Kasetsart J. (Nat. Sci.) 48 : 704 - 718 (2014)

Biodiversity of Plankton Communities in Inland Waters along the Tenasserim Range, Southern Thailand

Pailin Jitchum

ABSTRACT

Freshwater plankton diversity and environmental parameters were investigated along the Tenasserim Range in May 2007 and 2008. This area is recognized as the backbone of Thailand because it extends from the northern to the southern border of Thailand and Myanmar. Twenty-nine sampling stations were established in 14 inland waters, which were composed of 8 rivers, 5 reservoirs and 1 wetland in Phet Buri, Prachuap Khiri Khan and Chumphon provinces. The plankton samples were collected using a filtering technique and a 20 μm plankton mesh net. In total, 161 species of phytoplankton, 84 species of zooplankton and 4 larval stages were found. The dominant phytoplankton species, measured in terms of the frequency of occurrence, were: *Oscillatoria* sp., *Synedra ulna*, *Eudorina elegans*, *Aulacoseira granulata*, *Gyrosigma spencerii*, *Navicula* sp. and *Peridiopsis* sp. Moreover, three species of zooplankton (*Difflugia lebes*, *Polyarthra* sp. and *Arcella vulgaris*) and two larval stages (copepod nauplius and copepodid larvae) were abundant in this study. The results revealed the specific species composition of the plankton communities between the river and reservoir ecosystems and indicated that these communities could potentially provide support for pelagic production. Further investigation of the annual cycle of the plankton community is required for the development of a biodiversity conservation plan in the future.

Keywords: biodiversity, plankton community, inland waters, Tenasserim Range

INTRODUCTION

During the last two decades, freshwater biology has been one of the most challenging research topics and has been extensively studied (Myers *et al*., 2000). Freshwater bodies are extremely important in terms of water supply, irrigation, fisheries, recreation activities and other economic purposes around the world and this valuable resource makes up only 0.01% of the Earth's water supply (Dudgeon *et al*., 2005). Currently, the increasing demand on freshwater resources is leading to overexploitation, water pollution and flow modification by the man-made destruction of freshwater habitat (Basima *et al*., 2006). In addition, climate change is likely to have a direct effect on precipitation and runoff patterns, which would contribute to major problems with regard to declining freshwater resources (Naiman and Turner, 2000). Dramatic changes to freshwater environments could be a severe threat to freshwater biodiversity that has declined faster than in terrestrial and marine taxa (Sala *et al.*, 2000). With respect to this concern, many international projects have been promoted for water conservation such as Water for Life,

Department of Fishery Biology, Faculty of Fisheries, Kasetsart University, Bangkok 10900, Thailand.
E-mail: ffisplj@ku.ac.th

Received date : 04/09/13 Accepted date : 04/08/14

2005–2015 (Sala *et al.*, 2000). Moreover, the Convention on Biological Diversity, the well known, worldwide biodiversity conservation agreement emphasizes the importance of global assessments on the ecological status and potential of freshwater biodiversity (Revenga and Kura, 2003).

For a better understanding of ecosystem diversity and enhancing the freshwater biodiversity conservation in Thailand, the Office of Natural Resources and Environmental Policy and Planning has supported projects entitled Biodiversity Importance Area and Biodiversity Hotspots, including the investigation of inland water resources along the Tenasserim Range. This range is located in western Thailand, along 834 km from north to south on the border of Thailand and Myanmar. This range originates at the Three Pagodas pass on the Myanmar frontier and runs southward to the Malay Peninsula ending in Ranong province in Thailand. The Tenasserim Range is composed of plains, valleys and coastal regions. Much of the relatively limited information on the flora and fauna biodiversity in this area is out of date and therefore, it is classified as a biodiversity hotspot according to Myers *et al* (2000). As a result, the biodiversity and ecological resilience of this area should to be reinvestigated.

In freshwater environments, plankton species are one of the most important organisms that have various functions and are involved in structuring and balancing the ecosystem. For example, they show the highest potential for influencing the pelagic food supply that shapes aquatic production and nutrient cycling (Likens, 2010). Moreover, both phytoplankton and zooplankton are quite sensitive to environmental variation and they can be used as bio-indicator species (Qingyun *et al*., 2008; Yilmaz, 2013).

This study aimed to investigate the species composition and abundance of phytoplankton and zooplankton in the inland water ecosystems along the southern Tenasserim Range. The results from this study will establish primary data regarding the biodiversity of freshwater plankton in a hotspot area of Thailand and will detail the specific pattern of plankton communities according to their habitats.

MATERIALS AND METHODS

Study area

The study areas was composed of 14 inland waters along the southern Tenasserim Range, (Figure 1), consisting of 8 running waters, 5 standing waters and 1 wetland. Twenty-nine sampling stations were selected in three provinces (Phet Buri, Prachuap Khiri Khan and Chumphon). For running water ecosystems, eight rivers were chosen based on differences in their geographical habitats: the Phet Buri, Pran Buri, Kui Buri, Bang Saphan, Bang Saphan Noi and Chumphon rivers and the Rap Ror and Tha Sae canals. In addition, the characteristics of each water system (the head water basin, running stream and river mouth) were considered in the selection of the sampling stations in each river. All rivers originate in the western high hills, run across the lower catchment area and end in the sea on the eastern coast of the Gulf of Thailand. Five important reservoirs were selected to consider standing water habitats: the Mae Prachan, Kaeng Krachan, Pran Buri, Yang Chum and Chang Rag reservoirs. They provide the main water supply for agricultural and domestic use in the local communities. Only one wetland system—Sam Roi Yod—was selected in this study. Sam Roi Yod is the most well known wetland in Thailand, and it consists of three ecosystems: freshwater, brackish water and coastal zones (United Nations Environmental Program, 2004). The details of coordinates using the Universal Transverse Mercator system and the height above mean sea level of all 29 sampling stations are presented in Table 1

Environmental variables

Measurements of environmental parameters were carried out during daylight hours. At each station, physical environmental factors were analyzed for water temperature and dissolved oxygen (DO) using a DO meter (YSI 550; YSI Inc; OH, U.S.A), for salinity using a refractometer (ATAGO(Thailand) Co.,Ltd.; Nonthaburi, Thailand) and for pH using a pH meter (YSI 60; YSI Inc; OH, U.S.A). Water samples were collected 50 cm below the surface. Concentrations of chlorophyll a were analyzed using a spectrophotometric method in the laboratory (Strickland and Parsons, 1968).

