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Original Article

Diversity and composition of zooplankton in rice fields during a crop cycle at Pathum Thani province, Thailand

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Abstract

A study of zooplankton communities in three rice fields (RF1, RF2 and RF3) at Pathum Thani province was carried out from August to November 2005. A total of 88 taxa were identified. Of these, 74 belonged to Rotifera, 11 were Cladocera and 3 were Copepoda. The highest number of zooplankton species was recorded in RF1 (75 species), followed by RF2 (55 species) and RF3 (51 species). The highest average *H'* was registered in RF2 (1.83), followed by RF3 (1.59) and RF1 (1.52). The highest average zooplankton abundance was reported from RF3 (22,630.7 indL^{-1}), followed by RF2 (1,756.8 indL^{-1}) and RF1 (1,519.5 indL^{-1}). The main zooplankton components in the three areas were nauplii, rotifers and Cladocera. Cladocera played a major role in structuring rotifer communities in rice fields.

Keywords: Rotifera, Cladocera, Copepoda, biodiversity, rice field fields

1. Introduction

At present, biological diversity is a primary concern in the conservation and management of any area. Ninety-five percent of all terrestrial habitats are managed land. Of these, 30% are occupied by agriculture (Collins and Qualset, 1999). Therefore, agroecosystems comprise almost one-third of the total global land area. A study of biodiversity interrelated with agroecosystems is significantly important for agroecologists and conservation biologists because biodiversity conservation is necessary for agricultural production and yields as well as ecologically sustainable agriculture. In turn, agricultural lands are essential for the maintenance of the world's biological diversity (Bambaradeniya *et al.*, 2004).

One of the largest agricultural systems in Thailand, and a significant contribution to the Thai economy, is rice fields. Rice fields can be scientifically defined as temporary and intermittent wetlands, where the hydrologic regime plays a crucial role as a driving force in these artificial aquatic ecosystems (Bambaradeniya *et al.*, 2004), and can contribute significantly to total regional biodiversity (e.g. see Segers and Sanoamuang, 2007). In addition, these areas consist of rapidly changing ecotones, which are sustained by fast growing as well as rapidly colonizing organisms (Heckman, 1997). Making up a large portion of metazoan diversity in aquatic ecosystem, zooplankton plays a fundamental role in wetland habitats, for example, in the energy transfer along the food chain and in nutrient cycling in the ecosystem (Chittapun *et*

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al., 2002; Dowining and Leibold, 2002).

Among previous studies of fauna inhabiting rice field ecosystems, agronomic aspects such as the rice pests have been received considerable attention throughout the world whereas few works have examined the biodiversity. Species richness of aquatic invertebrates associated within rice fields have been comprehensively studied in Sri Lanka (e.g. Bambaradeniya *et al.*, 1998; Bambaradeniya *et al.*, 2004). The seasonal dynamics, abundance and composition of zooplankton throughout a year were examined in Malaysia by Ali (1990). However, in Thailand most research reported mainly on species richness based on survey sampling (Heckman, 1979). Studies on the diversity and composition during a full crop cycle of rice are scarce. To learn more about the dynamics of zooplankton communities during such a cycle, we examined the species richness, species diversity and composition of zooplankton communities during a crop cycle in rice field ecosystems based on weekly zooplankton sampling.

2. Materials and Methods

2.1 Study areas

This work was carried out in three paddy fields, located in Pathum Thani province, Thailand. These areas are irrigated rice fields and are direct seeding paddies. The three fields each had a different rice variety. (RF1: Rachinee 35 variety, a 95 days rice; RF2: Koawpathum variety, a 95 days rice; RF3: Suphunburee1 variety, a 115 days rice). Characteristics of the rice varieties and the sampling periods as imposed by the farmer's practices are summarized in Table 1.

