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Ground Water Recharge in Central Kalimantan Deduced from Isotopic Hydrology

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Abstract

From 1997 to 1999, various water samples were collected and analyzed for oxygen isotope composition in order to understand hydrology in Central Kalimantan. Rainwater, lake water, river water, and ground water from wells and peat ponds were collected during our expedition. Ground water was found to be isotopically lightest among the water samples and rain water samples collected in both dry and wet seasons were found to be heaviest of all, indicating that ground water has to be provided from the water supply other than the local precipitation. Isotope compositions of all other water samples including lake water and river water distributed between ground water and rain water, suggesting that those water formed from the mixing ground water and rain water. The most probable source of water for the ground water in Central Kalimantan is precipitation in the high mountainous area on the north of Central Kalimantan. Many mountains are with several thousand-meter elevations. The isotope composition in the precipitation in the area is expected to be substantially light because of so-called altitude effect on the isotope composition in precipitation. Rainwater *in situ* in Central Kalimantan recharges negligible amount of the ground water. Therefore, it is believed that protection in the northern mountain range is essential to maintain the ground water in high quality and quantity in Central Kalimantan.

Key words: Ground water, Kalimantan Indonesia, Isotope, Recharge, Protection of ground water.

Introduction

In Central Kalimantan, there is vast peat land forest, which is subjected to recent development for food production for sustaining Indonesian growing population. Its devastation during the developments are widely known recently by the internationally recognized forest fire, which had been uncontrollable in 1997, partly due to exceptional dryness in the region due to El Nino Southern Oscillation. Biomass burning is common practice in this region but the extent is far more exceeded to its own capacity for the sustainability. Surface water in peat land like Central Kalimantan has unsuitable quality for drinking water and domestic use because of high organic contents and low pH. The ground water is, however, maintained somehow in pretty good conditions for human consumption. The ground water is, therefore, should be wisely managed for domestic consumption and irrigation. Although knowledge on the ground water hydrology is very essential for its usage in sustainable manner, little is known about recharge rates, locations and flow pattern. Clearing forest for agricultural development could lead to major change in hydrological feature as well as material balance in the region, including carbon, nutrients and soil. In order to avoid unrecoverable devastation to the ecosystems and the fresh water resources, we have to accumulate enough scientific knowledge to assess possible impacts induced by developmental activities. This study is conducted in part of Core University Program between Hokkaido University and R & D Center for Biology, LIPI, Indonesia sponsored by Japan Society for Promotion of Science (Tokura, 1998). Isotope compositions of easily accessible water bodies were surveyed for obtaining first grab of the hydrology in this region.

Sampling and Analytical Methods

All samples for isotope analysis were listed in the Table 1 together with analytical results. The Kahayan River, major sampling location is shown in Fig. 1. Rainwater samples were collected in dry and wet seasons in Central Kalimantan, Bogor Botanical Garden in Bogor, and Cibinong, Java, Indonesia. Several lakes in southern and central part of Kalimantan were surveyed and 1998. Well water are collected at farmhouse at Tumbang Tahai , which has opened several years ago as new plantation near Palangka Raya. Stream waters and peat waters from boreholes after peat core collection at Lahei site were also analyzed for isotope composition. Samples are stored in polyethylene bottles or glass bottles in a cool place and transferred to Japan for the isotope analysis.

Five ml from each water sample was transferred in the bottles attached to the equilibrator on a mass spectrometer. Water samples in the bottles are evacuated once and filled with pure CO_2 gas and let equilibrated for 6 h in an isothermal water bath. Then, CO_2 gas was introduced into inlet of the mass spectrometer and analyzed for the isotope composition. All above process is automatically carried out and the equilibrator can handle 24 bottles at once. All process for 24 sample analyses will take about 12 h. The analytical precision is 0.03 ‰ for oxygen isotope analysis and 0.6 ‰ for hydrogen isotope analysis. Analytical results were given in a delta notation as ‰ deviation from the Viena international isotope standard seawater (VSMOW) sample.

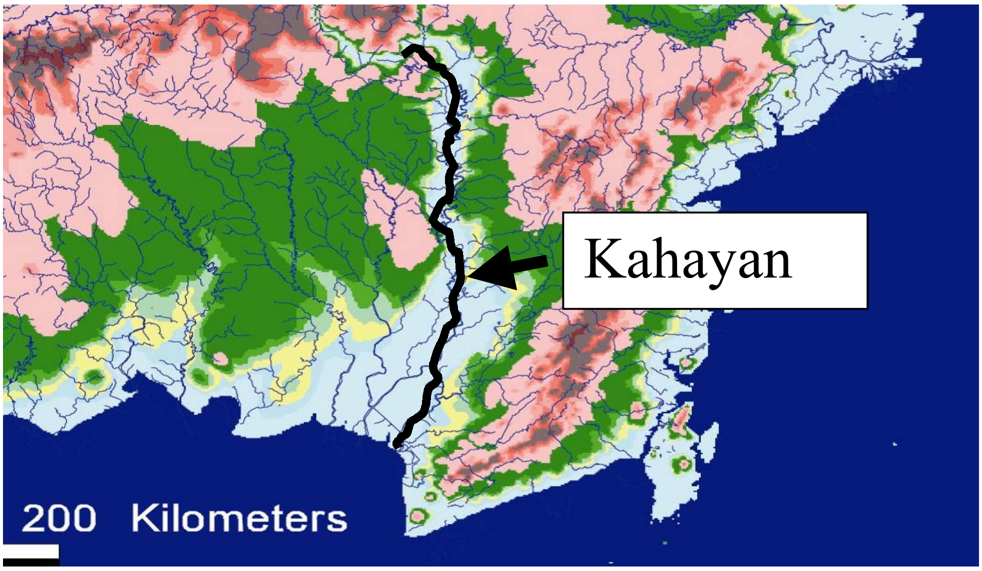

Fig. 1. Map of Central Kalimantan (Solid line represents Kahayan River)

Results and Discussion

Analytical results were listed in Table 1 together with sample description. Isotope composition of natural water observed in the Kahayan River watershed were plotted

Table1. A list of samples and oxygen isotope composition

Location	Date	Sample types.	$\delta^{18}O_{VSMOW}$
Bogor	98/1/13	Rain water	-2.37
Cibinong	99/4/29	Rain water	-5.11
	99/5/21	Rain water	-3.66
Palangka Raya	98/1/18	Rain water	-3.46
	98/9/11	Rain water	-2.30
	99/4/23	Rain water	-1.45
	99/4/25	Rain water	-1.79
	99/5/01	Rain water	-13.19
	99/5/09	Rain water	-6.99
	99/5/14	Rain water	-12.87
Tewah	99/4/25	Rain water	-1.49
Tamban Tahai	98/1/20	Groundwater	-7.06
G. Obos	98/9/17	Groundwater	-8.19
Bukit Batu	98/9/18	Groundwater	-8.54
Sampit	98/9/19	Groundwater	-7.66
Basarang	98/9/21	Groundwater	-7.04
Pulang Pisau	98/9/21	Groundwater	-7.68
Sepang Simin	99/4/25	Groundwater	-8.33
Bawan	99/4/26	Groundwater	-6.54
Tb. Posu	99/5/24	Spring water	-9.13
Tb. Marikoi	99/5/24	Spring water	-8.88
Tb. Maraya	99/5/24	Spring water	-8.94
Tb Miri	99/5/24	Spring water	-8.96
Penda Rangas	99/5/24	Spring water	-9.58
Tewah	99/5/25	Spring water	-8.81
Tanjunguntung	99/5/25	Spring water	-8.99
Upunbatu	99/5/25	Spring water	-7.74
Goha	99/5/26	Spring water	-8.27
Palangka Raya	99/5/28	Spring water	-8.77
Lahei	98/1/17	Peat water	-7.28
Baamang	98/9/19	Peat pond water	-6.60
Pundu	98/9/19	Peat pond water	-7.26
Kotabesi	98/9/19	Peat pond water	-6.12
Mintin	98/9/21	Peat pond water	-6.91
Garung	98/9/21	Peat pond water	-5.88
Lake Sabuah	98/2/22	North 0 m depth	-6.59
	98/2/22	Central 0 m depth	-6.37
	98/9/11	Entrance 0 m depth	-8.06
	98/9/11	Central 0 m depth	-7.68
	98/9/11	Central 0 m depth	-7.67
	98/9/11	Central 0.5m depth	-7.68
	98/9/11	Central 1.5 m depth	-7.51
	98/9/11	Central 2 m depth	-7.93
	98/9/11	Central 3 m depth	-8.14
Lake Sembuluh	98/2/25	North 0 m depth	-5.79
	98/2/25	Central 0 m depth	-5.51
Lake Rantep	98/9/11	0 m depth	-7.90
	98/9/11	0.5 m depth	-7.96
	98/9/11	1 m depth	-8.23
	98/9/11	1.5 m depth	-7.98
	98/9/11	2 m depth	-8.04

Table1 (continued)

Location	Date	Sample types.	$\delta^{18}O_{VSMOW}$
Lake Tundai	98/9/15	0.5 m depth	-7.10
	98/9/15	1 m depth	-7.12
	98/9/15	1.5 m depth	-7.15
	98/9/15	2 m depth	-7.16
	98/9/18	2 m depth	-6.94
	98/9/18	3 m depth	-6.93
	98/9/18	4 m depth	-7.01
	98/9/18	5 m depth	-6.95
	98/9/18	6 m depth	-6.98
	98/9/18	7 m depth	-7.06
	98/9/18	8 m depth	-7.11
Lahei	98/1/17	Stream water	-6.85
Tanjung Puting	98/2/24	Swamp water	-5.45
	98/2/24	River water	-5.41
	98/2/24	River water	-5.46
	98/2/24	River water	-5.50
Kumai River	98/2/24	River water	-4.41
Kahayan River			
Tb. Maraya	99/4/24	River water	-8.81
Tb. Marikoi	99/4/24	River water	-8.61
Penda Rangas	99/4/24	River water	-8.67
Tb. Habaon	99/4/25	River water	-8.57
Kuala Kurun	99/4/25	River water	-8.33
Kampuri	99/4/26	River water	-8.52
Tb. Miwan	99/4/27	River water	-8.39
Palangka Raya	99/5/08	River water	-8.77
Palangka Raya	99/5/08	River water	-8.68
Pilang	99/11/26	River water	-8.66
Garong	99/11/26	River water	-8.60
Buntoi	99/11/26	River water	-8.30
Banunai	99/11/26	River water	-7.43

against the distance from Palangka Raya city in Fig. 2. Rainwater samples collected in Palangka Raya in both wet and dry seasons ranged -1.45 to -3.46 ‰, showing heaviest isotope composition among examined natural waters. In Palangka Raya, extremely light oxygen isotope composition was observed (as low as –13 ‰) in dry season. However, it is obvious that the rain in dry season cannot penetrate into the soil due to low rainfall and fast evaporation in the dry season. The source for precipitation with such low oxygen isotope ratio is evapo-transpiration from local vegetation. Rainwater collected at Bogor in wet season was -2.37 ‰. Rainwater collected at Cibinong had -5.11 ‰. Ground waters collected at Palangka Raya, Tumbang Tahai, G. Obos, Bukit Batu, Sampit, Basarang,Tb Miri, Tb Marikoi, Tb Posu, Sepang Simin, Tewah, Penta Rangas, Goha, Tunjunguntung, Upanbatu and Pulang Pisau ranged -7.04 to -8.54 ‰. River water from Kumai and Tanjung Puting were from -4.14 to -5.50 ‰. Upstream water of Kahayan River from Palangka Raya has -8.67 to -8.33 ‰. Downstream water from Palangka Raya were also found to have the comparable isotope composition to those at the upstream. Peat waters from peat ponds and others at Lahei, Baamang, Pundu, Mintin and Garung ranged -5.88 to -7.28 ‰. Lastly, lake waters from Sabuah, Sembuluh, Rantep and Tundai ranged -5.51

to -8.23 ‰. Lake waters analyzed were the most similar to the isotope composition of the ground water. Peat ponds have the next close value and river water has the closest value to the rainwater, although the value is still significantly lower than the rainwater (Table 2). Isotope data for rainwater is painfully limited in this area.

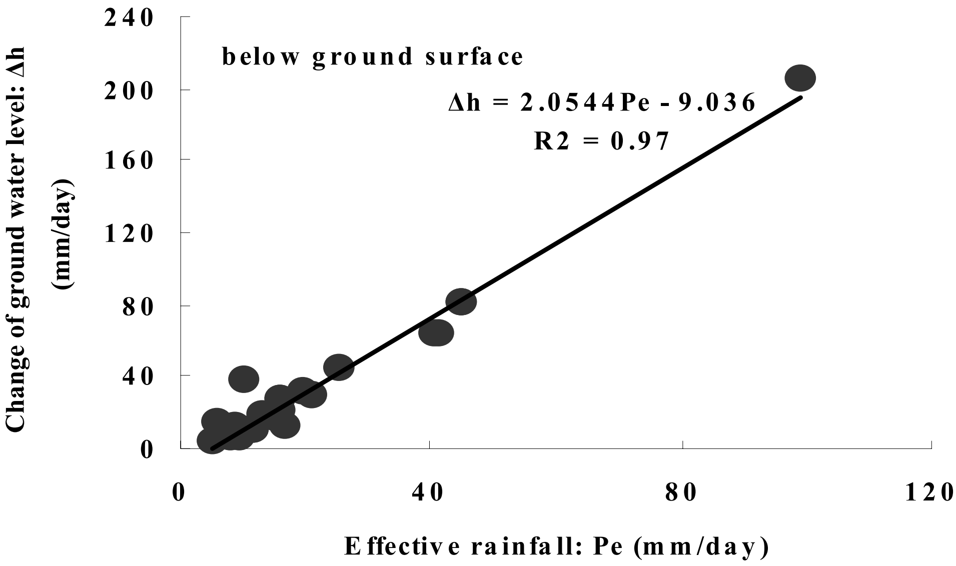

Fig. 2. Oxygen isotope composition of natural waters in the Kahayan River watershed, Central Kalimantan, Indonesia.

Table 2. Summary of oxygen isotope analysis in Kalimantan.

