus*. The environmental factors are temperature, pH, salinity, conductivity, transparency, depth, total solid, dissolved oxygen, chlorophyll a<20 μm and chlorophyll a 20-200 μm. Circles represent genera and arrow lines represent environmental gradients. Length of lines reflects strength of their effect. Genera and lines in the same quadrate indicate a positive correlation whereas genera and lines in opposite quadrates represent a negative correlation.

3.3.3 Relationships between zooplankton and Chlorophyll *a*

Pearson correlation analysis indicated that total microzooplankton and mesozooplankton abundance were not significantly correlated with two size fractions of chlorophyll *a* (P>0.05). There was strong positive correlation between microzooplankton and mesozooplankton abundance (*r*=0.231, *P*<0.01) and between chlorophyll *a* of <20 μm and chlorophyll *a* of 20-200 μm fractions (*r*=0.575, *P*<0.01).

With regard to the different microzooplankton groups, chlorophyll *a* of fraction size <20 μm was significantly correlated (*P*<0.01) with Protozoa (*r*=0.224), especially *Trachelomonas* spp. (*r*=0.283, *P*<0.05), *Peridinium* sp. (*r*=0.218, *P*<0.05), *Phacus* spp. (*r*=0.169, *P*<0.05), while *Stentor* sp. (*r*=0.283, *P*<0.05) showed significant negative correlations. Significant correlations with chlorophyll *a* < 20 μm fraction were also found for Rotifera *Ascomorpha* spp. (*r*=0.182, *P*<0.05), *Colurella* spp. (*r*=-0.276, *P*<0.05), *Euchlanis* sp. (*r*=-0.333, *P*<0.01), *Hexathra* sp. (*r*=-0.181, *P*<0.05), *Lecane* spp. (*r*=-0.230, *P*<0.05), *Lepadella* spp. (*r*=-0.281, *P*<0.05), *Monommata* sp. (*r*=-0.181, *P*<0.05) and *Testudinella* spp. (*r*=-0.186, *P*<0.05). Cladocera, *Chydorus* spp. and *Alona* spp. displayed a weak but significant (*P*<0.05), negative correlation with chlorophyll *a* < 20 μm fraction (*r*= -0.253 and *r*= -0.184, respectively). Regarding chlorophyll *a* 20-200 μm fraction, only *Arcella* sp. (*r*=0.167), *Ascomorpha* spp. (*r*=0.167) and *Asplanchna* spp. (*r*=0.177) showed significant positive correlations (*P*<0.05). Moreover, *Colurella* spp. (*r*=-0.211, *P*<0.05), *Euchlanis* sp. (*r*=-0.207, *P*<0.05), *Hexathra* sp. (*r*=-0.318, *P*<0.01) and *Lepadella* spp. (*r*=-0.183, *P*<0.05) displayed negative correlations with chlorophyll *a* 20-200 μm fraction (Table 21).

With regard to mesozooplankton, no significant relationships were obtained between mesozooplankton and chlorophyll *a* of <20 μm fraction size but significant relationships were obtained between mesozooplankton and chlorophyll *a* of 20-200 μm fraction size. The correlation analysis between different mesozooplankton groups and chlorophyll *a* of 20-200 μm fraction size revealed significant correlations with only Ostracoda (r=0.17, $P<0.05$) and Copepoda (r=0.233, $P<0.01$). However, positive significant correlations with chlorophyll *a* of 20-200 μm fraction size were also found for Cladocera *Diaphanosoma* spp. (r=0.211, $P<0.05$). In addition, Ostracoda *Cypricercus* sp. (r=0.182, $P<0.05$), Copepoda *Metacyclops* sp. (r=0.255, $P<0.01$) and *Acartia* sp.(r=0.179, $P<0.05$) exhibited a weak but significant positive correlation with chlorophyll *a* of 20-200 μm fraction size (Table 22). Other groups did not show any clear relationship with these two size fractions of chlorophyll *a*.

Table 21. Pearson correlation between microzooplankton and two size fractions of chlorophyll *a*.

	Chlorophyll *a* <20 µm	**Chlorophyll *a* 20-200 µm**
Protozoa	0.224*	ns
Arcella	ns	0.167*
Peridinium	0.218*	ns
Phacus	0.202*	ns
Stentor	-0.165*	ns
Trachelomonas	0.283*	ns
Rotifera	ns	-0.199*
Ascomorpha	0.182*	0.167*
Asplanchna	ns	0.177*
Colurella	-0.276**	-0.211*
Euchlanis	-0.333**	-0.207*
Hexathra	-0.181*	-0.318**
Lecane	-0.230*	ns
Lepadella	-0.281*	ns
Monommata	-0.181*	ns
Testudinella	-0.186*	ns
Cladocera	-0.175*	ns
Alona	-0.184*	ns
Chydorus	-0.253*	ns
Crustacean nauplii	ns	-0.173*

*ns=not significant; *P <0.05; **P <0.01.*

Table 22. Pearson Correlation between mesozooplankton and two size fractions of chlorophyll *a*.

	Chlorophyll *a* <20 µm	Chlorophyll *a* 20-200 µm
Ostracoda	ns	0.17*
Cypricercus	ns	0.182*
Cladocera	ns	ns
Diaphanosoma	ns	0.211*
Copepoda	ns	0.233*
Acartia	ns	0.198*
Metacyclops	ns	0.255**

*ns= not significant; *P <0.05; **P <0.01.*

CHAPTER 4

DISCUSSION

4.1 Environmental variables in Thale-Noi

In the present study, the areas of Thale-Noi were divided into four zones according to habitat differences: the peat swamp, the small inlet, the resident and the pelagic zones. Sampling sites within each zone were similar to previous studies (Tunsakul, 1983; Angsupanich and Rukkhiaw, 1984; Angsupanich, 1985; Chiayvareesajja *et al.*, 1988; Nookua, 2003) but the study criteria and objectives for the present study were different. Previous studies did not concentrate on habitat differences but tried to provide complete sampling coverage of all areas. Even though Thale-Noi is comprised of many diverse microhabitats, the environmental variables in each zone did not show clear differences during the study period. However, most of the environmental variables were obviously different among season. The small inlet zone showed relatively high levels of depth, total solid, conductivity and salinity as compared to other zones. This may have been due to the influence of water run-off, the retention time of materials and the incorporation of nutrients (Chiayvareesajja *et al.*, 1988). Low pH values were observed in the peat swamp zone compared to other zones. This was due to the fact that this zone receives acidic water directly from the peat swamp forest. The resident and the pelagic zones do not have distinct environmental characteristics. However, these zones which had optimum pH and rather high dissolved oxygen were found to be have more fluctuation all year round. Also, environmental characteristics of the resident zone are probably due to the additional effects of discharged water from domestic areas and agricultural land (Tunsakul, 1983; Chiayvareesajja *et al.*, 1988). High organic production and nutrient enrichment encouraged the growth of aquatic plants and phytoplankton which in turn led to high levels of dissolved oxygen. Additionally, environmental factors at the pelagic zone may be explained by the input of water nutrient from the area around Thale-Noi and also the effect of the wind action.

Seasonal changes of environmental factors in Thale-Noi are subject for the influence of the precipitation and monsoon systems (Aiumnau *et al.*, 2000). While these features are common to a large number of the freshwater environments (Chaiubol, 1998), the present study has shown a clear pattern of seasonal environmental factors. The patterns in the light rainy and the dry periods were quite similar, but it was differences in the rainy period.

The present study showed that water depth at Thale-Noi was directly correlated to rainfall as previously observed by Nookua (2003) and Buapetch (2002). It has been demonstrated that water depth closely follows precipitation values. However, the result of precipitation measurement during the year long study was not as expected. Instead of the dry period having the lowest precipitation value, the lowest value was found to be in the light rainy period. This may have been due to the received effects of the southwest monsoon (Suphakason, 1992).

In Thale-Noi, transparency was inversely correlated to pH. Therefore, higher values of transparency were observed in months with lower pH values. Remarkably, the study showed that pH values of water samples collected from the small inlet zone were quite low in the rainy period. This may have been due to the effects of the leaching of acidic water from the peat swamp forests during periods of flooding (Chiayvareesajja *et al.,* 1988). With regard to pH value, it can be observed that the range of pH values in Thale-Noi, especially in the rainy (5.9-7.7) and the dry (5.0-8.7) periods, were less than the optimum range of pH for fish production (6.5-9.0) (Swingle, 1969).

Seasonal variation of water salinity, total solid and conductivity are essentially controlled by the river flow from Songkhla Lake (Pornpinitpong, 2004). Values for these factors were higher in the light rainy and the dry periods while, in contrast, they were rather low in the rainy period. This was probably due to the great influx of seawater when the water level of the lake is low, and is consistent with a previous study by Pornpinitpong (2004) who found that seawater intrusion in Thale-Noi occurs during the dry season or when the water level is low. An increase in turbidity is caused by the transportation of sediment from canals while in the rainy period the lake receives the effects of dilution from superficial water. In addition, the small inlet zone located in the canals was found to have the highest values of conductivity as per previous investigations (Nookua, 2003; Keowsurat, 1987).

The pattern of seasonal Dissolved Oxygen (DO) variations in Thale-Noi showed rather high levels in the dry period and quite low levels in the light rainy period. However, normal DO concentrations were measured during the rainy period which indicates that the environment is suitable for organism-living. DO concentrations may be dependent on the rate of photosynthesis and temperature variations (Iqbal *et al.,* 2006). Additionally, higher levels of DO may have been the result of wind action which causes the different water layers to mix together (Torres and Rylander, 2006). The DO in Thale-Noi varied widely (0.9-9.1 $mg.l^{-1}$) but was within the same range as previous studies (0.9-8.8 $mg.l^{-1}$; Nookua, 2003 and 1-8 $mg.l^{-}$

^{1}; Buapetch, 2002). Furthermore, the patterns of DO concentrations were found to be similar in all zones.

The results of the present investigation indicate that for most of the annual cycle the pico-nanophytoplankton (chl *a* <20 μm) fraction size is the most abundant fraction size of total chl *a* in Thale-Noi. This fraction accounted for 43 and 82 % of the total chl *a* throughout the year, the only exception being recorded in early July when chl *a* of fraction size 20-200 μm dominated the overall concentration. This observation is similar to those of Paphavasit *et al.* (2006) for nearby water areas in Thailand. Investigations in other freshwater (Jong-Jeon *et al.*, 2001) and marine environments (Bruno *et al.*, 1983; Cole *et al.*, 1986; Froneman *et al.*, 2004; Shiomoto, 1997) have also revealed nanophytoplankton to be the most abundant size group. The important question to consider here is why chl *a* < 20 μm become abundant at this time of year? Pico-nanoplankton have been hypothesized to have advantages due to intrinsically higher growth and photosynthetic rates, and to nutrient uptake rates of small algal cells with high surface-to-volume ratios, compared to that found in large cells (Cole *el at.*, 1986; Hamasaki *et al.,* 1998).

Chl *a* fraction size of < 20 μm ranged from 1,192-5,670 mg.m^{-3}; the mean value of concentration was the highest at the small inlet zone. This indicates that this zone is affected the most by nutrients in the water flowing from Thale Luang through Nang Riam Canal, Ban Glang Canal and Yuan Canal and by wind mixing of surface layers associated to active growth. Chl *a* fraction size of 20-200 μm ranged from 582-3,885 mg.m^{-3}; the mean value of concentration was the highest at the resident zone, which might have been influenced by the waste water flowing in from the surrounding city area, containing a lot of essential nutrients for microphytoplankton growth. This result was similar to the results found by Tunsakul (1983), Chiayvareesajja *et al.* (1988) and Nookua (2003) all of whom reported that the highest chlorophyll *a* or phytoplankton density in Thale-Noi was found at station 1 which is closest to the resident area. Although there was no significant difference between sampling periods between the two size fractions of chl *a,* it appears that light and temperature are important factors regulating the dynamics of both size fractions of phytoplankton, and that nutrients are relatively unimportant since they are available in sufficient amounts to meet phytoplankton demand. This has been suggested previously for Thale-Noi (Nookua, 2003) and for marine water in general (Bruno *et al.*, 1983).

4.2 Zooplankton communities in Thale-Noi

The present study has shown a clear pattern (in density) of seasonal total zooplankton fluctuation, as has been observed in other freshwater ecosystems, e.g. Aug kaew Reservoir, Thailand (Chaiubol, 1998), River Danube, Austria (Reckendorfer *et al.*, 1999) and Lake Bracciano, Italy (Ferrara *et al.*, 2002). The results were related to environmental effects, especially seasonal rainfall. In the rainy period, a high abundance of total zooplankton seemed to coincide with high chl *a* concentrations < 20 µm (Inpang *et. al*, 2007), which may indicate increased growth and survival in high productive areas. Moreover, in this period the lake was subject to periodic flooding, which is generally when the greatest density of zooplankton occurs. This is because the flooding establishes a connection with the lower lake which increases food availability by bringing nutrient and material input. In the dry period, a clear pattern in total zooplankton community structure was observed, associated with a high chl *a* concentration of 20-200 μm fraction size (Froneman, 2001; Inpang *et al*, 2007), which was due in turn to a large phytoplankton bloom (Nookua, 2003). The dry period brings greater stability and food availability due to organic matter production and decomposition, as exemplified in other freshwater environments (Lam-Hoai *et al.*, 2006; Silva *et al.*, 2004). In the light rainy period, the lack of a peak is probably caused by low chl *a* concentrations. Moreover, we found that predators such as fish larvae and crab larvae, etc. occurred in this period. A similar result was noted by Aiumnau *et al.* (2000) who observed a high abundance of fish in Thale-Noi during this same period. Thus, it may explain that zooplankton density is limited by the presence of predators. Currently, little is known about the size structure of freshwater zooplankton. In Thale-Noi, the small size fraction of zooplankton (20-200 μm), consisting mainly of protozoans and rotifers, accounts for > 70% of total zooplankton. Zooplankton in the size range > 200 μm (mainly cladocerans and copepods) represents the second most important group, generally contributing < 20% of total zooplankton. This result indicates that smaller organisms may be of importance in the community structure as a trophic link between classical and microbial food webs. By virtue of their small body size, these organisms can exploit small food particles that are unavailable to most meso-and macrozooplankton, and thus act as trophic intermediaries between pico-and nanoplankton and meso-and macro-carnivores (Godhantaraman, 2003).

4.2.1 Species composition and diversity

In the present study, the number of phyla found was higher than that found from previous studies in Thale-Noi (Angsupanich, 1995; Chiayvareesajja *et al.*, 1988) and also higher than that found in previous studies for other freshwater bodies in Thailand, such as Ang Kaew Reservoir (Chaiubol, 1998) and Pasak Jolasid Reservoir (Jithlang and Wongrat, 2004). The microzooplankton composition of Thale-Noi consists mainly of protozoans, rotifers, cladocerans, copepods, including larvae and juvenile forms such as juvenile ostracods, crustacean nauplii and copepodite copepods. While the mesozooplankton composition, in addition to the holoplanktonic groups found in the microzooplankton also consists of some meroplanktonic groups such as shrimp larvae, gastropod larvae, bivalve larvae, crab larvae and fish larvae. These meroplanktonic groups were observed in low densities and frequencies. In the rainy period, the freshwater movement from other parts of the lake has a strong influence and the intrusion effect flushes several species out of the lake. This, in turn, allows protozoans, rotifers, cladocerans and copepods to grow, even in areas covered with macrophyte, such as the peat swamp and resident zones which have a higher number of taxa, especially rotifers and cladocerans than those of other areas. This observation is similar to those found by Jithlang and Wongrat (2004) and Pinto-Coelho *et al.* (2005).

Rotifera was the group with the highest taxonomic richness (33 genera) in Thale-Noi. This result concurs with reports from other freshwater environments, especially in the tropical region (Starling, 2000; Sampaio *et al.*, 2002; Akin-Oriola, 2003; Keppeler, 2003; Wansuang and Sanoamuang, 2006). The large species number of this group is due to the fact it is considered to be an opportunistic species in different environments (Keppeler, 2003). There is a series of advantages in the rotifer's system of reproduction which could favor the participation of most of these animals in an opportunistic, colonizing lifestyle (Birky and Gilbert, 1971). Additionally, the wide spectrum of food particles exploited by this group, which display the ability to consume bacteria, algae and detritus of different size, allows quite distinct diets for the many species simultaneously present in a body of water (Sampaio *et al.*, 2002). The Rotifera families with the greatest number of species were Brachionidae and Lecanidae, which are considered typical for, and most frequent in, tropical environments (Dumont, 1983; Keppeler and Hardy, 2004).

Cladocera was the second most diverse group of the community, as has been reported in other investigations (Pholpunthin, 1997; Maria-Heleni *et al.*, 2000; Ferrara *et al.*, 2002; Bekleyen, 2003). The diversity of Cladocera in Thale-Noi was rather high (26 genera) as compared to other studies on species diversity of cladocerans in temporary waters (Wansuang and Sanoamuang, 2006). This may have been due to Thale-Noi having diverse aquatic plants which act as a habitat, food source and refuge for cladocerans. According to Sa-ardrit (2002), cladocerans prefer to inhabit areas which are largely colonized by submerged and emerging macrophytes. Regarding Cladocera diversity and abundance, it can be observed that Cladocera was equally diversity and abundance in both microzooplankton and mesozooplankton community. This may be due to the effects of clogging of plankton net.

There is little previous data on Protozoa species in the lake, so it is difficult to assess how communities are changing. It is also difficult to make distinct classifications for certain species of protozoa, whether they are zooplankton or phytoplankton. The 25 protozoan taxa were comprised of seven flagellates (including algal flagellates), ten sarcodines and eight ciliates, indicating less species diversity than previously found in freshwater environments in Thailand (Charubhun and Charubhun, 2000). In general, regarding these three groups of protozoa, the ciliates exhibited the greatest diversity in the lake (Baldock *et al.*, 1983), but it is very difficult to identify some species of the smaller organisms after the preservation process. Many factors are involved, such as water quality, predation and other environmental elements, in influencing species composition and community development of protozoa in aquatic ecosystems (Xu *et al.*, 2005).