Sampling techniques

Plankton sampling was carried out in May 2007 and 2008. Phytoplankton samples were collected using the filtering technique. Fifty liters of sub-surface water at 30 cm depth were collected and filtered through a 20 µm mesh plankton net. Phytoplankton samples were immediately fixed in 4% buffered formaldehyde solution as the final concentration in the bottle. The samples were identified to the species level and enumerated in a 1 mL Sedgwick-Rafter counter slide under a light microscope using the average from three replicates. Major references for the species identification were: Yamagishi (1992) and Wongrat (2001). The abundance of phytoplankton was determined as the number of units per liter (Wongrat and Boonyapiwat, 2003).

Zooplankton samples were collected using vertical hauling with a 60 µm mesh size for the species diversity study and by the filtering technique in 50 L water samples for determination of abundance. Samples were immediately preserved in 5% borax-buffered formaldehyde solution as the final concentration. Zooplankton was sorted and identified to the species level or in the higher taxa to the larval stage under a

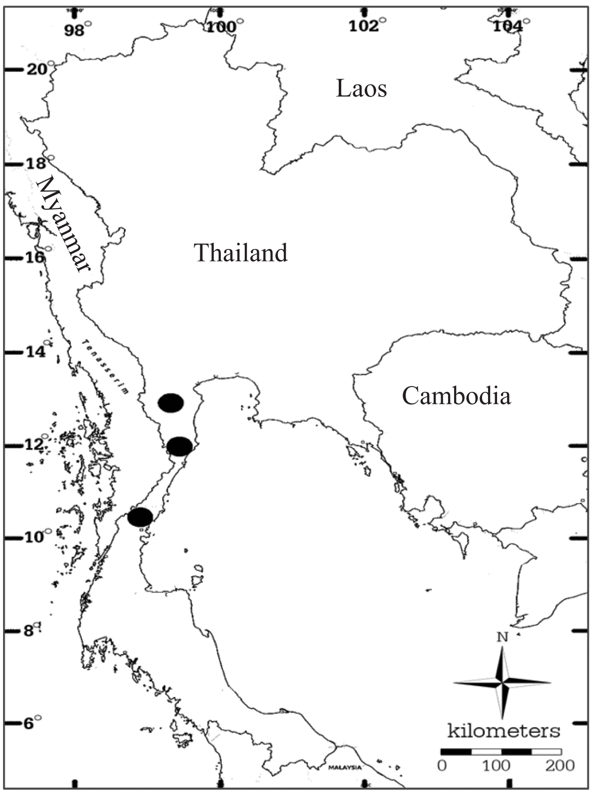

Figure 1 Three study areas (●) in Phet Buri, Prachuap Khiri Khan and Chumphon provinces, Thailand along the southern Tenasserim Range on the Thai-Myanmar border.

Table 1 Sampling station coordinates and height above mean sea level (H) along the southern Tenasserim Range.

Study sites	Northing	Easting	H (m)	Locality
Phet Buri River System				
1. Kaeng Krachan Reservoir	568615	1426519	111	Phetchaburi
2. Mae Prachan Reservoir	571921	1457952	108	Phetchaburi
3. Phet Buri River	583620	1415820	38	Phetchaburi
4. Phet Buri River	593461	1432624	22	Phetchaburi
5. Phet Buri River	598866	1441327	16	Phetchaburi
6. Phet Buri River	602737	1454175	6	Phetchaburi
Pran Buri River System				
7. Pran Buri Reservoir	586298	1377228	66	Prachuap Khiri Khan
8. Pran Buri River	596837	1371017	15	Prachuap Khiri Khan
9. Pran Buri River	602708	1342498	6	Prachuap Khiri Khan
Sam Roi Yod				
10. Sam Roi Yod	580514	1342807	96	Prachuap Khiri Khan
11. Sam Roi Yod	600209	1347600	12	Prachuap Khiri Khan
12. Sam Roi Yod	602708	1342498	6	Prachuap Khiri Khan
Kui Buri River system				
13. Yang Chum Reservoir	575742	1335238	61	Prachuap Khiri Khan
14. Kui Buri River	594437	1333262	9	Prachuap Khiri Khan
Bang Saphan River System				
15. Khlong Khanan	540321	1242258	63	Prachuap Khiri Khan
16. Khlong Bang Saphan	547489	1242624	30	Prachuap Khiri Khan
Bang Saphan Noi River System				
17. Huai Chang Rag	538112	1226441	111	Prachuap Khiri Khan
18. Chang Rag Reservoir	540761	1224821	67	Prachuap Khiri Khan
19. Khlong Sak	540424	1220210	65	Prachuap Khiri Khan
20. Khlong Yai	540646	1223096	60	Prachuap Khiri Khan
Rap Ror Canal				
21. Rap Ror Canal	508841	1195983	79	Chumphon
22. Rap Ror Canal	505525	1176003	30	Chumphon
Tha Sae Canal				
23. Tha Sae Canal	529167	1207722	60	Chumphon
24. Tha Sae Canal	518568	1177922	29	Chumphon
Chumphon River System				
25. Khlong Chumphon	507789	1160565	21	Chumphon
26. Khlong Phanang Tak	524023	1163748	15	Chumphon
27. Tha Tapao River	521776	1156442	10	Chumphon
28. Khlong Thungkha	516305	1149164	10	Chumphon
29. Khlong Ai Led	524968	1147478	7	Chumphon

stereomicroscope in the laboratory. Abundance was performed as the number of individuals in one liter (individual.L^{-1}). Major references for zooplankton identification were: Ogden and Hedley (1980); Charubhun and Charubhun (2000); Wongrat (2000) and Qin *et al*. (2011).