Samples	Locations	$\delta^{18}O_{vsmow}$ (‰) range
Rain water	Palangka Raya, Bogor, Cibinong, Tewah	-1.49~-5.11(4)[1]
River water	Kumai(estuary), Tanjung Puting, Kahayan, Miri, Tb Miwan	-4.14~-8.67(17)[c]
Peat ponds and leachate	Lahei, Baamang, Pundu, Kotabesi, Mintin, Garung	-5.88~-7.28(7)[1]
Lake water	Sabuah, Sembuluh, Rantep, Tundai	-5.51~-8.23(34)[1]
Ground water	Tb Tahai, G.Obos, Bukit Batu, Sampit, Basarang, Pulang Pisau, Tb Marikoi, Tb Miri, Tb Posu, Upanbatu, Tanjunguntung, Tb Maraya, Sepang Simin, Goha, Palangka Raya, Penda Rangas,	-6.54~-9.58(18)[1]

1: Number of samples are given in parentheses.

International Atomic Energy Agency (IAEA) has been collecting precipitation for isotopic analysis at two locations (Djakaruta, Java and Djajapura, Irian Jaya) since 1962. The averaged oxygen isotope composition of precipitation at Djakaruta (8 m a.s.l) from

1962 to 1987 obtained by weighting by the monthly rainfall is -5.6‰. Throughout the observation period from 1962 to 1987, No seasonal trend in isotope composition has been observed (IAEA, 1969-1990). According to Giggenbach (1992), the oxygen isotope compositions of rainwater at Keli Mutu, Merapi and Sirung ranged -4.0 to -5.1 ‰ (presented as pers. commun. with J. C. Varekamp and R. Freulen (1990)). The isotope composition clearly differs from values from our study. Although the value is not necessarily applicable in the Central Kalimantan, it can be speculated that there is a sampling bias due to limited number of samples in our study. Nevertheless, under considering all currently available data for oxygen isotope in rainwater in Indonesia, to our best knowledge, rainwater should be an end member with heaviest isotope composition among natural water in the Central Kalimantan. Obviously, it is highly desirable to obtain precipitation all year round in Central Kalimantan and analyzed for stable isotope soon. Post-depositional alternation in the isotope composition by lateral flow, evaporation, evapo-transpiration could make isotope composition heavier or no change. Consequently, there is no process which forces isotope composition isotopically lighter in the Central Kalimantan. It can be safely stated that the local precipitation never becomes isotopic composition in the ground water. It can be very clearly concluded that the ground water in the Central Kalimantan is not locally recharged at all and that main body of surface water in the Central Kalimantan is originated from ground water. Rainwater, therefore, in the Central Kalimantan should flows out possibly as surface flow or returns to the atmosphere through evapo-transpiration. Thick peat layer in Central Kilimantan is apparently preventing *in situ* ground water recharge in this area.

Then, what is the origin of the ground water? There are three possibilities; 1) fossil water, 2) remotely recharged rainwater and 3) local precipitation thermally altered by volcanic activity. Volcanic water vapor in Indonesia has been studies by Allard (1983) and was found oxygen isotope composition of +7.7 ‰, which is substantially heavier than the regular surface water in Indonesia. The oxygen isotope shift toward heavy isotopic composition of surface water in geothermal activities is well known phenomenon due to oxygen exchange between minerals and water. The effect is opposite one from what we expect. Therefore, the ground water cannot be the local precipitation altered by volcanic activity. The possibility for fossil water is easily denied because of abundant discharge of the ground water as lake and river waters. Annual precipitation in central Kalimantan is about 3,000 mm. Fossil origin water cannot maintain such discharge for a long period. Therefore, this can be easily denied. It is preferable for us to pick up remote recharge of the central Kalimantan ground water, possibly somewhere in Northern mountainous area. There is no observational proof whether the region can sustain enough groundwater recharge, since it is not known the precipitation rates in the region. However, from the observation in Yakushima, the precipitation rate in the high altitude in this Island could easily exceed more than couples of thousand millimeters per year. It is well known that the precipitation in high altitude has significantly lower isotope composition, which is called "elevation effect". Elevation effect is a kind of composite effect of temperature and distance from seashore, water vapor source region. The typical elevation effect in oxygen isotope is -0.2 to -0.5 ‰/100 m elevation (Waseda and Nakai, 1983). In order to achieve -3 to -5 ‰ shift in the oxygen isotope composition, the elevation effects for more than 1,000 m altitude is required. Mountains more than 1000 m elevation are located around Central Kalimantan, except southern area, opening to the ocean. The dating of ground water and identification of active recharge area and rate are desirable for better managing ground water resources in the Central Kalimantan.

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References

Allard, P. 1983 The origin of hydrogen, carbon, sulfur, nitrogen, and rare gases in volcanic exhalations: evidence from isotope geochemistry. In: Tazieff, H. and Sabroux, J.C. (eds.), *Forecasting Volcanic E*vent, Elsevier, pp. 337-386.

Giggenbach, W. F. 1992. Isotopic shifts in waters from geothermal and volcanic systems along convergent plate boundaries and their origin. *Earth & Planet. Sci. Lett*., 113: 495-510.

IAEA. 1969-90. *World Survey of Isotope Concentration in Precipitation, Environmental Isotope Data*. No.1- No. 9.

Tokura, S. 1998. *Environmental Conservation and Land Use Management of Wetland Ecosystem in Southeast Asia, Annual Report and Proceedings for International Workshop, 6-9 August 1997, Palangka Raya, Central Kalimantan, Indonesia,* 221 pp.

Waseda, S. and Nakai, N. 1983. Stable isotope composition in Central and Tohoku Japan, *Chikyuukagaku*, 17: 83-91 (in Japanese)

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Surface Water Quality in Central Kalimantan, Indonesia

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Abstract

This study investigated water quality at total 13 sites in 4 rivers (Kapuas, Murung, Kahayan and Sebangau Rivers), 2 channels (Dadahup and Kelambangau), 1 lake (Lake Tundai) and 1 pond (for fish culture) in Central Kalimantan, Indonesia to assess as a base-line study of aquatic environment in Kalimantan. It was noted that the pH values of water samples from rivers except the Kahayan were low indicating that the river water maintained acidic condition. It is surprising that the water of Dadahup channel located in the region of one hundred million hector project showed pH 2.6 and 2.9. The acidic condition of the channel water was estimated to be caused by sulphonic ions, which was considered to be unsuitable for agriculture and drinking water. In sample water from Lake Tundai, lead concentration was higher than that of Japanese Environmental Standard. At a few sampling sites, the lead concentration from rivers also showed a high level. As in the Central Kalimantan, motorboats are utilized as an important public transportation measure, the fuel containing lead may cause lead pollution in these rivers and lakes. Other risk factors such as cadmium and mercury were scarcely detected at all the sampling sites. Further investigation will be needed to clarify the quality of the aquatic environment and effects of water quality on habitant health in Central Kalimantan in Indonesia.

Introduction

In the world, river water has been used as drinking water, irrigation for agriculture and fish culture. In Central Kalimantan of Indonesia, the rivers also play important roles on traffic and economic activities. Guidelines for water reuse (WHO 1989) are controversial. Studies of the water quality are needed to test their validity. Cross-sectional studies of the impact of excreta use in aquaculture, and of waste water use in irrigation have been carried out in several countries. In South Kalimantan of Indonesia, Prihartono *et al.* (1994) reported that 37% of the households regularly or occasionally mix boiled with unboiled water for drinking, or use unboiled water alone. Blumenthal *et al.* (1992) described that in Indonesia, waste water/excreta was used but some health protection that measure existed did not have domestic exposure to pond water, whose quality was around forty times higher than the tentative WHO bacterial guideline for fishpond water. Sometime water reuse has caused the habitants to be infected with diseases. Cross *et al.* (1976) reported that 5.6% of 3,017 inhabitants in West Kalimantan were detected malaria infection.

On the other hand, it is well known that the haze has occurred by the slash-and-bun agriculture in Kalimantan. This fire is considered to influence aquatic ecosystem to ground water and peat water. The Kenyah Dayak in East Kalimantan, who migrated from their mountainous homeland to a riverine village in the 1940s, have subsisted on slash-and-burn rice cultivation. To cope with rapidly increasing population, the villagers have not changed their farming practice to increase land productivity but instead have exploited fields in remote riverbanks, using motorized canoes (Abe *et al*., 1995).

However there is little information of water quality in Central Kalimantan, Indonesia. From views of the information, in this study, in order to assess as a base-line study of aquatic environment, we assayed water quality of river, lake, channel in Central Kalimantan. The significance of the obtained results was discussed to elucidate the geographical distribution and the background levels of total trace elements in water environmental in Central Kalimantan.

Materials and Methods

Sample collection

Water from the rivers of Kapuas, Kahayan and Sebangau was collected on December 11-14, 1998. In addition, water samples of Tundai Lake, two channels and fish culture center were also collected to compare the water quality with river water. All water samples were stored in sterilized polypropylene conical tubes (Falcon, USA) (50 ml). Total number of the sampling sites was 13 sites as shown in Fig. 1. The GPS data of sampling sites are listed in Table 1.

Table 1 GPS data of water sampling sites

Site No.	Site	Date	Time (local)	Location	
				long. °E	lat. °S
1	Murung River	December 11, 1998	16:16	114.5996	2.7990
2	Kapuas River	December 12, 1998	8:32	114.3702	2.9148
3	Kahayan River 1	December 13, 1998	12:59	113.9204	1.6236
4	Kahayan River 2	December 13, 1998	14:55	113.9511	1.9372
5	Sebangau River 1	December 14, 1998	12:00	113.8519	2.3027
6	Sebangau River 2	December 14, 1998	13:15	113.9064	2.2978
7	Channel Dadahup 1	December 11, 1998	14:10	114.6208	2.6954
8	Channel Dadahup 2	December 11, 1998	14:42	114.6227	2.6949
9	Channel Jembatan Kalampangan	December 14, 1998	16:12	114.0333	2.2887
10	Lake Tundai 1	December 12, 1998	11:33	113.9983	2.2111
11	Lake Tundai 2	December 12, 1998	15:32	114.0096	2.2084
12	Lake Tundai 3	December 12, 1998	16:01	114.0141	2.2327
13	Fish culture pond	December 11, 1998	16:10	114.3702	2.7587

Sample preparation and analysis

The water temperature, conductivity and pH of the samples were measured immediately at each sampling point with a thermometer (Tanita model 5432, Japan), a pH meter (Shindengen, model pH boy-P2, Japan) and a specific conductivity meter (Iuchi model TDS-can3, Japan), respectively. For measuring anion concentrations, the water samples were filtered suction through a 0.45 µm Millipore (USA) filter. The anion concentrations (SO_4^{2-} and Cl^-) of the samples were determined with a high performance liquid chromatography (Hitachi HPLC system Lachrom, Japan) using an anion column (4.6 × 50 mm) (Waters IC-Pak, USA). To determine metal contents in water samples, 5 ml of ultrapure analytical grade concentrated HNO_3 (Tawa Chemical, Japan) was added to 5 ml of the samples. After digestion of insoluble materials at 80°C for 12 hr, the contents of Mg, Co, Sn, Au, Cd, Pb, Hg, Fe, Cu and Zn in the water samples were analyzed with an inductively coupled plasma mass spectrometry (ICP-MS, Seiko SPQ-6500, Tokyo, Japan) as previously described (Hanada *et al*., 1998). Furthermore Na, K and Ca contents of the samples were measured with a flame atomic absorption spectrophotometer (Hitachi model 180-80, Japan).

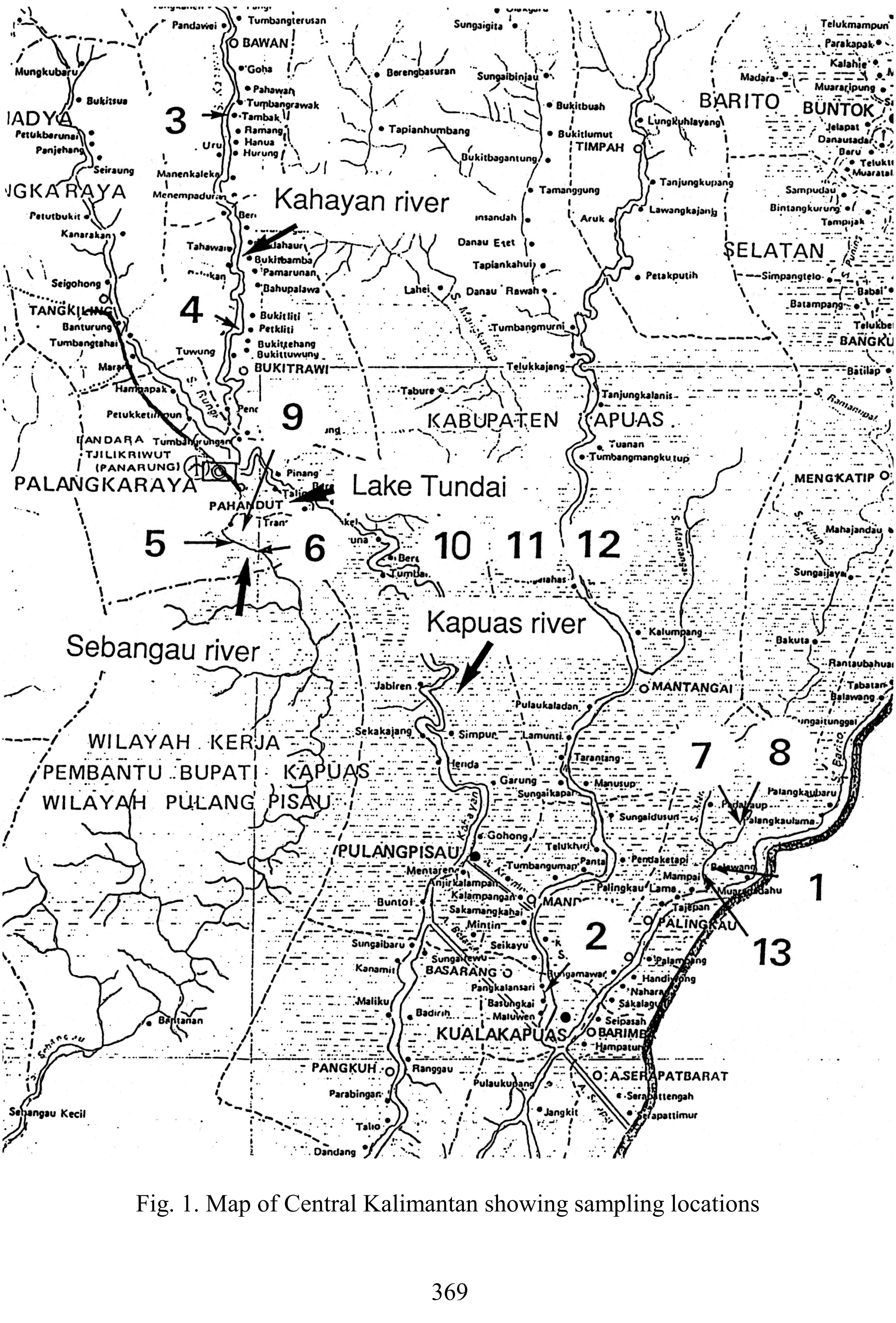

Fig. 1. Map of Central Kalimantan showing sampling locations

Results and Discussion

The air temperature, water temperature, conductivity, pH and 2 anion ions (SO_4^{2-} and Cl^-) concentrations of water samples from rivers, channels, lake and pond in Central Kalimantan are listed in Table 2. Metal concentrations (Mg, Co, Sn, Zn, Cu, Cd, Pb, Hg, Fe, Au, Na, K and Ca) of water samples from the respective sites are shown in Table 3.