2.2 Zooplankton Sampling

During a crop cycle, from August to October 2005, the three rice fields were sampled weekly for zooplankton at a water gate site and at four stations within the rice field. Sampling was carried out by filtering 15 liters of water through a 60 mm plankton net. These samples were immediately preserved in 4% formalin. While sampling, temperature, pH, dissolved oxygen, salinity and conductivity were measured using a YSI 85-10 DO/SCT multiprobe (Table 2).

In the laboratory, rotifers, cladocerans, copepods and ostracods were sorted, identified and counted using an Olympus CH-2 compound microscope. Identification to species level focused on rotifers, cladocerans and copepods following Koste (1978), Idris (1983), Koste and Shiel (1987), Koste and Shiel (1989), Korovchinsky (1992), Shiel and Koste (1992), Smirnov (1992), Nogrady and Pourriot (1995), Segers (1995), Smirnov (1996), De Smet and Pourriot (1997). Ostracods were only counted. Abundance and relative abundance were calculated and expressed per liter. Diversity was performed and compared using Shannon-Wiener index (*H'*) and evenness (*J*) (Colwell and Coddington, 1994). Correlation analysis was performed using SPSS program.

3. Results and Discussion

3.1 Environmental variables

Temperature ranged between 27.1-37.1°C. Water depth ranged from 0 to 28.3 cm. The pH ranged between 6.84 and 9.8. On the other hand, the dissolved oxygen range was wide and varied between 1.46 and 10.86 mgL^{-1}.

3.2 Species composition

A total of 88 species of zooplankton was identified during a crop cycle in the three rice fields. Of these, 74 taxa were Rotifera, 11 taxa were Cladocera and 3 taxa were Copepoda, all of which have been previously recorded from Thailand (Table 3). However, the number of zooplankton species recorded in this report is higher than in previous

Table 1. Rice varieties and sampling periods of three rice fields.

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

Table 2. Environmental variables among the three rice fields.

Areas	Water depth (cm)	Temperature (°C)	Dissolved oxygen (mgl^{-1})	pH	Salinity (psu)	Conductivity (*100ms)
RF1	0-28.3	27.3-34.4	1.46-10.76	6.84-9.1	1-5.7	2.22-13.22
RF2	0-8.3	29.2-34.1	2.27-7.35	7.37-9.8	1-3	2.59-7.03
RF3	2-10.3	27.1-37.1	1.84-6.3	7.14-7.9	1-4	2.13-9.41