Data analysis

The index of diversity was determined based on the sample size and number of species and calculated from Shannon's formula (Postel *et al*., 2000). The relationship between diversity and the number of species in two different samples (evenness or equitability) was calculated by Pielou's index of evenness. Furthermore, the frequency of occurrence was used to determine how often each species was recorded overall at the 14 sampling sites, and was classified into five categories: regularly present (100–80% of occurrence at the 14 sampling sites), mostly present (80–60%), commonly present (60–40%), occasionally present (40–20%) and rarely present (20–1%), respectively (Yilmaz, 2013).

RESULTS

Environmental parameters

The average water temperature varied from 25.0 to 31.7 °C. The average salinity readings ranged from 0 to 2.7 psu. The average pH value fluctuated from 6.8 in the Sam Roi Yod Wetland to 8.7 in the Yang Chum Reservoir. The minimum level of turbidity was 5.0 nephelometric turbidity units (NTU) in the Yang Chum Reservoir and the maximum was 170 NTU in the Pran Buri River. Average dissolved oxygen varied from 3.0 mg.L^{-1} in the Sam Roi Yod Wetland to 9.9 mg.L^{-1} in the Chang Rag Reservoir, while the chlorophyll a concentration ranged between 0.56 mg.m^{-3} in the Tha sae Canal and 40.6 mg.m^{-3} in the Yang Chum Reservoir. The average values of the environmental parameters in the 14 study sites are presented in Table 2.

Phytoplankton diversity, distribution and abundance

In total, 161 species 92 genera 38

Table 2 Average values of water temperature (T), salinity (S), pH, turbidity (Tb), dissolved oxygen (DO,) and chlorophyll a concentration (Chl a).

Study site	T (°C)	S (psu)	pH	Tb (NTU)	DO (mg.L^{-1})	Chl a (mg.m^{-3})
Phet Buri River	29.6	0.10	7.4	92.5	5.9	3.20
Pran Buri River	29.3	0.60	7.3	170.0	5.5	5.90
Kui Buri River	27.7	0.30	7.6	50.0	6.0	0.67
Bang Saphan River	28.3	0.05	7.0	17.0	7.3	1.34
Bang Saphan Noi River	27.0	0.10	7.0	45.3	7.3	3.00
Rap Ror Canal	25.0	0.00	7.8	46.0	7.3	1.07
Tha sae Canal	25.2	0.10	8.0	40.7	7.0	0.56
Chumphon River	26.7	2.70	7.7	32.6	6.6	3.40
Mae Prachan Reservoir	29.8	0.10	7.9	7.4	7.0	1.92
Kaeng Krachan Reservoir	31.7	0.10	8.3	6.2	8.6	8.84
Pran Buri Reservoir	30.1	0.20	8.4	22.0	8.5	6.40
Sam Roi Yod, Wetland	30.5	1.20	6.8	8.3	3.0	12.70
Yang Chum Reservoir	29.9	0.20	8.7	5.0	9.3	40.60
Chang Rag Reservoir	29.4	0.10	7.4	10.0	9.9	20.80

NTU = Nephelometric turbidity units

families 13 orders and 8 classes in 3 divisions were recorded in the 14 inland waters along the southern Tenesserim Range in Phet Buri, Prachuap Khiri Khan and Chumphon provinces. The most diverse class was the Chlorophyceae, which was comprised of 69 species, followed by the Bacillariophyceae (41 species), Euglenophyceae (21 species), Cyanophyceae (16 species), Dinophyceae (9 species), Xanthophyceae (2 species), Chrysophyceae (2 species) and Dictyochophyceae (1 species), respectively. The species composition of phytoplankton is shown in Appendix I. The number of species, abundance, diversity index and evenness of phytoplankton are shown in Table 3. The maximum number of species recorded was 88 in the Chumphon River and the lowest number recorded was 19 species in both the Kui Buri River and the Kaeng Krachan reservoirs. The average abundance varied from 648 units.L^{-1} in the Tha Sae Canal to 197,684 units.L^{-1} in the Chang Rag Reservoir.

The Shannon diversity index (H′) and Pielou's index of evenness (J′) were analyzed. The diversity index of phytoplankton varied from the minimum of 0.71 in the Kui Buri River to the maximum of 3.36 in the Tha Sae Canal. Evenness was recorded from 0.24 to 0.85. Table 3 shows the species richness, abundance, evenness and diversity index of phytoplankton in Phet Buri, Prachuap Khiri Khan and Chumphon provinces. The relationship between diversity and the number of species or the evenness in the study areas fluctuated greatly in both the river and reservoir ecosystems.

A comparison of conditions in the river and reservoir ecosystems indicated that the average phytoplankton abundance in running water ranged from 648 units.L^{-1}in the Tha Sae Canal to 9,698 units.L^{-1} in the Bang Saphan River. On the other hand, the standing water varied from 1,599 units.L^{-1} in the Mae Prachan Reservoir to 197,684 units.L^{-1} in the Chang Rag Reservoir (Table 3). Thus, the average abundance of phytoplankton in reservoirs was 14 times higher than in river ecosystems. There were 19 to 88 species in the river ecosystems and 19 to 71 species in the reservoir ecosystems, indicating that the species richness of phytoplankton in the river ecosystems

Table 3 Number of species, abundance, evenness (Pielou's index = J') and the Shannon diversity index (H′) of phytoplankton in Phet Buri, Prachuap Khiri Khan and Chumphon provinces.

Study site	Number of species	Abundance (units.L^{-1})	Evenness (J')	Diversity index H'(log_e)
Phet Buri River	50	1,768	0.64	2.50
Pran Buri River	51	2,023	0.74	2.89
Kui Buri River	19	3,800	0.24	0.71
Bang Saphan River	51	9,698	0.50	1.97
Bang Saphan Noi River	29	2,725	0.32	1.09
Rap Ror Canal	53	1,279	0.73	2.90
Tha sae Canal	53	648	0.85	3.36
Chumphon River	88	3,084	0.67	2.99
Mae Prachan Reservoir	22	1,599	0.56	1.72
Kaeng Krachan Reservoir	19	15,109	0.40	1.19
Pran Buri Reservoir	27	11,268	0.54	1.79
Sam Roi Yod, Wetland	71	13,402	0.63	2.67
Yang Chum Reservoir	24	24,751	0.41	1.29
Chang Rag Reservoir	26	197,684	0.27	0.90

was 1.6 times higher than in the reservoirs. The phytoplankton distribution in terms of percentage contribution and class composition were compared among the 14 study sites (Figure 2).