Table 2. pH, conductivity and anion concentrations of waters from rivers, channels, lake and pond

Site No.	Site	Air temperature, °C	Water temperature, °C	Specific conductivity, mS m^{-1}	pH	SO_4^{2-} mgl^{-1}	Cl^- mgl^{-1}
1	Murung River	32.0	31.3	10.0	4.8	24.9	0.8
2	Kapuas River	32.6	29.6	6.0	4.2	10.7	0.8
3	Kahayan River 1	33.1	30.8	2.0	6.7	N.D.	0.8
4	Kahayan River 2	33.6	30.0	2.0	6.6	N.D.	2.0
5	Sebangau River 1	32.8	28.8	6.0	4.0	N.D.	0.7
6	Sebangau River 2	33.4	31.8	5.0	3.9	N.D.	0.7
7	Channel Dadahup 1	34.0	31.0	38.0	2.9	75.3	1.4
8	Channel Dadahup 2	34.3	33.0	61.0	2.6	110.0	6.2
9	Channel. Jembatan Kalempangan	32.1	30.8	4.0	4.0	N.D.	0.8
10	Lake Tundai 1	35.0	30.3	1.5	4.6	2.5	0.4
11	Lake Tundai 2	35.8	34.6	4.0	3.8	N.D.	0.9
12	Lake Tundai 3	35.0	31.0	2.0	4.5	3.6	0.3
13	Fish culture pond	32.0	34.1	12.0	4.2	24.8	0.5

N.D. means not detected

Table 3. Metal concentrations of waters from rivers, channels, lake and pond

Site No.	Site	Mg mgl^{-1}	Co μg l^{-1}	Sn μg l^{-1}	Zn μg l^{-1}	Cu μg l^{-1}	Cd μg l^{-1}	Pb μg l^{-1}	Hg μg l^{-1}	Fe μg l^{-1}	Au μg l^{-1}	Na mgl^{-1}	K mgl^{-1}	Ca mgl^{-1}
1	Murung River	1.156	2.46	0.05	15.03	0.64	0.014	1.71	N.D	117.2	N.D	2.31	3.27	0.625
2	Kapuas River	0.492	0.91	0.11	12.41	1.57	0.015	0.96	N.D	268.6	N.D	1.94	1.44	0.431
3	Kahayan River 1	0.581	1.12	1.90	22.15	3.42	0.068	5.23	N.D	32.6	N.D	2.27	1.31	1.228
4	Kahayan River 2	0.477	0.85	0.09	6.40	2.71	0.013	2.09	N.D	215.4	N.D	2.23	1.29	1.161
5	Sebangau River 1	0.040	N.D	0.01	1.50	0.54	N.D	0.09	N.D	492.7	N.D	0.45	0.73	0.139
6	Sebangau River 2	0.059	0.02	0.01	5.12	0.66	0.004	0.41	N.D	485.6	N.D	0.75	1.75	0.200
7	Channel Dadahup 1	2.225	6.45	0.13	16.83	1.50	0.031	0.33	N.D	251.2	0.01	7.07	4.47	0.611
8	Channel Dadahup 2	3.077	10.13	0.08	39.69	1.65	0.028	1.28	0.29	232.4	0.01	8.34	7.20	1.014
9	Channel. Jembatan Kalempangan	0.039	0.02	0.01	2.76	0.32	N.D.	0.10	N.D	487.3	N.D	1.08	1.96	0.098
10	Lake Tundai 1	0.314	0.16	0.05	7.99	1.57	0.003	11.48	N.D	237.7	N.D	1.42	1.10	1.028
11	Lake Tundai 2	0.136	0.10	0.05	5.75	1.90	0.015	0.28	N.D	447.8	N.D	3.42	1.18	0.708
12	Lake Tundai 3	0.235	0.40	0.13	8.36	1.47	0.013	0.76	N.D	208.9	N.D	1.27	1.25	1.194
13	Fish culture pond	1.105	2.22	0.09	13.49	2.35	0.012	0.51	N.D	340.7	N.D	2.16	2.61	0.694

N.D. means not detected

It was noted that the pH values of water samples from rivers except the Kahayan were low indicating that these river water maintained acidic condition. Usually it is considered that pH of river water should show a neutral range, about pH 6.5 to 8.0 to use the drinking water and irrigated water for agriculture (Yamagata, 1979). As shown in Table 2, it is surprising that the water of Dadahup channel (Sites 7 and 8) located in the region of one hundred million hector planning showed pH 2.6 and 2.9. This channel has been used as an irrigation water for rice cultivation and a living water for habitants. From the analyses of anion ions, the acidic condition of the channel water was estimated to be caused by sulphonic ions (Table 2). The reasonable explanation regarding that the sulphonic ion has been accumulated in the water is still unclear. However we speculate that these acidic condition was occurred by the peat soil after slush-and-bun agriculture. As other remarkable features in the Dadahup channel, high specific conductivity (Table 2), high magnesium, cobalt and zinc concentrations and also high sodium and potassium concentrations (Table 3) were observed. There was no major differences of the other metal concentrations between Dadahup region and other regions including river and lake sites. The pH, conductivity, and sulphonic anion concentration of water samples from the Murung River and fish culture pond were shown the same tendency in comparison with that from Dadahup channel. These sites were thought to receive the influence of Dadahup channel, because the water from Dadahup flowed into near the sampling sites of the Murung River and this river water was incorporated into fish culture pond. In conclusion, from the data presented here the water relating to Dadahup channel is considered to be unsuitable for agriculture and drinking water. If the rice cultivation would be continued in this region, the water and soil should be neutralized using of alkali reagents for efficient rice cultivation and protecting inhabitant health.

In sample water from Lake Tundai (Site 10), lead concentration was higher than that of Japanese Environmental Standard (10 μg/l) (Global Environmental Forum, 1997). In a few sampling sites, the lead concentration from rivers also showed a high level, although the lead level is lower than that of Japanese Environmental Standard (Table 3). Recently Foo and Tan (1998) reported that hair from Singapore contained more mercury, but less cadmium and lead compared to hair from the islands of Indonesia. In Jakarta, Heinze *et al.* (1998) supposed that children attending schools in urban areas with high traffic density belonged a high risk group for lead poisoning. To evaluate lead pollution in each area, they collectrd soil samples and tap water. The mean blood lead concentration was higher in the central district than in the southern district (8.3 ± 2.8 vs. 6.9 ± 3.5 μg/100 ml; $p<0.05$) in a total of 131 children. It is well known that lead poisoning may lead to anaemia, because activities of haem synthesis enzymes are inhibited by lead exposure. In the case of Jakarta, Heinze *et al*. (1998) presumed that from analyses of tap water and soil Indonesian children living in urban areas were receiving lead poisoning by increasing of automobile at increased risk for blood lead levels above the actual acceptable limit. The same speculation was also described by Soemantri *et al.* (1997).

In the Central Kalimantan, motorboats are utilized as an important public transportation measure. We also observed a great deal of traffic by motorboats in these rivers during the investigation period. The fuel containing lead might have caused the lead pollution in these rivers and lakes. The fuel should be changed to that without lead.

There were many miners to obtain alluvial gold in the Kahayan River. In the purification process of gold, mercury is widely used. Then we expected to detect mercury in the water sample from the Kahayan River. However no mercury was detected in all the samples except that from Dadahup Channel (Table 3). Mercury should be analyzed by using Parr bombs during acid digestion, because after heating mercury change to vapor. As in this study, we used open system for acid digestion, it was difficult to determine whether mercury was contaminated into water of the Kahayan River. Regarding mercury poisoning in Indonesia, there are several recent reports as follows. Burger and Gochfeld

(1997) reported on the concentration of heavy metals and selenium in the feathers of cattle egrets *Bubulcus ibis* that were examined from nesting and roosting sites in Bali and Sulawesi, Indonesia. Mercury and manganese concentrations were significantly higher in cattle egrets from Bali compared to Sulawesi, but otherwise there were no significant differences, and there were significant differences in lead, cadmium and mercury among the three egret species nesting on Bali. The cadmium and mercury concentrations related to size and trophic level (insectivorous cattle egrets had the lowest concentrations, fish-eating intermediate egrets had the highest concentrations). Nakagawa and Hiromoto (1997) described that total mercury and methyl mercury levels in hair of residents of Indonesia was lower than in residents of Japan, and that in Indonesia, no subjects had high levels of methylmercury in hair. However their total mercury levels in Indonesian are still higher than that in South Asian countries (Feng *et al*., 1998). This finding suggested that the high total mercury levels observed in some residents of Indonesia reflected exposure to inorganic mercury.

Other risk factors such as cadmium were detected as low level in the all sampling sites in Central Kalimantan in comparison with the level of Japanese Environmental Standard (Table 3). Suzuki *et al*. (1980) found that Cadmium contents in 116 polished and unpolished rice samples produced in the Java Islands of Indonesia were determined to be 0.040±0.042 mg kg^{-1}. Considering the fact that Indonesians consume about 300 g of rice daily, the daily intake of Cd would exceed the tolerable limit proposed by the FAO/WHO and could cause slight chronic renal damage to the rice eaters. However in Central Kalimantan cadmium content in the rice grown using the water at the present sampling site was expected to be lower than that reported by Suzuki *et al*. (1980). Especially the Sebangau River, the concentration of metals showed adequate levels. However other rivers contained zinc and iron enough to use as drinking water. As only drinking water, total dietary intakes of zinc of the people from these rivers except Sebangau was estimated to be more than 20 mg/person, which was higher than the recommended dietary allowance of daily zinc intake from foods by the American standard diet (15 mg/person).

Prihartono *et al*. (1994) performed follow-up survey of the same households during 6 months to measure prevalence. The results of the study indicated that 97% of the households report that they regularly boil their drinking water. However, 37% of the households regularly or occasionally mix boiled with unboiled water for drinking, or use unboiled water alone. They concluded that the use of unboiled water was associated with higher rates of childhood diarrhoeas in the households studied. From the viewpoint of public health, non boiling water has carried risk of infection.

Two years' follow-up investigation of a hepatitis E virus (HEV) outbreak in West Kalimantan, Indonesia in 1991 was reported to investigate the epidemiology of epidemic HEV transmission. Overall, the prevalence of anti-HEV IgG among the 445 subjects (representing 127 households) was 59% (Corwin *et al*., 1995). They described that use of river water for drinking and cooking ($P < 0.001$) was associated with high prevalence communities (Blumenthal et al., 1992). WHO (1989) guidelines can be tested using cross-sectional epidemiological studies which indicate that guidelines for restricted irrigation and for aquaculture may be around the right level. Mosquito species which intermediated malaria were reported to inhabit irrigated and rain-fed rice fields of North Sulawesi, Indonesia (Mogi *et al.*, 1995). The effect of irrigation system introduction on regional mosquito abundance cannot be evaluated by the enlarged surface water area alone. Prevalence rates of malaria were consistent in the four villages in Irian Jaya, averaging 10% for infants, 50% for children 1-4 years of age, 35% for those 5-9 years old, 28% for those 10-14 years old, and 16% for adults (greater than 15 years old) (Anthony *et al.*, 1992). Changes in habitat quality and custom, expressed as the abundance per dip (index of density per unit water area), also need to be investigated to elucidate the risk of infection concerning water quality.

Further investigation will be needed to study the water environment and effects of water quality on habitant health in Central Kalimantan in Indonesia.

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References

Abe, T., Ohtsuka, R., Watanabe, M., Yoshida, M. and Futatsuka, M. 1995. Adaptation of the resettled Kenyah Dayak villagers to riverine environment in East Kalimantan: a preliminary report. *J. Hum. Ergol.*, *(Tokyo)* 24: 33-36.

Anthony, R. L., Bangs, M. J., Hamzah, N., Basri, H., Purnomo and Subianto, B. 1992. Heightened transmission of stable malaria in an isolated population in the highlands of Irian Jaya, Indonesia. *Am. J. Trop. Med. Hyg*., 47: 346-356.

Blumenthal, U. J., Abisudjak, B., Cifuentes, E., Bennett, S. and Ruiz-Palacios, G. 1991-92. Recent epidemiological studies to test microbiological quality guidelines for wastewater use in agriculture and aquaculture. *Public Health Rev.*, 19: 237-242.

Burger, J. and Gochfeld, M. 1997. Heavy Metal and Selenium Concentrations in Feathers of Egrets from Baliand Sulawesi, Indonesia. *Arch. Environ. Contam. Toxicol*., 32: 217-221.