Table 3. 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, 1851 1,1*,2,2*,3
A. navicula Rousselet, 1911 2,3
Asplanchna sieboldii (Leydig, 1854) 1,1*,2,2*,3,3*
Brachionus angularis Gosse, 1851 1,2,2*,3,3*
B. calyciflorus Pallas, 1766 2,2*,3,3*
B. caudatus Barrois & Daday, 1894 1,2,2*,3,3*
B. diversicornis (Daday, 1883) 1,2
B. falcatus Zacharias, 1898 1,2,2*,3,3*
B. forficula Wierzejski, 1891 3,3*
B. quadridentatus Hermann, 1783 1,1*,2,2*,3
B. rotundiformis Tschugunoff, 1921 2*,3
B. rubens Ehrenberg, 1838 1
B. urceolaris Müller, 1773 1,1*,2,2*,3,3*
Cephalodella sp. 1,2,2*,3
Colurella colurus (Ehrenberg, 1830) 1
C. sanoamuangae Chittapun, Pholpunthin & Segers, 1999 1
C. uncinata (Müller, 1773) 1,2
Dicranophorus epicharis Harring & Myers, 1928 2,2*,3,3*
D. sp. 1,1*,2,3
Dipleuchlanis propatula (Gosse, 1886) 1,2,3
Epiphanes sp. 2,2*
Euchlanis dilatata Ehrenberg, 1832 1,2,3
Filinia camasecla Myers, 1938 1,2,2*,3,3*
F. longiseta (Ehrenberg, 1834) 1,1*,2,2*,3,3*
F. novaezealandiae Shiel & Sanoamuang, 1993 1,1*,2,2*, 3,3*
F. opoliensis (Zacharias, 1898) 1,2,2*,3,3*
Hexarthra sp. 1,2,2*,3
Itura sp. 1
Keratella lenzi Hauer, 1953 1,2,2*,3
K. tropica (Apstein, 1907) 1,2,2*,3,3*
Lecane bulla (Gosse, 1851) 1,1*,2,2*,3
L. closterocerca (Schmarda, 1859) 1
L. curvicornis (Murray, 1913) 1,2,2*,3
L. elegans Harring, 1914 1,2
L. hamata (Stokes, 1896) 1,2,3,3*
L. hornemanni (Ehrenberg, 1834) 2,3
L. inermis (Bryce, 1892) 1,2
L. lateralis Sharma, 1972 1,2,3
L. leontina (Turner, 1892) 1
L. luna (Müller, 1776) 1,2,3,3*
L. palinacis Harring & Myers, 1926 1
L. papuana (Murray, 1913) 1,1*,2,2*,3,3*
L. pyriformis (Daday, 1905) 1,2,3
L. quadridentata (Ehrenberg, 1830) 1
L. rhenana Hauer, 1929 3
L. segersi Sanoamuang, 1996 1
L. signifera (Jennings, 1896) 2
L. stenroosi (Meissner, 1908) 1,2,3
L. thienemanni (Hauer, 1938) 1
L. unguitata (Fadeev, 1925) 1,2,3
L. ungulata (Gosse, 1887) 1
Lepadella (Lepadella) acuminata (Ehrenberg, 1834) 3
L. (L.) ovalis (Müller, 1786) 1
L. (L.) patella (Müller, 1773) 1
L. (L.) rhomboides (Gosse, 1886) 1,2,3
Lophocharis salpina (Ehrenberg, 1834) 1
Mytilina bisulcata (Lucks, 1912) 1
M. unguipes Lucks, 1912 1
M. ventralis (Ehrenberg, 1830) 1,2,3
Notommata sp. 1,2,2*
Plationus patulus (Müller, 1786) 1,2,2*,3,3*
Platyias quadricornis (Ehrenberg, 1832) 1,2,3
Polyarthra vulgaris Carlin, 1943 1,2,2*,3,3*
Pompholyx complanata Gosse, 1851 1
Scaridium sp. 1
Synchaeta sp. 1,1*,2,2*
Sinantherina spinosa (Thorpe, 1893) 1
Testudinella patina (Hermann, 1783) 1,2,3
T. tridentata Smirnov, 1931 1
Trichocerca braziliensis (Murray, 1913) 1
T. insulana (Hauer, 1937) 1,2,3
T. pusilla (Jennings, 1903) 1,2,2*,3,3*
T. similis grandis Hauer, 1965 1,2
Trochosphaera aequatorialis Semper, 1872 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

Copepoda

Phyllodiaptomus praedictus Dumont and Reddy, 1994 2,3
Mesocyclops thermocyclopoides Harada, 1931 2,2*,3,3*
Thermocyclop decipiens (Kiefer, 1929) 1,1*,2,2*,3,3*

studies in Laos (17 species) (Heckman, 1974), Malaysia (71 species) (Ali, 1990) and Sri Lanka (36 species) (Bambaradeniya *et al.*, 2004), but it is lower than in recent report from Laos (135 species) (Segers and Sanoamuang, 2007). The highest species richness was recorded from RF1 (75 species), followed by RF2 (55 species) and RF 3 (51 species).