Figure 2 shows the trend of the dominant group of phytoplankton in the running water was the diatoms, with the exception of the Phet Buri River where it was cyanobacteria. The dominant group in the standing water varied among the six reservoirs. The average abundance of phytoplankton in the eight rivers showed that diatoms dominated with the highest percentage contribution of 59% with a mean of 1,854 ± 1,796 units.L^{-1}, followed by cyanobacteria (18%, 562 ± 487 units.L^{-1}), dinoflagellates (10%, 319 ± 722 units.L^{-1}), green algae (8%, 247 ± 196 units.L^{-1}), euglenoids (4%, 139 ± 212 units.L^{-1}), and other (1%, 7 ± 20 units.L^{-1}), respectively.

The dominant species in each class of the eight rivers were Cyanophyceae (*Oscillatoria* sp. 90% of the total cyanophycean abundance), Chlorophyceae (*Eudorina elegans* 40%, *Pandorina morum* 17% and *Pediastrum simplex* 12% of the total chlorophycean abundance), Euglenophyceae (*Lepocinclis ovum* 35%, *Euglena acus* 11% and *Strombomonas fluviatilis* 11% of the total euglenoid abundance; diatoms (*Synedra ulna* 50%, *Navicula* sp. 19% and *Aulacoseira granulata* 15% of the total diatom abundance) and dinoflagellates (*Peridiopsis* sp. 75% and *Peridinium* sp. 21% of the total dinoflagellate abundance).

On the other hand, chrysophytes were the dominant group in the Mae Prachan Reservoir, whereas dinoflagellates dominated in the Kaeng Krachan and Chang Rag reservoirs. The cyanobacteria were found in large numbers

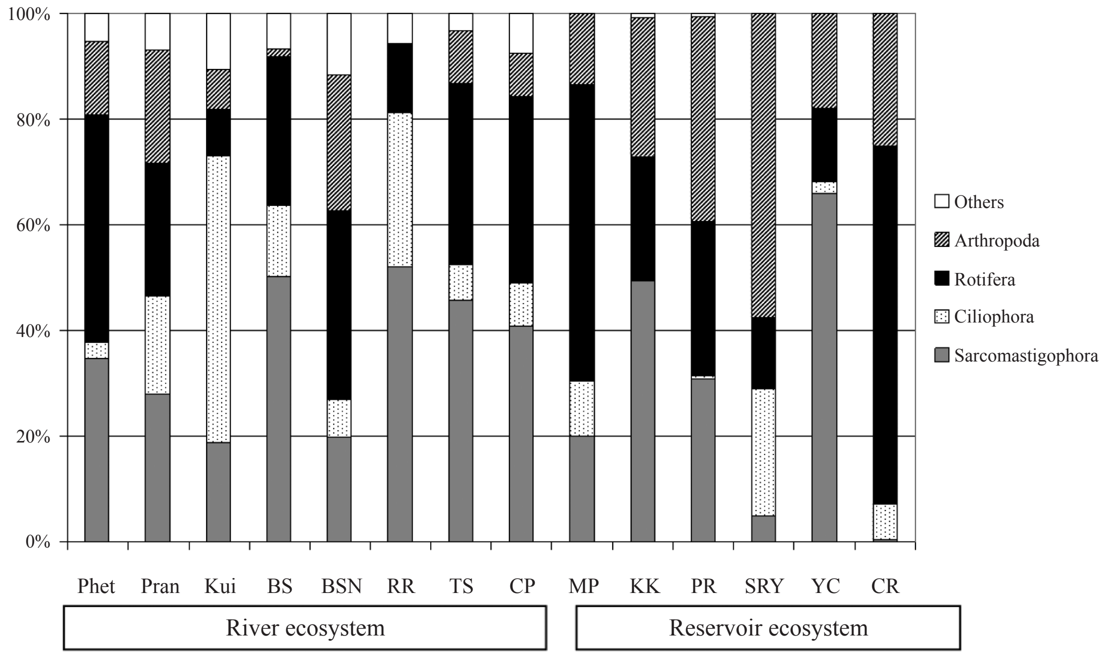

Figure 2 Percentage contribution of phytoplankton in 14 inland waters along the Tenasserim Range, in Phet Buri, Prachuap Khiri Khan and Chumphon provinces, Thailand. (Phet = Phet Buri River, Pran = Pran Buri River, Kui = Kui Buri River, BS = Bang Saphan River, BSN = Bang Saphan Noi River, RR = Rap Ror Canal, TS = Tha Sae Canal, CP = Chumphon River, MP = Mae Prachan Reservoir, KK = Kaeng Krachan Reservoir, PR = Pran Buri Reservoir, SRY = Sam Roi Yod Wetland, YC = Yang Chum Reservoir, CR = Chang Rag Reservoir.)

in the Pran Buri, Sam Roi Yod and Yang Chum reservoirs. Moreover, the average abundance of phytoplankton in the six reservoirs indicated that the dinoflagellates showed the highest proportion of 59 % with mean 25,845 ± 53,245 units.L^{-1} among the reservoir groups. The percentage and mean abundance values of the other classes in descending order were: diatoms (14%, 6,129 ± 11,628 units.L^{-1}), green algae (14%, 6,126 ± 13,431 units.L^{-1}), cyanobacteria (12%, 5,156 ± 6,035 units.L^{-1}) and euglenoids (1%, 576 ± 1,151 units.L^{-1}), respectively (Figure 2).

The dominant species of phytoplankton in the six reservoirs were: Cyanophyceae (*Oscillatoria* spp. 69% and *Cylindrospermopsis raciborskii* 13% of the total cyanophycean abundance), Chlorophyceae (*E. elegans* 91% and *P. simplex* 5% of the total chlorophycean abundance), Euglenophyceae (*L. ovum* 39%; *Trachelomonas crebea* 18% and *Phacus acuminatus* 13% of the total euglenoid abundance), diatoms (*A. granulata* 83% of the total diatom abundance) and dinoflagellates (*Peridiopsis* sp. 99% of the total dinoflagellate abundance). Finally, chrysophytes were represented by *Dinobryon sertularia* making up 99% of the total abundance.