Corwin, A., Jarot, K., Lubis, I., Nasution, K., Suparmawo, S., Sumardiati, A., Widodo, S., Nazir, S., Orndorff, G. and Choi, Y. 1995. Two years' investigation of epidemic hepatitis E virus transmission in West Kalimantan (Borneo), Indonesia. *Trans R. Soc. Trop. Med. Hyg*., 89: 262-265,.

Cross, J. H., Clarke, M. D., Cole, W. C., Lien, J. C., Partono, F., Djakaria, Joesoef, A. and Oemijati, S. P 1976. arasitic infections in humans in West Kalimantan (Borneo), Indonesia. *Trop. Geogr. Med.*, 28: 121-130.

Feng, Q., Suzuki, Y. and Hisashige, A. 1998. Elements in the hair of South-east Asian islanders. *Sci. Total Environ.*, 209: 185-192.

Foo, S. C. and Tan, T. C. 1998. Hair mercury levels of residents in China, Indonesia, and Japan. *Arch. Environ. Health*, 53: 36-43.

Global Environmental Forum1997. *Environmental data*. Kokin Syoin, Tokyo.

Hanada, T., Isobe, H., Saito, T., Ogura, S., Takekawa, H., Yamazaki, K., Tokuchi, Y. and Kawakami, Y. Intracellular accumulation of thallium as a m1998 arker of cisplatin cytotoxity in nonsmall cell lung carcinoma. *Cancer*, 83: 930-935.

Heinze, I., Gross, R., Stehle, P. and Dillon, D. 1998 Assessment of lead exposure in schoolchildren from Jakarta. *Environ. Health Perspect*, 106: 499-501.

Mogi, M., Memah, V., Miyagi, I., Toma, T. and Sembel, D. T. 1995. Mosquito (Diptera: Culicidae) and predator abundance in irrigated and rain-fed rice fields in north Sulawesi, Indonesia. *J. Med. Entomol*. 32: 361-367.

Nakagawa, R. and Hiromoto, M. 1997. Geographical distribution and background levels of total mercury in air in Japan and neighbouring countries. *Chemosphere* 34: 801-806.

Prihartono, N., Adisasmita, A., Costello, C., Damayanti, R., Prasetyo, S. and Syarif, S. 1994. Water preparation practices in south Kalimantan, Indonesia. *J. Diarrhoeal Dis. Res*., 12: 279-286.

Soemantri, A. G., Hapsari, D. E., Susanto, J. C., Rohadi, W., Tamam, M., Irawan, P. W. and Sugianto, A. 1997. Daily and weekly iron supplementation and physical growth of school age Indonesian children. *Southeast Asian J. Trop. Med. Public Health* 28 Suppl., 2: 69-74.

Suzuki, S., Djuangshi, N., Hyodo, K. and Soemarwoto, O. 1980. Cadmium, copper, and zinc in rice produced in Java. *Arch. Environ. Contam. Toxicol.* 9: 437-449.

Yamagata, N. (ed.) 1979. Standard values in Environment; a back ground on the basis of science. Japanese Chemical Association, Tokyo.

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Relationship of Water Level to Water Quality in an Oxbow Lake of Central Kalimantan

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Abstract

Long-term monitoring of water quality was conducted in the oxbow Lake Takapan (50.42 ha), in the main river (Kahayan River) and its tributary (Rungan River) to clarify the relationships between water level and water quality parameters or between water quality of rivers and that of lake. Water level relative to bank overflow was measured daily and basic water quality parameters, such as dissolved oxygen, pH, water and air temperatures, conductivity, turbidity and oxidative reductive potentials (ORP) were measured five days a week between August 1996 to December 1997. Mean and 95% confidence limits of water level was –95.53±15.61 cm, which indicated that most of the time the water level was below the bank overflow level. Means and 95% confidence limits of pH, dissolved oxygen, conductivity, turbidity, water temperature and ORP were 5.31±0.08, 2.51±0.20 mg/l, 0.007±0.001 mS/cm, 60.92±6.23 NTU, 28.35±0.16°C, 26.96±0.13°C and 348.95±7.88 mV, respectively. All water quality parameters except turbidity were significantly correlated with water level ($p<0.05$). With increasing water level, pH, water temperature, air temperature and dissolved oxygen decreased whereas conductivity and ORP tended to increase. The water quality of Lake Takapan was influenced by that of the inflowing Rungan River more significantly than the Kahayan River.

Introduction

Oxbow lake is a surface water body that develops due to change in river watercourse in geological time scale. The occurence of deposition and erosion zones are always found at the bend of the river course. If we observe the river water course from upstream to downstream, the deposition of eroded matters always located on the inner side of the bend and the scouring process could be observe in the outer side of the bend. Through the change of the strength of water flow in their maturity process, the river course may move to the different location nearby. As the consequence, it will leave a more or less lentic water body that has a variety of connections to the river. The lake basin usually of crescent shape resembles the bow on the back of an ox. The degree of connection of river water to the oxbow lake depends on the stage of river and the lake maturity. The combination of natural forces, in its turn determined the availability of spatial habitat resources for aquatic life especially the freshwater fishes. On the other hand, the form and structure of fish community are linked to habitat type (Barella and Petrere, 1994).

Oxbow lakes and related water bodies are important habitat types supporting inland water fishery production in Central Kalimantan (Hartoto, 1998). Oxbow lakes as the representative of the cut-off portion of meander bend in a floodplain system are known to sustain spatial resources for feeding, roaming and spawning of several fish species. The fishes that inhabit the oxbow lake are the white fishes, e.g., “ikan Pipih”

(=feather backs, *Notopterus notopterus*) and “Baung” (*Mystus nemurus*) and the blackfishes, e.g., “ikan Sepat” (=Goramis, *Trichogaster pectoralis*) and “Snake heads” (*Channa micropeltes*). The availability of habitat resources for river fishes in the oxbow lake depends on the water level relative to the bank overflow level. Usually, during the time of the long dry season, most of the white fishes change their mass body tissue (fat and protein) into generative material, such as ovaries (Hartoto, 1983). The fishes with the ripe gonad then wait for the environmental signals, such as the existence of pheromone, abundant food resources for the young and the petrochor as the trigger for the spawning process (Boyd, 1990). There is a question if in any case the water quality in the oxbow lake is always suitable, for at least temporarily sustain the fish life requirement. Experience show that the time of bank overflow is one of important phenomenon for the success of several fish species, since many oxbow lake dwelling fish species spawn, feed or take refuge in the lake in this period. Change in water level may alter the hydrological conditions such as exchange of water between the lake and adjacent rivers. In the above context, as initial step, the present study was aimed to reveal the relationship between water level and general water quality parameters based on the long-term monitoring in an oxbow lake.

Materials and Methods

Description of study site

This study is conducted in Lake Takapan, an ear shaped oxbow lake of 50.42 ha surface area that is located in Palangkaraya Municipality, Central Kalimantan (Fig. 1). The lake is classified as Oxbow Lake Type III, which at high water time receives water both from the main river (Kahayan River) and one of its tributaries (Rungan River) (Hartoto, 1998). Lake Takapan have two connecting channels with the Rungan River and one connecting channel with the Kahayan River. During the long dry season, the lake first lose its connection with the Kahayan River but always remain connected to the Rungan River through the channel at south of the lake. The maximum depth of the lake is more than 10 m at high water time. Lake Takapan and its vicinity are the fishing ground for more than 30 local fishers and many other fishers from other areas. This lake is also a fish-trading place for the fishers. In the vicinity of Lake Takapan there is one big spawning site for fishes (Lake Tabiri) well known to the fisher which serve as the refugia for the young fishes, spawning and nursery sites for the adult blackfishes such as the Climbing Perches (*Anabas testudineus*) and the Kissing Gouramis (*Helostoma temminckii*). The list of fish species recorded in this lake is up to 62 species, which is dominated by the Cyprinids (Hartoto, 1998).

Water level monitoring

The monitoring site was located at Jelawat Research Station of Central Kalimantan Fishery Office, which lies near the southern connecting channel of the lake with the Rungan River. Water level was recorded at 06.00, 12.00 and 18.00 everyday from 24 August 1996 until 21 December 1997 (484 days) to the nearest 1 cm using a scaled staff gauge which was erected at the connecting mouth of the lake with the Rungan River. The average of the data at the three-observation times was then corrected with the level of bank overflow (0 m). Water levels below the bank overflow level were recorded with negative signs whereas those above the bank overflow level with positive signs.

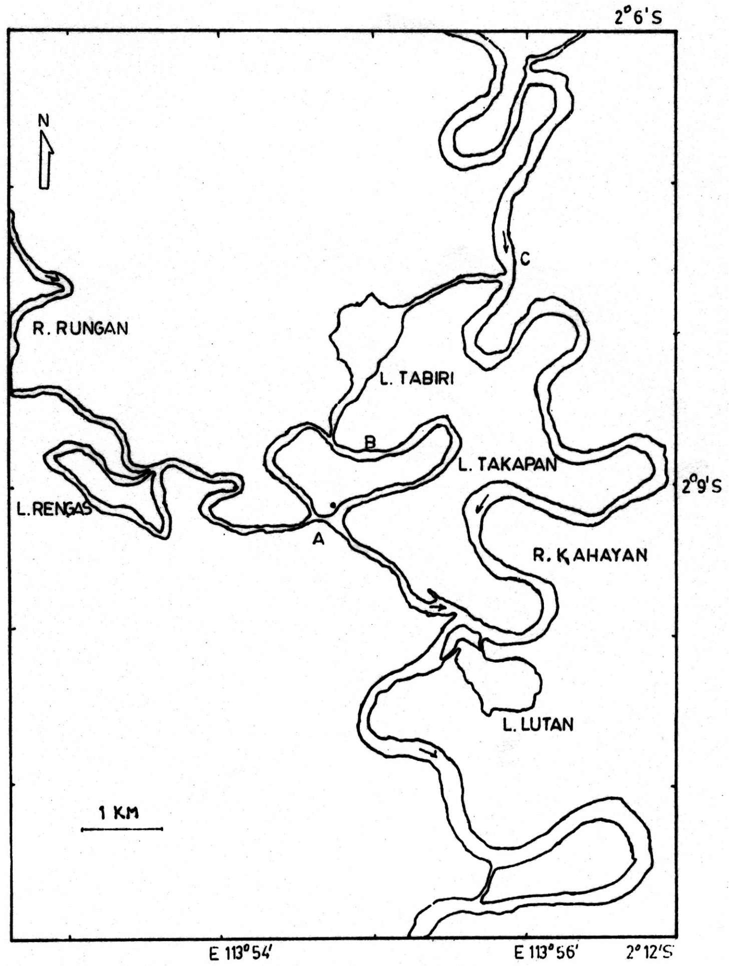


Fig. 1. Map of Lake Takapan and adjacent segment of the Rungan River and the Kahayan River.

Water quality measurement

Air and water temperatures, pH, dissolved oxygen, conductivity and turbidity were measured using a HORIBA water quality checker. Oxidative reductive potentials (ORP) was measured with TRX-90 TOKO ORP meter. The water quality parameters at 1 m depth were measured in triplicate at Jelawat Research Station at 05.00 (sunrise), 15.00 (highest photosynthesis period) and 18.00 (sunset) Sunday through Thursday every week. Average values of nine (three by three) measurements were used for statistical analyses. To give an insight whether or not the water quality of the Kahayan River and the Rungan River influenced the lake water quality, a simultaneous monitoring of these three habitats was conducted on the same day in the Rungan River (Station A in Fig. 1), middle of Lake Takapan (Station B) and in the Kahayan River (Station C). At each station, a triplicate measurement of each parameter for a depth profile of 1-m intervals was collected 10 times between August 1996 to March 1997. A rain gauge was also installed at the station from October 1996 to December 1997.

Data analysis

The data collected were plotted a using Microsoft Excel 97 and analyzed statistically. according to the methods described by Steel and Torrie (1967) with the aids of MICROSTA Program.

Results and Discussion

Water level

The water levels in Lake Takapan were generally under the bank overflow level with mean and 95% confidence limits -110.96±14.56 cm (Fig. 2). During the 484 observation days, only 157 days (32.4%) the water level was above the bank overflow level. In that period, the Central Kalimantan was in the time of long drought due to El Nino phenomenon. However Lake Takapan was always connected to the Rungan River through its southern connecting channel even at the period of lowest water.

The highest water level (+269 cm) was observed on 15 December 1996 and the lowest water level (-347 cm) occurred about 9 months later, on 3 September 1997. From the changes in monthly precipitation (Fig. 3), we can observe five consecutive months (June to October 1997) with very little rain although the total yearly rainfall (1,826 mm) between October 1996 to September 1997 was still high (> 1,500 mm). This type of precipitation data was a characteristic of global climatic classification as tropical rain forest climate or monsoon wet tropical climate. The monthly average number of rainy days during the study period was 8.2 days and monthly average rainfall 149.6 mm.

The draw down in this oxbow lake was very high (6.16 m), which was calculated from the data in Fig. 2, From this, we can deduct that there are a lot of contraction and expansion in the size and the depth of the oxbow lake even though the time of the study was not an ordinary one.

