



**Completed report**

**Title**

**Species composition of zooplankton in paddy fields of  
Pathum Thani province, Thailand**

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Species composition of zooplankton in paddy fields of  
Pathum Thani province, Thailand

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ศึกษาสังคมแพลงก์ตอนสัตว์ในพื้นที่นาข้าวจำนวน 3 แปลง (แปลงที่ 1 ปลูกข้าวพันธุ์ราชินี 35 อายุ 95 วัน แปลงที่ 2 ปลูกข้าวพันธุ์ขาวปทุม อายุ 95 วัน และแปลงที่ 3 ปลูกข้าวพันธุ์สุพรรณบุรี 1 อายุ 115 วัน) ในเขตจังหวัดปทุมธานี ตั้งแต่เดือนสิงหาคม ถึงเดือนตุลาคม พ.ศ. 2548 เก็บตัวอย่างแพลงก์ตอนสัตว์เชิงปริมาณทุกอาทิตย์โดยกรองน้ำผ่านถุงแพลงก์ตอนขนาดตา 60 ไมโครเมตร พร้อมทั้งวัดปัจจัยสิ่งแวดล้อมบางประการ รายงานชนิด องค์ประกอบ และความหลากหลายของแพลงก์ตอนสัตว์ที่พบในนาข้าว และวิเคราะห์หาปัจจัยสิ่งแวดล้อมที่มีผลต่อสังคมแพลงก์ตอนสัตว์ในนาข้าว

พบแพลงก์ตอนสัตว์ทั้งสิ้น 88 ชนิด ในจำนวนนี้เป็นไรติเฟอร์ 74 ชนิด คลาโดเซอร่า 11 ชนิด และโคพีพอด 3 ชนิด พื้นที่ที่มีจำนวนชนิดของแพลงก์ตอนสัตว์มากที่สุดได้แก่ แปลงที่ 1 (75 ชนิด) รองลงมาคือ แปลงที่ 2 (55 ชนิด) และแปลงที่ 3 (51 ชนิด) จำนวนชนิดของแพลงก์ตอนสัตว์ที่พบในนาข้าวมีมากกว่าที่พบในคลองส่งน้ำเข้าสู่ นา องค์ประกอบหลักของแพลงก์ตอนสัตว์ในนาข้าวทั้งสามแปลงคือ ไรติเฟอร์ (แปลงที่ 1 = 85.3 เปอร์เซ็นต์ แปลงที่ 2 = 87.3 เปอร์เซ็นต์ และแปลงที่ 3 = 84.3 เปอร์เซ็นต์) รองลงมาคือ คลาโดเซอร่า (แปลงที่ 1 = 13.3 เปอร์เซ็นต์ แปลงที่ 2 = 7.3 เปอร์เซ็นต์ และแปลงที่ 3 = 9.8 เปอร์เซ็นต์) และโคพีพอด (แปลงที่ 1 = 1.4 เปอร์เซ็นต์ แปลงที่ 2 = 5.4 เปอร์เซ็นต์ และแปลงที่ 3 = 5.9 เปอร์เซ็นต์) ตามลำดับ ค่าเฉลี่ยดัชนีความหลากหลายสูงสุดคำนวณได้จากนาแปลงที่ 2 มีค่าเท่ากับ 1.825 รองลงมาได้แก่แปลงที่ 3 (1.586) และแปลงที่ 1 (1.515) ตามลำดับ และพบว่าค่าดัชนีความหลากหลายของแพลงก์ตอนสัตว์นี้มีความสัมพันธ์กับความลึกของน้ำในนาข้าว ค่าเฉลี่ยความสม่ำเสมอสูงสุดคำนวณได้จากนาแปลงที่ 2 มีค่าเท่ากับ 0.577 รองลงมาได้แก่แปลงที่ 3 (0.568) และแปลงที่ 1 (0.449) ตามลำดับ ความหนาแน่นของแพลงก์ตอนสัตว์สูงสุดของนาแปลงที่ 1 2 และ 3 เท่ากับ 1,519.5 1,756.8 และ 22,630.7 ตัวต่อลิตร ตามลำดับ องค์ประกอบหลักของแพลงก์ตอนสัตว์ในรอบการปลูกข้าวของนาทั้งสามแปลงคือ นอเพลียส การล้าของคลาโดเซอร่าและโคพีพอดมีผลต่อโครงสร้างของสังคมไรติเฟอร์ โดยคลาโดเซอร่าจัดเป็นผู้ล่าที่มีประสิทธิภาพต่อสังคมไรติเฟอร์มากที่สุด

การวิเคราะห์โดยใช้ Canonical correspondence analysis พบว่า ความเค็ม ค่าการนำไฟฟ้า ปริมาณออกซิเจนที่ละลายในน้ำ ความเข้มข้นของฟอสเฟต และ pH มีผลต่อสังคมแพลงก์ตอนสัตว์ในนาข้าวทั้งสามแปลง แต่การทดสอบ Monte Carlo test พบว่าไม่มีความสัมพันธ์ระหว่างข้อมูลของสังคมแพลงก์ตอนสัตว์และข้อมูลของปัจจัยแวดล้อม ดังนั้นผลของปัจจัยสิ่งแวดล้อมต่อสังคมแพลงก์ตอนสัตว์จึงไม่นับสำคัญ

จากผลที่ได้จากการศึกษาครั้งนี้ชี้ให้เห็นว่าพื้นที่นาข้าวมีความหลากหลายของแพลงก์ตอนสัตว์สูง ซึ่งเป็นผลเนื่องมาจากการจัดการในพื้นที่นาของเกษตรกร โดยเฉพาะปัจจัยระดับน้ำในนาข้าว

คำหลัก: แพลงก์ตอนสัตว์ องค์ประกอบ ความหลากหลาย นาข้าว

## ABSTRACT

**Project Code:** MRG4880168

**Project Title:** Species composition of zooplankton in paddy fields of  
Pathum Thani province, Thailand

|                                         |                              |
|-----------------------------------------|------------------------------|
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Zooplankton communities from three rice fields (RF1: grown Rachinee 35 (95 days), RF2: grown Koawpathum (95 days) and RF3: grown Suphunburee1 (115 days)) located in Pathumthani province were studied from August to November 2005. Quantitative samples were taken on weekly basis by filtering water through a 60  $\mu\text{m}$  plankton net, and some environmental variables were measured. Species, composition and diversity of zooplankton in rice fields were reported, and the important factors influencing on zooplankton communities were investigated.

Eighty-eight species of zooplankton were identified from three rice fields during a crop cycle. Of these, 74 species were Rotifera, 11 taxa were Cladocera and 3 taxa were Copepoda. The highest species richness was recorded from RF1 (75 species), followed by RF2 (55 species) and RF 3 (51 species). In addition, number of species richness within rice fields was more diverse than within irrigated canals. The majority of zooplankton composition in every areas was rotifers (RF1=85.3%, RF2=87.3%, RF3=84.3%), followed by cladocera (RF1=13.3%, RF2=7.3%, RF3=9.8%) and copepod (RF1=1.4%, RF2=5.4%, RF3=5.9%) respectively. The highest average diversity index was reported from RF2 (1.825) followed by RF3 (1.586) and RF1 (1.515) respectively. Moreover, zooplankton diversity within the three rice fields fluctuated in relation to water depth. The highest average evenness was shown in RF2 (0.577) followed by RF3 (0.568) and RF1 (0.449). The highest densities were 1,519.5, 1,756.8 and 22,630.7  $\text{indL}^{-1}$  in RF1, RF2 and RF3 respectively. Nauplius was a major composition in all areas. Cladoceran and

copepod predation did affect of rotifer population structure with the most effective predator was cladocera.