It was noticeable that the differences in the species composition in each reservoir was established by the different characteristics of habitats. In the Mae Prachan reservoir, the dominant species was *Dinobryon sertularia* representing 49% of the total abundance of phytoplankton, followed by *Microcystis wesenbergii* (23%). In the Pran Buri Reservoir, *Oscillatoria* sp. had the highest percentage of 32%, followed by *C. raciborskii* (29%) of the total abundance. In the Kaeng Krachan Reservoir, the most abundant species was *Peridiopsis* sp. with 74% of the total abundance. In the Sam Roi Yod Wetland, the dominant group was *Spirulina platensis* (23%), followed by *Oscillatoria* sp. (18%) and *Cyclotella* sp. (16%) of the total abundance, respectively. In the Yang Chum Reservoir, *Oscillatoria* sp. was recorded at 60%, followed by *Peridiopsis* sp. with 25% of the total abundance. Finally, in the Chang Rag Reservoir, *Peridiopsis* sp. made up 67%, followed by *E. elegans* (17%) and *A. granulata* (15%) of the total abundance, respectively.

The results of frequency of occurrence were used to describe the majority of phytoplankton species in term of how often they were observed among the total sampling sites. Meanwhile seven species, including *Oscillatoria* sp., *S. ulna*, *E. elegans*, *A. granulata*, *Gyrosigma spencerii*, *Navicula* sp. and *Peridiopsis* sp., were established in regularly present.

Zooplankton diversity, distribution and abundance

In total, 84 species from 41 genera 29 families 14 orders 17 classes in 8 phyla and 4 larval stages were recorded. The most diverse phylum was the Rotifera, which was composed of 41 species, followed by the Sarcomastigophora (16 species), Arthropoda (12 species) and Ciliophora (12 species), respectively. The least diverse phyla were the Annelida (1 species), Cnidaria (1 species), and Nematoda (1 species). Two phyla of meroplankton were recorded: the Annelida and Mollusca. The number of species, abundance, evenness (J’) and diversity index (H′) of zooplankton in the study area are shown in Table 4. The number of species varied from 14 in the Rap Ror Canal to the maximum of 45 in the Phet Buri River. The abundance of zooplankton ranged from a minimum of 68 individuals.L^{-1} in the Bang Saphan River to the maximum of 1,846 individuals.L^{-1} in the Yang Chum Reservoir. The Shannon diversity index of zooplankton ranged from a minimum of 1.45 in the Yang Chum Reservoir to a maximum of 3.07 in the Phet Buri River and the evenness value varied from 0.51 in the Yang Chum Reservoir to 0.94 in the Tha Sae Canal (Table 4).

The mean abundance of zooplankton was compared between the river and reservoir ecosystems. The average values were 142 ± 70 individuals.L^{-1} in the running water and 974 ± 570 individuals.L^{-1} in the standing water. The average abundance of zooplankton in reservoirs was seven times higher than in rivers. In the river ecosystems, the lowest abundance was recorded as 68 individuals.L^{-1} in the Bang Saphan River, whereas the highest abundance was 282 individuals.L^{-1} in the Phet Buri River. In the reservoir ecosystems, the lowest abundance was found in the Mae Prachan Reservoir (462 individuals.L^{-1}) and the highest value was recorded in the Yang Chum Reservoir (1,846 individuals.L^{-1}). The comparison of the percentage contribution of zooplankton between the running and standing water samples is presented in Figure 3 and the results show the majority were in different groups with regard to running and standing water.

To compare the river and reservoir ecosystems, the composition of zooplankton among the eight rivers was expressed as the percentage contribution of the total abundance, with the highest abundance in the phylum Sarcomastigophora (34%, 49 ± 26 individuals.L^{-1}), followed by the Rotifera (28%, 40 ± 35 individuals.L^{-1}), Ciliophora (18%, 26 ± 30 individuals.L^{-1}), Arthropoda (12%, 17 ± 16 individuals.L^{-1}) and others (8%, 10 ± 5 individuals.L^{-1}), respectively.

The dominant species of zooplankton in the rivers showed a different pattern from the reservoir ecosystems. Firstly, *Arcella vulgaris* dominated in the phylum Sarcomastigophora, contributing 30 % to total testate amoeba abundance, followed by *Difflugia tuberculata* (23%) and *D. lebes* (16%), respectively. Secondly, the tintinnid ciliate*, Tintinnopsis meunnier,* accounted for 23 % of the total ciliated protozoan abundance, followed by *T. elongata* (18%) and *Payxicola affinis* (16%). Finally, in the phylum Rotifera *Polyarthra* sp. constituted 17% of the total rotifer abundance, followed by *Keratella tropica* (16%) and *Ascomorpha* sp. (13%), respectively. For larval specimens, two larval stages of the phylum Arthropoda were abundant, accounting for 68% of copepod nauplius and 15% of copepodid larvae.

On the other hand, the composition of zooplankton in the six reservoirs showed the highest abundance of the phylum Rotifera (34%, 335 ± 351 individuals.L^{-1}), followed

Table 4 Number of species, abundance, evenness (Pielou's index = J') and Shannon diversity index (H´) of zooplankton in Phet Buri, Prachuap Khiri Khan and Chumphon provinces.

Study site	Number of species	Abundance (individuals.L^{-1})	Evenness (J')	Diversity index H'(log_e)
Phet Buri River	45	282	0.81	3.07
Pran Buri River	33	182	0.84	2.94
Kui Buri River	18	170	0.76	2.20
Bang Saphan River	17	68	0.90	2.55
Bang Saphan Noi River	24	91	0.89	2.83
Rap Ror Canal	14	139	0.85	2.25
Tha sae Canal	20	76	0.94	2.83
Chumphon River	26	129	0.87	2.84
Mae Prachan Reservoir	18	462	0.81	2.35
Kaeng Krachan Reservoir	21	620	0.71	2.18
Pran Buri Reservoir	27	789	0.67	2.19
Sam Roi Yod, Wetland	39	602	0.57	2.08
Yang Chum Reservoir	17	1,846	0.51	1.45
Chang Rag Reservoir	24	1,526	0.73	2.33

by the Sarcomastigophora (32%, 316 ± 4581 individuals.L^{-1}), Arthropoda (27%, 265 ± 125 individuals.L^{-1}), Ciliophora (6%, 57 ± 57 individuals.L^{-1}) and others (1%, 2 ± 3 individuals.L^{-1}), respectively. The zooplankton composition and abundance are shown in Appendix I.