The number of species at the gate site was lower than within the rice fields (Table 3). 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). Because rice fields are temporary aquatic habitats, zooplankton inhabiting these habitats should be able to survive dry periods by producing resting stages. When favorable conditions return, these hatch or re-emerge and serve as inoculum to recolonize the system. Moreover, zooplankton can be introduced via zoochory by waterbirds (e.g. Figuerola and Green, 2002; Figuerola *et al.*, 2003) that forage in rice fields. Waterbirds may be an important disperser of aquatic organisms and invertebrate propagules. This occurs either by transportation of ingested propagules (internal dispersal, endozoochory) or by propagules attached to the outside of the vector, e.g., in mud on duck's feet (external dispersal, ectozoochory) (Figuerola and Green, 2002). For example, abundant brine shrimp cysts were observed in migratory waders pellets (Sánchez *et al.*, 2007) and various invertebrate propagules can survive passage through the avian digestive tract (Figuerola *et al.*, 2003; Segers and De Smet, 2008). Because at the beginning of the growing cycle we observed numerous birds foraging in all three paddies, it may be assumed that zooplankton were transported to the rice fields via waterfowl.

The major component of zooplankton in each area was rotifers (RF1=85.3%, RF2=87.3%, RF3=84.3%), followed by Cladocera (RF1=13.3%, RF2=7.3%, RF3=9.8%) and Copepoda (RF1=1.4%, RF2=5.4%, RF3=5.9%) respectively (Figure 1). This result agrees with previous studies in Laos (Heckman, 1974) and Sri Lanka (Bambaradeniya *et al.*, 2004) but it is in discordance with the report from Malaysia (Ali, 1990). A 80 mm plankton net was used for zooplankton sampling in the Malaysian rice fields, hence some small rotifer species that can pass through such large net pores have been missed. This may results in a lower number of rotifer species being record from Malaysia. In addition, the lists of rotifer species in Malaysia (33 taxa) and Sri Lanka (18 taxa) were shorter than in this report, while the number of Cladocera in Sri Lanka was higher than in this study (Ali, 1990; Bambaradeniya *et al.*, 2004). Rotifer species richness in Laotian paddy was number than in Thai rice fields (Heckman, 1974; Segers and Sanoamuang, 2007). This may result from the lavish use of fertilizers and pesticides by farmers in Thailand, which leads to eutrophication and consequently negatively affects rotifer diversity (Segers and Sanoamuang, 2007).

Among rotifers, *Lecane* was the dominant genus. A predominance of *Lecane* species has been reported from many wetlands in Thailand (e.g. Sanoamuang, 1998; Chittapun and Pholpunthin, 2001). *Asplanchna sieboldi, Brachionus angularis, B. falcatus, B. urceolaris, Filinia longiseta, Lecane papauna, Plationus patulus, Polyarthra vulgaris, Diaphanosoma exisum* and *Ceriodaphnia cornuta* were common zooplankton in three rice fields. Among them, *F.*

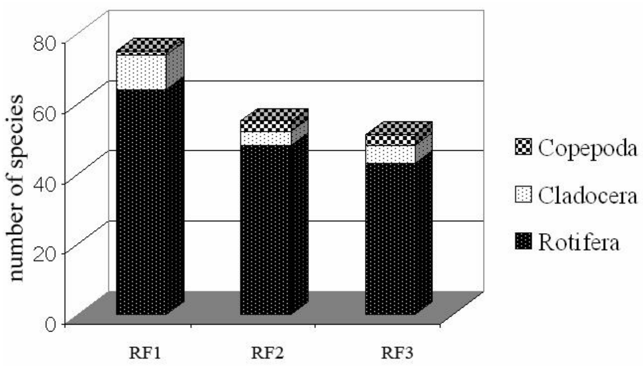

Figure 1. Species composition of zooplankton during a crop cycle in three rice fields of Pathum Thani province

longiseta and *P. patulus* had been reported as major rotifer species from Malaysia (Ali, 1990). Of the three copepods recorded, *Mesocyclop thermocyclopoides* has been recorded from Malaysia (Ali, 1990), while *Thermocyclops decipiens* had been reported from Sri Lanka (Bambaradeniya *et al.*, 2004).