Overall, eleven genera of Copepoda were identified in the present study. The genera found were generally similar to those described in previous studies from Northeast Thailand (Sanoamuang and Faitakum, 2005; Wansuang and Sanoamuang, 2006) and Southern Thailand (Pholpunthin, 1997), the exceptions being some species such as *Acartia* cf. *southwelli* which may be newly recorded species for Thailand. However, in Thailand, the taxonomic richness of Copepoda and Ostacoda is quite low. This may possibly be due to the fact that key to identification of these groups has been limited. However, copepodite copepods and crustacean nauplii were found throughout this study.

Of the Meroplankton community in Thale-Noi, only shrimp larvae were found constantly throughout the present study while the remaining groups appeared only during the dry and light rainy periods. This may have been due to low rainfall which indicates the period most meroplankton groups reproduce and spawn. Although previous zooplankton studies have not reported the presence of merozooplankton in Thale-Noi, it was evident in Thale Sap Songkhla, where it bloomed during a month of low temperature and low rainfall (Augsupanish, 1997).

In the present study, apart from zooplankton groups, meiofauna and other groups such as, amphipods, gastrotrichs, water mites, chaoborus, midge larvae, oligochaete, free-living nematode, insect larvae and hydra, etc. were usually found in the water samples. This had not been reported in Thale-Noi before. Angsupanich *et al.* (1997) and Angsupanich (1997) found some species of amphipods in Thale Sap Songkhla that typically inhabit the seawater zone. It is of little surprise, perhaps, that this study found them only in the small inlet zone (Nang Riam station), and only in the light rainy period. Possibly, this location obtains seawater from Thale Sap Songkhla through a small canal when the water level is at its lowest.

4.2.2 Occurrence of zooplankton in Thale-Noi

The zooplankton found in Thale-Noi are common species and most genera are cosmopolitan, as recorded in Kanchanaburi province, Thailand (Pipatcharoenchai, 2001), and also similar to those recorded by other authors in tropical regions (Bekleyen, 2002; Keppeler, 2003). In this study, only two genera of zooplankton were represented by season. *Floscularia* occurred during the dry period while *Macrochaetus* occurred during the light rainy period. In Bonita Pond, these genera were the littoral rotifers genera (Starling, 2000). In Lake Vortsjarv, among the recorded species, *Keratella cochlearis*, *Polyarthra dolichoptera, Filinia* sp. and *Trichocerca* species are well-known indicators of eutrophy (Haberman, 1998). Additionally, *Brachionus* has been used as an indicator organism for trophic characterization of lakes (Mageed, 2007). Higher genera frequency, mainly of protozoans occurred during the dry period whereas a higher frequency of rotifers and cladocerans occurred in the rainy period than that of other periods. Variations in genera occurrence and changes due to environmental conditions were generally obvious during all sampling periods.

4.2.3 Relative abundance and density of zooplankton

In the present investigation, microzooplankton was dominated by Protozoa and Rotifera, which made up nearly 70% of the total microzooplankton. The dominance of Protozoa or Rotifera in tropical freshwaters has already been described by Torres-Orozco and Zannatta (1998), Sampaio *et al.* (2002) and Sandacz *et al.* (2006). In this study, the dominant zooplankton groups exhibit differences with previous research (Chiayvareesajja *et al.,* 1988; Angsupanich, 1995). They reported that rotifers were the most abundant group throughout the study, followed by nauplii larvae or copepodite stages. The scarcity of protozoans in their samples suggests that they could have used a mesh diameter wider than 20 μm, and this could have led to underestimating the quantity of smaller organisms. This may be one reason why there was a lack of small groups in previous studies as compared to this study. However, it is difficult to make definite conclusions on the causes of group differences between different studies because of the differences in sample size, differences in sampling methods and differences in sampling frequencies.

In the present study there was a succession of microzooplankton species throughout the year. During the light rainy period, different species of rotifers alternated in dominance, represented mainly by *Polyarthra* and *Anuraeopsis*. This is supported by the fact that these genera were commonly found in many other lakes

(Naves *et al.*, 2003; Yildiz *et al.*, 2007) and were dominant species in tropical freshwater environments (Jithlang and Wongrat, 2004). It is also in agreement with the results of Mageed (2007), who discovered that *Hexathra, Polyarthra* and *Filinia* are greatest during the hot period. Torres-Orozco and Zanatta (1998) found that the relative abundance of rotifers was directly related to water temperature variations. It has been demonstrated that abundance of rotifers closely follows temperature variations because temperature has a major influence on their reproductive rate, feeding, movement and longevity (Miksci, 1989). From November to December (the rainy period), low water temperature and high rainfall led to a decrease in rotifer populations and they were replaced by protozoans, represented by *Trachelomonas* and *Peridinium.* Up until the dry period, protozoans were strongly dominant in the community. This is similar to the findings of Graham *et al.* (2004), who found that *Peridinium limbatum* was the dominant dinoflagellate in the sense that it persisted throughout the entire open-water season and was the dominant community in the summer. Hadas and Berman (1998), who studied seasonal abundance and vertical distribution of Protozoa in Lake Kinneret, Israel, have suggested that during the *Peridinium* bloom in late February there was a rise in ciliate abundance, concomitant with the increase of particulate organic detritus and dissolved organic matter, which stimulated bacterial and heterotrophic nanoflagellates outgrowth and they found high numbers of heterotrophic nanoflagellates, coinciding with peaks of chlorophyll *a* and primary production.

The high population density of rotifers has been attributed to their parthenogenesis reproductive pattern, short life cycles and wide tolerance to a variety of environmental factors (Akin-Oriola, 2003; Keppeler and Hardy, 2004; Park and

Marshall, 2000). The abundance of protozoans suggests that it plays a substantial role in nutrient regeneration in the water column, indicating that they often become the main zooplankton in the community. This suggests that protozoans must have a key trophic role that may contribute to the high productivity of the lake food web (Pirlot *et al.*, 2005). In general, and particularly in tropical waters, the microzooplankton distribution and abundance varies considerably due to seasonal fluctuations (Sampaio and Lopez, 2000). This observation agrees with studies of the reservoirs of the Paranapanema River (Sampaio *et al.*, 2002). The highest density of microzooplankton, particularly protozoans, in the dry period may be attributed to a combination of temperature, salinity and chlorophyll *a* concentrations, which are often considered the most important factors in acceleration of the growth rate (Eskinazi-Sant'Anna and Bjornberg, 2006).

Regarding spatial variation, there were no significant differences in microzooplankton density among zones. However, microzooplankton densities at stations located at the small inlet zone, connected to Songkhla Lake, were high as compared to those of other zones. It may be that this zone had high water level and inputs of suspended sediments. The results indicate that these factors, combined with high nutrient levels, are essential for plankton growth (Conde-Porcuna *et al.,* 2002; Pinto-Coelho *et al.,* 2005). Thus, spatial differences in density seem to be related with the entrance of the river waters, as a result of increased food availability due to nutrient and material input. This is consistent with Chiayvareesajja *et al.* (1988) who suggested that this zone seems to be the most appropriate site for aquaculture in Thale-Noi.

The dominant groups of microzooplankton were similar in all zones but difference species dominated. Based on the number of sampling times in which a species was numerically dominant in the microzooplankton, the dominance hierarchy for the peat swamp zone was *Trachelomonas* (3) > *Peridinium* (2) = *Stentor* (2) = *Polyarthra* (2) > *Lepocinclis* (1) = *Dinobyon* (1) = *Arcella* (1). In the small inlet zone, *Trachelomonas* (4) > *Polyarthra* (3) > *Keratella* (2) > *Anuraeopsis* (1) = *Tintinopsis* (1). In the resident zone, *Polyarthra* (5) > *Trachelomonas* (3) > *Peridinium* (1) = *Stentor* (1) = *Lecane* (1). In the Pelagic zone, *Trachelomonas* (6) > *Anuraeopsis* (2) > *Polyarthra* (1) = *Keratella* (1) = *Stentor* (1) = *Euglena* (1). The dominance of *Polyarthra* in the resident zone was very common as found in other environments (Duggan *et al.*, 2002). These results are consistent with Torres-Orozco and Zanatta (1998) who suggested that a eutrophic lake is characterized by rotifers genera *Polyarthra, Brachionus, Keratella, Filinia, Conochilus* and *Trichocerca.* Additionally, it was discovered in the peat swamp zone that several species of protozoans alternated in dominance; suggesting that water quality in this zone is favorable for protozoan reproduction. The causes for high protozoan levels in this zone could have been high organic production (due to perished vegetation), low water level which made it difficult to sample zooplankton, and possible clogging of the plankton net by organic matter which then led to the measurement of protozoan numbers being overestimated.

The Mesozooplankton group, Cladocera was found to have a relatively high abundance of > 80% in the rainy period while Copepoda and other groups showed a relatively high level of abundance in the light rainy and dry periods. The presence of a clear seasonal pattern in the total abundance of the mesozooplankton community, as in Thale-Noi, has also been recorded at Lake Heyes (Burns and Mitchell, 1980). The higher densities of mesozooplankton in the rainy period associated with eutrophic water mass may be due to increased quantities of pico-nanophytoplankton and microzooplankton, which are consumed by the mesozooplankton (Pedersen *et al.*, 2005). In addition, the absence or low density of fish, crab and shrimp larvae (predators of zooplankton) during the rainy period may be one of the main causes of the increase in small mesozooplankton. There was a succession of mesozooplankton species throughout the year. Cladocera, mainly *Chydorus* spp., *Bosminopsis deitersi*, Copepoda *Neodiaptomus yangtsekiangensis* and *Acartiella sinensis* alternated in community dominance in the light rainy period while high densities of Cladocera were registered mainly in the rainy period, especially *Bosminopsis deitersi*. In the dry period, the mesozooplankton community was dominated by Cladocera *Chydorus* spp. and *Dunhevedia crassa.* During population peaks, a large amount of *Bosminopsis deitersi* was recorded (1,512,000 ind.m^{-3}) (Table 6), which might reflect short-term changes in reproductive potential for parthenogenesis, depending on changes in the abundance of food (Paranagua *et al.*, 2005). Some author (Viroux, 2002) have questioned the capacity of cladocerans to accomplish their life cycle in rivers, given the usually short time at their disposal. A dominance of copepods in Thale-Noi occurred occasionally, e.g. *Neodiaptomus yangtsekiangensis* and *Acartiella senensis.* Allan (1976) suggested that the K-selected life history of copepods (such as low reproductive rates and low susceptibility to predation) give them a competitive advantage in seasonally stable ecosystems.

Regarding spatial variations, total mesozooplankton abundance was higher for the small inlet and pelagic zones than for the peat swamp and resident zones. This high abundance could possibly be due to high densities of cladoceran *Bosminopsis deitersi* during late November, copepods, mainly *Pseudodiaptomus* sp. in early March, and *Metacyclops* sp. in late march. The food supplied by freshwater inflow through the small inlets during the rainy period in November and December seemed to be important for inducing growth of all zooplankton taxa when salinity was very low (Angsupanich and Rukkheaw, 1997).

There were remarkable differences in dominant species among zones. Based on the number of sampling times in which a species was numerically dominant in the mesozooplankton, the dominance hierarchy for the peat swamp zone was *Bosminopsis* (5) > *Metacyclops* (2) > *Voticella* (2) > *Neodiaptomus* (1) = *Chydorus* (1) = *Testudinella* (1). In the small inlet zone, *Chydorus* (3) > *Bosminopsis* (2) = *Ephemeroporus* (2) = *Acartiella* (2) > *Mesocyclops* (1) = *Metacyclops* (1) = *Pseudodiaptomus* (1). In the resident zone, *Chydorus* (6) > *Bosminopsis* (2) = *Dunhevedia* (2) = *Latonopsis* (2). In the pelagic zone, *Chydorus* (4) = *Bosminopsis* (4) > *Metacyclops* (2) > *Neodiaptomus* (1) = *Microcyclops* (1). Remarkably, only the small inlet zone was found to have a distinct copepod domination, especially in the light rainy and dry periods. The present results support the theory that these copepods may be distributed from brackish water (Thale Luang). Furthermore, only a single zone of Thale-Noi (the resident zone) was dominated by cladocerans alone, indicating that some species of Chydorids prefer a weed or vegetation habitat (Blindow *et al.,* 2000; Goulden, 1971). The remarkable community of cladocerans indicates abundant phytoplankton with large habitat diversity (Cottenie and Meester, 2003; Lovik and Kjellberg, 2003; Nurminen *et al.,* 2007) and low predation (Ramdani *et al.*, 2001).

4.3 Relationships between zooplankton densities and environmental parameters

From CCA analysis it was revealed that, besides changes in seasonal temperature, salinity and total solids, the main environmental gradients were due to pH, transparency and dissolved oxygen. These gradients are a common feature of other freshwater ecosystems having a pronounced temporal effect on the zooplankton composition and distribution (Branco *et al.*, 2002; Ferrara *et al.*, 2002; Keppeler, 2003; Michaloudi and Kostecka, 2004; Mageed and Heikal, 2006). Nitrate and phosphate concentration, temperature and oxygen levels are very important in determining the seasonality in zooplankton species composition and abundance (Maria-Heleni *et al.*, 2000; Wang *et al.*, 2007). The controlling factor responsible for when species can survives in different periods in Thale-Noi is the individual species range of environmental tolerance. Environmental conditions in the light rainy and dry periods were similar, both periods being associated with low rainfall, which was opposite to that generally described in the rainy period.

According to the present results, the conductivity and pH increased while depth and transparency decreased during the light rainy period. This was due to very low rainfall and a lack of sediment flow which caused inorganic matters to accumulate, especially at the bottom. Similar results have been found in Thale-Noi (Nookua, 2003). The most abundant microzooplankton, such as *Loxodes, Peranema, Stentor, Anuraeopsis, Brachionus, Colurella, Collotheca, Euchlanis, Filinia, Hexathra, Lepadella, Macrochaetus, Testudinella, Trichocerca, Proales, Mytilina* and *Alona,* and species within the mesozooplankton community, such as *Moina, Moinodaphnia, Neodiaptomus* and *Mesocyclops,* reacted positively to conductivity and pH, but negatively to depth and transparency. It can be suggested that most of these genera have an optimum set of environmental conditions to ensure their survival. These findings were similar to those findings from the Funil Reservoir (Branco *et al.*, 2002), where *Hexathra mira* and amoeba related to low water transparency, while *Filinia longiseta* were the taxa most positively correlated with high water transparency. Wang *et al.* (2007) found that *Moina micrura* peaked in lakes with low SD (secchi disk visibility) and depth, and suggested that temperature seemed to be an important factor when determining the dominance of *Moina micrura*. Some taxons appeared in Lago Amapa at basic or neutral pH and relatively low dissolved oxygen levels, such as *Platyas guadricornis, Lepadella ovalis, Trichocerca similis and Testudinella patina*. The researchers suggested that these factors are not considered limiting for those species studied in the lake (Keppeler and Hardy, 2004). However, among rotifers, along with *Euchlanis dilatata, Trichocerca* sp., *Pompholyx* sp., *Keratell quadrata* and *Filinia longiseta* were often found in eutrophic lakes (Bekleyen, 2003).

Protozoans *Centropyxis, Euglyphra, Halteria, Tracheomonas, Undella,* rotifers *Plationus,* cladocerans *Alona, Chydorus, Ephmeroporus*, *Karualona, Macrothrix*, *Latonopsis*, ostracods, *Cypricercus, Stenocypris,* and copepods *Acartia, Euryalona, Metacyclops* and *Thermocyclops* were the most abundant and frequently observed taxa during the dry period. Although, this period has generally low rainfall, it was higher than that in the light rainy period. On the other hand, there was a gradient of moderate to high total solids, salinity, pH, conductivity, and the highest levels of dissolved oxygen and water temperature. The favourable combination of several factors, including intrusion effects from Thale Luang, results in Thale-Noi being colonized by a high biomass during the dry period, that is, phytoplankton, small zooplankton, vegetation, birds and shrimp (Storer, 1977; Tunsakul, 1983; Nookua, 2003; Leingpornpan and Leingporpun, 2005; Inpang, 2007). Protozoans are important components of microzooplankton communities in lakes during the dry period (Pirlot *et al.*, 2005). Dabes and Velho (2001) reported that the protozoan genus *Centropysis* was equally abundant in both the dry and the rainy seasons. Moreover, they found that some groups of species such as *Centropyxis* spp. and *Diffugiella* sp. were more abundant in the dry season, while *Diffugia, Euglypha* and *Trinema* spp. were more abundant during the rainy season (Dabes and Velho, 2001). Among factors that strongly influence the population density of planktonic protozoans are water quality, quantity of available food, temperature, and predation (Beaver and Crisman, 1990 cited by Xu *et al,* 2005). Cladoceran populations have been associated with trophic gradients in other lakes (Branco *et al.,* 2002). Pinto-Coelho *et al.* (2005a) suggested that cladocerans often occurred simultaneously with blooms of cyanobacteria and floating macrophytes, similar to Nookua (2003) who documented that high densities of blue green algae in Thale-Noi were observed in the dry period and who also found that Cyanophyta has a positive correlation with temperature in April. In addition, the studies of Leingpornpan and Leingpornpan (2005) on aquatic plants and their distribution mapping in Thale Noi Lake, found that the covering of aquatic plants in the dry period was higher than that in the rainy period. Thus, the presence of macrophyte beds in Thale-Noi also influences the zooplankton composition by including Cladocera (Fam.Chydoridae) as observed in the Formosa Pond, Brazilia (Starling, 2000) and in Lake Hanebjerb, Denmark (Romare *et al.,* 2003). Cladoceran species, especially *Chydorus,* live in vegetation habitats most probably to avoid predators such as midges (Goulden, 1971). Among the copepods, *Thermacyclops and*

Mesocyclops are predominant in the lake during this period, and are associated with feeding, hunting for large phytoplankton cells, or eating colonies of Cyanophyceae and small zooplankton, such as the nauplii of other species of Copepoda (Sampaio *et al.*, 2002).