The dominant species in each phylum found in the reservoir ecosystem was measured. For the testate amoeba, *D. lebes* accounted for 67% and *D. tuberculata* for 26% of total abundance in this group. The ciliated protozoans showed the dominant species as *Coleps* sp. (44%) and *Paramecium* sp. (14%), whereas the dominant rotifer species consisted of 44% *Polyarthra* sp., 11% *K. tropica* and 10% *Ascomorpha* sp. The dominant arthropod species belonged to the group of copepod nauplius (68% of the total arthropod abundance), followed by *Chaoborus* sp. (11%), copepodid larvae (7%) and *Bosminopsis deitersi* (7%), respectively. Additionally, the results for the frequency of occurrence showed that the majority of zooplankton species were classified as occasionally present which meant they were observed at some sampling sites. They were composed of 60% of the total number of species. Moreover, three zooplankton species (*D. lebes*, *Polyarthra* sp., *A. vulgaris*) and two larval stages (copepod nauplius and copepodid larvae) were regularly present in this study.

DISCUSSION

This study was carried out in May 2007 and 2008, and thus considered only the plankton community in the dry season and not the annual seasonality. The rainy season caused an increase in the turbidity and velocity of the inland water, and

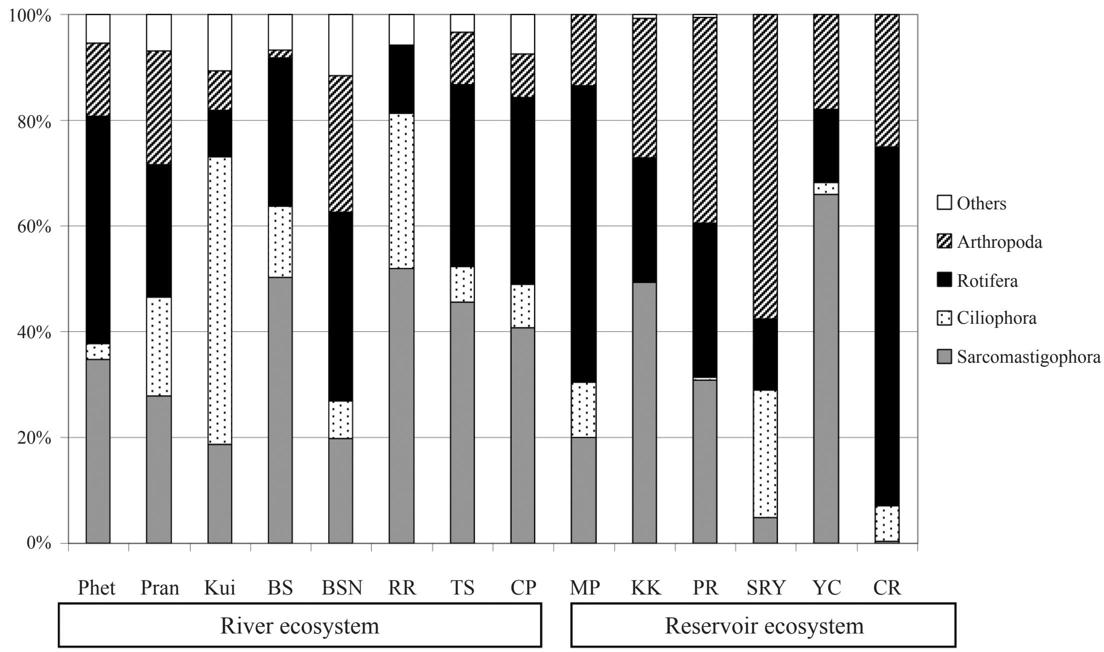

Figure 3 Percentage contribution of zooplankton in 14 inland waters along the Tenasserim Range, in Phet Buri, Prachuap Khiri Khan and Chumphon provinces. (Phet = Phet Buri River, Pran = Pran Buri River, Kui = Kui Buri River, BS = Bang Saphan River, BSN = Bang Saphan Noi River, RR = Rap Ror Canal, TS = Tha Sae Canal, CP = Chumphon River, MP = Mae Prachan Reservoir, KK = Kaeng Krachan Reservoir, PR = Pran Buri Reservoir, SRY = Sam Roi Yod Wetland, YC = Yang Chum Reservoir, CR = Chang Rag Reservoir.)

accordingly, the reduced light penetration limited the photosynthesis of phytoplankton in the water column (Likens, 2010). Consequently the number of species and abundance of phytoplankton and zooplankton may be reduced from those present in the dry season, especially in the river ecosystem. Moreover, the sampling technique and sampling periods during the day highly affected the abundance of zooplankton dispersed in the water column and some of them may exhibit diel vertical migration in the reservoir, as collection during the night demonstrated that the abundance and number of species of zooplankton were higher than from daylight collection because of the assemblage in surface water at night (Suthers and Rissik, 2009).

Furthermore, the diversity index of phytoplankton showed that the variation and the evenness were relatively low in both the river and reservoir systems (Table 3), which indicated that the data were not suitable for balancing the biodiversity, number of species and abundance. Meanwhile zooplankton showed a high diversity index value, being greater than 2.00 at all sites, except for the Yang Chum Reservoir and the evenness value was also high (Table 4). The high diversity index value (greater than 2.00) indicated that the suitable level of environmental conditions for the community was "moderate". Although the diversity index (H′) is extensively used to describe the complexity of a community, this index is not suitable for eutrophication studies, owing to the underestimation of the environmental quality in the aquatic system (Karydis, 2009).