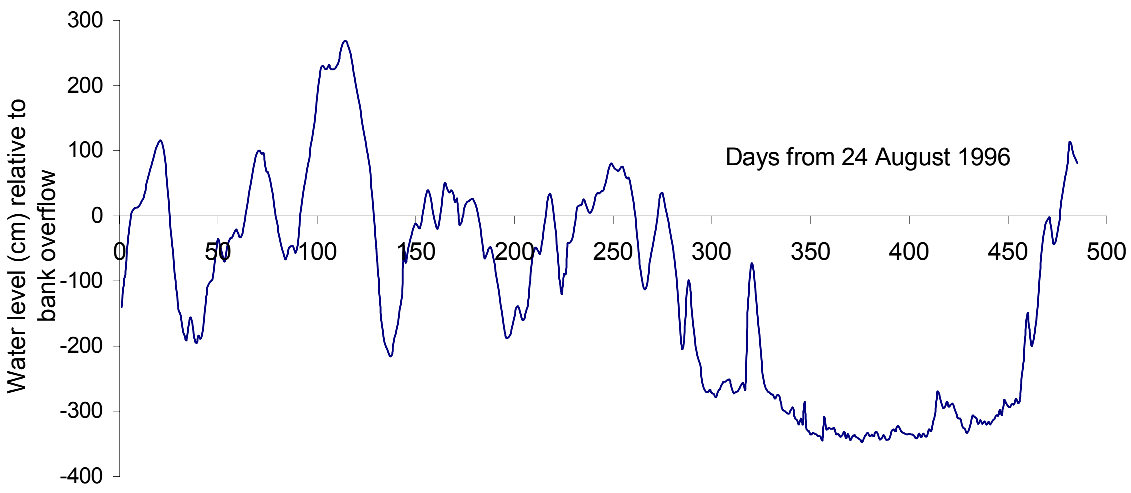


Fig. 2. Change in water level in Lake Takapan from 24 August 1996 until 21 December 1997

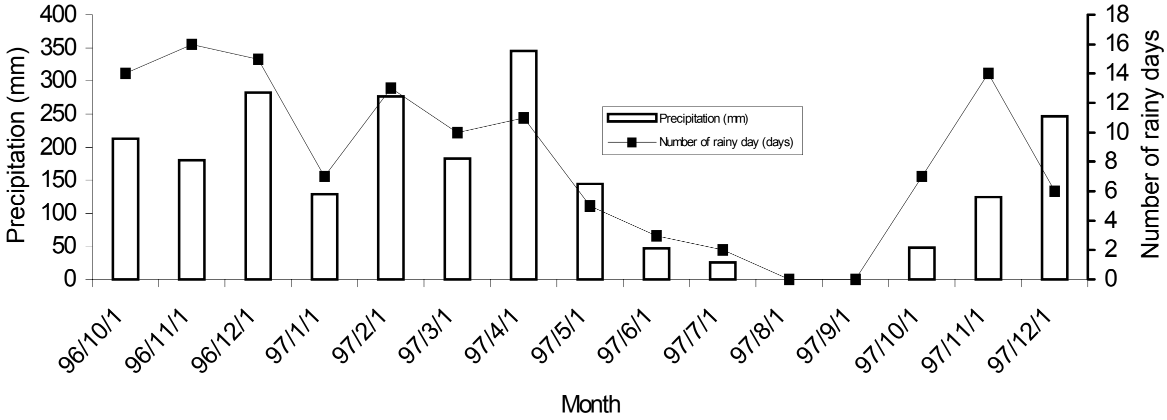


Fig. 3. Monthly precipitation and number of rainy days in Lake Takapan between October 1996 to December 1997

Water quality

Water quality data were recorded for 226 days (46.7%), of which 82 days were taken at the time when the water level was above the bank overflow level. However the average water level during the days of water quality measurement was below the bank overflow level (-60.92 ±19.05 cm, ±95% confidence limits). Among the many physical, chemical and biological processes, three basic mechanisms have been identified to control surface water chemistry, i.e., precipitation, the nature of the bedrock and the evaporation-crystallization process (Gibbs, 1970).

The pH (Table 1) in the connecting channel of Lake Takapan was relatively low (5.31±0.08) although it was always receiving water from the Rungan River. Lowest pH (4.47) observed on 2 December 1997 (at -91 cm), and the highest pH (6.95) on 4 November 1997 (at -315 cm). The pH values in this lake

Table 1. Mean and 95% confidence limits for general water quality parameters at the monitoring station in Lake Takapan

	Parameters							
	Water level (cm)	pH	DO (mg/l)	Conductivity (mS/cm)	Turbidity NTU	Water temperature (°C)	Air temperature (°C)	ORP (mV)
Mean	-60.92	5.31	2.51	0.008	60.9	28.4	27.0	348.9
Confidence limit	19.05	0.08	0.19	0.001	6.2	0.2	0.1	7.9
n	226	226	212	226	226	226	226	207

were comparable to pH values in limnetik swamp forest of Tasek Bera (4.45-6.10) (Ikusima *et al*., 1982a) but lower than the pH range (5.4-6.5) of two major lakes, Tasek Beringin and Tasek Bungor in the Ulu Lepar Wetland systems in Malaysia (Khan, 1990). The low pH values of Lake Takapan meets the range of pH (4-7) for the characteristics of blackwater lakes classified by Rai and Hill in Payne (1965). Although the low pH may not be suitable for fish life (Boyd, 1990), the fish species in Lake Takapan seems to have already adapted to this situation.

Average dissolved oxygen concentration was also low as 2.51±0.19 mg/l, with the lowest value (0.61 mg/l) observed on 17 December 1997 (at 113 cm water level) after the period of very long drought. These dissolved oxygen values was quite similar to the oxygen level in limnetic part of Tasek Bera ranging between 1.01-3.15 mg/l (Ikusima *et al*., 1982b). In the floodplain habitat of the river during the dry season, dissolved oxygen level usually links to several factors such as the size of water body, degree of thermal stratification, vegetation cover, phytoplankton growth and wind action. A higher number of cyprinid species are distributed in this area than the species with breathing organs, such as labyrinth and arborescent organs (Hartoto, 2000). Although they do not posses these organs cyprinid fish species seem to be capable of adapting to low dissolved oxygen water in other ways, e.g., having smaller dorsal oriented mouths and smaller heads and high blood affinity to oxygen (Lagler *et al*., 1977; Welcome, 1979)

The mean conductivity in Lake Takapan was 0.007±0.001 mS/cm (±95% confidence limits). The lowest conductivity value (0.002 mS/cm) was observed on 15 January 1997 at -72 cm water level whereas the highest value (0.032 mS/cm) on 25 November 1997 nearly at the end of long drought period (at -165 cm). Similarly to the low pH range, low conductivity is also a characteristic of a blackwater lake in Amazon watershed according to Ray and Hill's classification. Low conductivity is common in blackwater lakes suh as Tasek Bera where the value range between 0.0105-0.0230 mS/cm (Lim and Furtado, 1982).

The average turbidity was 60.9±6.9 NTU, with the lowest value (6 NTU) observed on 1 June 1997 at -96 cm water level and the highest value (232 NTU) on 12 December 1996 at the period (+ 238 cm). The average turbidity value was not so high but the range between the minimum and maximum values was large, which was probably due to the scouring effect of rain on some denuded forests loosening and washing some particles away from the forest floor, and carrying it as a part of surface run, which in the end might have increased the turbidity. There were in fact some denuded forest areas near Lake Takapan due to forest fire and timber cutting.

Average water temperature (28.4±0.2°C) was higher than the average air temperature (27.0±0.1°C). The lowest water temperature (24.6°C) was recorded on 3 December 1997 that coincided with the day of lowest air temperature (23.9°C). The highest water temperature (32.8°C) was observed on 28 September 1996 (at -156 cm water level) whereas the highest air temperature (29.7°C) was observed on 6 October 1996 (at -118 cm). This pattern revealed that there was a large temperature variation in this lake which in contrast to the lakes in Amazon basin where the water temperature is more stable at 29±1°C. A large variation (22-30°C) between the maximum and minimum temperatures within the upper water column is similarly observed in three lake systems in Rio Doce Valley Lakes in the southeast regions of Brazil (Henry *et al*.,, 1997). Different from the climate in Lake Takapan, the climate near the Brazilian Lakes is defined as semi humid tropical climate with 4 to 5 dry months (Tundisi, 1997). The degree of insolation, substrate composition, turbidity, ground-or rainwater inflows, wind and vegetation cover, can all influence the temperature of water in rivers and flood plain lakes (Welcome, 1979).

Oxidative reductive potential (ORP) in Lake Takapan was on average 348.9±7.9 mV, with the highest ORP values observed on 12 November 1996 when the water level was -32 cm. The lowest ORP level (248 mV) was observed on 30 August 1997 when the water level was low (at -337 cm) in the El Nino period. The ORP value is the index of the proportion of oxidized to reduced substances in the water. This fact means that although there were still some amount of oxidative materials, there were significant amounts of reduced substances during the present study. Possible source of the reduced substances might be aerosol materials originated from the haze produced by the forest fire, which have fallen onto the surface water. The present ORP values were lower than the range of ORP values (0.45-0.52 V) of oxygenated natural waters shown by Hutchinson (1957). In the pH range of Lake Takapan, according to the diagram described by Hem (1975), the oxidation-reduction condition of the lake was poised equilibrium at a value between -0.32 V to +0.89 V. In relation to sulfur species, the water of Lake Takapan cannot be classified as oxidized or reduced water. Most of the sulfur in the water was found as sulfate ion in the present pH range of 5.23-5.39.

Relationship of water level and water quality

The data in Table 2 indicate that turbidity is the only parameter under studied that not significantly correlated with the water level. Other general water quality parameters are significantly correlate to water level at $\alpha = 0.05$. The strongest correlation of water level is with pH, DO and water temperature. The contribution of variation of water level to variation of those parameters represented by $r^2 = 0.504$, 0.403 and 0.547 for pH, DO and water temperature respectively. Probably there are other environmental factors beside water level that contribute to the variation of pH, DO and water temperature. As shown by the data in Table 3 and Table 4, the water temperature in Lake Takapan is significantly influenced by water temperature both in the Rungan River and the Kahayan River. The dissolved oxygen level in the lake is correlated to the pH of the Rungan River. The pH of Lake Takapan is changing in coincidence with the changing of pH in River Rungan. The limnological data of the Rungan River (Table 3) indicate that the river with its weak tea to black coffee color low pH can be grouped as blackwater river as classified by Sioli (1984). On the other hand, the Kahayan River with its ochre color water and 0.20-m Secchi disk transparency classified as whitewater river according to the same classification.

Increasing conductivity of the Rungan River tend to decrease the pH in Lake Takapan. The water of the Rungan River as a blackwater river with low pH contains a lot of negative ions, (measured by conductivity). Presumably, it constitutes mostly by negative hydrogen ion. An increase of conductivity in the Rungan River will contribute a lot of hydrogen ion to Lake Takapan, so as its consequence, lowering the pH. The statement on the pattern further supported by regression Eq. 7 in Table 4.

Table 2. Linear regression equations for the relationship between water level (WL) and various general water quality parameters in Lake Takapan

No.	Equation of linear regression	n	R	R^2
1.	Log pH = -0.0002 WL + 0.7082	226	-0.720*	0.504
2.	Log DO = -0.0011 WL + 0.2635	212	0.634*	0.403
3.	Log Conductivity = -0.0009WL-2.2852	226	0.399*	0.197
4.	Log Turbidity = 0.0001WL +1.6638	226	0.059	0.003
5.	Log WT = -0.00008 WL +1.4474	226	-0.584*	0.341
6.	Log AT = -0.00003 WL + 1.428	226	-0.227*	0.052
7.	Log ORP = 0.0003 WL + 2.5531	207	0.538*	0.290

* Significant at 0.05 probability level

Table 3.Average values of water quality parameters in the middle of Lake Takapan, the Kahayan River and the Rungan River based on ten times simultaneous monitoring between August 1996 to March 1997

Parameter	Lake Takapan	Rungan River	Kahayan River
Water temperature (WT), °C	29.32	28.96	28.18
Dissolved oxygen (DO), mg/l	2.06	3.09	4.20
pH	4.75	4.72	5.48
Conductivity(Con), mS/cm	0.006	0.005	0.014
ORP, mV	459.4	399.1	355.6
Secchi depth, m	0.46	0.36	0.20
Air Temperature (AT), °C	26.21	30.03	29.03
Turbidity (Turb), NTU	41.1	70.8	148.5

Table 4. Regression equations for significant correlations between water quality parameters in the middle of Lake Takapan, the Kahayan River and the Rungan River based on ten times monitoring between August 1996 to March 1997

No	Equation	r	$r_{multiple}^2$	$R^2_{partial}$	F
1	$WT_{Takapan} = -15.0200 + 1.52626\ WT_{Rungan}$	0.6775*	0.4590		5.939
2	$WT_{Takapan} = 26.3512 + 0.0336 Turb_{Rungan}$	0.8056*	0.6490		11.09
3	$WT_{Takapan} = 25.7828 + 258.6826 Con_{Kahayan}$	0.7714*	0.5951		8.82
4	$DO_{Takapan} = -5.5350 + 1.7486 pH_{Rungan}$	0.9239*	0.9612		36.43
5	$pH_{Takapan} = 0.5598 + 0.8788 pH_{Rungan}$	0.9320*	0.8690		19.91
6	$pH_{Takapan} = 6.1355 - 299.5455 Con_{Rungan}$	-0.9016*	0.8130		13.04
7	$pH_{Takapan} = 2.8697 - 161.5078 Con_{Rungan} + 0.5559 pH_{Rungan}$	0.9940*	0.9880	r^2 Con = 0.9087 r^2 pH = 0.9087	86.20
8	$pH_{Takapan} = 1.2240 - 0.0058 Turb_{Rungan} - 126.0268 Con_{Rungan} + 0.9741\ pH_{Rungan}$	1.000**	0.9999	r^2 Con = 0.9087 r^2 pH = 0.9087 r^2Turb = 0.9930	3997.3 0
9	$Con_{Takapan} = 0.0198 + 0.0839\ pH_{Kahayan}$	-0.8798*	0.7740		10.30

* Significant at 0.05 probability level; ** Significant at 0.01 probability level

Eq. 8 in Table 4 indicated that higher turbidity in the Rungan River would decrease the pH of Lake Takapan. The pattern probably could be explained by the possibility that the material that composed the Rungan River turbidity was aquatic humic substances. As already stated before, the change of water level in the lake did not influence turbidity of Lake Takapan, but probably the input of water from the Rungan River contributed much more to vary turbidity in Lake Takapan.

Weakest correlation was indicated by the relationship between water level in Lake Takapan and log conductivity and air temperature (Table 2). A great number of physical phenomena, such as evaporation, condensation, transpiration and the countless plant and animal activities are closely linked to air temperature (Salati and Marques, 1984). Eq. 6 in Table 2 shows that when the water level increased, the air temperature tended to decrease. This is probably because more water surface expose to the air and sun, and as the result, more forest canopy submerged under high water. Consequently, it will further accelerate the evaporation process that in turn will decrease air temperature.

pH tend to decrease with increasing water level (Fig. 4). Increasing water level means more inundated land in adjacent riparian systems of the oxbow lake and as its consequences there occurs more intense dissolution of acidic materials originated from organic matter decomposition. It is well understood that there is a lot of organic material in the floor of tropical swamp forest.