In the rainy period, a period associated with the greatest water depth, were found *Arcella, Peridinium, Phacus, Lepocinclis, Asplanchna, Ascomorpha, Lecane, Polyarthra, Bosminopsis, Ceriodahnia, Diaphanosoma, Ilyocryptus* and *Microcyclops*. These findings can be related to low levels of salinity, total solids, pH and temperature, but moderate dissolved oxygen. Due to high rainfall during the rainy season, the lake water composition is affected by the ingress of water from the upper stream, the swamp forest, and the land which brings nutrient enrichment into the lake. As a result, some species of microzooplankton such as flagellate phytoplankton, become the primary producer and are well represented in terms of total density in Thale-Noi, similar to Chaohu Lake (Xu *et al.*, 2005). One might expect that small rotifer populations would be correspondingly large later on. *Polyarthra* can consume diverse food particles and it appears that niche differentiation among related species has a strong influence on Rotifera assemblage composition and diversity via competitive interactions (Sampaio *et al.*, 2002). The three dominant cladocerans, *Bosminopsis, Ceriodaphnia and Diaphanosoma,* occurred frequently and were relatively dominant in Thale-Noi, although being less competitive in exploiting resources than daphnia (Wang *et al.,* 2007). Some researchers believe that the predominance of small cladocerans (*Bosmina* and *Ceriodaphnia*) is related to the interference of filamentous blue green algae, which dominate the phytoplankton under eutrophic conditions (Sampaio *et al.*, 2002).

4.4 Relationships between zooplankton and chlorophyll *a*

The presence of phytoplankton blooms appeared to have a significant effect on the abundance of zooplankton during this study, as species abundance showed a clear seasonal pattern following phytoplankton blooms.

The correlation analysis suggests that protozoan and rotifer densities affected by chl *a* were of < 20 μm fraction size in Thale-Noi, whereas cladocerans, ostracods and copepods affected by chl *a* were of 20-200 μm fraction size. This result is similar to that at Lake Kinneret, Israel (Hadas and Berman, 1998). In the present study, *Peridinium and Trachelomonas* were the dominant genera of protozoans throughout the entire rainy period to the dry period, associated with high chl *a* of < 20 μm fraction size while large protozoans *Arcella* were related to chl *a* of 20-200 μm fraction size. This result is similar to other studies on Protozoa in Sao Francisco river floodplain, Brazil (Dabes and Velho, 2001), who suggested that smaller species such as *Difflugiella* and *Trinema* feed on bacteria, fungi and small protozoans. On the other hand, larger species consume filamentous algae, small rotifers and other testate amoebae. In the present study, among rotifers only *Ascomorpha* showed a positive relationship with chl *a* of < 20 μm fraction size, whereas other genera *Lecane, Lepadella, Monommata* and *Testudinella* showed a negative relationship with this fraction size. *Colurella, Euchlanis* and *Hexathra* showed a negative correlation with both size fractions of chl *a*. This may agree with the findings of Abdel Aziz *et al.* (2006) who revealed that the increase in rotifers counts was accompanied by a decrease in *Navicula, Scenedesmus, Kirchneriella* and *Actinastrum* in June and a decrease in *Actinastrum* in July. They suggested that this pattern may reflect the effect of temperature on grazing efficiency in different months at variable temperatures. It is remarkable that some zooplankton species demonstrated no food selectivity toward phytoplankton species, such as the rotifers *B. plicatilis* and *B. urceolaris*, and the cladoceran *M. micrura* and cirripede larvae, which grazed on phytoplankton species belonging to different algal groups, as indicated from the significant correlations (Abdel Aziz *et al.*, 2006). However, it has been discovered that *Polyarthra* spp. and *Synchaeta* spp. are indeed considered as specialist feeders on large (~30-40 μm) particles and are potential predators for ciliates (Joaquim-Justo *et al.,* 2006). The small cladocerans mainly *Alona* and *Chydorus* were significantly negatively correlated with chl *a* of < 20 μm fraction size. It is indicated that the dominance of small cladoceran species observed in Thale-Noi is probably related to interference in the feeding, given that Cyanophyceae were abundant at most times of the year (Nookua, 2003). However, *Diaphanosoma* was strongly correlated to chl *a* 20-200 μm fraction size, which concurs with the results of Hadas and Berman (1998) who discovered that herbivorous cladocerans (*Diaphanosoma brachyurum)* dominated the zooplankton community at the same time where there was a high abundance of flagellates. The present investigation has shown copepods to have a positive relationship with chl *a* 20-200 μm fraction size. Generally, the life histories of copepods reveal that while juvenile stages are herbivores, the adult stages are frequently carnivores (Abdul Azis *et al.,* 2003). Further, from correlation analysis it was found that copepod copepodites had a strong effect on protozoans. Thus, the preferential feeding by copepod copepodites on microzooplankton indicates that copepod grazing on protozoans can provide a mechanism for transport of the carbon found in smaller size fractions to higher trophic levels (Bundy *et al.,* 2005). A finding from this study was that seasonal changes in zooplankton abundance in Thale-Noi may be related to the interactive effects of food size-spectra (chl *a* size fractions).

CHAPTER 5

CONCLUSIONS

Annual changes in various sizes of zooplankton communities in Thale-Noi lake, Phatthalung province, were analysed over three periods: the light rainy period (July, August 2004), the rainy period (November, December 2004), and the dry period (March, April 2005); and in four different zones: the peat swamp zone, the small inlet zone, the resident zone and the pelagic zone. The present study can be concluded as the following:

1. The average total zooplankton abundance was 7.9×10^{6} ind.m^{-3}. Two seasonal zooplankton abundance peaks were found: one during the rainy period (22.0×10^{6} ind.m^{-3}) and the other in the dry period (16.4×10^{6} ind.m^{-3}). On average, approximately 95.4% (6.4 S.D.) of the total zooplankton density was microzooplankton. Mesozooplankton made up about 5% of the total zooplankton.

2. Zooplankton in different size fractions was composed of five phyla, namely Protozoa, Rotifera, Arthropoda, Mollusca and Chordata. The microzooplankton community was composed of 22 genera of Protozoa, 32 genera of Rotifera, 13 genera of Cladocera, and 3 genera of Copepoda. Ostracod juvenile, crustracean nauplii and copepodite of copepods were also found in the communities. The mesozooplankton community was composed of three genera of Protozoa, two genera of Rotifera, three genera of Ostracoda, 26 genera of Cladocera, 11 genera of Copepoda, and other invertebrates such as shrimp larvae, gastropod larvae, bivalve larvae, crab larvae and vertebrate fish larvae were also found. There was apparent seasonal variation of zooplankton species caused by hydrodynamics and rainfall.

The highest number of zooplankton species, both microzooplankton and mesozooplankton, was recorded in the peat swamp and resident zones during the rainy period.

3. There were two genera represented by season, the first was *Floscularia* found only in the dry period, and the second was *Macrochaetus* found only in the light rainy period. Additionally, we found that *Acartia* cf. *southwelli* might be new recorded to Thailand.

4. Microzooplankton abundance was highly variable within the study period, ranging between 1.47×10^4 ind.m^{-3} and 1.57×10^6 ind.m^{-3}. Seasonal variations in microzooplankton density among stations were shown in Figure 32. The highest microzooplankton density was recorded at station 6 (the small inlet zone) during the rainy period while the lowest density was recorded at station 4 (the small inlet zone) during the light rainy period. Mesozooplankton abundance showed a clear peak in the rainy period, the abundance was highest (3.2×10^6 ind.m^{-3}) in late November 2004. Seasonal variations in mesozooplankton density among stations were shown in Figure 33. The highest mesozooplankton density was recorded at station 6 (the small inlet zone) during the rainy period while the lowest density was recorded at station 10 (the pelagic zone) during the dry period.

5. Among the microzooplankton community, protozoans (8.6-94%) and rotifers (4.9-90.0%) alternated in dominance during each period. *Trachelomonas* spp. were the most frequently dominant of the protozoans in all zones, followed by *Peridinium* sp. and *Stentor* sp., respectively, whereas *Polyarthra* spp. were the most frequently dominant of the rotifers in all zones, followed by *Anuraeopsis* spp. and *Keratella* spp., respectively. Among the mesozooplankton community, cladocerans

and copepods alternated in dominance in each period. *Bosminopsis deitersi* was the most frequently dominant species of cladocerans in the peat swamp zone while *Chydorus* spp. were the most frequently dominant species of cladocerans in the remaining zones. Several species such as *Acartiella sinensis, Metacyclops* sp., *Mesocyclops* spp. and *Neodiaptomus yangtsekiangensis* were dominant among the copepods in all zones of Thale-Noi.

6. Rainfall and hydrodynamics controlling a combination of several environmental factors are the main causes affecting seasonal variation patterns of zooplankton in Thale-Noi. CCA analysis revealed that most of a significant variables influencing different zooplankton assemblage in the three sampling periods were temperature, pH, transparency, conductivity, total solids, dissolved oxygen. In addition to these factors, Pearson Correlation analysis reveal that chl *a* of < 20 μm fraction size tends to be positively related to the abundance of protozoans, while chl *a* of 20-200 μm fraction size was positively correlated with large cladocerans, ostracods and copepods.

Microzooplankton

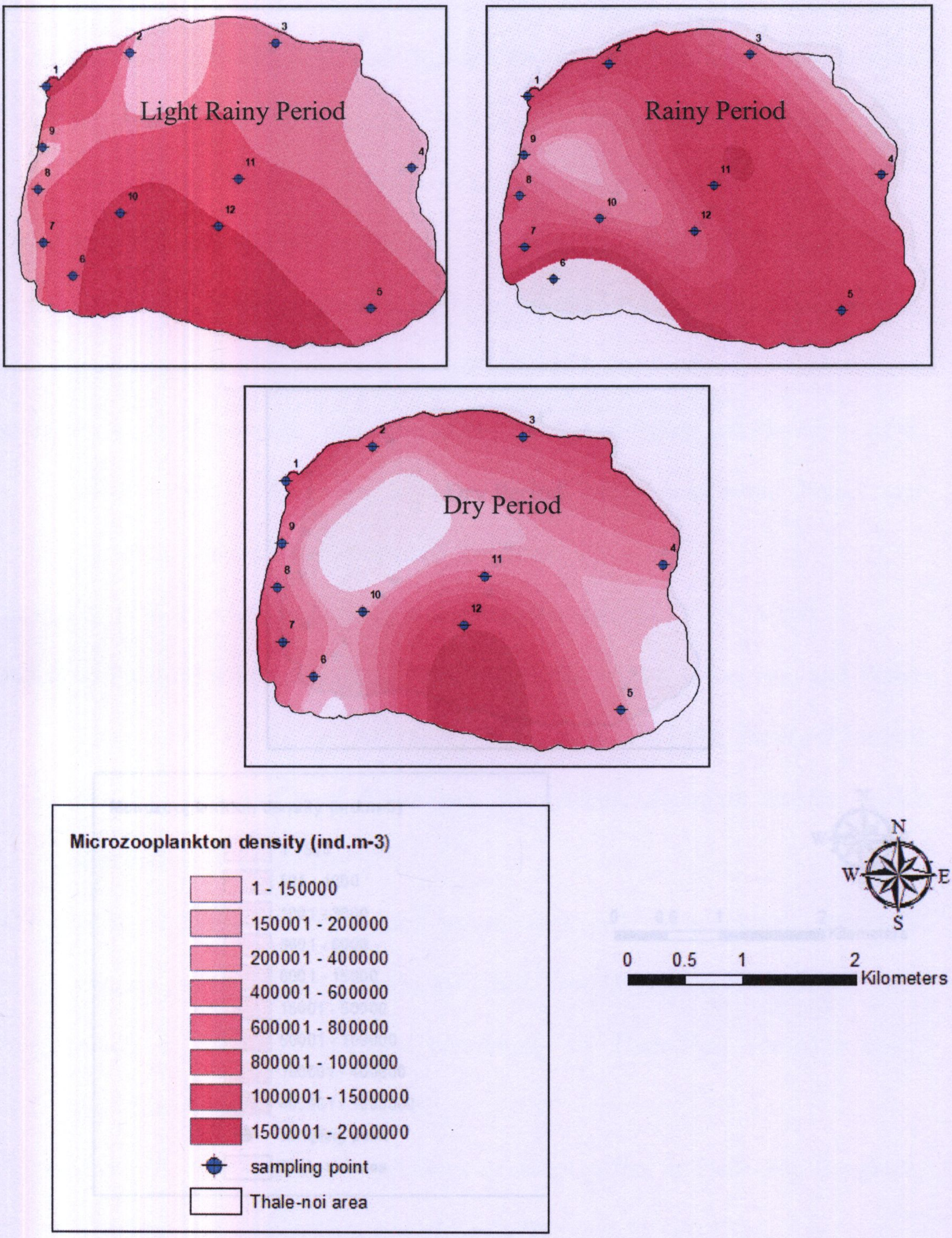


Figure 32. Overview of average microzooplankton density in twelve stations of Thale-Noi in three sampling periods.

Mesozooplankton

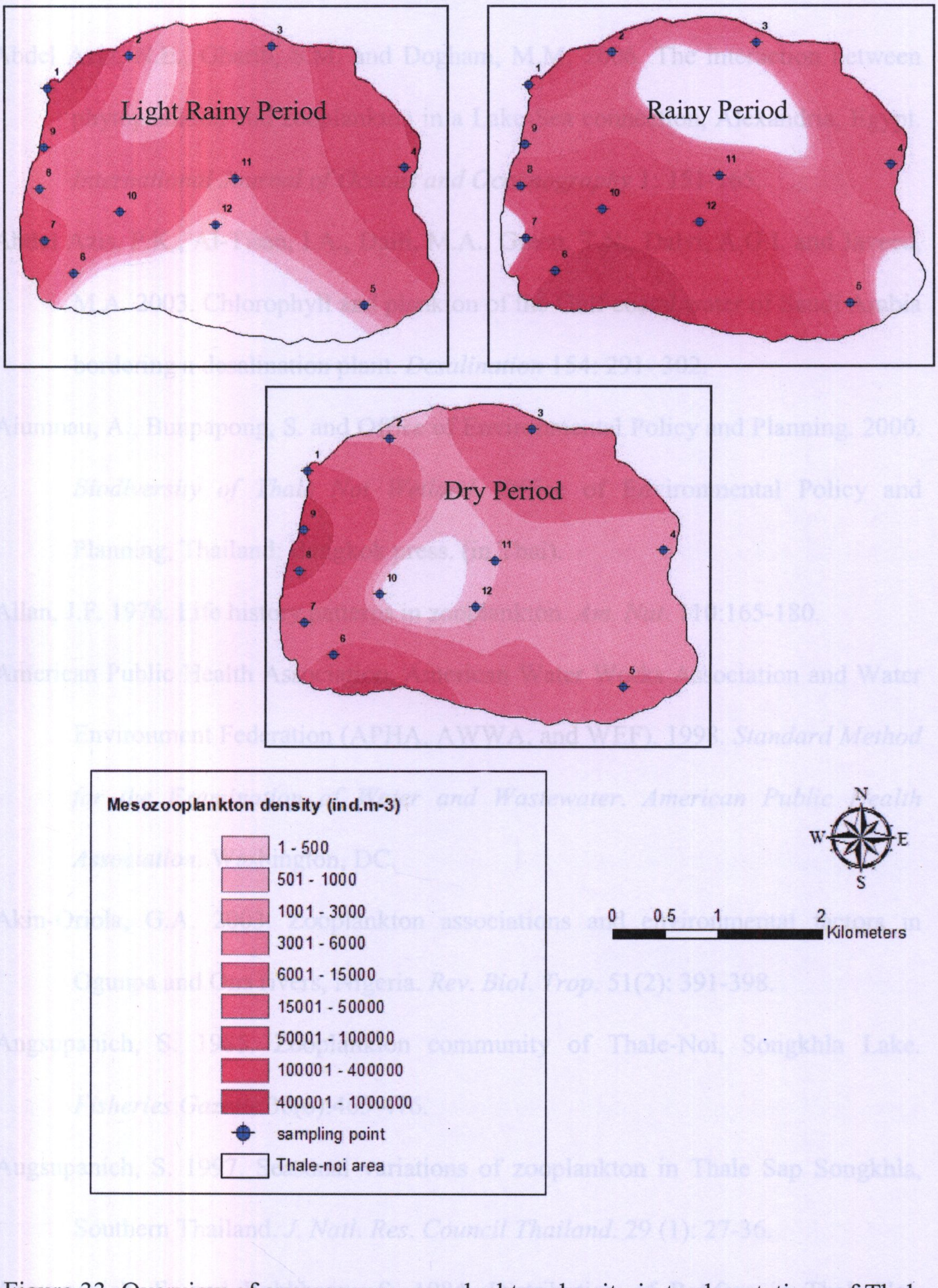


Figure 33. Overview of average mesozooplankton density in twelve stations of Thale-Noi in three sampling periods.

REFERENCES

Abdel Aziz, N.E., Gharib, S.M. and Dogham, M.M. 2006. The interaction between phytoplankton and zooplankton in a Lake-Sea connection, Alexandria, Egypt. *International Journal of Oceans and Oceanography* 1: 151-165.