The occurrence of dominant species, especially phytoplankton, can be used as an indicator of the water quality. For example, the chrysophyte *Dinobryon sertularia* showed a high abundance in the Mae Prachan Reservoir (49% of the total abundance) and this might indicate that the water has a neutral to low alkalinity, representing oligotrophic water (Suthers and Rissik, 2009; Likens, 2010) (Figure 2). Furthermore, the cyanobacteria were found at levels of more than 60% in the Pran Buri and Yang Chum reservoirs and this result is likely to indicate stable and nutrient-rich ecosystems in these standing water habitats. Nutrient-rich water may refer to the high level of dissolved total phosphorus in the water body, and this element is an important limiting factor in freshwater ecosystems. Considering this finding, the occurrence of eutrophic conditions in standing water could be explained by the rapid development of cyanobacteria. Moreover eutrophication could be common when the water column has a high pH and low dissolved carbon dioxide concentration (Likens, 2010) (Table 2).

The noticeable observation of small dinoflagellate blooming (*Peridiopsis* spp.) was established by a high abundance of more than 65% of the total abundance of phytoplankton in the Kaeng Krachan and Chang Rag reservoirs (Figure 2). This phenomenon seems to be specific to the water temperature, timing and duration of mixing in a water body. However, this plankton bloom should be monitored for the whole year cycle covering all seasons. Moreover, dinoflagellates can produce cysts that fall to the bottom sediment and may bloom at some later time of the year, for example in the temperate zone during summer (June to October) when the temperature is higher than in other periods due to the reduced water level (Likens, 2010). Thus, dinoflagellates may produce cysts during the dry season (high temperature) from March to April, and then a bloom of dinoflagellates will develop in May as verified by the high abundance of these species in this study period (Table 2).

In the river system, the dominant group of plankton was the diatoms as shown by the three highest percentage contributors, comprising *Synedra ulna*, *Navicula* sp. and *A. granulata* (Table 5). Their presence may be explained by their ability to occur in a wide range of freshwater habitats as they can rapidly adapt to a change in the nutrient concentrations and the environmental conditions. Furthermore, some species of diatoms have a high tolerance to dissolved nitrogen and phosphate in the water column and they can appear in many different forms such as free-living in the water column, forming cell chains, arranged within mucilage tubes or attached to any substratum, and this indicates that they possess an effective adaptation to environmental changes that assists their survival (Likens, 2010).

The result on the zooplankton community revealed differences in the species composition of ciliated protozoans and rotifers between the river and reservoir ecosystem (Table 5). Moreover the dominant groups of zooplankton showed different levels of percentage contribution (Table 6).

The results showed the different relationship between the plankton communities and environmental parameters in the inland waters along the southern Tenasserim Range (Table 6). These results can be used as a database on freshwater biodiversity in this area and show the correlation between the plankton composition and the environment. This study suggests that the long-term monitoring of plankton communities in this area should be investigated on an annual cycle to obtain a better understanding of the potential of the freshwater ecosystem and to develop conservation management scenarios. In addition, the data obtained based on long-term monitoring would be useful for the estimation of pelagic production, the prediction of fisheries resources conditions and the future study of a comprehensive, ecological model of freshwater ecosystems.

CONCLUSION

This study revealed plankton diversity in the inland waters of the southern Tenasserim Range with 161 species of phytoplankton and 84 species of zooplankton identified. The most diverse group of phytoplankton was the green algae, followed by diatoms, euglenoids, cyanobacteria, dinoflagellates, xanthophytes, chrysophytes and silicoflagellates, respectively. Seven species were dominant, comprising *Oscillatoria* sp., *Synedra ulna*, *Eudorina elegans*, *Aulacoseira granulata*, *Gyrosigma spencerii*, *Navicula* sp. and *Peridiopsis* sp. In addition, the most diverse group of zooplankton was the rotifers, followed by the testate amoeba, arthropods and ciliated protozoans, respectively. The five dominant zooplankton species were: *Arcella vulgaris*, *Difflugia lebes*, *Polyarthra* sp., and larval stages of copepod nauplius and copepodid larvae. The river and reservoir systems showed differences in the relationship between the dominant groups of plankton and environmental parameters. Each reservoir established its characteristics based on some dominant species dependent on the water quality but in the river ecosystems there were no noticeably dominant species. Diatoms were found at the highest level of abundance in the riverine ecosystems. The chrysophyte *Dinobryon sertularia* showed the highest abundance in the Mae Prachan Reservoir. The cyanobacteria dominated in the Pran Buri and Yang Chum reservoirs with more than 60%. Small dinoflagellates (*Peridiopsis* spp.) exhibited a rapid growth in the Kaeng Krachan and Chang Rag reservoirs. The relationship between environmental characteristics and plankton community structures could influence the specificity in biodiversity, abundance and distribution of pelagic production and might be used to predict the potential of the freshwater ecosystem in the future.

ACKNOWLEDGEMENTS

The author thanks the Office of Natural Resources and Environmental Policy and Planning, Ministry of Natural Resources and Environments for financial support. Assoc. Prof. Dr. Narong Veeravaitaya, Assist. Prof. Sommai Janekitkarn, Assist. Prof. Phongchate Pichitkul, Dr. Santi Poungcharean and Ms. Hatairat Chaiamatakul assisted with field work.

Table 5 Dominant species of phytoplankton and zooplankton between river and reservoir communities along the southern Tenasserim Range.