3.3 Zooplankton diversity

Weekly fluctuations in *H'* during a crop cycle was observed in the three areas (Figure 2). The highest average diversity index was reported from RF2 (1.83) followed by RF3 (1.59) and RF1 (1.52) respectively. The highest average evenness was shown in RF2 (0.58) followed by RF3 (0.57) and RF1 (0.45). Compared to other types of wetland habitats in Thailand, rice fields have as great a diversity as the pristine peat swamp, "Jik" studied by Chittapun (2004), (*H'*=1.84, *J*=0.51). This suggests that rice field ecosystems are important in maintaining biodiversity. As a distinctive habitat, rice fields should be conserved for freshwater biodiversity maintenance (Segers and Sanoamuang, 2007).

Zooplankton diversity fluctuated in relation to water depth in RF3 (r=0.54) (Figure 2). This could be a consequence of water volume providing niche in term of habitats for zooplankton. The hydrologic management associated with the rice fields acts as a controller of this ecosystem and influences the composition and abundance of the aquatic biota (Bambaradeniya and Amarasinghe, 2004). Therefore, different farming practices, such as water level control, results in different zooplankton diversity.

3.4 Zooplankton abundance

Zooplankton abundance during a crop cycle in three rice fields of Pathum Thani is shown in Figure 3. The highest densities were 1,519.5, 1,756.8 and 22,630.7 indL^{-1} in RF1, RF2 and RF3 respectively. Zooplankton abundances in Thailand were higher than in Malaysia (Ali, 1990). This is because the 80 mm plankton net used in Malaysia would allow small zooplankton to pass and result in an underestimate of abundance (see above).

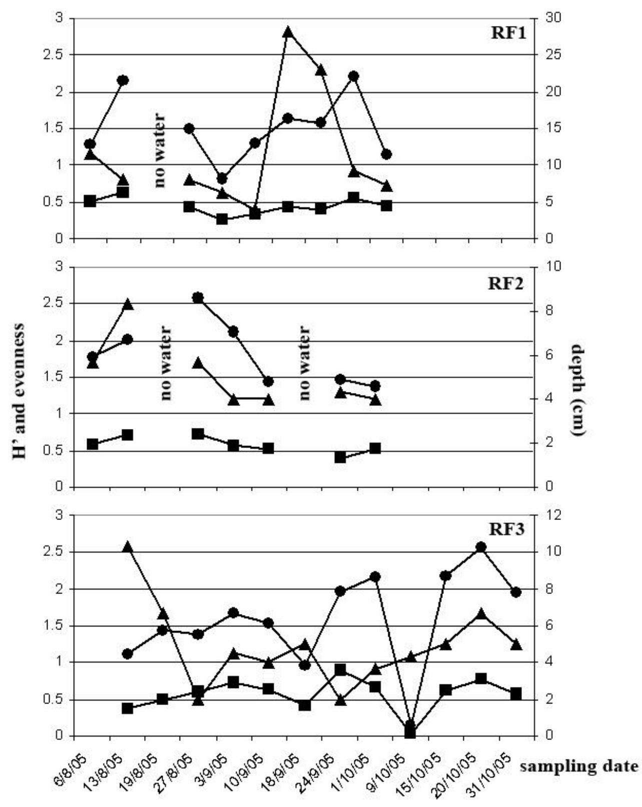

Figure 2. Weekly water levels, Shannon-Wiener diversity index (H') and evenness (J) of zooplankton communities during a crop cycle in three rice fields of Pathum Thani province (●: Shannon Wiener index, ■: evenness, ▲: water depth)