Abdul Azis, P.K., Al-Tisan, I.A., Daili, M.A., Green, T.N., Dalvi, A.G.I. and Javeed, M.A. 2003. Chlorophyll and plankton of the Gulf coatal water of Saudi Arabia bordering a desalination plant. *Desalination* 154: 291- 302.

Aiumnau, A., Bunpapong, S. and Office of Environmental Policy and Planning. 2000. *Biodiversity of Thale Noi Wetland.* Office of Environmental Policy and Planning, Thailand: Bangkok press. (in Thai).

Allan, J.F. 1976. Life history patterns in zooplankton. *Am. Nat.* 110:165-180.

American Public Health Association, American Water Works Association and Water Environment Federation (APHA, AWWA, and WEF). 1998. *Standard Method for the Examination of Water and Wastewater. American Public Health Association.* Washington, DC.

Akin-Oriola, G.A. 2003. Zooplankton associations and environmental factors in Ogunpa and Ona rivers, Nigeria. *Rev. Biol. Trop.* 51(2): 391-398.

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

Augsupanich, S. 1997. Seasonal variations of zooplankton in Thale Sap Songkhla, Southern Thailand. *J. Natl. Res. Council Thailand.* 29 (1): 27-36.

Angsupanich, S. and Rukkheaw, S. 1984. Distribution of Ratifera in Thale-Noi, Songkhla Lake. *Songkhlanakarin J. Sci. Technol.* 6(4):363-368. (in Thai).

Angsupanich, S. and Rukkheaw, S. 1997. Seasonal variation of phytoplankton community in Thale Sap Songkhla, a lagoon lake in southern Thailand. *Neth. J. Aquat. Ecol.* 30: 297-307.

Augsupanich, S., Phromthong, I. and Srichuer, K. 1997. Meiofauna in Thale Sap Songkhla, A Lagoon Lake in Southern Thailand. *J. Sci. Soc. Thailand.* 23: 347-358.

Baldock, B.M., Baker, J.H. and Sleigh, M.A. 1983. Abundance and productivity of protozoa in chalk streams. *Holarctic Ecology* 6: 238-246.

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

Bekleyen, A. 2003. A taxonomic study on the zooplankton of Goksu Dam Lake (Diyarbakir). *Turk. J. Zool.* 27: 95-100.

Birky, C.W.Jr. and Gilbert, J.J. 1971. Parthenogenesis in rotifers: the control of sexual and asexual reproduction. *Am. Zool.* 11: 245-266.

Blindow, I., Hargeby, A., Wagner, B.M.A. and Andersson, G. 2000. How important is the crustacean plankton for the maintenance of water clarity in shallow lakes with abundant submerged vegetation? *Freshwater Biology* 44: 185-197.

Bonacila, C. and Pasteris, A. 2001. Zooplankton of Lake Orta after limiting: an eleven years study. *J. Limnol.* 60(1): 101-109.

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

Branco, C.W.C., Rocha, M.I.A., Pinto, G.F.S., Gomara, G.A. and Filippo, R.D. 2002. Limnological features of Funil Reservoir (R.J., Brazil) and indicator properties of rotifers and cladocerans of the zooplankton community. *Lakes & Reservoirs Research and Management* 7: 87-92.

Brett, M.T. and Goldman, C.R. 1996. A meta-analysis of the freshwater trophic cascade. *Proc. Natl. Acad. Sci. USA*. 93: 7723-7726.

Bruno, S.F., Staker, R.D., Sharma, G.M. and Turner, J.T. 1983. Primary productivity and phytoplankton size fraction dominance in Temperate North Atlantic Estuary. *Estuaries* 6(3): 200-211.

Buapatch, K. 2002. *Life cycle and resource utilization among Odonate larvae in Thale Noi, Pattalung Province.* M. Sc. Thesis, Faculty of Environment Management, Prince of Songkla University, Thailand. (in Thai).

Bundy, M.H., Vanderploeg, H.A., Lavrentyev, P.J. and Kovalcik, P.A. 2005. The importance of microzooplankton versus phytoplankton to copepod populations during late winter and early spring in Lake Michigan. *Can. J. Fish. Aquat. Sci.* 62: 2371-2385.

Burns, C.W. and Mitchell, S.F. 1980. Seasonal succession and vertical distribution of zooplankton in Lake Hayes and Lake Johnson. *New Zealand Journal of Marine & Freshwater Research* 14(2): 189-204.

Calbet, A., Garrido, S., Saiz, E., Alcaraz, M. and Duarte, C.M. 2001. Annual zooplankton succession in coastal NW Mediterranean waters: the importance of the smaller size fractions. *Journal of Plankton Research* 23(3): 319- 331.

Calliari, D. 2007. Short-term changes in the concentration and vertical distribution of chlorophyll and in the structure of the mocroplankton assemblage due to a storm. *Pan-American Journal of Aquatic Sciences* 2(1): 13-22.

Chaiubol, C. 1998. *Relationship between water quality and distribution of phytoplankton and zooplankton in Ang Kaew Reservoir, Chiang Mai University, 1997-1998.* M. Sc. Thesis, Faculty of Science, Chiang Mai University, Thailand. (in Thai).

Charoenpol, P. 2003. *Dynamics of plankton in the Bangpakong River.* M. Sc. Thesis, Major Field Fisheries Science, Department of Fishery Biology, Kasetsart University, Thailand. (in Thai).

Chaleoisak, P. 2000. *Seasonal variation of plankton in the Tha-Chin River.* M. Sc. Thesis, Major Field Fisheries Science, Department of Fishery Biology, Kasetsart University, Thailand. (in Thai).

Charubhun, B. and Charubhun, N. 2000. Biology of freshwater Protozoa in Thailand. *Kasetsart J. (Nat. Sci.)* 34: 486-494.

Chiayvaresajja, S., Taweesak, S., Tansakul, P., Augsupanich, S. and Rakkeaw, S. 1988. Site selection for aquaculture in Thale Noi Lake, Thailand. *Thai J Agric. Sci.* 21: 245-252.

Chiayvaresajja, S., Sirikul, B., Sirimontraporn, P., Rakkeaw, S., Tansakul, R. and Sornprasit, A. 1987. Tilapia cage culture with aquatic weed mixture pellet in Thale Noi, Thailand. *The second International Symposium on Tilapia in Aquaculture,* Bangkok, Thailand, 16-20 March 1987, pp. 1-8.

Chittapun, S. 2004. *Human impact on rotifera communities of coastal peat swamps in Phuket province, Southern Thailand.* Ph.D. Dissertation, Faculty of Science, Prince of Songkla University, Thailand.

Chittapun, S., Pholpunthin, P. and Segers, H. 2003. Contribution to the knowledge of Thai microfauna diversity: note on rare peat swamp Rotifera, with the description of a new *Lecane* Nitzsch, 1872. *Hydrobilogia* 501: 7-12.

Cole, B.E., Cloern, J.E. and Alpine, A.A. 1986. Biomass and productivity of three phytoplankton size classes in San Francisco Bay. *Estuaries* 9(2): 117-126.

Conde-Porcuna, J.M., Ramos-Rodriguez, E. and Peraz-Martinez, C. 2002. Correlations between nutrient concentrations and zooplankton populations in a mesotrophic reservoir. *Freshwater Biology* 47: 1463-1473.

Cottenie, K and Meester, L.D. 2003. Connectivity and cladoceran species richness in a metcommunity of shallow lakes. *Freshwater Biology* 48: 823-832.

Dabes, M.B.G.S. and Velho, L.F.M. 2001. Assemblage of testate amoebae (Protozoa, Rhizopoda) associated to aquatic macrophytes stands in a marginal lake of the Sao Francisco river floodplain, Brazil. *Maringá* 23(2): 299-304.

David, V., Sautour, B., Chardy, P. and Leconte, M. 2005. Long-term changes of the zooplankton variability in a turbid environment: The Gironde estuary (France). *Estuarine, Coastal and Shelf Science* 64: 171-184.

Duggan, I.C. Green, J.D. and Shiel, R.J. 2002. Distribution of rotifer assemblages in North Island, New Zealand, lakes: relationships to environmental and historical factors. *Freshwater Biology* 47: 195-206.

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

Eckert, B and Walz, N. 1998. Zooplankton succession and thermal stratification in the polymictic shallow Muggelsee (Berlin, Germany): a case for the intermediate disturbance hypothesis. *Hydrobiologia* 387/388: 199-206.

Eskinazi-Sant'Anna, E.M. and Bjornberg, T.K.S. 2006. Seasonal dynamic of microzooplankton in the Sao Sebastiao Channel (SP, Brazil). *Braz. J. Biol.* 66(1B): 221-231.

Espindola, E.L.G., Matsumura-Tundisi, A.C., Rietzler, A.C. and Tundisi, J.G. 2000. Spatial heterogeneity of the Tucurui Reservoir (State of Para, Amazonia, Brazil) and the distribution of zooplanktonic species. *Rev. Bras. Biol.* 60(2): 179-194.

Fafioye, O. and Omoyinmi, G.A.K. 2006. The rotifers of Omi River, Ago-iwoye, Nigeria. *African Journal of Agricultural Research* 1(5): 186-188.

Ferrara, O., Vagaggini, D. and Margaritora, F.G. 2002. Zooplankton abundance and diversity in Lake Bracciano, Latium, Italy. *J. Limnol.* 61(2): 169-175.

Froneman, P.W. 2001. Seasonal Changes in Zooplankton Biomass and Grazing in a Temperate Estuary, South Africa. *Estuarin, Coastal and Shelf Science* 52: 543-553.

Froneman, P.W., Pakhomov, E.A. and Balarin, M.G. 2004. Size-fractionated phytoplankton biomass, production and biogenic carbon flux in the eastern Atlantic sector of the Southern Ocean in late austral summer 1997-1998. *Deep-Sea Research Part II* 51: 2715-2729.

Gifford, D.J. 1991. The protozoan-metazoan trophic link in pelagic ecosystems. *J. Protozool.* 38: 81-86.

Godhantaraman, N. 2001. Seasonal variations in taxonomic composition, abundance and food web relationship of microzooplankton in estuarine and mangrove waters, Parangipettai region, southeast coast of India. Indian. *J. Mar. Sci.* 30: 151-160.

Goulden, C.E. 1971. Environmental control of the abundance and distribution of the Chydorid Cladocera. *Limnology and Oceanography* 16(2): 320-331.

Graham, J.M. , Lauster, G.H. Yannarell, A.C. Graham, L.E. and Triplett, E.W. 2004. Seasonal dynamics of phytoplankton and planktonic protozoan communities in a Northern Temperate Humic Lake: Diversity in a dinoflagellate dominated system. *Microbial Ecology* 48: 528-540.

Grange, N. and Allanson, B.R. 1995. The influence of freshwater inflow on the nature, amount and distribution of seston in estuaries of Eastern Cape, South Africa. *Estuarine, Coastal and Shelf Science* 40: 403-420.

Haberman, J. 1998. Zooplankton of Lake Vortsjarv. *Limnologica* 28(1): 49-65.

Hadas, O. and Berman, T. 1998. Seasonal abundance and vertical distribution of Protozoa (flagellates, ciliates) and bacteria in Lake Kinneret, Israel. *Aquat Microb Ecol.* 14:161-170.

Hamasaki, K., Ikeda, M., Ishikawa, M., Shirasawa, K. and Taguchi, S. 1998. Fractionated chlorophyll a in Monbetsu Harbor, Hokkaido, northern Japan. *Plankton Biol. Ecol.* 45(2):151-158.

Harper, D. 1992. *Eutrophication of Freshwaters Principles, Problems and Restoration*, 327 pp. London SE1 8HN: Chapman & Hall.

Harris, R., Wiebe, P., Lenz, J., Skioldal, H.R. and Hantley, M. 2000. *Zooplankton Methodology Manual.* Beccles, Suffolk, Great Britain: Paston Prepress Ltd.

Havens, K.E. 2002. Development and application of hydrologic restoration goals for a large subtropical lake. *Lake and Reservoir Management* 18: 285-292.

Hembanthid, Y. 2001. *The management of natural resources and the environment in Thale Noi fishing community, Amphoe Khuankhanun, Changwat Phattalung.*

M. Sc. Thesis, Agricultural Development, Prince of Songkla University, Thailand. (in Thai).

Hessen, D. and Lydersen, E. 1996. The zooplankton story of humic Lake Skjervatjern during whole catchment acidification. *Environment International* 22(5): 643-652.

Howick, G.L. and Wilhm, J. 1984. Zooplankton and benthic macroinvertebrates in Lake Carl Blackwell. *Proc. Okla. Acad. Sci.* 64:63-65.

Idris, B.A.G. 1983. *Freshwater Zooplankton of Malaysia* (*Crustacea: Cladocera*), 153 pp. Kuala lumpur: Penerbit University Pertanian Malaysia.

Inpang, R. Pholpunthin, P. and Augsupanich, S. 2007. Composition and abundance of microzooplankton communities in Thale-Noi, Phattalung Province, Thailand. *Proceeding National Grad-Research 7th,* Prince of Songkla University, Surattani Campus, 4-5 April 2007, pp. 111-117.

Iqbal, F., Ali, M. and Kanwal, N. 2006. Limnological Study of River Soan (Punjab), Pakistan. *Agriculturae Conspectus Scientificus* 71(2): 65-73.

Jithlang, I. and Wongrat, L. 2004. Distribution of Zooplankton in the Pasak Jolasid Reservoir, Lop Buri Province. *Journal of Science Research* 3(1): 108-120. (in Thai).

James, M.R., Schallenberg, M., Gall, M. and Smith, R. 2001. Seasonal changes in plankton and nutrient dynamics and carbon flow in the pelagic zone of a large, glacial lake: effects of suspended solids and physical mixing. *New Zealand Journal of Marine and Freshwater Research* 35: 239-253.

Jamet, J.L., Jean, N., Boge, G., Richard, S. and Jamet, D. 2005. Plankton succession and assemblage structure in two neighbouring littoral ecosystems in the north-west Mediteranean Sea. *Marine and Freshwater Research* 56: 69-83.

Joaquim-Justo, C., Pirlot, S., Servais, P., Thome, J-P. and Descy, J-P. 2006. Trophic links in the Lowland River Meuse (Belgium): assessing the role of bacteria and protozoans in planktonic food webs. *Journal of Plankton Research* 28(9): 857-870.

Jong-Jeon, M., Lee, S.W., Hwang, S.J. and Oh, I.H. 2001. Seasonal fraction of chlorophyll *a* concentration in the size fraction of phytoplankton in Daechung Reservoir. *Korean J. Limnol.* 34(4): 277-284.

Keowsurat, P. 1987. *Freshwater algal species in Thale-Noi Lake.* M. Sc. Thesis, Biological Science, Prince of Songkla University, Thailand. (in Thai).

Keppeler, E.C. 2003. Comparative study of the zooplankton composition of two lacustrine ecosystems in Southwestern Amazonia. *Maringa* 25(2): 467-477.

Keppeler, E.C. and Hardy, E.R. 2004. Abundance and composition of Rotifera in an abandoned meander lake (Lago Amapa) in Rio Branco, Acre, Brazil. *Rev. Bras. Zool.* 21(2): 233-241.

Keppeler, E.C. and Hardy, E.R. 2004. Vertical distribution of zooplankton in the water column of Lago Amapa, Rio Branco, Acre, Brazil. *Rev. Bras. Zool.* 21(2): 169-177.

Korovchinsky, N.M. 1992. *Guides to the Identification of the Microinvertebretes of the Continental Waters of the World 3: Sididae and Holopediidae* (*Crustacea: Daphniiformes*), 82 pp. Netherlands: SPB Academic Publishing.

Koste, W. 1978. *Rotatoria: Die Rädertiere Mitteleuropas Ein Besttimmungswerk, begründet von Max Voigt Uberordnung Monogononta*, 673 pp.

Kovalev, A.V., Skrybin, V.A. and Zagorodnyaya, Y.A. 1999. The Black sea zooplankton: Composition, Spatial/Temporal Distribution and History of Investigations. *J. of Zoology*. 23: 195-209.

Kuwabara, R. 1995. *The coastal environment and ecosystem in Southeast Asia: studies on the Lake Songkhla lagoon system, Thailand*, 109 pp. Tokyo University of Agriculture.

Lam-Hoai, T., Guiral, D. and Rougier, C. 2006. Seasonal change of community structure and size spectra of zooplankton in the Kaw River estuary (French Guiana). *Estuarine, Coastal and Shelf Science* 68: 46-61.

Lampert, W., Sommer, U. and Haney, J. 1997. *Limnoecology: The ecology of lakes and streams,* 382 pp. New York: Oxford.

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

Leonard, M., Azemar, F., Bouletreau, S., Muylaert, K., Tackx, M. and Vyverman, W. 2005. Grazing by meso- microzooplankton on phytoplankton in the upper reaches of the Schelde estuary (Belgium/The Netherlands). *Estuarine, Coastal and Shelf Science* 64: 764-774.

Lovik, J.E. and Kjellberg, G. 2003. Long- term changes of the crustacean zooplankton community in Lake Mjosa, the largest lake in Norway. *J. Limnol.* 62(2): 143-150.

Mageed, A.A.A. 2007. Distribution and long-term historical changes of zooplankton assemblages in Lake Manzala (South Merditeranean, Egypt Sea). *Egyptian Journal of Aquatic Research* 33(1): 183-192.

Mageed, A.A.A. and Heikal, M.T. 2006. Factors affecting seasonal patterns in epilimnion zooplankton community in one of the largest man-mad lakes in Africa (Lake Nasser, Egypt). *Limnologica* 36:91-97.

Maiphae, S. 2005. *Taxonomy and Biogeography of the Cladocera from Southern Thailand, with specific reference to Alona Baird, 1843 and Macrothrix Baird, 1843*. Ph.D. Dissertation, Faculty of Science, Prince of Songkla University, Thailand.