Group	River	Reservoir
Phytoplankton		
Blue green algae	*Oscillatoria*	*Oscillatoria*
		Cylidrospermopsis raciborskii
		Microcystis aeruginosa
		Anabaena sp.
Green algae	*Eudorina elegans*	*Eudorina elegans*
	Pandorina morum	*Pediastrum simplex*
	Pediastrum simplex	*Staurastrum* sp.
	Pediastrum duplex	
Euglenoids	*Euglena acus*	*Lepocinclis ovum*
	Phacus ranula	*Trachelomonas crebea*
	Lepocinclis ovum	*Phacus acuminatus*
	Phacus tortus	
	Strombomonas fluviatilis	
Diatoms	*Synedra ulna*	*Synedra ulna*
	Navicula spp.	*Aulacoseira granulata*
	Gyrosigma spencerii	
	Bacillaria pyxillifer	
	Surirella robusta	
	Surirella tenera	
	Aulacoseira granulata	
Dinoflagellates	*Peridiopsis* spp.	*Peridiopsis* spp.
	Peridinium spp.	
Chrysophytes	*Dinobryon sertularia*	*Dinobryon sertularia*
	Mallomonas spp.	
Zooplankton		
Sarcomastigophorans	*Arcella vulgaris*	*Difflugia lebes*
	Difflugia lebes	*Difflugia tuberculata*
	Centropyxis aculeata	
Ciliophorans	*Tintinnopsis meunnier*	*Vorticella* sp.
	Tintinnopsis elongata	*Coleps* sp.
	Pyxicola affinis	*Paramecium* sp.
Rotifers	*Polyarthra* spp.	*Keratella tropica*
	Keratella tropica	*Polyarthra* sp.
	Ascomorpha spp.	*Tricocerca similis*
		Hexarthra sp.
		Anuraeopsis sp.
		Brachionus falcatus
Arthropods	Copepod nauplii	Copepod nauplii
	Copepodid copepods	Copepodid copepods
		Bosminopsis deitersi

Table 6 Percentage contribution of phytoplankton and zooplankton for riverine and standing water.

Phytoplankton				Zooplankton			
Riverine		Standing water		Riverine		Standing water	
Diatoms	59%	Dinoflagellates	59%	Testate amoeba	34%	Rotifers	34%
Cyanobacteria	18%	Green algae	14%	Rotifers	28%	Testate amoeba	32%
Dinoflagellates	10%	Diatoms	14%	Ciliates	18%	Arthropods	27%
Green algae	8%	Cyanobacteria	12%	Arthropods	12%	Ciliates	6 %
Euglenoid	4%	Euglenoid+others	1 %	Others	8%	Others	1%
Others	1%						

LITERATURE CITED

Basima, L.B., A. Senzanje, B. Marshall and K. Shick. 2006. Impacts of land and water use on plankton diversity and water quality in small man-made reservoirs in the Limpopo basin, Zimbabwe: A preliminary investigation. **Phys. Chem. of the Earth** 31: 821–831.

Charubhun, B. and N. Charubhun. 2000. Biodiversity of freshwater protozoa in Thailand. **Kasetsart J. (Nat. Sci.)** 34(4): 486–494.

Dudgeon, D., A.H. Arthington, M.O. Gessner, Z. Kawabata, D.J. Knowler, C. Lévêque, R.J. Naiman, A. Prieur-Richard, D. Soto, M.L.J. Stiassny and C.A. Sullivan. 2005. Freshwater biodiversity: importance, treats, status and conservation challenges. **Biol. Rev.** 81: 163–182.

Naiman, R.J. and M.G. Tuener. 2000. A future perspective on North America's freshwater ecosystem. **Ecol. Appl.** 10: 958–970.

Karydis, M. 2009. Eutrophication assessment of coastal waters based on indicators: A literature review. **Global NEST J.** 11(4): 373–390.

Likens, G.E. 2010. **Encyclopedia of Inland Waters: Plankton of Inland Waters.** Academic Press. Amsterdam, the Netherlands. 398 pp.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G. A. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. **Nature** 403: 853–858.

Ogden, C.G. and R.H. Hedley. 1980. **An Atlas of Freshwater Testate Amoeba.** Oxford University Press. Oxford, UK. 222 pp.

Postel, L., H. Fork and W. Hagen. 2000. Biomass and abundance, pp. 83–192. *In* R. Harris *et al*. (eds.). **ICES Zooplankton Methodology Manual.** Academic Press. London, UK.

Qin, Y., S. Xie, H.G. Smith, G.T. Swindles and Y. Gu. 2011. Diversity, distribution and biogeography of testate amoeba in China: Implications for ecological studies in Asia. **European J. Protistology** 47: 1–9.

Qingyun, Y., Y. Yuhe, F. Weisong, Y. Zhigang and C. Hongtao. 2008. Plankton community composition in the three Gorge Reservoir Region revealed by PCR-DGGE and its relationships with environmental factors**. J. Environ. Sci.** 20: 732–738.

Revenga, C. and Y. Kura. 2003. **Status and Trends of Biodiversity of Inland Water Ecosystems.** Technical Series 11, Secretariat of the Convention on Biological Diversity. Montreal, Quebec, Canada. 126 pp.

Sala, O.E., F.S. Chapin, J.J. Armesto, R. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L.F. Huenneke, R.B. Jackson, A. Kinzig, R. Leemans, D. Lodge, H.A. Mooney, M. Oesterheld, N.L. Poff, M.T. Sykes, B.H. Walker, M. Walker and D.H. Wall. 2000. Global biodiversity scenario for the year 2100. **Science** 287: 1770–1774.

Strickland, J.D.H. and T.R. Parsons. 1968. **A Practical Manual of Seawater Analysis.**

2nd ed. Fishery Research Canadian Bulletin, No. 167. Queen's Printer. Ottawa, Ontario, Canada. 311 pp.

Suthers, I. M. and D. Rissik. 2009. **Plankton: A Guide to Their Ecology and Monitoring for Water Quality.** CSIRO Publishing. Melbourne, VIC, Australia. 256 pp.

United Nations Environmental Program (UNEP). 2004. **Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand.** Integrated Promotion Technology, Co. Ltd., Bangkok, Thailand. 125 pp.

Wongrat, L. 2000. **Zooplankton.** Kasetsart University Press. Bangkok, Thailand. [in Thai]

Wongrat, L. 2001. **Phytoplankton.** Kasetsart University Press, Bangkok, Thailand. [in Thai]

Wongrat, L. and S. Boonyapiwat. 2003. **Manual of Sampling and Analytical Methods of Plankton.** Kasetsart University Press. Bangkok, Thailand. [in Thai]

Yamagishi, T. 1992. **Plankton Alage in Taiwan (Formosa).** Uchida Rokakuho. Tokyo, Japan. 252 pp.

Yilmaz, N. 2013. Phytoplankton composition of Sazlidere Dam lake, Istanbul, Turkey. **Maejo Int. J. Sci. Techno.** 7(2): 203–211.