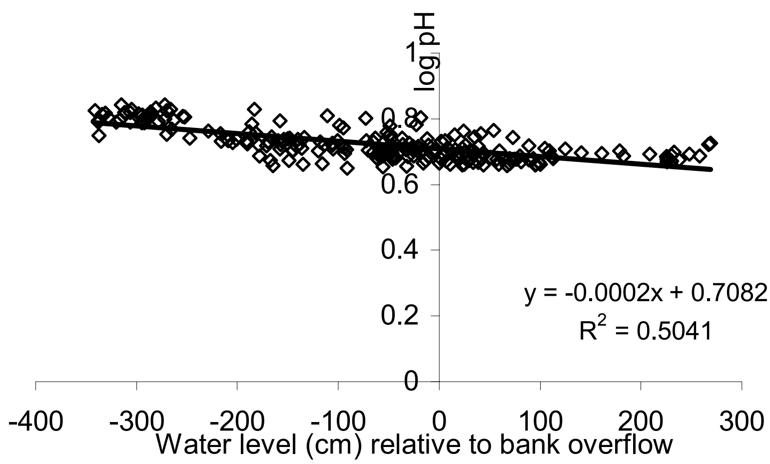


Fig. 4. Scatter diagram of relationship between water level and pH in Lake Takapan

Low water period is suspected to be the period of higher photosynthetic activity. This activity sustained by more concentrated nutrient due to the decrease in water volume and the settlement of dissolved organic matter such as aquatic humic substances to the sediment. The humic substances can absorb radiation in the UV and visible ranges (Thomas, 1997). Lake Takapan reported to have high humic acid concentration in the range of 23.05-361.91 mg/l (Hartoto and Yustiawati, 1999). This dissolved organic matter probably already settles to the bottom of the lake at the period when the water level was below the bank overflows level. This condition was suspected to be favorable for intensive photosynthesis that resulted in removal of carbon dioxide. The carbon dioxide removal, which is follow by consecutive carbonate accumulation and hydrolysis probably, can explain the increase of pH (Boyd, 1990).

Dissolved oxygen level and water temperature showed a similar pattern (Figs. 5 and 6) with the pH. The dissolved oxygen tend to decrease with increasing water level and oxygen depletion seems to occur when the water level was above the bank overflow level. This is probably due to high oxygen demand required for the decomposition of organic litter in the forest floor and increasing input of humic substances because wider land that was newly inundated. The land presumably contains a lot of peaty material that produced humic substances.

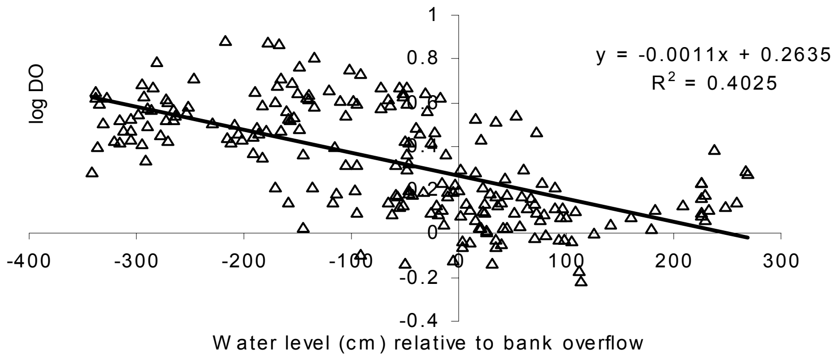


Fig. 5. Scatter diagram of relationship between water level and DO in Lake Takapan

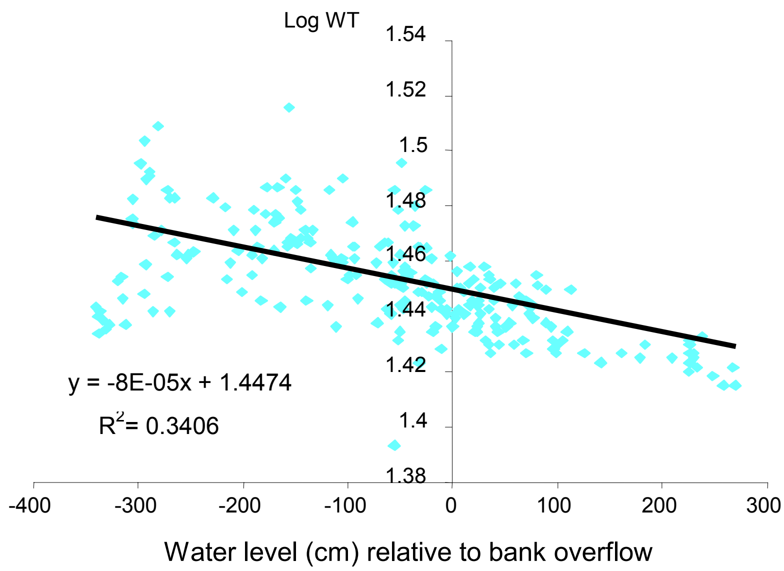
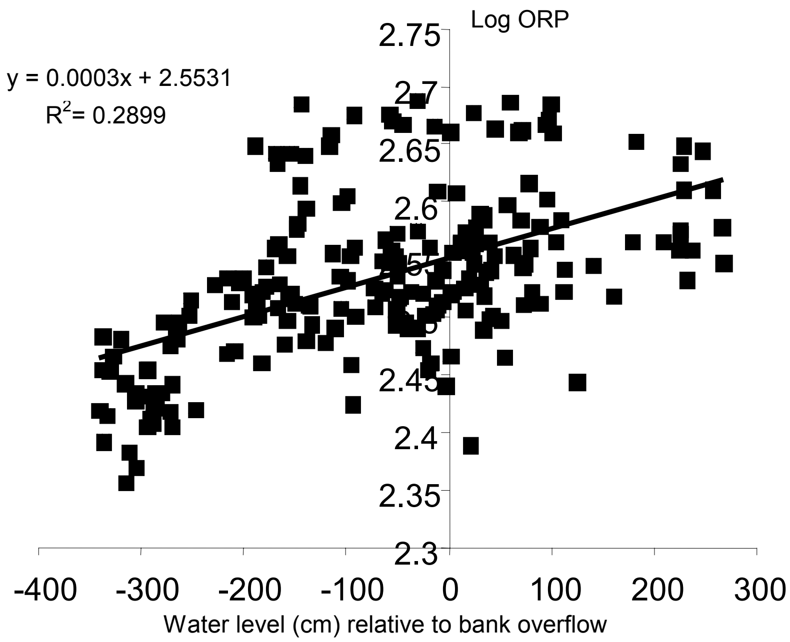


Fig. 6. Scatter diagram of relationship between water level and water temperature in Lake Takapan

Fig. 7 indicates that the ORP values tend to increase with increasing water level. The water level in the lake increased due to a higher input of relatively oxygenated river water through the Kahayan River (DO = 3.09 mg/l) and the Rungan River (DO = 4.20 mg/l) during the rainy season. Since the Kahayan River was connected to Lake Takapan only at the period of high water level, its seems that the Rungan River have much more influence to the water quality of Lake Takapan (Tables 3 and 4).



ig. 7. Scatter diagram of relationship between water level and ORP in Lake Takapan

Conclusion

In Lake Takapan, the variation of water quality parameters, such as pH, temperature, oxidative reductive potentials, dissolved oxygen and conductivity were significantly influenced by the fluctuation of water level relative to bank over flow height. Water quality of the Rungan River as one of the rivers that feed water to the lake affected Lake Takapan water quality more significantly than that of the Kahayan River.

References

Barella, W. and Petrere, M., Jr. 1994. The influence of environmental factors on fish community structure in the Jacare Oeoira River, Brazil. In: Cowx, I.G. (ed), *Rehabilitation of Freshwater Fisheries*, Fishing News Books, pp. 161-170.

Boyd, C. E. 1990. *Water Quality in Ponds for Aquaculture*. Alabama Agricultural Experiment Station. Auburn University, Alabama. USA. 482 pp.

Corner, E. J. H. 1978. *The Freshwater Swamp Forest of South Johor and Singapore.* Botanic Gardens Parks & Recreation Department. Singapore. 265 pp.

Gibbs, R. J. 1970. Mechanism controlling world water chemistry. *Science,* 170: 1088-1090

Hartoto, D. I. 2000. An overview of some limnological parameters and management status of fishery reserve in Central Kalimantan. *Report of the Suwa Hydrobiological Station, Shinshu University,* 12: 49-74.

Hartoto, D.I. and Yustiawati. 1999. Humic acid level at various type of inland water in Central Kalimantan. *Paper presented in Seminar on Tropical Peat Swamp Forest,* *Bogor 12 February 1999. Research and Development Center for Biology-Indonesian Institute of Sciences (LIPI).*

Hem, J. D. 1970. *Study and Interpretation of the Chemical Characteristics of Natural Water. A review of chemical, geologic and hydrologic principles and processes that control composition of natural water, with methods for studying and interpreting chemical Analysis.* United States Government Printing Office.663 p

Henry, R., Tundisi, J. G., Calijuri, M. D. C. and de Ibanez, M. D. S. R. 1997. A comparative study of thermal structure, heat content and stability of stratification in three lakes. In: J.G. Tundisi and Saijo, Y. (eds.), *Limnological Studies on the Rio Doce Valley Lakes, Brazil*. Brazilian Academy of Sciences. Graftex Comunicado Visual. Brazil, pp. 69-81

Hutchinson, G. E. 1957. *A Treatise on Limnology. Volume 1. Geography, Physics and Chemistry.* John Wiley & Sons, Inc. New York. 1015 p.

Ikusima, I., Lim R.P. and Mizuno, T. 1982. pH and RpH. The Ecology of a Freshwater Swamp, In: Furtado, J.L. and Mori, S. (eds), *Tasik Bera. The Ecology of a Freshwater Swamp.* Dr. W. Junk Publishers. The Haque, Netherland, pp.83-85.

Ikusima, I., Lim, R. P., Furtado, J. I. and Sato, O. 1982. dissolved gases: Oxygen and carbon dioxide in Tasik Bera. In: Furtado, J.I. and Mori, S. (eds), *Tasik Bera: The Ecology of a Freshwater Swamp.* Dr. Mari W. Junk Publishers. The Haque, Netherlands, pp. 76-83.

Khan, N. 1990. *Preliminary assessment of the water quality and pollution threat at the Ulu Lepar Wetland System*. Asian Wetland Bureau Publication No 60. 30 pp.

Lagler K.F., Barricade, J.E., Miller, R.R. and. May Passino, D.R. 1977. *Ichthyology. 2nd edn*. John Wiley & Sons. 506 pp.

Lim, R.P. and Furtado, J.I. 1982. Conductivity in Tasik Bera. In: Furtado, J.I. and Mori, S. (eds), *Tasek Bera*. *The Ecology of a Fresh Water Swamp*. Dr. Mari W. Junk Publishers. The Haque Netherland, pp. 86 - 88.

Payne, A.I. 1986. *The ecology of Tropical lakes and Rivers.* JohnWiley & Sons, Inc. 301 pp.

Salati, E. and Marques, J. 1984. Climatology of the Amazon Region. In: Sioli, H. (ed.), *The Amazon: Limnology and landscape ecology of a mighty tropical river and its basin*. Dr. W. Junk Publishers, Dordrechts. Netherlands, pp. 85-126.

Sioli, H. 1984. The Amazon and its main affluent: Hydrography, morphology of the river course and river types. In: Sioli, H. (ed.), *The Amazon. Limnology and landscape ecology of a mighty tropical river and its basin*. Dr. W. Junk Publishers, Dordrechts. Netherlands, pp. 127-166.

Thomas, J. D. 1997. The role of dissolved organic matter, particularly free amino acid and humic substances, in freshwater ecosystem. *Freshwater Biology*, 38: 1-36.

Tundisi, J. G. 1997. Climate. In: Tundisi, J.G. and Saijo, Y. (eds.), *Limnological Studies on the Rio Doce Valley Lakes, Brazil*. Brazilian Academy of Sciences. Graftex Comunicado Visual. Brazil, pp. 7-11

Welcomme, R.L . 1979. *Fisheries ecology of floodplain rivers*. Longman Group Limited. London, 317 pp.

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Limnological Characteristics of Lake Rengas Fishery Reserve in Central Kalimantan

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Abstract

The present study, which was based on primary and secondary data collection, was aimed to reveal and to compile the limnological database of Lake Rengas Fishery Reserve (LRFR, A=33.33 ha), one of the 13 fishery reserves in Central Kalimantan. Lake Rengas (z_{max} = 7 m) is a Type II oxbow lake that receives water from the Rungan River. Fishery reserve which is located in the oxbow lake ideally should include ecologically important habitat types such as the river segment, the connecting channel and the pelagic part of the lake. The primary data collection in this study included the depth profile of several water quality parameters in many habitat types conducted at eight sampling times, at several sampling sites during 1996 to 1997. In addition the secondary data were collected from several publications related to the reserves.

The 95 % confidence intervals of limnological parameters for the lake were: water temperature 27.51±0.31°C (dry season) and 27.39± 0.04°C (wet season), dissolved oxygen 1.91± 0.57 mg/l (dry season) and 2.47±0.25 mg/l (wet season), pH 4.40±0.13 (dry season) and 4.08±0.46 (wet season), turbidity 154.7± 76.0 NTU (dry season) and 35.1±9.2 NTU (wet season), oxidative reductive potentials 376.1± 31.8mV (dry season) and 469.0± 19.4mV (wet season) and conductivity 8.7±2.2 µS/cm (dry season) and 7.0±1.6 µS/cm (wet season). The relationship between depth and limnological parameters were mostly expressed by polynomial equations both in the lake and in the river.

The status of the water quality of LRFR was discussed based on the present results and other limnological parameters taken during the same period.