Canonical correspondence analysis revealed that salinity, conductivity, dissolved oxygen, phosphate concentration and pH influenced zooplankton communities in the three paddies. Unfortunately, a Monte Carlo test showed no relationship between the zooplankton communities and the water qualities data among the three axes ( $p > 0.05$ ). Therefore, the result was insignificantly.

The results showed that rice fields contain high diverse biodiversity of zooplankton which was affected by the agronomic management of the farmers especially on water level controller.

**Keywords:** zooplankton, composition, diversity, rice fields

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Research question

Rice is the predominant crop in term of dietary importance in Thailand. The rice fields are the largest agricultural contribution to relatively prosperous Thai economy. Most of rice fields in Thailand especially at Central part are the irrigated rice ecosystem. They are characterized by the presence of temporary and seasonal standing water body. Therefore, the rice fields can be scientifically defined as temporary wetland ecosystems.

The ecology of rice fields is dominated by rapid physical, chemical and biological changes. The primary factor that governs the ecology of the irrigated rice field ecosystem is the hydrologic regime, which plays a key role as a controller of this man-made wetland ecosystem. The source of the water supply influences the floodwater chemistry and the composition of the aquatic biota (flora and fauna). These internal factors of the rice field ecosystem are also influenced by two external governing factors: the climatic regime e.g. temperature and solar radiation, and agronomic practices e.g. irrigation, crop establishment, agrochemical application and weeding (Bambaradeniya and Amarasinghe, 2004). Previous studies on rice field ecology have clearly revealed that agronomic practices change the physical, chemical and biological conditions in the rice ecosystem. Moreover these agronomic procedures and practices affect the abundance and composition of the biotic community, especially its aquatic component (Halwart, 1993 -quoted by Bambaradeniya and Amarasinghe, 2004).

The aquatic flora and fauna in rice fields play an important role in nutrient recycling. Whether as producers or consumers, organisms excrete inorganic and organic forms of nitrogen and phosphorus and they are also a major factor in the exchange of nutrients between soil and water. For example, fertilization, while applied for the rice plant, affects the growth and development of all the aquatic organisms in the flood water. The algal growth is stimulated by phosphorus fertilized application. Thus their productivity has effect on the animals such as rotifers,

cladocerans, copepods and ostracods, which rely on the aquatic phytoplankton as food. In addition, this implies that rice fields offer the environmental services and opportunities for biodiversity conservation as the additional benefits and contribution of these major food-producing agroecosystems (Bambaradeniya and Amarasinghe, 2004).

Until the late 1980s, the prime focus of biological conservation was on undisturbed natural habitats, including protected areas that cover only about 5 % of the world land area. When attention was called to the fact that at least two-thirds of the terrestrial environment consisted of managed ecosystem, including agricultural systems, forestry systems and human settlements, the focus on undisturbed habitat was challenged at the dawn of the decade. Hence, it indicates that a large portion of the world's biological diversity coexists in these managed ecosystems (Bambaradeniya et al, 2004).

Today biodiversity is viewed as a fundamental principle in agricultural sustainability, and studies have been focused on biodiversity as an organizing principle in agroecosystem management (Stinner et al., 1997). The study of biodiversity associated with agroecosystems such as rice fields is of significance for agroecologists and conservation biologists, since maintenance of biological diversity is essential for productive agriculture, and ecologically sustainable agriculture is in turn essential for maintaining biological diversity (Pimental et al., 1992). Moreover, there is growing evidence that traditional agroecosystems such as rice fields contribute to sustain the regional biodiversity of many invertebrate and vertebrate species (Lawler, 2001 quoted by Bambaradeniya et al, 2004).

Previous studies on the biodiversity of rice fields focus mainly with agronomic aspects, where rice pests, their natural enemies and weeds have been surveyed extensively (e.g. Huan et al., 1999; Kathiresan, 2007, Hu et al., 2007; Moraes et al., 2007 ; Zheng et al., 2007). Comprehensive studies on the ecology and biodiversity of rice fields are scanty. Although the species composition of terrestrial arthropod pests and natural enemies in rice fields throughout the world is relatively well documented (e.g. Yusa et al., 2006; Price and Gurung, 2006), only a few studies have examined on zooplankton biodiversity during a crop cycle in rice fields (Ali, 1990; Heckman, 1974).

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Rice fields comprise a rich mosaic of rapidly changing ecotones, harboring a rich biological diversity, which is maintained by rapid colonization as well as by rapid reproduction as growth of organisms (Fernando 1995 and 1996 quoted by Bambaradeniya et al, 2004) such as zooplankton. Therefore, this research intends to examine the species richness, diversity and composition of zooplankton communities associated rice field ecosystem during a crop cycle in Pathum Thani province, Thailand based on weekly zooplankton sampling.

## **1.2 Objectives**

- 1.2.1 To study species composition of rotifers, cladocerans, copepods and ostracods in rice fields of Pathum Thani province
- 1.2.2 To study diversity and composition of zooplankton during a crop cycle of rice fields in Pathum Thani province
- 1.2.3 To study environment factors influence on zooplankton distribution in rice fields of Pathum Thani province

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Types of Rice Field Ecosystems

Rice-growing environments can be classified into 5 categories based on water regime, drainage, temperature, soil type and topography as following (Khush, 1984 quoted by Bambaradeniya and Amarasinghe, 2004).

- 2.1.1 Irrigated environments: These rice fields contain sufficient water available during the entire growing season, with controlled shallow water depth between 5–10 centimeters. They have assured water supply for one or more crops a year.
- 2.1.2 Rain-fed lowland environments: These rice fields are mainly dependent on the duration of rainfall, with an uncontrolled shallow water depth, ranging from 1-50 centimeters. Numbers of crops per year depend on an amount of precipitation.
- 2.1.3 Deep-water environments: These rice fields are unbunded fields with maximum sustained water depths from 0.5-3 meters.
- 2.1.4 Upland environments: These rice fields are banded or unbanded rain-fed fields with no surface or rhizosphere water accumulation.
- 2.1.5 Tidal wetlands: These rice fields are located near the seacoasts and inland estuaries, and are influenced by tides.

#### 2.2 Types of Rice cultivation practices (Figure2.1)

There are four generally recognized cultivation practices: upland, rainfall lowland, flood-prone and irrigated (Trinkley and Fick quoted Halwart and Gupta, 2004).

- 2.2.1 Upland rice is grown in rainfed, naturally well drained soils without surface water accumulation, normally without phreatic (ground of aquifer) water supply, and normally not banded. This rice is direct-seeded in no-flooded, well-drained soil and grows relying solely on rainfall. As a result, yields tend to be low.

- 2.2.2 Rainfed lowland systems have rice direct seeded in puddle soil on level slightly sloping, or diked fields. The depth and duration of flooding is dependent on local rainfall, so this system is subject to yield fluctuations. The difference between this approach and the upland pluvial rice cultivation is solely one of topography.
- 2.2.3 In irrigated rice cultivation, rice is transplanted or directly seeded in puddle soil on level fields with water control, generally in lowland areas.
- 2.2.4 Flood-prone cultivation requires that rice be directly seeded or transplanted in the rainy season on fields that are characterized by medium to heavy flooding from rivers or deltas. The crops are grown as the rivers (and flood waters) rise and are harvested after the waters recede. In some systems this is also called “deep water” cultivation.