Maiphae, S., Pholpunthin, P. and Domont, H.J. 2005. Species richness of the Cladocera (Branchiopoda: Anomopoda and Ctenopoda) in Southern Thailand, and its complementarity with neighboring regions. *Hydrobiologia* 537: 147-156.

Maiphae, S., Pholpunthin, P., Sanoamuang, L. and Domont, H.J. 2004. Taxonomic Problems of the Anomopoda: a study based on Specimens from Southern Thailand, with specific references to *Alona Baird,* 1843. *Journal of Science Research* 3(1): 45-55. (in Thai).

Manca, M. and Comoli, P. 1999. Studies on zooplankton of Lago Paione Superiore. *J. Limnol.* 58(2): 131-135.

Maria-Heleni, Z., Michaloudi, E., Bobori, D.C. and Mourelatos, S. 2000. Zooplankton abundance in the Aliakmon River, Greece. *Belg. J. Zool.* 130 (1): 29-33.

Mazzocchi, M.G. and Ribera d'Alcalà, M. 1995. Recurrent patterns in zooplankton structure and succession in a variable coastal environment. *ICES Journal of Marine Science* 52(3-4): 679-691.

Medina-Sanchez, J.M., Villar-Argaiz, M., Sanchez-Castillo, P., Cruz-Pizarro, L. and Carrillo, P. 1999. Structure changes in a planktonic food web: biotic and abiotic controls. *J. Limnol.* 58(2): 213-222.

Mengestou, S. and Fernando, C.H. 1991. Seasonality and abundance of some dominant crustacean zooplankton in Lake Awasa, a tropical rift valley lake in Ethiopia. *Hydrobiologia* 226: 137-152.

Michaloudi, E. and Kostecka, M. 2004. Zooplankton of Lake Koroneia (Macedonia, Greece). *Biologia, Bratislava* 59(2): 165-172.

Michaloudi, E., Zarfdjlan, M. and Economidis, P.S. 1997. The zooplankton of Lake Mikri Prespa. *Hydrobiologia* 351: 77-94.

Mikschi, E. 1989. Rotifer distribution in relation to temperature and oxygen content. *Hydrobiologia* 186/187: 209-214.

Modenutti, B., Queimalinos, C., Balseiro, E. and Reissing, M. 2003. Impact of different zooplankton structure on the microbial food web of a South Andean oligotrophic lake. *Acta Oecologica* 24: s289-s298.

Neves, I.F., Rocha, O., Roche, K.F. and Pinto, A.A. 2003. Zooplankton community structure of two marginal lakes of the River Cuiaba (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity. *Braz. J. Biol.* 63(2): 329-343.

Nookua, H. 2003. *Abundance and distribution of phytoplankton in Thale Noi, Phathalung Province.* M. Sc. Thesis, Faculty of Environmental Management, Prince of Songkla University, Thailand. (in Thai).

Nurminen, L., Horppila, J. and Pekcan-Hekim, Z. 2007. Effect of light and predator abundance on the habitat choice of plant-attached zooplankton. *Freshwater Biology* 52: 539-548.

Ouppabullung, A. and Augsupanich, S. 1995. Zooplankton Distribution in Phawong Canal, the Outer Songkhla Lake. *Thai J. of Aqua. Sci.* 2(1): 11-26. (in Thai).

Paphavasit, N., Piumsomboon, A., Siwaipram, A. and Pannarak, P. 2007. *Organisms in Mangrove Ecosystems, Pranburee, Thailand,* 269 pp. PTT, Ltd. (in Thai).

Paranagua, M.N., Neumann- Leitao, S., Nogueira- Paranhos, J.D., Silva, T.A and Matsumura-Tundisi, T. 2005. Cladocerans (Branchiopoda) of a tropical estuary in Brazil. *Braz. J. Biol.* 65(1): 107-115.

Park, G.S. and Marshall, H.G. 2000. The trophic contributions of rotifers in tidal freshwater and estuarine habitats. *Estuarine, Coastal and Shelf Science* 51: 729-742.

Pedersen, S.A., Ribergaard, M.H. and Simonsen, C.S. 2005. Micro-and mesozooplankton in Southwest Greenland waters in relation to environmental factors. *Journal of Marine Systems* 56: 85-112.

Pholpunthin, P. 1997. Freshwater zooplankton (Rotifera, Cladocera, and Copepoda) from Thale-Noi, South Thailand. *J. Sci. Soc.* 23: 23-24.

Pholpunthin, P. 2001. *Technique in Plankton Identification,* 93 pp. Supported by Faculty of Science, Prince of Songkla University, Thailand. (in Thai).

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

Pinto-Coelho, R.M., Bezerra-Neto, J.F. and Morais-JR, C.A. 2005a. Effects of Eutrophication on size and biomass of crustacean zooplankton in a tropical reservoir. *Braz. J. Biol.* 65(2): 325-338.

Pinto-Coelho, R., Pinel-Alloul, B., Methot, G. and Havens, K.E. 2005b. Crustacean zooplankton in lakes and reservoirs of temperate and tropical regions: variation with trophic status. Can. *J. Fish. Aguat. Sci.* 62: 348-361.

Pipatcharoenchai, W. 2001. *Diversity of zooplankton in Changwat Kanchanaburi.* M. Sc. Thesis, Major Field Fisheries Science, Department of Fishery Biology, Kasetsart University, Thailand. (in Thai).

Pirlot, S., Venderheyden, J. Descy, J.P. and Servais, P. 2005. Abundance and biomass of heterotrophic microorganisms in Lake Tanganyika. *Freshwater Biology* 50: 1219-1232.

Primicerio, R. 2000. Seasonal changes in vertical distribution of zooplankton in an Oligotrophic, Subarctic Lake (Lake Takvatn, Norway). *Limnologica* 30: 301-310.

Pornpinitpong, S. 2004. Hydrodynamics and salinity intrusion in Thale Noi. *Research Reports*, Prince of Songkla University, pp. 1-20. (in Thai).

Ramdani, M., Elkhiati, N., Flower, R.J. Birks, H.H. Kraiem, M.M., Fathi, A.A. and Patrick, S.T. 2001. Open water zooplankton communities in North African wetland lakes: the Cassarina project. *Aquatic Ecology* 35: 319-333.

Reckendorfer, W., Keckeis, H., Winkler, G. and Schiemer, F. 1999. Zooplankton abundance in the River Danube, Austria: the significance of inshore retention. *Freshwater Biology* 41: 583-591.

Romare, P., Berg, S., Lauridsen, T. and Jeppesen, E. 2003. Spatial and temporal distribution of fish and zooplankton in a shallow lake. *Freshwater Biology* 48: 1353-1362.

Romare, P. Schindler, D.E., Scheuerell, M.D., Scheuerell, J.M., Litt, A.H. and Shepherd, J.H. 2005. Variation in spatial and temporal gradients in zooplankton spring development: the effect of climatic factors. *Freshwater Biology* 50: 1007-1021.

Sa-ardrit, P. 2002. *Diversity and distribution of freshwater cladocera in Trang Province*. M. Sc. Thesis, Faculty of Science, Prince of Songkla University. (in Thai).

Sa-ardrit, P. and Beamish, F.W.H. 2005. Cladocera diversity, abundance and habitat in a Western Thailand Stream. *Aquatic Ecology* 39: 353-365.

Sampaio, E.V., and Lopez, C.M. 2000. Zooplankton community composition and some limnological aspects of an oxbow lake of the Paraopeba River, Sao Francisco River Basin, Minas Gerais, Brazil. *Braz. Arch. Biol. Technol.* 43: 285-293.

Sampaio, E.V., Rocha, O., Matsumura-Tundisi, T. and Tundisi, J.G. 2002. Composition and abundance of zooplankton in the limnetic zone of seven reservoirs of the Paranapanema river, Brazil. *Braz. J. Biol.* 62(3): 525-545.

Sandercock, G.A. 1967. A study of selected mechanisms for the coexistence of *Diaptomus* spp. in Clark Lake, Ontario. *Limnol. Oceanogr.* 12: 97-112.

Sanoamuang, L. 2002. *Freshwater Zooplankton: Calanoid Copepods in Thailand*, 159 pp. Khonkean : Khonkean University press. (in Thai).

Sanoamuang, L. and Faitakum, S. 2005. Species diversity of cladocerans and copepods in the floodplain of the River Mun, Northest Thailand. *KKU Res J.* 10(2): 106-113. (in Thai).

Sanoamuang, L. and Savatenalinton, S. 2001. The rotifer fauna of Lake Kud-Thing, a shallow lake in Nong Khai Province, Northeast Thailand. *Hydrobiologia* 446/447: 297-304.

Santhanam, R. and Srinivasan, A. 1994. *A manual of marine zooplankton*, 160 pp.

Savatenalinton, S. and Segers, H. 2005. Rotifers from Kalasin Province, Northeast Thailand, with note on new and rare species. *Zoological Studies* 44(3): 361-367.

Sergers, H. 1995-1996. *Introduction to the Practice of Identifying Rotifera.* International Trainning Course, 69 pp. Universiteit Gent.

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

Sendacz, S., Caleffi, S. and Santos-Soares, J. 2006. Zooplankton biomass of reservoirs in different trophic conditions in the State of Sao Paulo, Brazil. *Braz. J. Biol.* 66 (1b): 337-350.

Shinada, A., Ikeda, T., Ban, S. And Tsuda, A. 2000. Seasonal changes in micro-zooplankton grazing on phytoplankton assemblages in the Oyashio region, western subarctic Pacific. *Plankton Biol. Ecol.* 47(2):85-92.

Shiomoto, A. 1997. Size-fractionated chlorophyll *a* concentration and primary production in the Okhotsk Sea in October and November 1993, with special reference to the influence of dichothermal water. *Journal of Oceanography* 53: 601-610.

Silva, A.P., Neumann-Leitao, S., Schwamborn, R., Oliveira Gusmao, L.M. and Silva, T.A. 2004. Mesozooplankton of an impacted bay in North Eastern Brazil. *Braz. Arch. Biol. Technol.* 47(3): 485-493.

Smirnov, N.N. 1992. *Guides to the identification of the microinvertebrates of the Continental Water of the world 1: The Macrothricidae of the world*, 143 pp. the Netherlands: SPB Academic Publishing.

Starling, F.L.R.M. 2000. Comparative study of the zooplankton composition of six Lacustrine Ecosystems in central Brazil during the dry season. *Rev. Brazil. Biol.* 60(1): 101-111.

Storer, P.J. 1977. A study of the waterfowl at Thale Noi waterfowl reserve area. *Nat. Hist. Bull. Siam Soc.* 26: 317-338.

Suphakason, R. 1992. *A study of poverty in Thale Noi community.* M. Sc. Thesis, Faculty of Environmental Management, Prince of Songkla University, Thailand. (in Thai).

Swingle, H.S. 1969. *Methods of analysis for water, organic matter and pond bottom solids used in fisheries research,* 119 pp. USA: Auburn University, International Centre for Aquaculture.

Tansakul, P. 1983. Phytoplankton biomass in Thale-Noi. *Seminar report on management and development of Songkhla Lake,* Biology Department, Faculty of Science, Prince of Songkla University. 17-19 July 1983, pp. 113-116. (in Thai).

Tansakul, R. and Sirimontraporn, P. 1982. The cycle of dissolved oxygen in Thale Noi (Lake Songkhla, Thailand). *Regional workshop on limnology and water resources management in the developing countries of Asia and the Pacific,* University of Malaya, pp. 1-6.

Tansakul, R., Tansakul, P., Rittabhonbhun, N. and Meekaew, D. 1986. Utilization of herbivorous fish in the Thale Noi ecosystem to control aquatic weed. *Proceeding of the regional seminar on the utilization of Urba and Rural Wastes: Technologies for Microbial Conversion of Wastes,* Bangkok, Thailand, 16-19 December 1986, pp. 311-329.

Theodore, L.J., Eugene, C.B. and Frances, F.J. 1979. *How to Know the Protozoa*, 279 pp. the USA: Wm. C. Brown company Publishers.

Thungwa, S., Masae, A. and Hembanthid, Y. 2002. The evolution and patterns of natural resources and environmental management in Thale Noi fishing community, Changwat Phatthalung. *Songklanakarin J. of Social Sciences and Humanities*. 8(2): 227-242. (in Thai).

Torres, L.E. and Rylander, K. 2006. Diversity and abundance of litteral cladocerans and copepods in nine Ecuadorian highland lakes. *Rev. Biol. Trop.* 54(1): 131-137.

Torres-Orozco, R.E. and Zanatta, S.A. 1998. Species composition, abundance and distribution of zooplankton in a tropical eutrophic lake: Lake Catemaco, Mexico. *Rev. Biol. Trop.* 46(2): 285-296.

Uye, S., Shimazu, T., Yamamuro, M., Ishitobi, Y., Kamiya, H. 2000. Geographical and seasonal variations in mesozooplankton abundance and biomass in relation to environmental parameters in Lake Shinji–Ohashi River–Lake Nakaumi brackish-water system, Japan. *Journal of Marine Systems* 26:193–207.

Virroux, L. 2002. Seasonal and longitudinal aspects of microcrustacean (Cladocera, Copepoda) dynamics in a lowland river. *Journal of Plankton Research* 24(4): 281-292.

Wang, S., Xie, P., Wu, S. and Wu, A. 2007. Crustacean zooplankton distribution patterns and their biomass as related to trophic indicator of 29 shallow subtropical lakes. *Limnologica* 37: 242-249.

Wansuang, P. and Sanoamuang, L. 2006. Species diversity of rotifers, cladocerans and copepods in temporary waters in Ubon Ratchathani Province. *BRT Research Report,* pp. 105-118. (in Thai).

Wetzel, R. G. 2001. *Limnology lake and river ecosystems.* USA.

Wongrat, L. 2000. *Zooplankton,* 787 pp. Bangkok : Kasetsart University press. (in thai).

Xu, M., Cao, H., Deng, D., Feng, W. and Xu, J. 2005. The temporal and spatial distribution, composition and abundance of Protozoa in Chaohu Lake, China: relationship with eutrophication. *European Journal of Protistology* 41: 183-192.

Yakovlev, V. 2001. Zooplankton of subarctic Imandra Lake following water quality improvements, Kola Peninsula, Russia. *Chemosphere* 42: 85-92.

Yildiz, S., Altindag, A. and Ergonul, B.E. 2007. Seasonal fluctuations in the zooplankton composition of a eutrophic lake: Lake Marmara (Manisa, Turkey). *Turk. J. Zool.* 31: 121-126.

Zhensheng, L., Chunsheng, W., Zhinan, Z., Chenggang, L. and Guanming, Y. 2006. Seasonal dynamics of zooplankton and grazing impact of microzooplankton on phytoplankton in Sanmen Bay, China. *Acta Ecologica Sinica* 26(12): 3931-3941.

APPENDICES

APPENDIX A

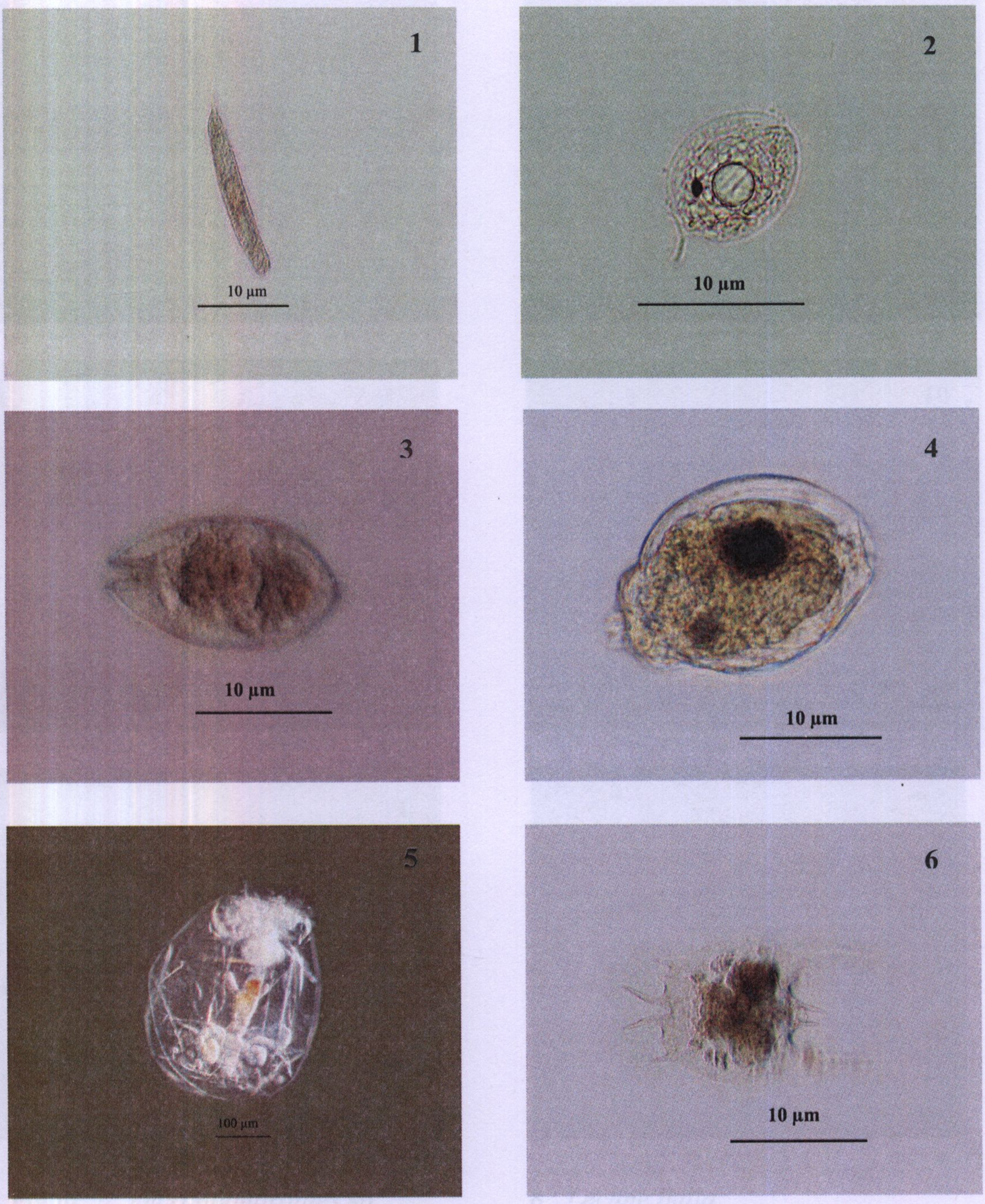


Figure 1 : *Euglena* sp.
2 : *Phacus* sp.
3 : *Anuraeopsis fissa*
4 : *Ascomorpha* sp.
5 : *Asplanchna* sp.
6 : *Brachionus quadridentatus*