Introduction

The existence of fishery reserves in Central Kalimantan; that is legitimated by the Republic of Indonesian Act Number 9 Year 1985 on Fishery; is very important to guarantee the natural availability of brood stock and fingerling. It is recorded that total area of inland water in Central Kalimantan is about 1,944,260 ha, that consists of peat swamps (80.7 %), and the rest are rivers and lakes. From 1988 to 1993 its reported that total average fish production was 23.3 kg/(ha year), currently is about 45,301,258 kg/year. Potentially the inland water of Central Kalimantan has fishery production of 130,000 tons/year. Economically, the estimated value of this commodity have value not less than 40 million US$ per year (Hartoto, 2000). Fishery reserve or "Suaka perikanan" is used as conservation measures and management tools for fishery production. However, it is expected to function as an area for supplying the fingerlings and broodstock to the adjacent fishing ground and its vicinity.

Hartoto *et al.* (1998a) proposed the definition of fishery reserve as an inland water area that have a part where the fishes is prohibited to be caught by any method, at any time and by anyone. The fishery reserves managed to sustain or to increase production based on adjacent natural fish stock for the welfare of the fisher. There are thirteen inland water fisheries known in Central Kalimantan Province. The existence of a fishery reserve is important to sustain the fish production based on natural stock in adjacent inland waters. Beside that, for Indonesian condition, the fishery reserve also can function as a social safety net since it also a source of income for ordinary fishers and other small stake holders. To develop a scientifically-based management practices, it is clear that detailed limnological information of fishery reserves is pre-requisite. Hartoto (2000) have already reported a general overview on some inland fishery reserves on Central Kalimantan. Evaluation of management status of LRFR show that the lake achieved the highest score (1.62) compared with other reserves in Central Kalimantan, even though it still belongs to the second class (or "Muda" Class) of management status.

Oxbow lakes in Central Kalimantan is important because most of the harvest fishery reserves are located in the oxbow lakes. From the viewpoint of fishery ecology, oxbow lakes are classified into three types. Lake Rengas is known as an oxbow lake that receives water from a tributary (Rungan River) of a main river (Kahayan River) and is classified as the type II oxbow lake (Hartoto, 2000). The objective of this study was to reveal the vertical profiles of some limnological parameters and its temporal variation in Lake Rengas. Other published parameters on any other aspect for Lake Rengas are also presented here as a compilation of available data.

Material and Methods

Lake Rengas (surface area 33.33 ha) is located in Palangkaraya Municipality. It receives water from the Rungan River, a tributary of the Kahayan River. To understand temporal variation between seasons, water quality monitoring was conducted eight times, i.e., four times in the wet season (September, October, November 1996 and January 1997) and four times in the dry season (April, May, June and November 1997). Dissolved oxygen (DO), conductivity, pH, temperature, and turbidity were measured with Horiba Water Quality Checker. Oxidative reductive potentials (ORP) were measured using a TOKO ORP-meter TRX 90. The data were taken from the middle of Lake Rengas and the Rungan River segment. The maximum depth, and Secchi depth, were also measured at the same time.

Other parameters are also compiled from reports, such as nitrogen fractions (Hartoto and Awalina, 1999b), humic acids levels (Hartoto and Yustiawati, 1999), phosphorus finger prints (Yustiawati and Hartoto, phytoplankton community (Sulastri and Hartoto, 2000), heavy metals (Hartoto and Awalina, 1999a) and fish species and management status (Hartoto, 2000), in order to comprehend Lake Rengas limnology more holistically. The compilation was considered to be reasonable because all those parameters were sampled in coincidence with the data sampling for the present study.

The data collected was analyzed pictorially and statistically. The simple statistical analysis include descriptive statistics and regression analysis.

Results and Discussion

Depth profile of water quality

Table 1 and Table 2 show the values of general water quality parameter of both in Lake Rengas and the Rungan River. Figs. 1 to 6 indicate the vertical profile of these parameters. The DO tended to be higher in the wet season than that in the dry season both in Lake Rengas and River Rungan (Table 2). This pattern began to develop at 1-m water depth, but in the surface layer, the dissolved oxygen in the dry season was always higher than that in the wet season (Figs. 1 and 2). The pattern was probably due to the input of more oxygenated water from the river segment through the channel to Lake Rengas. Vertically, the DO seemed to be constant from the surface to the bottom in the wet season but on the contrary, it tended to decline with depth in the dry season.

The pH in the wet season tended to be lower than that in the dry season both in Lake Rengas and in the Rungan River. In both seasons, the average pH values in Lake Rengas tended to decrease with increasing water depth. On the contrary, in the Rungan River, the average pH values seemed to be constant from the surface layer to the bottom both in the dry and wet seasons (Figs. 1 and 2).

Table 1. Descriptive statistics of water quality parameters from Lake Rengas.

	Limnological parameter					
	Water temperature, °C	DO, mg/l	pH	Conductivity, µS/cm	ORP, mV	Turbidity, NTU
a. Dry season						
Mean	27.51	1.91	4.40	8.7	376.1	154.7
Standard error	0.15	0.28	0.06	1.0	14.8	37.1
Standard deviation	0.84	1.53	0.35	5.5	57.4	103.4
95% confidence interval	0.31	0.57	0.13	2.2	31.8	76.0
Median	27.25	2.20	4.41	6	378.4	30.7
Count	30	30	30	30	15	30
b. Wet season						
Mean	27.39	2.47	4.08	7.0	469.0	35.1
Standard Error	0.21	0.12	0.09	0.6	9.0	4.5
Standard deviation	1.06	0.49	0.46	3.0	35.0	21.4
95% confidence interval	0.44	0.25	0.19	1.3	19.4	9.2
Median	26.9	2.55	3.98	6	469.6	28
Number of samples	25	17	25	25	15	23

Table 2. Descriptive statistics of water quality parameters for the Rungan River.

	Limnological parameter					
	Water temperature, °C	DO, mg/L	pH	Conductivity, µS/cm	ORP, mV	Turbidity, NTU
A. Dry season						
Mean	28.17	3.33	4.71	6.48	426.0	101.0
Standard deviation	0.85	0.36	0.51	4.15	74.5	127.6
Standard error	0.15	0.07	0.09	0.75	19.2	22.9
95% confidence interval	0.31	0.13	0.19	1.52	41.3	46.8
Median	28.2	3.52	4.47	4	457.7	51.4
Number of samples	30	31	31	31	15	31
B. Wet season						
Mean	27.28	3.29	4.36	5.4	497.9	33.8
Standard deviation	0.80	0.54	0.54	2.8	33.06	11.1
Standard error	0.22	0.15	0.14	0.8	10.5	3.07
95% confidence interval	0.48	0.33	0.32	1.7	23.7	6.7
Median	27.1	3.3	4.19	4	513.5	32
Number of samples	13	13	13	13	10	13

In Lake Rengas, that have maximum water depth around 1.0 to1.5 m, the conductivity in the wet season was higher than that in the dry season. The conductivity in the wet season was lower than the values in the dry season at depths of 2-7 m (Figs. 3 and 4). The conductivity tended to increase vertically with increasing water depth in the dry season. In the wet season, on the other hand, the values tended to decrease with increasing depth (Fig. 3). In the Rungan River, the conductivity values were constant throughout the water column (0-5 m depths) in the dry season whereas in the wet season, the values tended to decrease at depths of 3-5 m (Fig. 4).

The water temperature tended to be constant vertically both in Lake Rengas and the Rungan River and in both seasons. No significant difference of temperature was observed between dry and wet seasons for Lake Rengas, but for the Rungan River the temperature was relatively lower in the wet season than in the dry season except at 4-5 m depths where temperatures did not differ between the two seasons (Figs. 3 and 4).

Turbidity seemed to be lower in the wet season than in the dry season both for Lake Rengas and the Rungan River. Vertical profile of turbidity was straight from the surface to the bottom in the wet season. On the contrary, the turbidity in the dry season for Lake Rengas was not constant and rapidly decreased between 4-5 m depths. Vertical profile of turbidity in the Rungan River was relatively more constant than in Lake Rengas, even though the turbidity was slightly decreased at 2-4 m depths and tended to increase near the bottom (Figs. 5 and 6).

Both in the pelagic part of Lake Rengas and in the Rungan River, the ORP values in the dry season were much higher than those in the wet season. It deserve to note here that in the dry season, the ORP averages of Lake Rengas pelagic habitat were quite higher than the average ORP in the Rungan River. The vertical pattern of ORP in dry season on both habitat were quite similar, which shown a tendency to increase at 0-1.5 m depths followed by rapid decrease at 2-7 m depths.

In the wet season the ORP values in Lake Rengas was constant only at 0-4.5 m depths and rapidly decreased at 5-7 m depths. Almost similar pattern was observed in the Rungan River in the wet season. The pattern was quite different where its seems to be more constant than ORP profile of the Lake Rengas pattern (Figs. 5 and 6).

Condition of water quality

The water quality data for Lake Rengas and the Rungan River segment in both dry and wet seasons (Tables 1 and 2) were still good and met the requirement to support aquatic life (Boyd, 1990).

The average water temperature of the Lake Rengas was relatively high throughout the year, i.e., 27.51±0.84°C for dry season (mean±SD) and 27.39±1.06°C for rainy season. The slight but insignificant difference of water temperature between these two seasons may appreciably be caused by the quantity of sunlight during the seasons. In this water temperature range phytoplankton productivity is relatively high (Boyd, 1990).

The average DO concentrations in the lake were 1.91±1.53 mg/L for the dry season and 2.47±0.49 mg/L for the wet season. The value in the dry season was the same as the average DO (1.90 mg/L) in Tasek Bera (Ikushima *et al*., 1982). The low DO concentration in the oxbow lake might be caused by the high rate of oxygen consumption for decomposing organic matter originated from adjacent riparian forest systems (allochthonous natural debris) and also by the limited oxygen supply from the air.

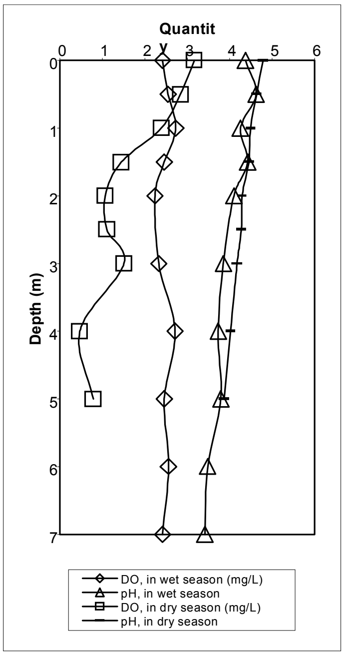

Fig. 1. Depth profiles of average pH and DO at the center of Leke Rengas.

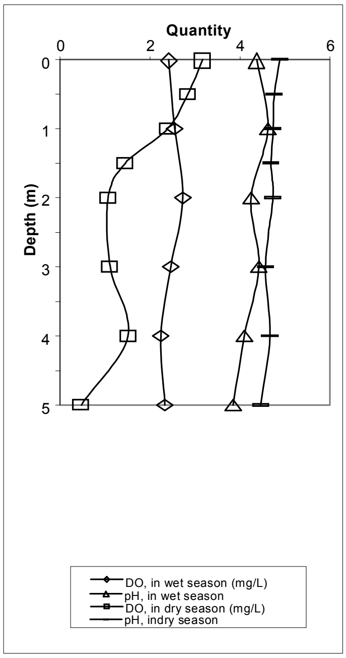

Fig. 2. Depth profiles of average pH and DO in the Rungan River.

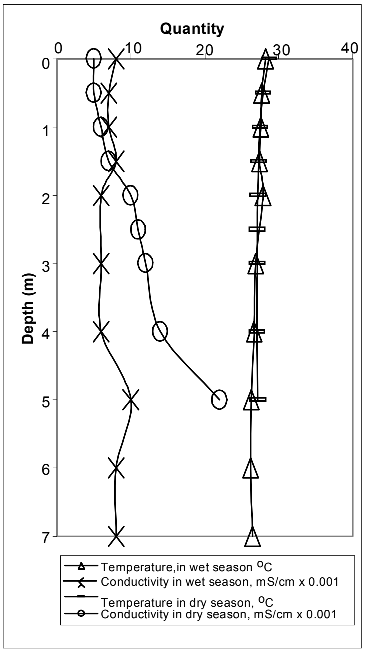

Fig. 3. Depth profiles of average temperature and conductivity at the center of Lake Rengas.

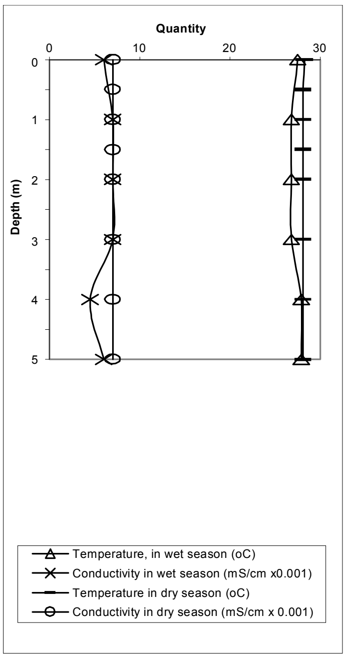

Fig. 4. Depth profiles of average temperature and conductivity in the Rungan River.

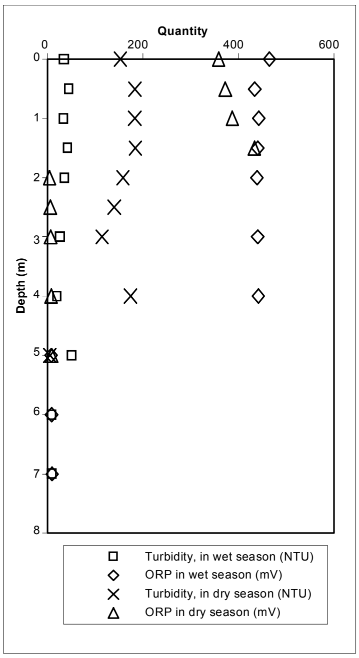

Fig. 5. Depth profiles of average turbidity and ORP at the center of Leke Rengas.