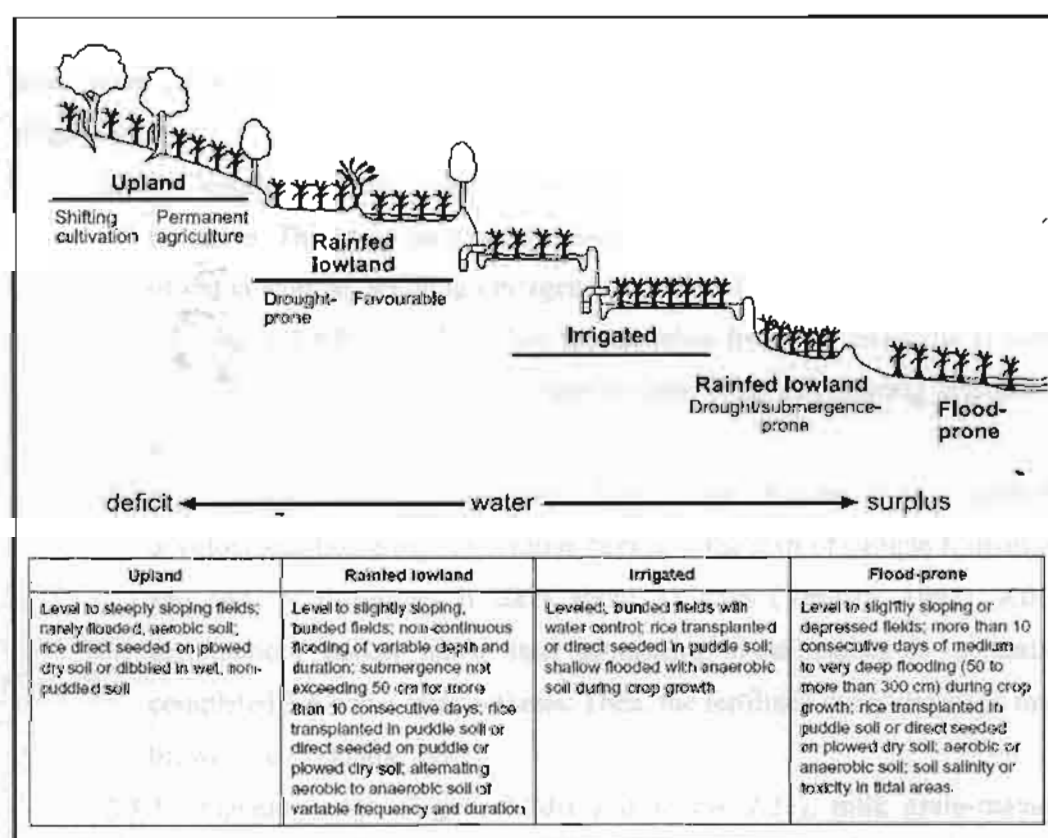


Figure 2.1 Types of rice field ecosystems (modified from Halwart and Gupta, 2004)

In Thailand, the traditional hand methods of cultivating and harvesting rice are still practiced. The fields are prepared by plowing (typically with simple plows drawn by water buffalo), fertilizing (usually with dung or sewage), and smoothing (by dragging a log over them). With wet-rice cultivation, the seedlings are started in seedling beds and, after 30 to 50 days, are transplanted by hand in rows in slightly drained, or puddled, fields. Whereas, in paddy-sown field, rice plants are directed seeding in drained fields. Throughout growing, water levels in paddy fields are kept to a few centimeters deep to prevent weed growth and ensure there's enough water for the plants to grow. This is done by either flooding during the rainy season, or by planting the rice in naturally swampy areas, or by irrigating using a series of canals or wells. Fields are sometimes temporarily drained for weeding and fertilizing.

### 2.3 A single rice cycle

A rice plant undergoes several phonological stages, which can be divided into three main growth stages as following (Bambaradeniya and Amarasinghe, 2004) (Figure 2.2 and 2.3).

2.3.1 Vegetative stage (Figure 2.2a and Figure 2.3b-c): germination-panicle initiation. This stage includes germination, the appearance of the white tip of the coleoptile, seedling emergence, the tip of a seedling emerges from the soil, and tillering, branches that develop from the leaf axils at each unelongated node of the main shoot or from other tillers during vegetative growth (Vergara, 1992).

2.3.2 Reproductive stage (Figure 2.2b-c and Figure 2.3d): panicle development-flowering. This phase begins at the start of panicle formation and ends at flowering. It takes about 35 days (Vergara, 1992). After germination, pollen tubes start elongating. Fertilization is normally completed 5-6 hours after anthesis. Then, the fertilized ovary develops into brown rice (Yoshida, 1981).

2.3.3 Ripening stage (Figure 2.2d-f and Figure 2.3e): milk grain-mature grain. This period is characterized by grain growth, increase in size and weight, change in grain color and senescence of leaves. At the early stages of ripening, the grains are green and turn yellow as they mature. The texture of the grains changes from a milky, semifluid state to a hard solid.

On the basis of such changes the ripening period is subdivided into milky, dough, yellow ripe, and maturity stages (Yoshida, 1981).

The duration of the vegetative stage differs according to the rice cultivar, while the other two stages remain the same irrespective of the cultivar (Reissing et al. 1986 quoted by Bambaradeniya and Amarasinghe, 2004).



Figure 2.2 A single rice cycle (a: vegetative stage, b-c: reproductive stage, d-f: ripening stage)

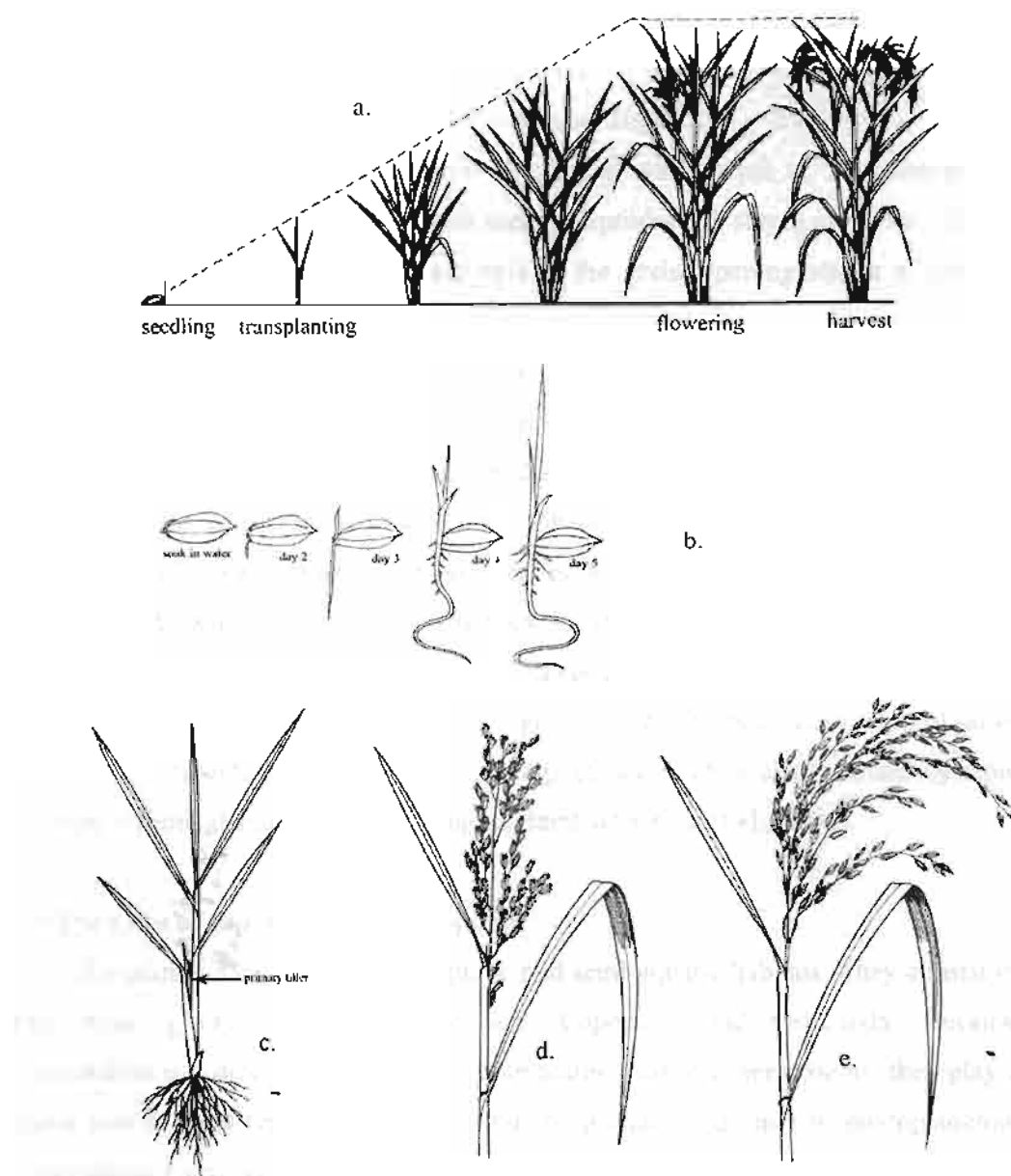


Figure 2.3 Growth phases and stages of rice (a: growth stages, b: stages of germination, c: primary tiller, d: reproductive phase, e: ripening phase) (modified from Vergara, 1992)