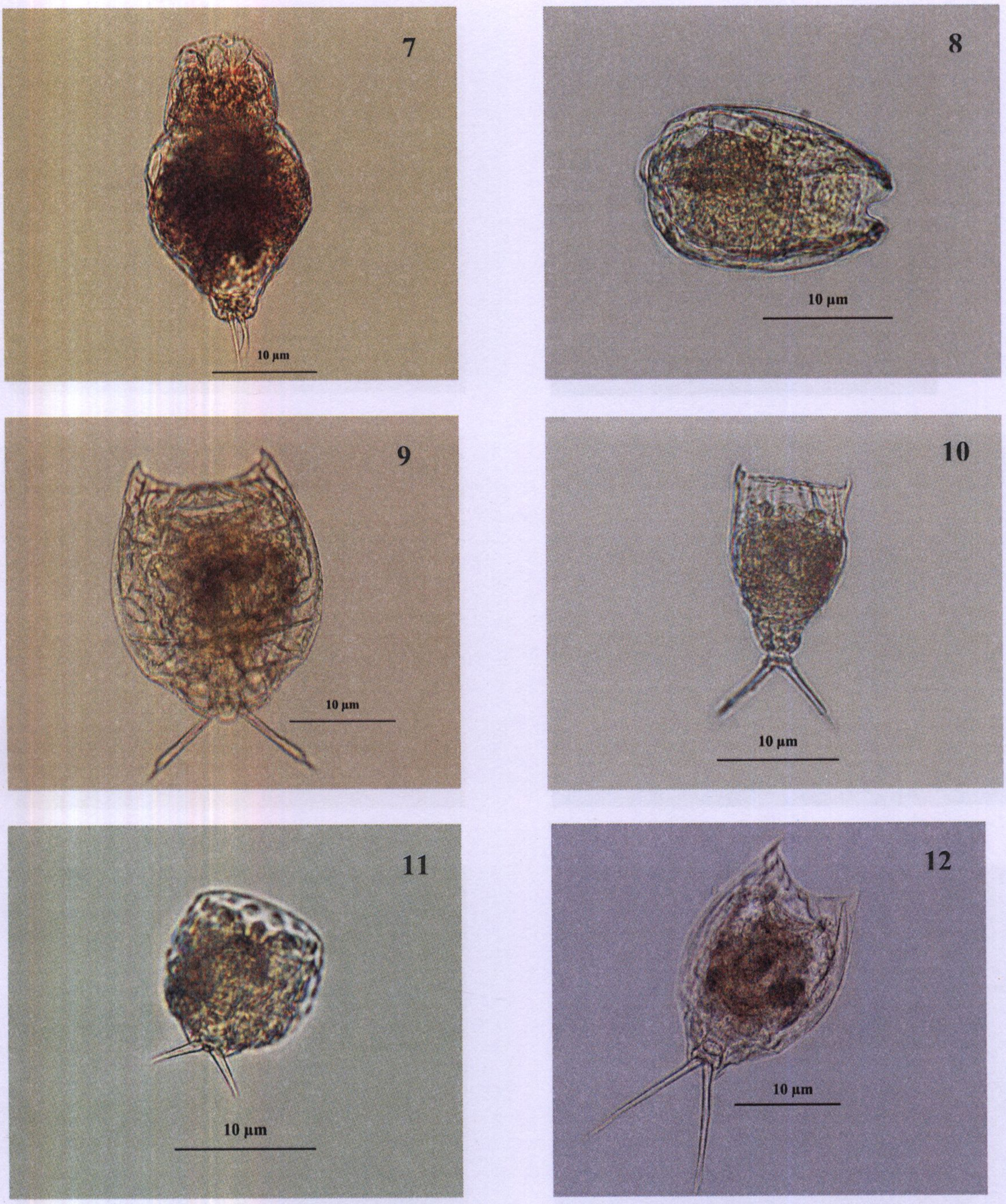
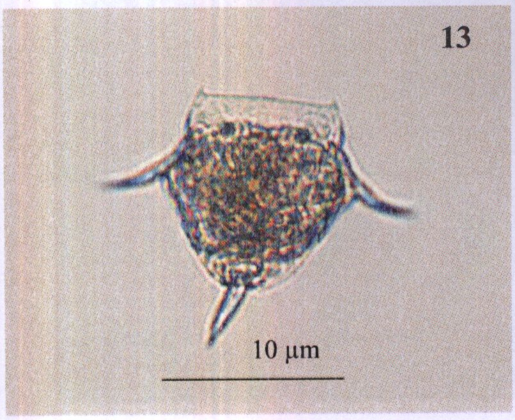
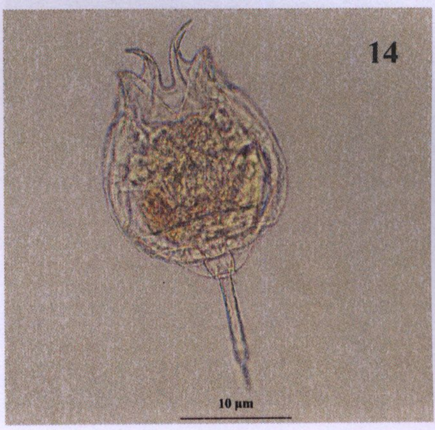


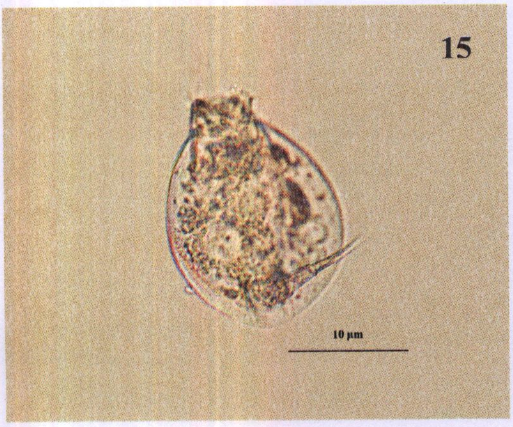
Figure 7 : *Dicranophoroides* sp.		8 : *Lecane bulla*

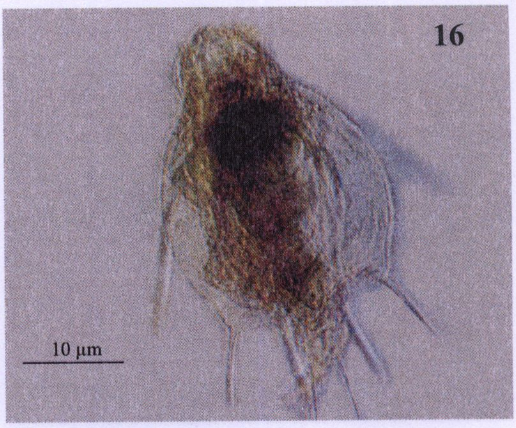
9 : *Lecane curvicornis*		10 : *Lecane crepida*

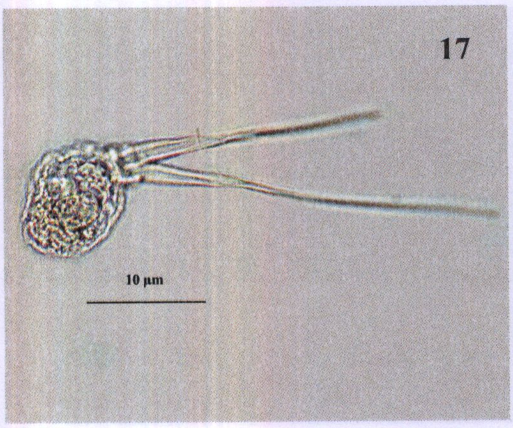
11 : *Lecane hornemanni*		12 : *Lecane leontina*











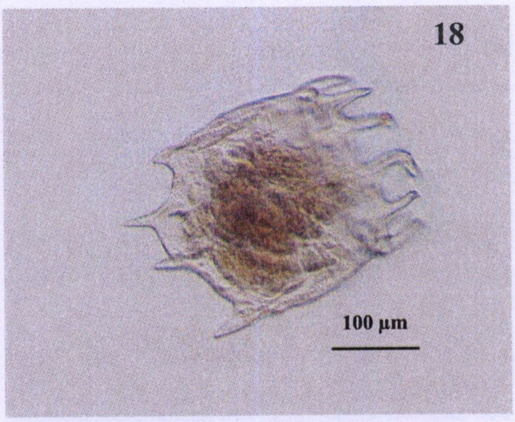


Figure 13 : *Lecane monostyla*

14 : *Lecane quadridentata*

15 : *Lepadella* sp.

16 : *Macrochaetus* sp.

17 : *Monommata* sp.

18 : *Plationus* sp.

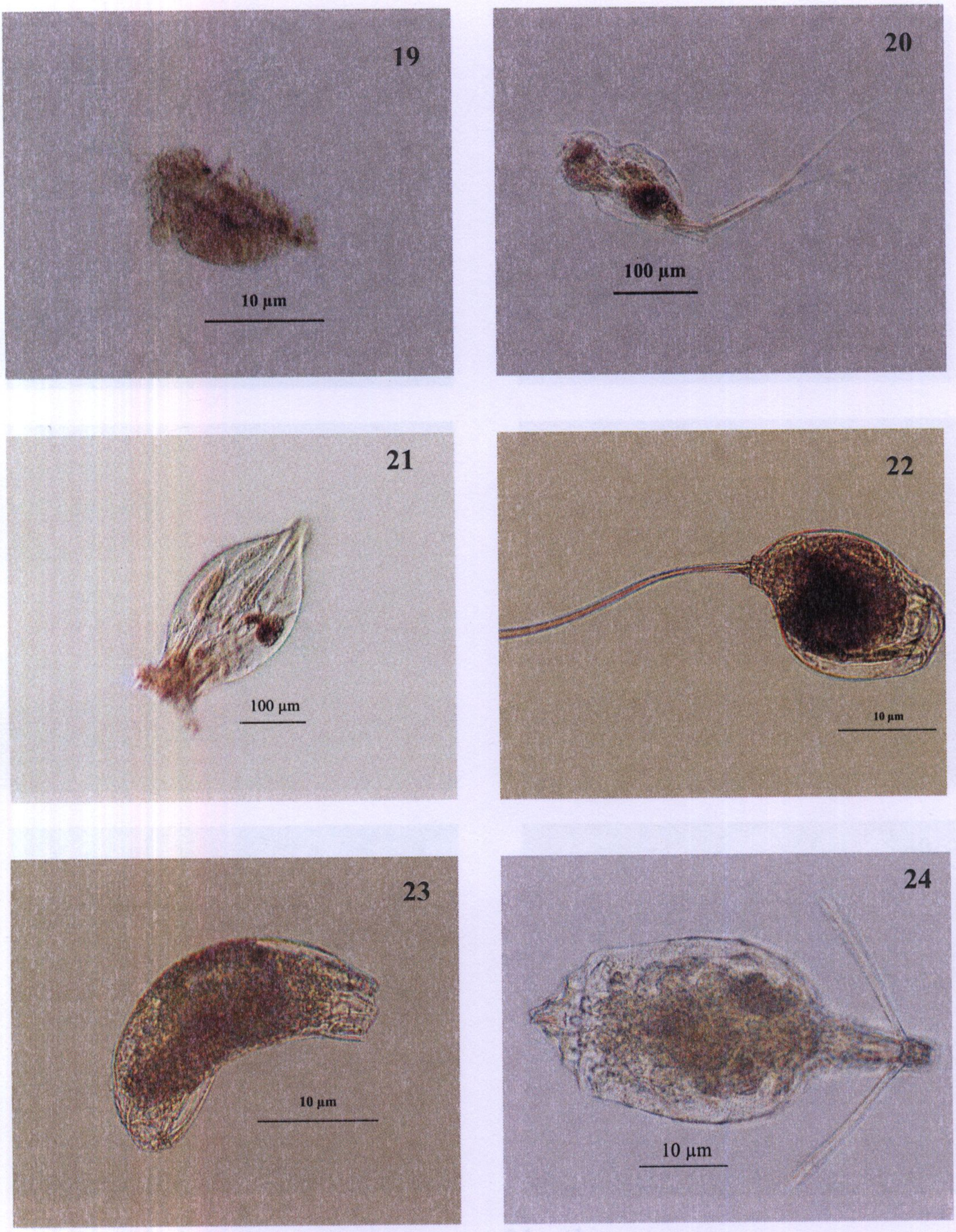


Figure 19 : *Polyarthra* sp.

20 : *Scaridium* sp.

21 : *Testudinella* sp.

22 : *Trichocerca flagellata*

23 : *Trichocerca tropis*

24 : *Trichotria* sp.

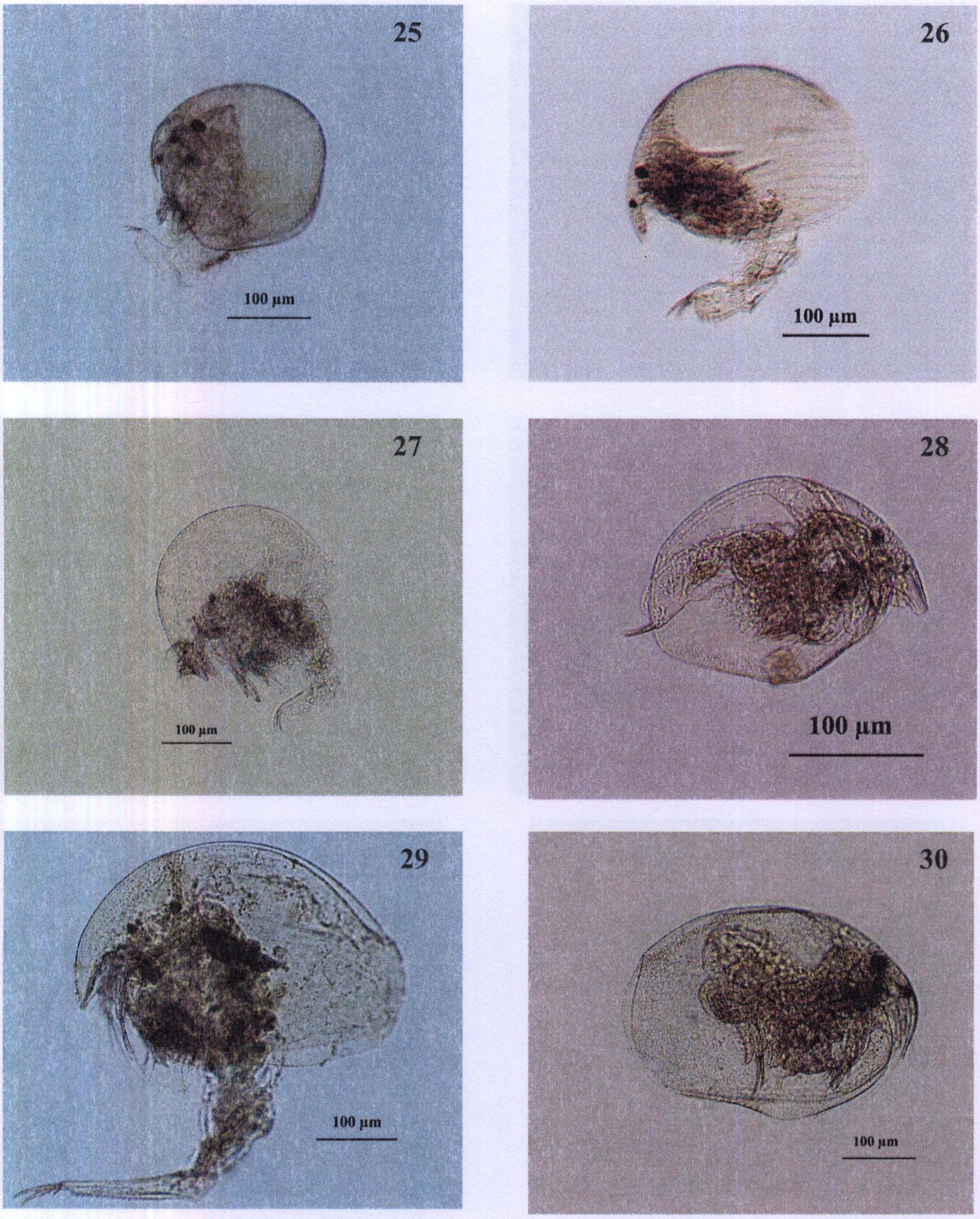


Figure 25 : *Chydorus* sp. 26 : *Alona verucosa*

27 : *Alona* sp. 28 : *Alona sarasinorum*

29 : *Camptocercus australis* 30 : *Kurzia* sp.