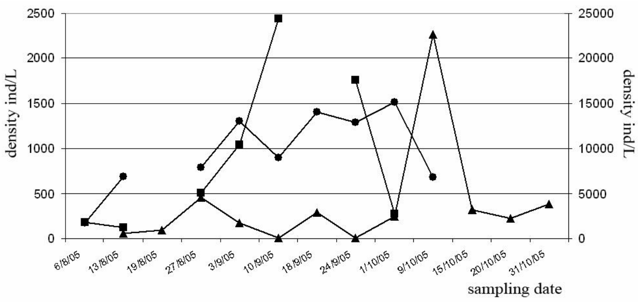

Figure 3. Weekly zooplankton abundance during a crop cycle among three rice fields in Pathum Thani (the left axis for ●: RF1, ■: RF2 and the right axis for ▲: RF3)

3.5 Zooplankton composition

Temporal changes of zooplankton communities during a crop cycle in three rice fields of Pathum Thani province are shown in Figure 4. Nauplii were a major component of the zooplankton in all areas. The compositional contribution of rotifers fluctuated in relation to that of Cladocera and Copepoda (RF2: r = -0.58 and -0.46, respectively). This had already been described in Malaysian rice fields (Ali, 1990).

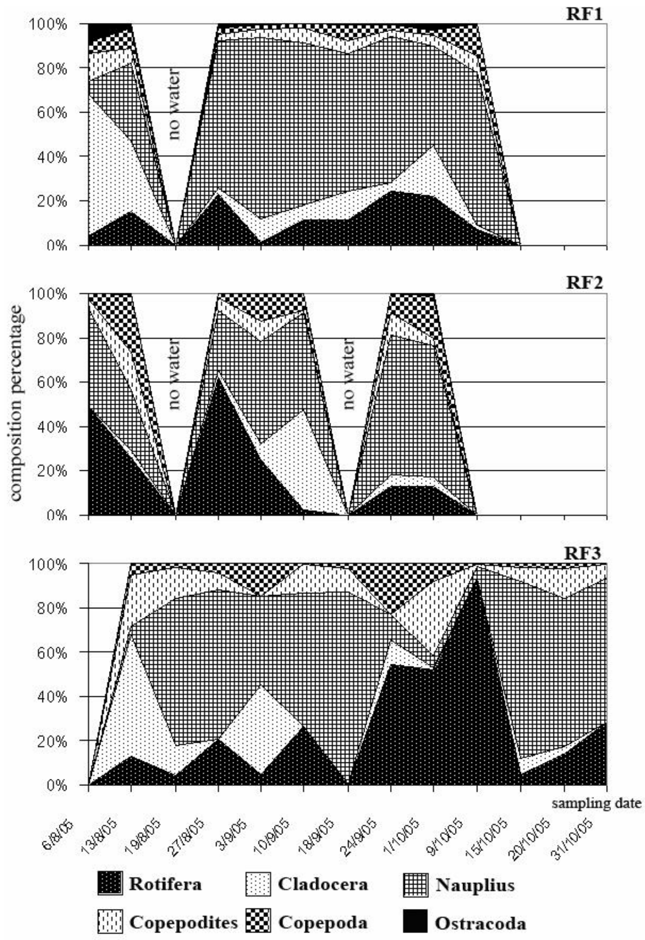

Figure 4. Weekly compositional changes of zooplankton during a crop cycle in three rice fields of Pathum Thani province

Rotifers reached much higher densities when Cladocera were absent. Among crustacean plankton, Cladocera has been identified as effective suppressor of rotifers densities whereas copepods play a minor in this (Nogrady *et al.*, 1993, Fussmann, 1996). Cladocerans have greater clearance rates than rotifers. Therefore, high cladoceran density results in suppression of rotifer abundance (Nogrady *et al.*, 1993). Moreover, rotifers have a narrower food niche, size range of food cells, than cladocerans. Rotifer populations can be limited by cladocerans (Nogrady *et al.*, 1993). In addition, Cladocera communities changed according to the abundance of Copepoda at nauplius and copepodite stage (RF3: r= -0.95 and 0.77 respectively). Gliwicz (1994) reported that the presence of copepods reduces the growth rate of Cladocera. Therefore, cladocerans and copepods appear to play a role in the structuring of rotifer populations.

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