## 2.4 Physical structure of Rice field agroecosystem

Rice field is a monoculture agroecosystem. During a single paddy cultivation cycle, the rice field undergoes three major ecological phases as following. (Fernando, 1993 quoted by Bambaradeniya and Amarasinghe, 2004)

- 2.4.1 Aquatic phase has a shallow fluctuating water depth of 5-30 centimeters and represents the vegetative and the reproductive stages of the rice plant.
- 2.4.2 Semi-aquatic phase corresponds to the grain ripening stages of the rice crop.
- 2.4.3 Terrestrial dry phase concurs with the grain ripening stages of the rice crop. When the rice starts to ripen, the plants need very little water and usually the rice fields are drained about 10 days before harvest to make the work easier (Halwart and Gupta, 2004)

The physical status of floodwater is variable during a cycle. There is consecutive flow through, stagnation and drying off the aquatic habitat as the seasons progress. Consequently, the physico-chemical composition of the floodwater changes accordingly. These changes are made by agronomic practices such as application of fertilizer and biocides. As a whole, the ecology of rice fields is characterized by rapid physical, chemical and biological changes (Bambaradeniya et al., 2004).

## 2.5 The roles of zooplankton in ecosystem

Zooplankton can be found in aquatic and semi-aquatic habitats. They consist of four main groups: Rotifera, Cladocera, Copepoda and Ostracoda. Because zooplankton is a diverse component of both lentic and lotic ecosystems, they play a major role in most type of wetland habitat. As primary consumer of phytoplankton, zooplankton converts energy and matter to higher trophic levels. As a result of their high reproductive rate, high feeding and assimilation efficiency, they play a pivotal part in energy flow and nutrient cycling. Moreover, due to their small size, they are suitable as food for fish larvae. Their biochemical composition; proteins and lipids, slow movement making them easy to catch, renders them are suitable used as transporter of nutrition and drug to aquatic larvae. Including because of their easy to mass production, an enormous biomass of rotifer, cladocera and copepod is convenient to use as food for aquatic animal larvae during first period of exogenous

feeding (e.g. Lubezens et al., 1993). Currently, zooplankton such as *Brachionus plicatilis* are well known and worldwide using as food for aquatic animals.

Moreover by reason of their widespread occurrence and range of environmental preferences, zooplankton can be used as indicator to the trophic state and classify water body (Mäemets, 1983; Marneffe et al., 1998). For example in Estonia, it is possible to distinguish three main indicator groups among rotifer: (1) for oligo- and mesotrophic lakes (*Ploesoma hudsoni*, *Keratella serrulata*, *Synchaeta grandis*, *Asplanchna herricki*, *Ascomorpha ovalis*, *Gastropus stylifer*, *Conochilus hippocrepsis*); (2) for meso- and eutrophic lakes (*Trichocerca capucina*, *Filinia longiseta*, *F. limnetica*, *Keratella quadrata*, *K. cochlearis tecta*, *K. hispida*, *Polyarthra euryptera*, *Keratella hiemalis*, *Trichocerca porcellus*, *T. pusilla*); (3) for eutrophic lakes (*Brachionus* spp., *Anuraeopsis fissa*, *Pompholyx sulcata*, *P. complanate*, *Trichocerca cylindrical*, *Hexarthra mira*) (Mäemets, 1983).

Besides, recently zooplankton, especially *Brachionus calyciflorus*, *B. plicatilis* and *Daphnia magna*, are particularly suited as test organism for ecotoxicological studies due to their cosmopolitan distribution, rapid reproduction, short generation time and easy to culture (Janssen et al., 1993; Ferrando et al., 1993; Fernández-Casalderrey et al., 1993; Nogrady and Rowe, 1993; Hoang et al., 2007).

## 2.6 Zooplankton

In aquatic areas, the major components of zooplankton communities compose of rotifer, cladocera, copepod and ostracoda.

### 2.6.1 Rotifera

Rotifers are a cosmopolitan zooplankton group belonging to the Phylum Rotifera, which is composed of more than 2,000 species (Nogrady et al., 1993). This Phylum is typically characterized by an unsegmented, pseudocoelomate, primary bilateral symmetrical body, and a complete digestive system (Nogrady et al., 1993; Miller and Harley, 1996). The members are probably derived evolutionarily from ancestral acoelic turbellarians and related to the gnathostomulids (Ruttner-Kolisko, 1974 quoted by Segers, 1995-1996).

Rotifers in general can be distinguished from other zooplankton by two unique features: the presence of a corona and a mastax (Nogrady *et al.*, 1993) (Figure 2.4). The corona is an annular band of cilia of the apical hypodermis, which surrounds the apical field. The cilia serve for locomotion and for directing food towards the mouth. The mastax is a muscular organ in the pharynx working for selection, catching and processing of food (Nogrady *et al.*, 1993; Segers, 1995-1996; Solomon *et al.*, 2002). It consists of a number of hard elements called trophi (Figure 2.5). The trophi is the most important morphological feature used in the classification and identification of monogonont rotifers to species level (Segers, 1995-1996).

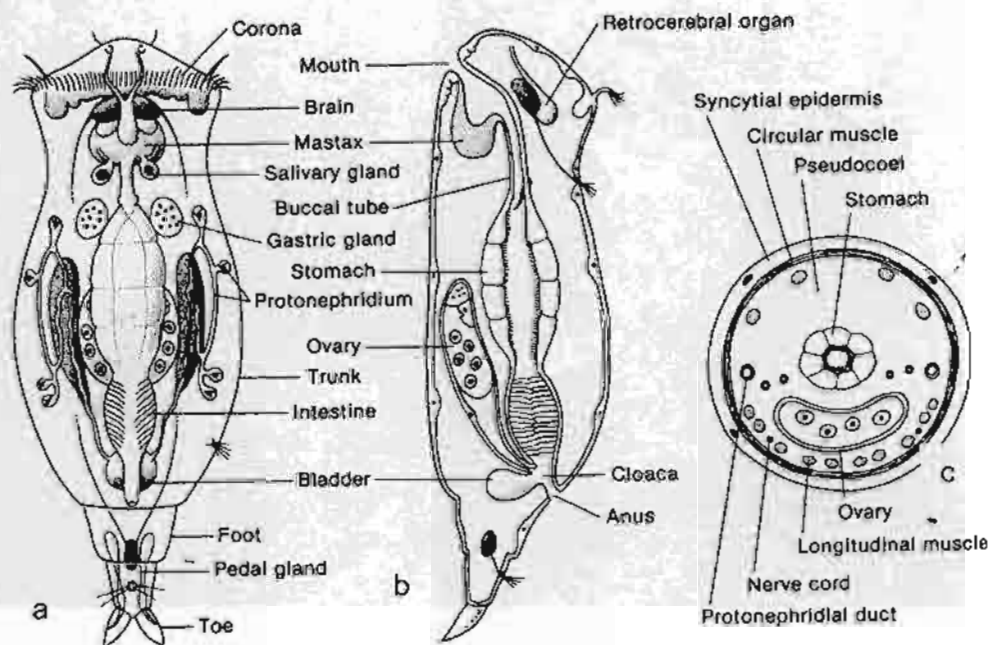


Figure 2.4 Rotifer anatomy; a: Dorsal view, b: Lateral view and c: Cross section (Ruppert and Barnes, 1994, p. 308).