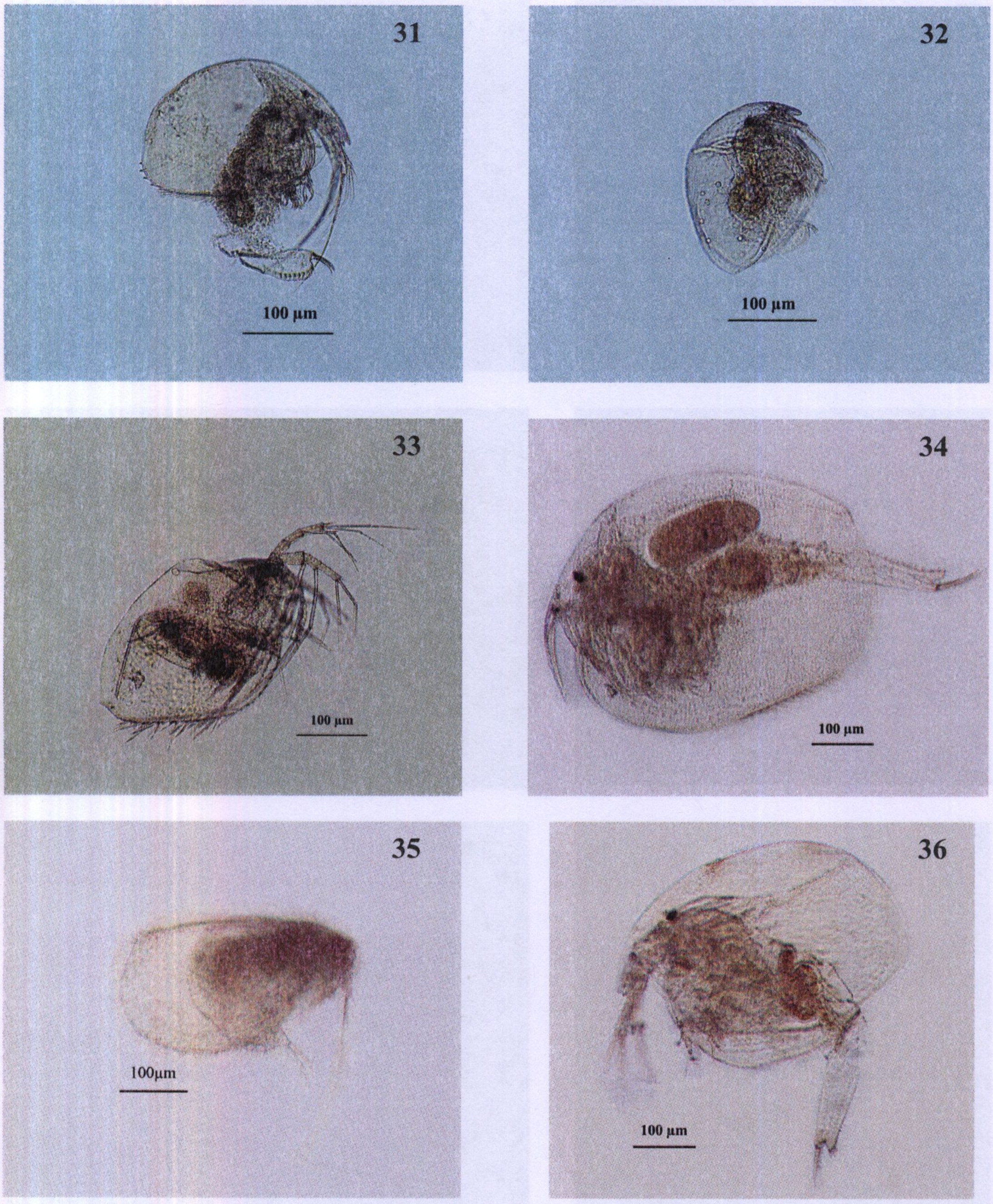
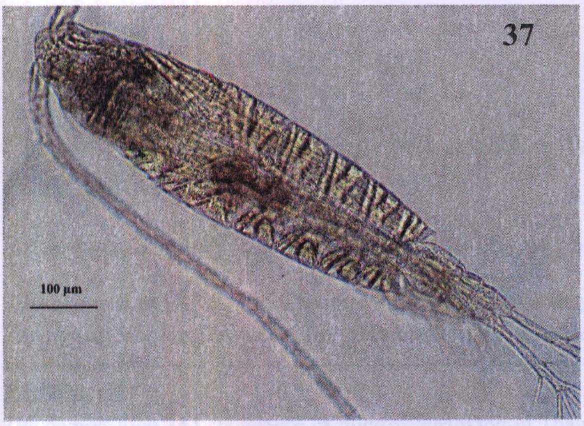
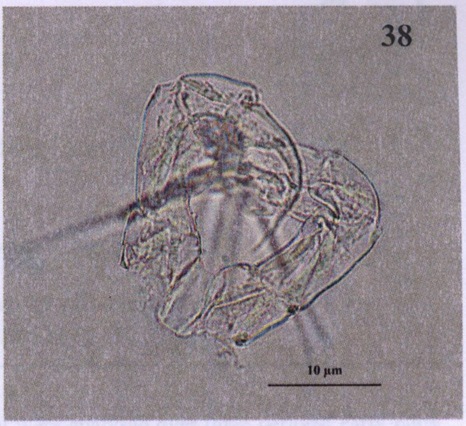


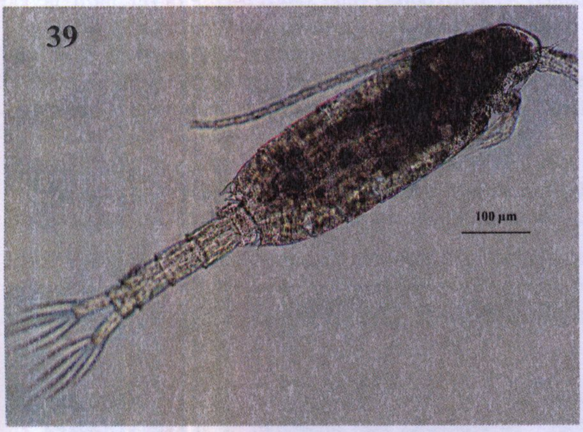
Figure 31 : *Karaualona* sp. 32 : *Dunhevedia crassa*

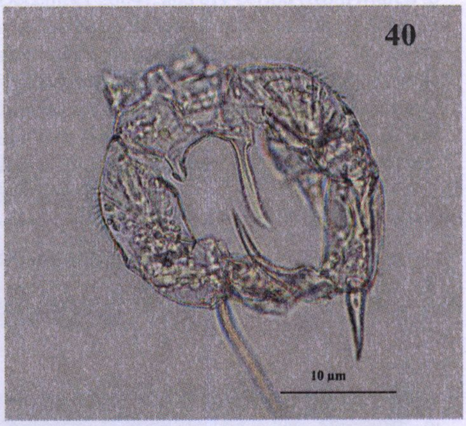
33 : *Macrothrix* sp. 34 : *Kurzia longirostris*

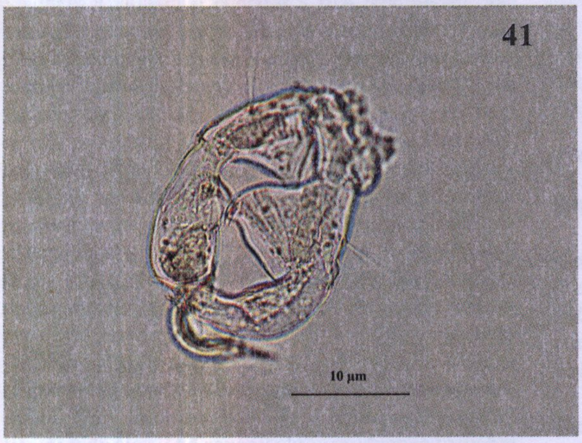
35 : *Ilyocryptus* sp. 36 : *Euryalona* sp.











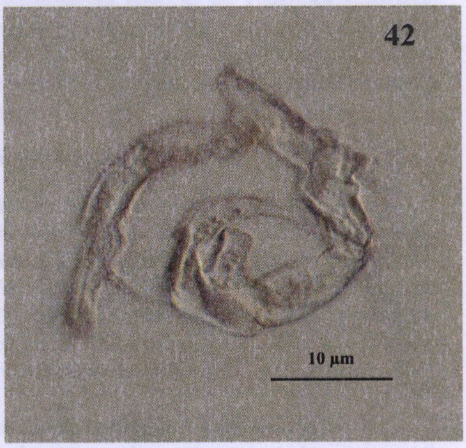


Figure 37 : *Sinocalanus* sp. 38: P5 *Sinocalanus* sp.

39 : *Pseudodiaptomus* sp. 40 : P5 *Pseudodiaptomus* sp.

41 : P5 *Acartiella sinensis* 42 : P5 *Acartia* cf. *southwelli*

Composition and Abundance of Microzooplankton Communities in Thale-Noi, Phatthalung Province, Thailand

Rattanawan Inpang[1,*], Pornsilp Pholpunthin[1], and Soawapa Angsupanich[2]

[1]Department of Biology, [2]Department of Aquatic Science (Faculty of Natural Resources)
Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla

ABSTRACT

The composition and abundance of microzooplankton in Thale-Noi were analysed over three periods; early rainy period (from July to August 2004), rainy period (from November to December 2004), and dry period (from March to April 2005). Quantitative samples were taken twice a month to investigate the variation of microzooplankton in relation to environmental parameters and habitats. The microzooplankton community was composed of 25 genera of Protozoa, 32 genera of Rotifera, 13 genera of Cladocera, 1 genera of Ostracoda and 3 genera of Copepoda. Larvae and juvenile forms such as Polychaete larvae, Ostracod juvenile, Crustracean nauplii and copepodite of Copepoda were also found. Two seasonal microzooplankton peaks were found in the present study: one during rainy period (1.4x107ind.m^{-3}) and another in dry period (1.6x107 ind.m^{-3}). Cladodera, Copepoda and Crustacean nauplii were most abundance in rainy period, while Rotifera was the most abundance in dry period.

KEYWORDS : Composition, Abundance, Microzooplankton Community, Thale-Noi

*Corresponding author Tel.: 0817981777 E-mail: harpacticoid@yahoo.com

Introduction

Thale-Noi lake is an important bird sanctuary in Southern Thailand. It contains a rich biodiversity, the resources of which enable local residents to earn a living from activities such as fishing, agriculture and especially tourism. However, because of the ongoing expansion of the near-shore village, waste water is being constantly discharged into the lake. The result is that the Thale-Noi ecosystem and its water quality are subjected to continuously changing and unnatural source. The waste water adds nutrients to the lake, which affect the aquatic community structure and may lead to the destruction of the food web in the area. Microzooplankton has long been thought to be a major consumer of small particles unavailable to meso-and macrozooplankton (Gifford, 1991), and these organisms also act as a significant food source for a variety of invertebrate and vertebrate predators (Godhantaraman, 2001). Thus, microzooplankton is an important link in transferring pico- and nanoplankton production to higher trophic levels (Eskinazi-SantíAnna & Bjornberg, 2006).

The previous study of zooplankton in Thale-Noi lake has been intensively investigated especially in taxonomy (Pholpunthin, 1997; Segers & Pholpunthin, 1997). Few studies have reported on zooplankton community variations affecting the lakeís physico-chemical factors (Angsupanich and Rukkeaw, 1984; Angsupanich, 1985) but not one has paid attention on size-fractions of Chlorophyll a in relation to the abundance of microzooplankton. Therefore, in order to examine the status of the Thale-Noi ecosystem we studied its microzooplankton community (composition and abundance), as well as the possible influence of two size-fractions of chlorophyll a on the microzooplankton community.

Material and Methods

Study site

Thale-Noi, a shallow roundish lake, is located in the most north of the overall Songkhla Lake system (7° 45′ N to 7° 55′ N, 100° 05′ E to 100° 15 E) (Fig. 1). It covers a 30 km2 area, has a shoreline of about 20 km, and has contained about 32 M m3 of water. The lake is rather shallow with a mean depth being 1.1 m (Kuwabara,1995).

Zooplankton sampling and analysis

Quantitative samples were conducted twice a month in three bimonthly periods, comprising the moderate-water phase (early rainy period) in July and August 2004, the high-water phase (rainy period) in November and December 2004 and the low-water phase (dry period) during March and April 2005. Plankton samples were collected at twelve stations (Fig. 1).

The samples were taken by filtering 20-50 liters of water through a 20 mm plankton net. They were immediately preserved in a 5% formaldehyde solution and brought to laboratory for further analysis. At the same time as zooplankton sampling, surface water samples for chlorophyll a were collected. Size-fraction of the chlorophyll a was extracted in 90% acetone and analyzed, using a filtrated 250 ml water sample from each station, by utilizing a 200 mm mesh net to eliminate zooplankton from the water sample. The filtrated water sample was then poured sequentially through 20 mm mesh nets. The residual on the 20 mm net was re-suspended in distilled water and analyzed for chlorophyll a fraction of 20-200 mm. The samples that passed through the 20 mm mesh net were analyzed for chlorophyll a fraction of < 20 mm.

At the laboratory, microzooplankton samples (20-200 mm) were separated by filtering plankton samples through a 200 mm sieve. Counting and identification of the plankton to genus or species levels was done under the Olympus CH-2 Compound and Olympus SZ-40 Stereo microscopes. Zooplankton identification was based on the following experts: Theodore et al. (1979), Idris (1983), Smirnov (1992), Korovchinsky (1992), Sergers (1995-1996), Wongrat (2000), Sanoamuang (2002) and Maiphae (2005). The density of organisms was calculated from the volume of water filtered and the size of each sub-sample, and expressed as numbers of individuals per cubic meter. Correlations between abundance of each genus and chlorophyll a concentrations were examined. The data were transformed to logarithm scale (Log x+1) prior to the analysis.

Results and Discussion

Composition of microzooplankton in Thale-Noi

A total of 25 genera of Protozoa, 32 genera of Rotifera, 13 genera of Cladocera, 1 genera of Ostracoda and 3 genera of Copepoda were recorded (Table 1). Larvae and juvenile forms such as Polychaete larvae, Ostracod juvenile, Crustacean nauplii and copepodites of Copepoda were also found. The largest number of genera was found in the rainy period, the lowest in the early rainy period. Rotifera was the group with the highest taxonomic richness in Thale-Noi. This pattern is common in tropical freshwater, whether in lakes, ponds, rivers, or streams (Neves et al., 2003). The large species number of this group is considered to be the opportunistic species in different environments (Keppeler, 2003). There is a series of advantages in the rotifers system of reproduction, which could favor the participation of most of these animals in an opportunistic, colonizing lifestyle. Opportunistic organisms show wide fluctuations in population, being adapted to reproduce in relatively limiting conditions (Birky and Gilbert, 1971). Additionally, the wide spectrum of food particles exploited by this group, which display the ability to consume bacteria, algae and detritus of different size, allows quite distinct diets for the many species simultaneously present in a body of water (Sampaio et al., 2002). The Rotifera families with the greatest number of species were the Brachionidae and Lecanidae, which are considered typical for, and most frequent in, tropical environments (Dumont, 1983).

The Protozoa formed the dominant group in the lake, representing about 56% of total microzooplankton, followed by Rotifera (36%), Crustacean nauplii (7%), and Polychaeta (1%). The contribution of Cladocera, Ostracoda, and Copepoda to the total microzooplankton were rather weak (<1%) (Table 2). In the present study, the numerical dominance of Protozoa in the zooplankton community concurs with results in the Sâo Sebastiâo Channel, where Protozoa were predominant with a mean of 52% (Eskinazi-Sant'Anna and Bjornberg, 2006). Because of their small size and high metabolic rate, they play a substantial role in nutrient regeneration in the water column, indicating that they often become the main zooplankton in the community. This suggests that protozoans must have a key trophic role that may contribute to the high productivity of the lake food web (Pirlot et al., 2005). However, Angsupanich (1985) reported that Rotifera is the dominant group in Thale-Noi, with both the highest species richness (15 genera) and population densities (70% of total zooplankton) in the lake. These may due to the using of a net with a mesh size larger than 30 mm, as this could have led to underestimating the quantity of smaller organisms. Microcrustaceans, especially cladocerans and copepods, were poorly represented in Thale-Noi. In populations of Copepoda, the numerical predominance of young forms, especially nauplii, is the most common pattern.

Relative abundance and density of microzooplankton

The relative abundance of the microzooplankton varied from 7% to 94%, among Protozoa; from 5% to 70% for Rotifera; from 0.1% to 2.3% for Cladocera; from 0% to 3% for Ostracoda; from 0.04% to 1.7% for Copepoda; from 0% to 23% for Polychaeta and 0.17% to 28.3 % for Crustacean nauplii. The highest density of microzooplankton, 1.6x107 ind.m-3, occurred in early April 2005, the lowest, 1.8x105 ind.m-3, in early March 2005.

During the early rainy period (July to August 2004), Rotifera was the dominant group in all sampling periods (Fig.2). There was a great abundance of Polyarthra in July (27% and 53% of rotifers in early and late July, respectively) and Anuraeopsis in August (43% and 39% of rotifers in early and late August, respectively). Stentor and Euglena were the most abundant group of Protozoa.

In the rainy period, different groups of microzooplankton alternated in dominance. Rotifers were the most abundant in early November and early December, whereas protozoans were most abundance in late November and late December. The dominant group of the Rotifera was Polyarthra (28% and 57% of rotifers in early November and late December, respectively) and among the Protozoa it was Trachelomonas

(57% of protozoans in late November) and Peridinium (51% of protozoans in early December).

In the dry period, there was a dominance of Protozoa over the other groups during all four sampling periods. There was a great abundance of Tintinopsis (40% of protozoans) in early March, and of Trachelomonas (91%, 78% and 75% of protozoans in late March, early and late April, respectively) in the other periods.