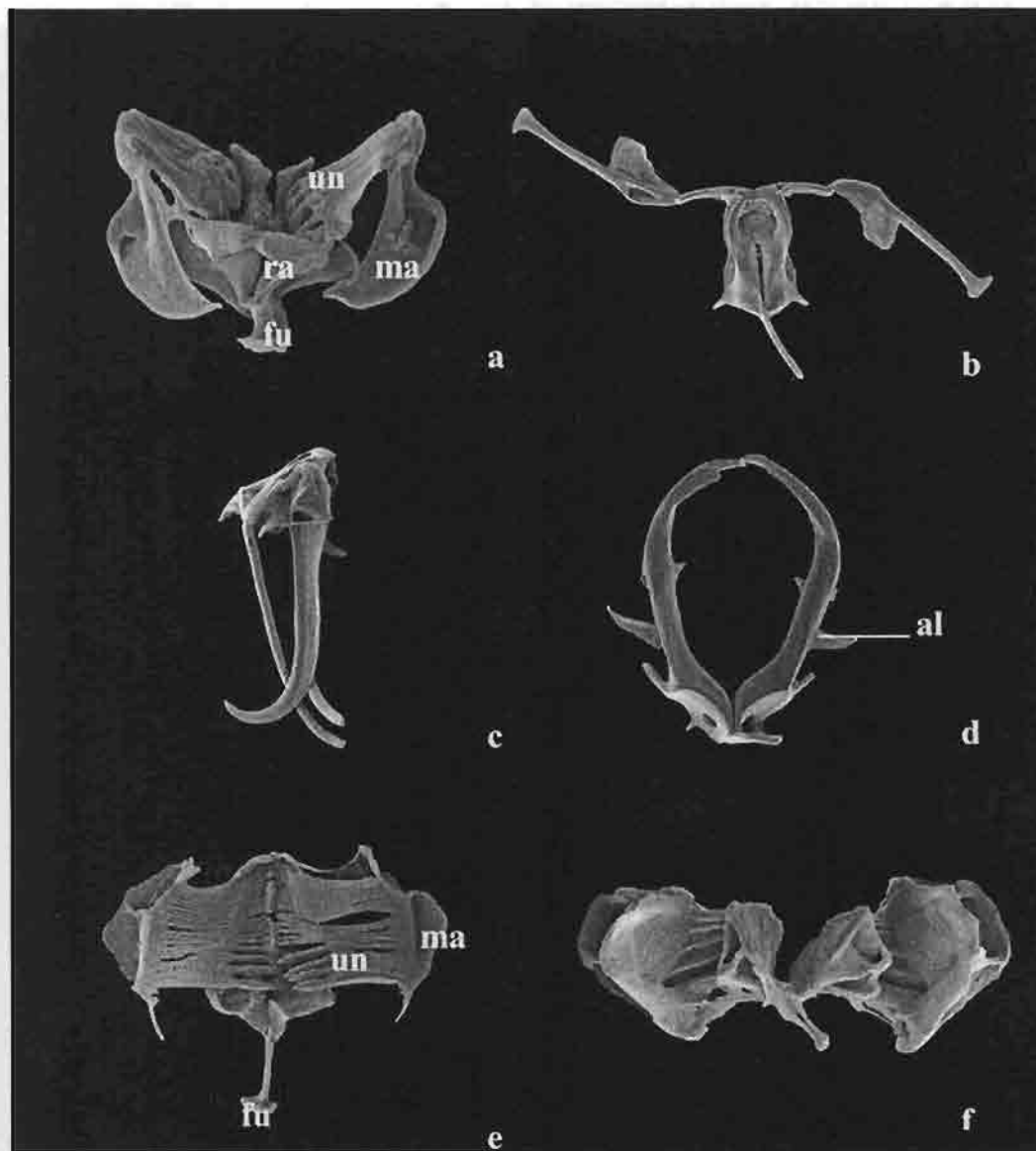


Figure 2.5 Some major types of trophi; a: Malleate trophi of *Brachionus*; b: Forcipate trophi of *Dicranophorus*; c: Virgate trophi of *Trichocerca*; d: Incudate trophi of *Asplanchna*; e and f: Malleoramate trophi of *Filinia* and *Hexathra*, respectively (fu: fulcrum, ra: ramus, ma: manubrium, un: uncus, al: alula). (Chittapun, 2004)

### 2.6.2 Cladocera

Cladocera or water fleas belong to Phylum Arthropoda, subphylum Crustacea, class Branchiopoda and order Cladocera. They are characterized by Carapace bivalved without hinge, enclosing trunk and its appendages. Head is separated from the body by a deep indentation. A beak projecting forward of head is rostrum. A single compound eye is on lateral side. Their thorax is short with 4 – 6 segments. At terminal of body is a postabdomen with a pair of terminal claws. Body length ranges from 0.2 - to 12 mm. Males with antennules often modified for clasping during copulation.

Like rotifers, cladocera reproduce by both sexual and asexual reproduction. Female cladocera has a large space at the back of dorsal side of the carapace. This area functions as a brood pouch, where the eggs are laid and developed.

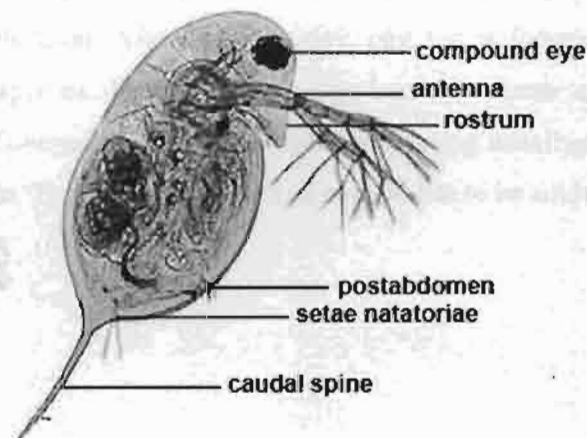


Figure 2.6 Morphology of cladocera

(modified from <http://www.apus.ru/im.xp/049056054124052057056055055048.jpg>)

### 2.6.3 Copepoda

Copepods belong to Phylum Arthropoda, subphylum Crustacea, Class Maxillopoda and subclass Copepoda. They are characterized by body segmentation, exoskeleton and long antennae. They look like small krill. Body size ranges between 1mm-1cm.

Body consists of prosome and urosome (Figure 2.7). Prosome or cephalothorax is composed of cephalosome and thorax. Cephalosome is formed by fusing 1-6 segments with a pair of appendage on each segment. They have an ocellus on antero-dorsal view of the first segment. This single eye uses for differentiate between light and dark. Mouth part is on ventral side. Thorax, male copepod has five separated segment (1<sup>st</sup> -5<sup>th</sup> segment), while female copepod has four segments (1<sup>st</sup> -3<sup>rd</sup> segment and 4<sup>th</sup>-5<sup>th</sup> fusing segment). Urosome or abdomen carries no appendages. The telson carries pair furcal rami at terminal.

Copepods have only sexual reproduction. Males produce spermatophore, which will be expelled to genital field of the females during copulation. It is internal fertilization. After hours or day, egg sac is formed either one or two depend on species. Females attach egg sacs, a cluster of eggs, with their abdomens. Copepods have metamorphosis, passing usually 6 naupliar stages to be copepodite. There are five stages of copepodite to be adult.

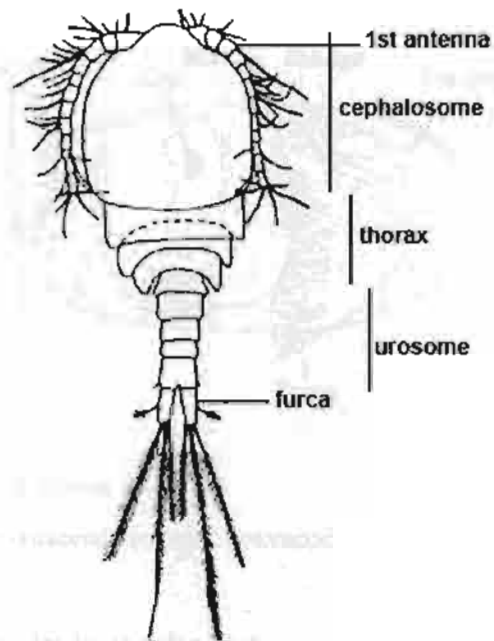


Figure 2.7 Copepod structure

(modified from <http://www.scielo.br/img/fbpe/bjb/v61n4/a07fig08.gif>)

#### 2.6.4 Ostracoda

Ostracods are Metazoa belonging to Phylum Arthropoda, subphylum Crustacea and class Ostracoda. They are characterized by lateral compress and bilateral symmetry. Body parts are encased by chitinous or calcarious carapaces as dorsally hinged bivalve-like (Figure 2.8). Their valves can be used to study palaeoenvironment since their shapes and structure of the valves were reflected via their ecology. The body consists of a cephalon (head), thorax and abdomen. There are 5-8 appendages. Ostracods are varies in size between 0.2-30 mm and can be found in all aquatic ecosystems.

Like other Crustacea, ostracods have metamorphosis, passing nine instars to reach maturity. They can reproduce via sexual and asexual (parthenogenesis) strategies. They can produce resistant eggs which can endure under dry environment. Ostracods are sexual dimorphisms; carapaces are different in size and shape. Because of sexual dimorphisms and nine stages developing, it is difficult to identify the ostracoda to species level.

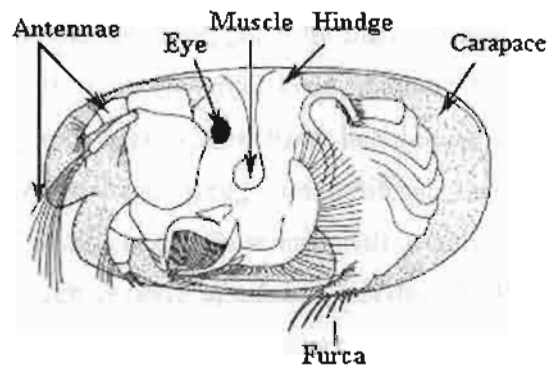


Figure 2.8 Ostracod structure

(modified from [www.personal.psu.edu/.../ostracod%20anatomy.gif](http://www.personal.psu.edu/.../ostracod%20anatomy.gif))

## 2.7 Reproductive modes in zooplankton

Most of rotifers cladocera and ostracod reproduce both by parthenogenesis and by sexual reproduction called heterogony (Figure 2.9) (Nogrady et al., 1993).

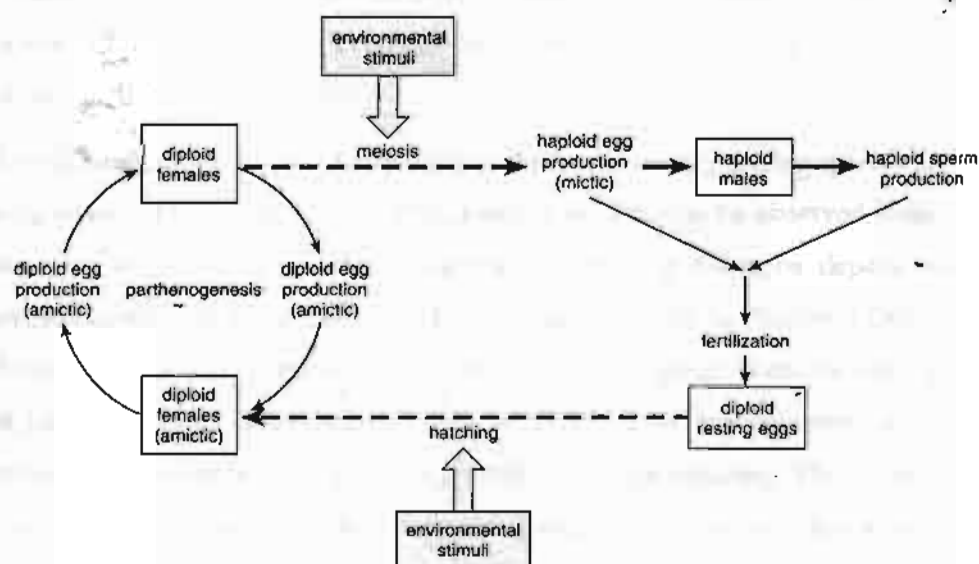


Figure 2.9 The life cycle of zooplankton (modified from Pechenik, 2000, p. 196).

Reproduction in rotifers and cladocera is dominated by asexual parthenogenesis; amictic females produce diploid eggs, which develop into amictic females. Sexual reproduction is triggered by the occurrence of adverse conditions or as a result of specific environmental cues. Amictic females will produce mictic females giving haploid eggs. Unfertilized haploid eggs will develop into males producing sperm. When haploid eggs are fertilized, these will develop into thick-shelled eggs, called resting eggs. These eggs will accumulate in the sediment and are able to survive through periods of adverse conditions. When favorable conditions return, they hatch as amictic female, which will start reproducing parthenogenetically.

Resting eggs (diapause form) are the product of sexual reproduction, which is cued by variety of stimuli that are directly or indirectly predictive of environmental deterioration. As favorable conditions return or as a result of specific cues, they develop and hatch to reestablish their population again. These dormant forms represent a biodiversity bank as the eggs survive through adverse environmental conditions, preserve species diversity and provide a reliable colonization source when conditions improve. The biodiversity bank assures genetic continuity through periods of environmental adversity. It means that resting eggs represent a bank, like the seed pool of plants, from which recolonization of the environment can occur at a later time (Pourriot and Snell, 1983; Ricci, 2001).

The duration of the period of dormancy is different not only among species but also among clones of the same species. The emergent rotifers can be observed within a few hours or after several months of incubation. These phenomena depend on environmental conditions. In rotifers, two hatching patterns can be observed (Ricci, 2001). First, the eggs hatch individually at more or less regular intervals over an extended period of time. This pattern could be adaptive in environments where conditions that are favorable for population growth occur unpredictably. This strategy spends more in wasted hatching. The alternative pattern is synchronous hatching of large numbers of eggs over a short period of time, in response to some environmental cues. An advantage of this pattern is that no wasted hatching under unsuitable environmental conditions will occur, therefore this pattern could be adaptive to predictable environments (Pourriot and Snell, 1983).

## **2.8 A study of zooplankton in rice fields**

Among previous studies of fauna inhabiting rice field ecosystems, agronomic aspects such as the rice pests have been conducted extensively throughout the world whereas a few works have examined on biodiversity. Species richness of aquatic invertebrates associated within rice fields have been comprehensively conducted in Sri Lanka (e.g. Bambaradeniya et al. 2004). Seasonal dynamic, abundance and composition of zooplankton were examined throughout a year in Malaysia (Ali 1990) and Laos (Heckman, 1974). Whereas in Thailand, most of researches reported mainly on species richness based on survey sampling (Heckman 1979). Studies on the diversity and composition of them during a crop cycle of rice are scarce. Therefore, this research intends to examine the species richness, diversity and composition of zooplankton communities associated during a crop cycle in rice field ecosystems based on weekly zooplankton sampling.