In most samples taken, Protozoa and Rotifera were the most abundant group, representing more than 70% of the microzooplankton. These organisms are strategists, or opportunists, of small size, with short life cycles and wide tolerance to a variety of environment factors. In general, and particularly in tropical waters, the microzooplankton distribution and abundance varies considerably due to seasonal fluctuations (Sampaio and Lopez, 2000). This observation agrees with the reservoirs of the Paranapanema River (Sampaio et al., 2002). The highest density of microzooplankton, particularly protozoans, in the dry period may be attributed to a combination of temperature, salinity and chlorophyll a concentrations, which are often considered the most important factors in acceleration of the growth rate (Eskinazi-SantíAnna & Bjornberg, 2006).

Biological factors

There were significant differences among size fractions of chlorophyll a ($P<0.05$) but not among the sampling periods. Chlorophyll a concentrations of < 20 mm ranged from 1,192 to 5,670 mg.m-3; the highest concentration occurred during the rainy period. Chlorophyll a fraction of 20-200 mm ranged from 582 to 3,885 mg.m-3, with a maximum in dry period (late March) (Fig. 3). Throughout the study, total chlorophyll a was dominated by the chlorophyll a of < 20 mm fraction, which comprised between 43 and 82% of the total chlorophyll a. An exception was recorded during early July, as then chlorophyll a fraction of 20-200 mm dominated the overall concentration (Fig. 3). The small size fraction of chlorophyll a may caused by the contribution of pico-nanophytoplankton as observed by Shiomoto (1997). The predominance of small-size phytoplankton in natural waters has been hypothesized to be due to intrinsically higher growth and photosynthetic rates, and to nutrient uptake rates of small algal cells with high surface-to-volume ratios, compared to what is found with large cells (Cole el at., 1986).

Relationships between microzooplankton and Chlorophyll *a*

Pearson correlation analysis indicated that total microzooplankton abundance was not significantly correlated with size fractions of chlorophyll a ($P<0.05$). However, chlorophyll a of < 20 mm fraction was significantly correlated ($P<0.01$) with Protozoa ($r=0.26$), especially Trachelomonas spp. ($r= 0.28$, $P<0.05$) and Phacus spp. ($r=0.23$, $P<0.05$). The significant correlations with chlorophyll a of < 20 mm were also found in Ascomorpha spp. ($r=0.21$, $P<0.05$), Colurella spp. and Lepadella spp. (both $r= -0.25$, $P<0.05$). Regarding to Chlorophyll a of 20-200 mm fraction, only Bosminopsis deitersi showed significant positive correlations ($r=0.27$, $P<0.01$). According to Mageed and Heikal (2006), the lowest zooplankton coincides with the lowest chlorophyll a values. During our investigation, total microzooplankton, especially Protozoa was strongly correlated to chlorophyll a of <20 mm fraction, suggesting that the seasonal changes in microzooplankton abundance in the Thale-Noi may be related to the interactive effects of food size-spectra.

Acknowledgements

The research was supported by TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT T_349001 and by financial support of the Graduate School, Prince of Songkla University.

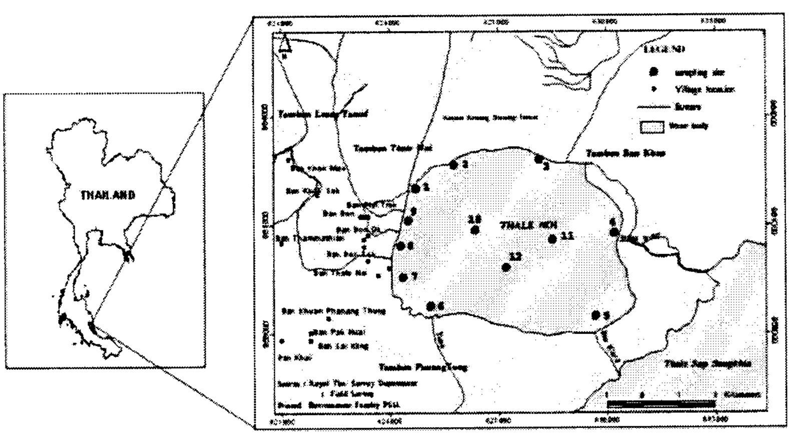


Figure 1. Study area and sampling stations in Thale-Noi, Phatthalung Province.

Table 1. Composition of microzooplankton communities of three sampling periods at Thale-Noi during July 2004 to April 2005.

Genus	Thale-Noi Lake			Genus	Thale-Noi Lake		
	Early rainy	Rainy	Dry		Early rainy	Rainy	Dry
Protozoa				**Rotifera (cont.)**			
Actinophrys	+	+	-	*Hexathra*	+	+	+
Arcella	+	+	+	*Keratella*	+	+	+
Bursaria	-	+	+	*Lecane*	+	+	+
Centropyxis	+	+	+	*Lepadella*	+	+	+
Ceratium	-	-	+	*Macrochaetus*	+	-	-
Codonella	-	+	+	*Monommata*	+	+	-
Coleps	-	+	+	*Mytilina*	+	+	+
Difflugia	+	+	+	*Notommata*	+	+	-
Dinobryon	+	+	+	*Plationus*	+	+	+
Euglena	+	+	+	*Platyias*	+	+	+
Euglyphra	+	+	+	*Polyarthra*	+	+	+
Favella	-	-	+	*Proales*	+	+	+
Halteria	+	+	+	*Ptygura*	+	+	-
Holophrya	-	+	+	*Scaridium*	+	+	-
Lepocinclis	-	+	+	*Squatinella*	+	-	-
Loxodes	+	+	+	*Synchaeta*	-	+	+
Paramecium	+	+	+	*Testudinella*	+	+	+
Peranema	+	+	+	*Trichocerca*	+	+	+
Peridinium	-	+	+	*Trichotria*	+	+	+
Phacus	+	+	+	**Ostracoda**			
Stentor	+	+	+	*Stenocypris*	-	-	+
Tintinopsis	+	+	+	**Cladocera**			
Trachelomonas	+	+	+	*Alona*	+	+	+
Undella	-	+	+	*Alonella*	+	-	-
Volvox	-	+	+	*Bosminopsis*	+	+	+
Rotifera				*Ceriodaphnia*	-	+	-
Anuraeopsis	+	+	+	*Chydorus*	+	+	+
Ascomorpha	+	+	+	*Dunhevedia*	+	+	+
Asplanchna	+	+	+	*Ephemeroporus*	+	+	+
Brachionus	+	+	+	*Karualona*	+	+	+
Cephalodella	+	+	+	*Latonopsis*	+	-	-
Coliotheca	+	+	+	*Macrothrix*	+	-	+
Colurella	+	+	+	*Moina*	-	+	-
Dicranophorus	+	+	-	*Moinodaphnia*	+	-	-
Dicranophoroides	-	-	+	*Notoalona*	+	-	-
Dipleuchlanis	-	+	+	**Copepoda**			
Euchlanis	+	+	+	*Neodiaptomus*	+	+	+
Filinia	+	+	+	*Mesocyclops*	+	+	+
Floscularia	-	-	+	*Metacyclops*	-	+	-

Note: + = present and - = not present in the waterbody

Table 2. Total density (ind.m^{-3}) and % abundance of major zooplankton assemblages in each sampling period.

Zooplankton assemblages	Early rainy		Rainy		Dry	
	Total	%	Total	%	Total	%
Protozoa	1.7x106	13	2.3x107	62	1.8x107	66
Rotifera	8.9x106	64	1.1x107	31	7.9x106	29
Polychaeta	9.1x105	7	-	-	1.7x103	<1
Cladocera	1.7x104	<1	3.0x105	1	7.1x104	<1
Ostracoda	7.9x104	1	1.3x104	<1	2.8x104	<1
Copepoda	3.3x104	<1	9.3x104	<1	6.3x104	<1
Crustacean nauplii	2.1x106	15	2.2x106	6	1.3x106	5
Sum	1.3x107	100	3.8x107	100	2.7x107	100

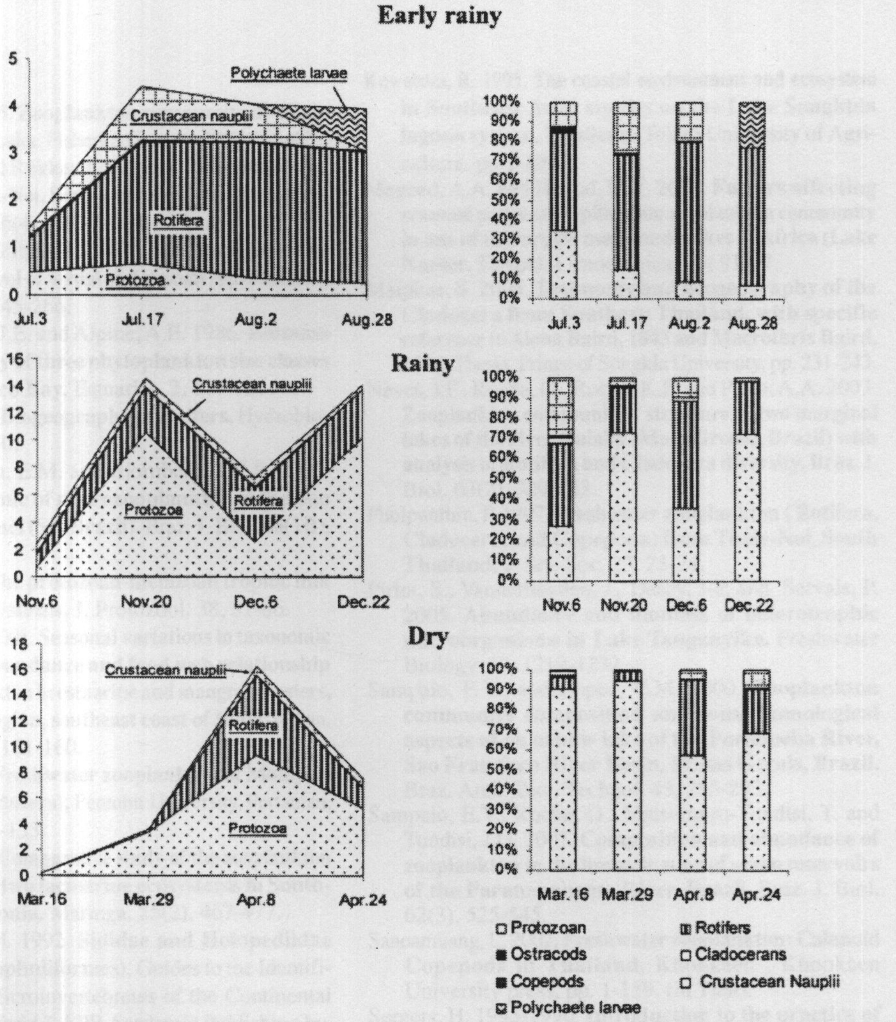


Figure 2. Changes in absolute densities and relative abundance of the microzooplankton in Thale-Noi during, July 2004 to April 2005.

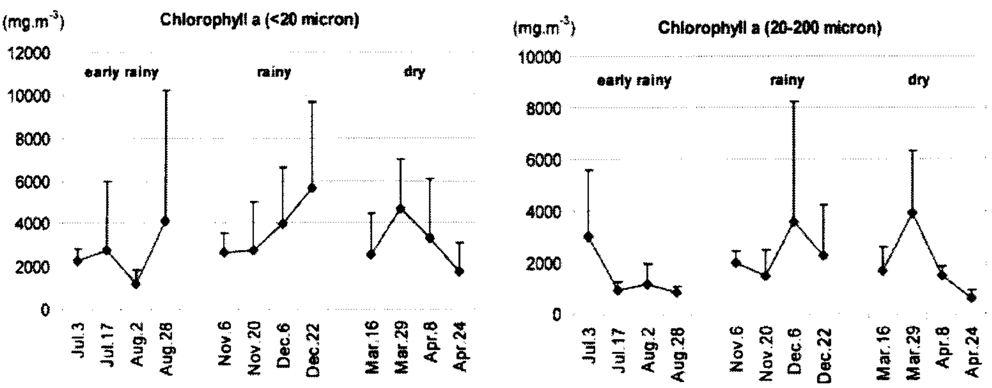


Figure 3. Seasonal patterns of size-fractioned of chlorophyll *a* during sampling period from July 2004 to April 2005.

References

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

Angsupanich, S. and Rukkeaw, S. 1984. **Distribution of Rotifera in Thale-Noi, Songkhla Lake.** Songkhlanakarin J. Sci. Technol. 6(4), 363-368. (in Thai).

Birky, C.W.Jr. and Gilbert, J.J. 1971. **Parthenogenesis in rotifers: the control of sexual and asexual reproduction.** Am. Zool. 11, 245-266.

Cole, B.E., Cloern, J.E. and Alpine, A.E. 1986. **Biomass and productivity of three phytoplankton size classes in San Francisco Bay.** Estuaries. 2, 117-126.

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

Eskinazi-Sant'Anna, E.M. and Bjornberg, T.K.S. 2006. **Seasonal dynamic of microzooplankton in the Sao Sebastiao channel (SP, Brazil).** Braz. J. Biol. 66(1B), 221-231.

Gifford, D.J. 1991. **The protozoan-metazoan trophic link in pelagic ecosystems.** J. Protozool. 38, 81-86.

Godhantaraman, N. 2001. **Seasonal variations in taxonomic composition, abundance and food web relationship of microzooplankton in estuarine and mangrove waters, Parangipettai region, southeast coast of India.** Indian. J. Mar. Sci. 30, 151-160.

Idris, B.A.G. 1983. **Freshwater zooplankton of Malaysia (Crustacea: Cladocera),** Perenbit University, Pertanian, Malaysia, pp. 1-153.

Keppeler, E.C. 2003. **Comparative study of the zooplankton composition of two lacustrine ecosystems in Southwestern Amazonia.** Maringa. 25(2), 467-477.

Korovchinsky, N.M. 1992. **Sididae and Holopediidae (Crustacea: Daphniiformes),** Guides to the Identification of the Microinvertebretes of the Continental Waters of the World 3. SPB Academic Publishing bv, the Netherlands, pp. 1-82.

Kuwabara, R. 1995. **The coastal environment and ecosystem in Southeast Asia: studies on the Lake Songkhla lagoon system, Thailand,** Tokyo University of Agriculture, pp.1-109.

Mageed, A.A. and Heikal, M.T. 2006. **Factors affecting seasonal patterns in epilimnion zooplankton community in one of the largest man-made lakes in Africa (Lake Nasser, Egypt).** Limnologica. 36, 91-97.

Maiphae, S. 2005. **Taxonomy and Biogeography of the Cladocera from Southern Thailand, with specific reference to Alona Baird, 1843 and Macrothrix Baird, 1843,** Thesis, Prince of Songkla University, pp. 231-243.

Neves, I.F., Rocha, O., Roche, K.F. and Pinto, A.A. 2003. **Zooplankton community structure of two marginal lakes of the river Cuiaba (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity.** **Braz.** J. Biol. 63(2), 329-343.

Pholpunthin, P. 1997. **Freshwater zooplankton (Rotifera, Cladocera, and Copepoda) from Thale-Noi, South Thailand.** J. Sci. Soc. 23, 23-24.

Pirlot, S., Vanderheyden, J., Descy, J-P. and Servais, P. 2005. **Abundance and biomass of heterotrophic microorganisms in Lake Tanganyika.** Freshwater Biology. 50, 1219-1232.

Sampaio, E.V., and Lopez, C.M. 2000. **Zooplankton community composition and some limnological aspects of an oxbow lake of the Paraopeba River, Sao Francisco River Basin, Minas Gerais, Brazil.** Braz. Arch. Biol. Technol. 43, 285-293.

Sampaio, E.V., Rocha, O., Matsumuru-Tundisi, T. and Tundisi, J.G. 2002. **Composition and abundance of zooplankton in the limnetic zone of seven reservoirs of the Paranapanema River, Brazil.** Braz. J. Biol. 62(3), 525-545.

Sanoamuang, L. 2002. **Freshwater zooplankton: Calanoid Copepods in Thailand,** Khonkaen , Khonkaen University press, pp. 1-159. (in Thai).

Sergers, H. 1995-1996. **Introduction to the practice of identifying Rotifera,** International Trainning Course,

Universiteit Gent, pp. 1-69.
Sergers, H. and Pholpunthin, P. 1997. **New and rare Rotifera from Thale-Noi, Phatthalung Province, Thailand, with a note on the taxonomy of Cephalodella (Notommatidae).** Annls Limnol. 33(1), 13-21.
Shiomoto, A. 1997. **Size fractionated chlorophyll a concentration and primary production in the Okhotsk Sea in October and November 1993, with special reference to the influence of Dichothermal water.** Journal of Oceanography. 53, 601-610.
Smirnov, N.N. 1992. **The Macrothricidae of the world, Guides to the identification of the microinvertebrates of the Continental Water of the world 1,** SPB Academic Publishing bv, the Netherlands, pp.1-143.
Theodore, L.J., Eugene, C.B. and Frances, F.J. 1979. **How to know the protozoa,** Wm. C. Brown Company Publishers, U.S.A., pp. 1-279.
Wongrat, L. 2000. **Zooplankton,** Bangkok, Kasetsart University press, pp. 1-787. (in Thai).

VITAE

Name Miss Rattanawan Inpang

Student ID 4622082

Education Attainment

Degree	Name of Institution	Year of Graduation
Bachelor of Science	Walailuk University	2001

Scholarship Awards during Enrolment

- TRF/BIOTEC Special program for Biodiversity Research and Training BRT T_349001.
- Grant from Faculty of Science, Prince of Songkla University, Hat Yai campus, Hat Yai, Songkhla Province.

List of Publication and Proceeding

- Inpang, R., Pholpunthin, P. and Angsupanich, S. 2007. Composition and abundance of microzooplankton communities in Thale-Noi, Southern Thailand. Physical Science and Technology: Proceedings 7th National Graduate Research Conference, April 4-5, 2007. Prince of Songkla University, Surat Thani Campus, pp. 111-117.