## CHAPTER 3

### MATERIALS AND METHODS

#### 3.1 Study areas

This work was carried out in three rice fields of Pathum Thani province, Central Thailand (Figure 3.1). These three areas were irrigated rice fields, where rice plants were directed seeding in wet soil. These rice fields were cultivated three different rice varieties.



Figure 3.1 Map of Pathum Thani province in Thailand

The first area (RF1), located at Mhoo 1, Bang Luang District, Amphur Maung, Pathum Thani province, is occupied by Mr. Manus Panngean. This area was grown rice variety Rachinee 35, a 95 days rice. (Figure 3.2)

Mr. Thumrongsak Khumraksa owns the second paddy (RF2), located at Mhoo 9, Koo Bang Luang District, Amphur Lad Lhum Kaew, Pathum Thani Province. This area were planted rice variety Koawpathum, a 95 days rice. (Figure 3.3)

The last one (RF3), located at Mhoo 7, Bang Luang Distric, Amphur Maung, Pathum Thani Province, is under Mrs. Prakob Soyraya ownership. This area was cultivated rice variety Suphunburee1, a 115 days rice. (Figure 3.4)

Rice varieties and farmer's practices affected in different sampling periods among the areas (Table 3.1)

Table 3.1 sampling period among the three rice paddies

| Areas | Sampling period             |
|-------|-----------------------------|
| RF1   | 6 August – 9 October 2005   |
| RF2   | 6 August – 1 October 2005   |
| RF3   | 13 August – 31 October 2005 |

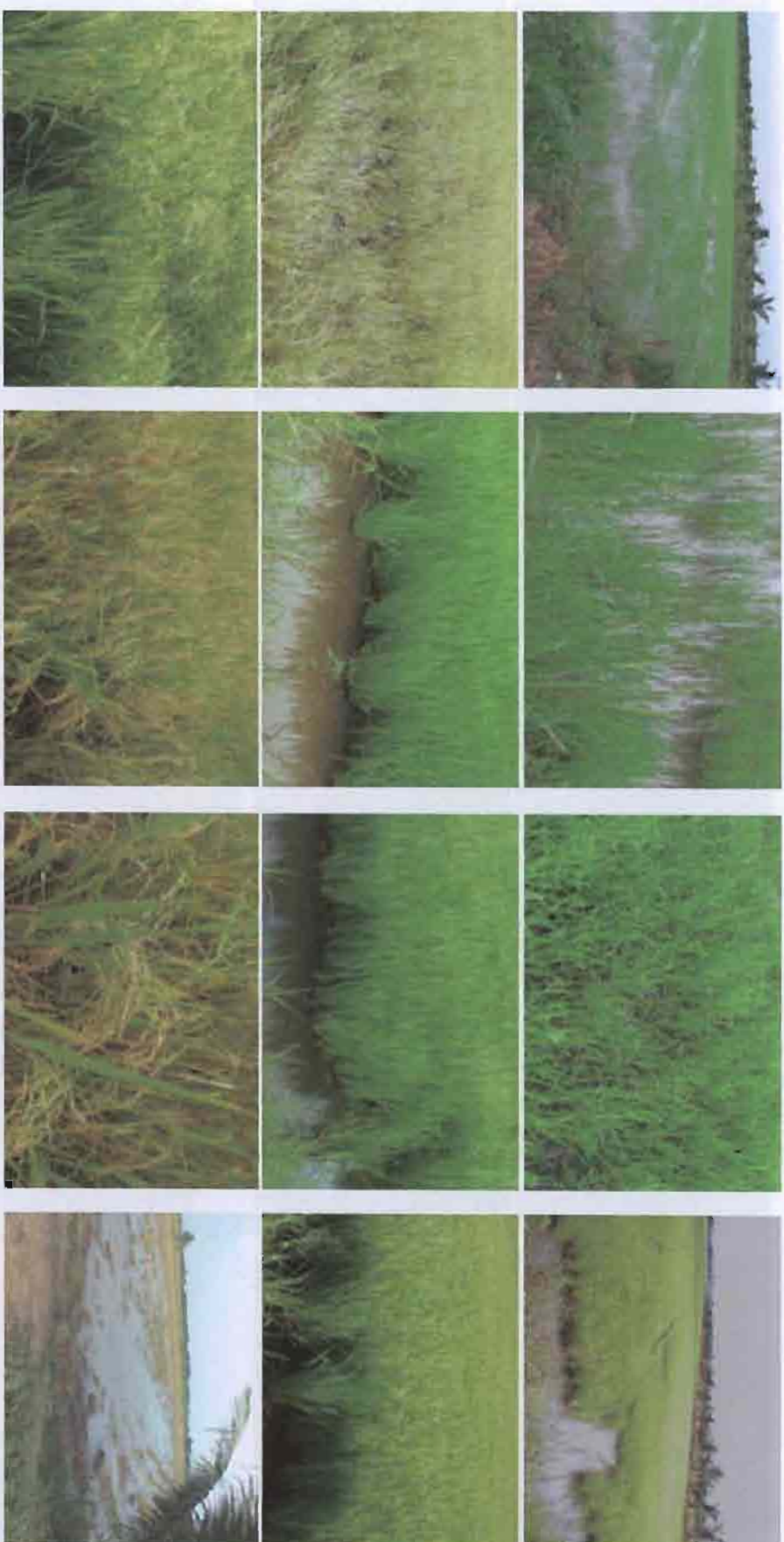


Figure 3.2 A crop cycle of Manus's rice field



Figure 3.3 A crop cycle of Thumrongsak's rice field



Figure 3.4 A crop cycle of Prakob's rice field

### 3.2 Sampling methods

During a crop cycle of the three rice paddies, August to October 2005, zooplankton was sampled weekly at a water gate site and four stations within rice fields. Sampling was carried out by filtering water 15 liters volume through a 60  $\mu\text{m}$  plankton net. Then, the concentrated samples were preserved in 4% formalin immediately.

During sampling, temperature, pH, dissolved oxygen, salinity and conductivity were detected using YSI 85-10 DO/SCT multimeter. In addition, chlorophyll a, nitrate and phosphate concentration were measured following spectrophotometric, cadmium reduction and ascorbic acid method respectively.

At laboratory, rotifers, cladocerans, copepods and ostracods were sorted, identified and counted under an Olympus CH-2 compound microscope. Identification to species level was mainly focused on rotifers, cladocerans and copepods. Since ostracods are difficult to identified, they were only counted number of individuals. Some specimens were taken a photo following Chittapun et al. (2003).

There are several identification keys, which were used in this study, e.g. Koste (1978), Idris (1983), Koste and Shiel (1986), Koste and Shiel (1989), Shiel and Koste (1992), Segers (1995) and Nogrady and Pourriot (1995).

### 3.3 Statistic analysis

Abundance and relative abundance were calculated and reported per liter.

Diversity was performed and compared using Shannon-Wiener diversity index ( $H'$ ). Shannon-Wiener diversity index and its evenness ( $J$ ) are the most frequently used non-parametric indices of species diversity. They can be called diversity indices. The diversity indices have many advantages. Firstly, they are a helpful method to condense data because they make no data assumptions and can facilitate the ecological interpretation of huge data sets. In addition, people in different expertise can be able to understand the results.

$$\text{Shannon-Wiener maximal index } (H') = \frac{-\sum_{i=1}^S p_i \ln p_i}{\ln S} \quad \text{Shannon \& Weaver (1963)}$$

$$\text{Shannon-Wiener's evenness } (J) = \frac{H}{H_{\max}} \quad \text{Hurlbert (1971)}$$

To analyses and identify important variables influencing on zooplankton communities, the data was performed Canonical Correspondence analysis (CCA) by using PC-ORD program version 3.02 (MjM Softward Design, Gleneden Beach, Oregon, USA).

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## CHAPTER 4

### RESULTS AND DISCUSSION

#### 4.1 Species richness

A total of 88 species of zooplankton was identified during a crop cycle of three rice fields. Of these, 74 taxa were Rotifera, 11 taxa were Cladocera and 3 taxa were Copepoda (Table 4.1). All of them had been previously recorded from Thailand (e.g. Sanoamuang, 1998; Chittapun and Pholpunthin, 2001; Chittapun et al., 2002; Chittapun, 2004; Maiphae, 2005). However, the number of zooplankton species in this report was higher than the previous studies in Laos (17 species) (Heckman, 1974), Malaysia (71 species) (Ali, 1990) and Sri Lanka (36 species) (Bambaradeniya et al., 2004). The highest species richness was recorded from RF1 (75 species), followed by RF2 (55 species) and RF 3 (51 species).

The number of species composition in drawing water was lower than within rice fields (Table 4.1). This result suggests that the aquatic fauna is derived not only from irrigation water but also from resistant or dormant stages of aquatic animals within the rice fields (Fernando et al., 1979). Since rice fields are temporary aquatic habitats, zooplanktons do survive dry periods by producing resting eggs. When favorable conditions return, they hatch and recolonize resources. Moreover, zooplankton can be dispersed from outside by transport service of many vectors such as waterbirds and ducks, invasion and foraging within rice fields. This was observed among the three areas. Numerous birds came and sought for food at the beginning of growing rice. Waterbirds have been believed as a main disperser of aquatic organisms and invertebrate propagules. To facilitate dispersal, waterbirds may ingest propagules of aquatic fauna into their guts (internal dispersal) or be attached to their bodies (external dispersal) (Figuerola and Green, 2002). There are many evidences supporting this believes. For example abundant brine shrimp cysts were observed in migratory waders pellets (Sánchez et al., 2007) and various invertebrate propagules can survive passage throught the avian digestive tract (Figuerola et al., 2003).

Table 4. 1 List of zooplankton species during a crop cycle of three rice fields in Pathum Thani province, Thailand (1, 2, 3 : within RF1, RF2, RF3 and 1\*, 2\*, 3\* : at water gate of RF1, RF2, RF3)

### Rotifera

- Anuraeopsis fissa* (Gosse) 1,1\*,2,2\*,3  
*A. navicula* Rousselet 2,3  
*Asplanchna sieboldi* (Leydig) 1,1\*,2,2\*,3,3\*  
*Brachionus angularis* Gosse 1,2,2\*,3,3\*  
*B. calyciflorus* Pallas 2,2\*,3,3\*  
*B. caudatus* Barrois & Daday 1,2,2\*,3,3\*  
*B. diversicornis* (Daday) 1,2  
*B. falcatus* Zacharias 1,2,2\*,3,3\*  
*B. forficula* Wierzejski 3,3\*  
*B. quadridentatus* Hermann 1,1\*,2,2\*,3  
*B. rotundiformis* Tschugunoff 2\*,3  
*B. rubens* Ehrenberg 1  
*B. urceolaris* (Müller) 1,1\*,2,2\*,3,3\*  
*Cephalodella* sp. 1,2,2\*,3  
*Colurella colurus* (Ehrenberg) 1  
*C. sanoamuangae* Chittapun, Pholpunthin & Segers 1  
*C. uncinata* Müller 1,2  
*Dicranophorus epickaris* Haring & Myers 2,2\*,3,3\*  
*D. sp.* 1,1\*,2,3  
*Dipleuchlanis propatula* (Gosse) 1,2,3  
*Epiphanes* sp. 2,2\*  
*Euchlanis dilatata* Ehrenberg 1,2,3  
*Filinia camasecla* Myers 1,2,2\*,3,3\*  
*F. longiseta* (Ehrenberg) 1,1\*,2,2\*,3,3\*  
*F. novaezealandiae* Shiel & Sanoamuang 1,1\*,2,2\*,3,3\*  
*F. opoliensis* (Zacharias) 1,2,2\*,3,3\*  
*Hexarthra* sp. 1,2,2\*,3

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*Itura* sp. 1  
*Keratella lenzi* Hauer 1,2,2\*,3  
*K. tropica* (Apstein) 1,2,2\*,3,3\*  
*Lecane bulla* (Gosse) 1,1\*,2,2\*,3  
*L. closterocerca* (Schmarda) 1  
*L. curvicornis* (Murray) 1,2,2\*,3  
*L. elegans* Harring 1,2  
*L. hamata* (Stokes) 1,2,3,3\*  
*L. hornemanni* (Ehrenberg) 2,3  
*L. inermis* (Bryce) 1,2  
*L. lateralis* Sharma 1,2,3  
*L. leontina* (Turner) 1  
*L. luna* (Müller) 1,2,3,3\*  
*L. palinacis* Harring & Myers 1  
*L. papuana* (Murray) 1,1\*,2,2\*,3,3\*  
*L. pyriformis* (Daday) 1,2,3  
*L. quadridentata* (Ehrenberg) 1  
*L. rhenana* Hauer 3  
*L. segersi* Sanoamuang 1  
*L. signifera* (Jennings) 2  
*L. stenroosi* (Meissner) 1,2,3  
*L. thienemanni* (Hauer) 1  
*L. unguitata* (Fadeev) 1,2,3  
*L. ungulata* (Gosse) 1  
*Lepadella acuminata* (Ehrenberg) 3  
*L. ovalis* (Müller) 1  
*L. patella* (Müller) 1  
*L. rhomboides* (Gosse) 1,2,3  
*Lophocharis salpina* (Ehrenberg) 1  
*Mytilina bisulcata* (Lucks) 1  
*M. unguipes* (Lucks) 1

*M. ventralis* (Ehrenberg) 1,2,3  
*Notommata* sp. 1,2,2\*  
*Plationus patulus* (Müller) 1,2,2\*,3,3\*  
*Platylas quadricornis* (Ehrenberg) 1,2,3  
*Polyarthra vulgaris* Carlin 1,2,2\*,3,3\*  
*Pompholyx complanata* Gosse 1  
*Scaridium* sp. 1  
*Synchaeta* sp. 1,1\*,2,2\*  
*Sinatherina spinosa* (Thorpe) 1  
*Testudinella patina* (Hermann) 1,2,3  
*T. tridentata* Smirnov 1  
*Trichocerca braziliensis* (Murray) 1  
*T. insulana* (Hauer) 1,2,3  
*T. pusilla* (Lauterborn) 1,2,2\*,3,3\*  
*T. similis* (Wierzejski) f. *grandis* Hauer 1,2  
*Trochosphaera equatorialis* (Semper) 1

#### Cladocera

*Alona costata* Sars, 1862 1,2,3  
*Alona* cf. *puchella* King, 1853 1  
*Ceriodaphnia cornuta* Sars, 1885 1,2,2\*,3  
*Diaphanosoma excisum* Sars, 1885 1,2,2\*,3  
*Euryalona orientalis* (Daday, 1898) 1  
*Guernella raphalis* Richard, 1892 1  
*Kurzia longirostris* (Daday, 1898) 1  
*Ilyocryptus spinifer* Herrick, 1882 3  
*Macrothrix spinosa* King, 1852 1  
*Moinodaphnia macleayii* (King, 1853) 1,2,2\*,3,3\*  
*Scapholeberis kingi* Sars, 1903 1