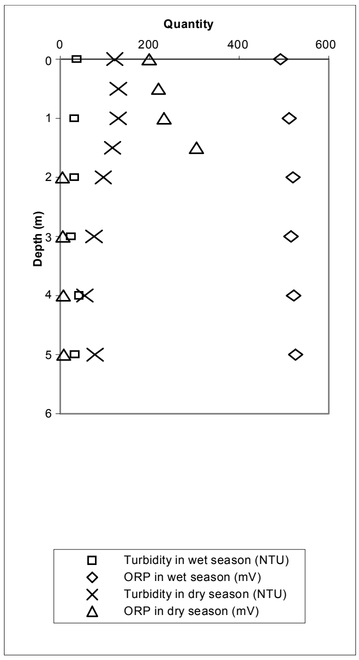

Fig. 6. Depth profiles of average turbidity and ORP in the Rungan River.

The average pH value in the lake was 4.40±0.35 for the dry season and 4.08±0.46 for the wet season. These values were similar to those in Tasek Bera (4.57-6.83, Ikusima *et al.*, 1982) and a freshwater swamp in Amazon basin (Sioli, 1967). Hartoto (1997) and Hartoto *et al*. (1998a) observed that many natural fish populations in black water in Kalimantan and Sumatra are adapted to low water pH. In Lake Rengas, pH value in the dry season tended to be higher than that in the wet season presumably due to the higher photosynthetic rate in the dry season, which finally resulted in higher pH. Photosyntesis affects pH through a mechanism of reduced CO_2 and carbonates accumulation followed by hydrolysis that induces increase in pH (Boyd, 1990).

The average conductivity in the lake was 8.7±5.5 µS/cm for dry season and 7.0±3.0 µS/cm for wet season. Conductivity is low in freshwaters with very low ionic content according (Boyd, 1990). The average conductivity of water in several habitat types of Tasek Bera was 14.2 µS/cm (Lim and Furtado, 1982). A similar value has been observed in Rio Doce Valley Lake system in Brazil by Mitamura and Hino (1997).

The average ORP in the lake was 376.1±57.4 mV for dry season and 469.0±35.0 mV for rainy season. Hartoto (2000) have reported that the ORP value observed in Lake Rengas is highest among the oxbow lakes in Central Kalimantan. Since ORP in oxygenated water is from 450 mV to 520 mV (Hutchinson, 1957), water of Lake Rengas might be more oxygenated in the wet season than in the dry season. This is probably because Lake Rengas contain higher concentrations of organic suspended matter in the dry season than in the wet season as indicated by turbidity which tended to be higher in the dry season (154.7±103.4 NTU) than in the wet season (35.1±21.4 NTU) (Table 1).

Regression equation of relationship between some limnological parameters and water depth (x) in Lake Rengas (both for the middle part and riverine segment) is presented in Table 3. Most of the relation of water temperature, DO, pH, Turbidity, Conductivity, ORP to water depth were polynomial respectively. So, its clear that relationship of each of limnological parameter to water depth is not only include one parameter but also other limnological parameters.

Table 3. Regression equation of relationship between some limnological parameters and water depth (x) in Lake Rengas.

No.	Equation	r^2	R	n	Type of equation
a. Middle of Lake Rengas					
1	$WT = 0.0043x^2 -0.491 x + 28.299$	0.2320	0.482*	55	Polynomial
2	$DO = 0.0237x^2 -0.1221x + 3.3713$	0.0218	0.148	47	
3	$pH = 4.7663 e^{-0.0392x}$	0.2829	0.532*	55	Exponential
4	$Turb = 49.109 e^{-0.1167x}$	0.0204	0.1438	53	
5	$Cond. = 0.216 x^2 -1.7641x - 6.4293$	0.0605	0.258	55	
6	$ORP = 7.9317x^2 -+ 6.9525 x + 393.02$	0.2716	0.5212*	30	Polynomial
b. Rungan River Segment					
7	$WT = 0.0349 x^2 -11.034x +104.78$	0.0241	0.155	43	
8	$DO = 0.0373x^2 -0.0394x + 2.905$	0.0927	0.305*	44	Polynomial
9	$pH = 4.717 e^{-0.0184x}$	0.0677	0.260	44	
10	$Turb. = -11.034x + 104.78$	0.0244	0.156	44	
11	$Cond = -0.293 x^2 + 1.162 x + 5.809$	0.0398	0.199	44	
12	$ORP = -0.9706 X^2 + 26.28 x + 428.25$	0.1654	0.407*	25	Polynomial

Published limnological information on Lake Rengas

In order to comprehend the limnological characteristics of Lake Rengas more holistically, it is necessary to compile more information from any other published papers that are related to this lake. We add here those data which have been obtained at the same time as the present field research.

According to Hartoto (2000), average Secchi disk transparency is 0.51 m, average air temperature at sampling times is 26.4°C. The number of fish species is 52 of which Cyprinidae are dominant.

The average of nitrogen fractions have been reported as N-NO_2 4.1 μg/l, N-NO_3 1024.0 μg/l, N-NH_3 225.2 μg/l, total N (TN) 5319.0 μg/l, total P (TP) 448.0 μg/l and TN/TP ratio 26. Ammonia content in this lake is the highest as compared with other types of oxbow lake in Central Kalimantan (Hartoto and Awalina, 1999b). It is also reported that Lake Rengas has phosphorus limiting growth factor, and N-NO_2, N-NO_3, N-NH_3 contents was still save concentration for aquatic life according to Boyd (1990).

Humic acid level in Lake Rengas has already been studied by Hartoto and Yustiawati (1999) as follows. Average content range 91.2-308.6 mg/l. The humic acid concentration of lotic habitat showed higher average (206.0 mg/L) than the average of lentic habitat (172.8 mg/l). This pattern is also found on Fe content as catalyst for organic material oxydation. Seemingly, this lake has a favorable condition for the production of humic acid that is recognized as one of the oxydized organic matter component.

Phosphorus is the external function that determines internal condition or productivity in natural inland waters. Hartoto *et al*. (1998b) proposed the utilization of the ratio of dissolved and particulate acid hydrolizable-P to Total P as an indicator for the dependency of an aquatic system to detritus, in terms of energy and material balance. This ratio than refer as the detritus dependency indicator. Yustiawati and Hartoto (1999) reported that in Lake Rengas the detritus dependency indicator dominated by dissolved acid hydrolizable-P which indicate that organic material decomposition occurs quite well.

Average concentrations of some heavy metals (Fe, Mn, Pb, and Hg) in water and sediment of Lake Rengas are 1.199 mg Fe/l, 0.027 mg Mn/l, 0.056 mg Pb/l, and 0.008 mg Hg/l for lake water while in sediment the average contents are 2045.7 mg Fe/kg dry weight, 110.5 mg Mn/kg dry weight, 10.74 mg Pb/kg dry weight, and 0.887 mg Hg/kg dry weight. Fe, Mn, and Pb, in Lake Rengas water is still within natural range but Hg in water and sediment exceeded the safe concentration (Hartoto and Awalina, 1999a).

Sulastri and Hartoto (2000) have reported that the average phytoplankton density in Lake Rengas is 3,254 individuals/l. *Chlorophyceae* is the common dominant genera in this lake. In the dry season the density was highest and the phytoplankton is dominated by the genes *Oocyst*. In the wet season the dominant genera were Chlorophyceae such as *Oedogonium* and *Trochisia*, and some genera belonging to the group of desmid such as *Closterium, Gonatozygon and Pleurotaenium*.

Hartoto (2000) have already conducted an evaluation on the management status of fishery reserve using a scoring method (Hartoto *et al*., 1998b) of Lake Rengas. The result indicate that Lake Rengas had the highest average score (1.62) compared to other fishery reserve in Central Kalimantan. According to Evaluation criteria and Classification of inland water fishery reserve this average score is belong to “Muda” or Class II.

References

Awalina and Hartoto, D.I. 1999. Heavy metals pollution in rivers at Tanjung Puting National Park, Central Kalimantan. *Paper presented in Seminar on Tropical Peat Swamp Forest, Bogor 12 Februari 1999*. Puslitbang Biologi-LIPI.

Boyd, C.E. 1990. *Water Quality in Ponds for Aquaculture*, Auburn University, Alabama, USA. 482 pp.

Hartoto, D.I. 1997. Notes on limnological condition of Lake Loa Kang as fishery reserve and its potential as food supply habitat for Mahakam Freshwater Dolphin. In: *Rehabilitasi Lingkungan Perairan Danau Semayang, Kalimantan Timur,* by Tim Peneliti. Seri Laporan Pep-LIPI No.7. Puslitbang Ekonomi dan Pembangunan, Lembaga Ilmu Pengetahuan Indonesia, pp. 63-85.

Hartoto, D. I. 2000. An overview of some limnological parameters and management status of fishery reserve in Central *Kalimantan. Report of the Suwa Hydrobiological Station, Shinshu University*, 12: 49-74.

Hartoto, D .I. and Awalina. 1999a. Metals bioconcentration of freshwater fishes in Central Kalimantan as an evaluation criteria for management of inland water fishery reserve. *Paper presented in Seminar on Tropical Peat Swamp Forest, Bogor 12 Februari 1999. Puslitbang Biologi-LIPI.*

Hartoto, D.I. and Awalina.1999b. Nitrogen fractions variation in some Oxbow Lakes of Central Kalimantan. *Paper presented in the Poster Session in Seminar of R&D Activities of RDCL, 1998-1999, Cibinong, 13 April 1999.*

Hartoto, D. I. and Yustiawati.1999. Humic acid level at various type of inland water in Central Kalimantan. *Paper presented in Seminar on Tropical Peat Swamp Forest, Bogor 12 Februari 1999. Puslitbang Biologi-LIPI.*

Hartoto, D. I., Sarnita, A. S., Sjafei, D .S., Awalina, Yustiawati, Sulastri, M. M. Kamal and Siddik, Y. 1998a. *Dokumen: Kriteria Evaluasi Suaka Perikanan Perairan Dara*t. Paper presented in Research Development Center for Limnology Yearly Seminar, Bogor, April 1998.Pusat Penelitian dan Pengembangan Limnologi, Lembaga Ilmu Pengetahuan Indonesia. 51 p. (in Indonesian)

Hartoto, D.I., Syawal, M.S. and Ridwansyah, I. 1998b. Phosphorus fingerprints of Lake Semayang. In: Lukman and Hartoto, D.I. (eds), *Rehabilitasi Lingkungan Perairan Danau Semayang, Kalimantan Timur.* by Puslitbang Ekonomi dan Pembangunan, LIPI, pp. 35-50.

Hem, J.D. 1975. *Study and Interpretation of the Chemical Characteristics of Natural Water*. 2nd edition’s Printing Office, Washington. 363 p .

Hutchinson, G.E. 1957. *A Treatise on Limnology. Volume I. Geography, Physics and chemistry*. John Willey & Sons, New York, 1015 pp.

Ikusima, I, Lim R.P. and Mizuno, T. 1982. pH and RpH Tasek Bera. The Ecology of Freshwater Swamp, In: Fortado, J.L. and Mori, S. (eds). *Tasek Bera: The Ecology of a Freshwater Swamp.* Dr. W. Junk Publishers, The Hague, pp. 83-85.

Ikusima, I, Lim R.P, Furtado, J.I. and Sato, O. 1982. Dissolved gases Oxygen and carbon Dioxyde in Tasek Bera., In: Fortado, J.L. and Mori, S. (eds). *Tasek Bera: The Ecology of a Freshwater Swamp.* Dr. W. Junk Publishers, The Hague, pp. 76-83.

Lim, R.P. and Furtado, J.I. 1982. Conductivity in Tasek Bera. In: Furtado, J.I. and Mori, S. (eds), *The Ecology of a Freshwater Swamp*. Dr. W. Junk Publishers, The Hague, pp. 86-88.

Mitamura , O and Hino, K 1997. Distribution of biogeochemical constituents in the waters. In : Tundisi J.G. and Saijo, Y. (eds). *Limnological Studies on The Rio Doce Valley Lakes, Brazil*. Brazilian Academy of Sciences. Graftex communicado Visual. Brazil. pp 97-108.

Sioli, H. 1967. Studies in Amazonian Waters. Amazoniona. 3 (Limnologia): 9-50.

Sulastri and Hartoto, D. I. 2000. Comparative analysis of phytoplankton community in some inland water habitat of Central Kalimantan, Indonesia. *Report of the Suwa Hydrobiological Station, Shinshu University*, 12: 9-17.

Yustiawati and Hartoto, D.I. 1999. Phosphorus nutrient finger prints of some inland water types in Central Kalimantan. *Paper presented in the Poster Session in Seminar of R &D Activities of RDCL, 1998-1999, Cibinong, 13 April1999*.

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TROPICAL PEATLANDS
Bogor, Indonesia, 22-23 November 1999
Hokkaido University & Indonesian Institute of Sciences
pp. 397-411 (2000)

Distribution of Phytoplankton in Some Oxbow Lakes of Central Kalimantan

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Abstract

Oxbow lake is the backwater of the main channel remaining in communication with the main river and lentic, having many of the characteristic of floodplain lagoon. It was reported that usually rich of nutrient, giving rise to plankton bloom. Some studies reported that phytoplankton in backwater or oxbow lake are more abundant and scarce in the river system. This study was aimed to describe the distribution of phytoplankton in some oxbow lakes of Central Kalimantan, by analysis the density and composition of phytoplankton from some habitat types of the lake and river segment. Some water parameters and physical condition at each study site were also described. The study was conducted in Lakes Lutan, Takapan, and Rengas, as a part of Kahayan River system between 1996 to 1997. The result show that the phytoplankton density of Lake Lutan is highest in the middle of the lake with a total density of 3,495 individuals/l and the phytoplankton community was dominated by Euglenophyta group especially *Trachelomonas* and *Euglena*. While in Lake Takapan the highiest density was found in the river habitat or Kahayan River segment with a total density of 3,337 individuals/l and the phytoplankton community was dominated by Chrysophyta and Chlorophyta especially *Navicula*, *Synedra*, *Tabellaria*, *Closterium* and *Spirogyra*. The highest density of phytoplankton in Lake Rengas is 2,948 individuals/l found in river habitat or Rungan River segment and the community was dominated by Cyanophyta group especially *Anabaena* and *Nostoc*. The difference of phytoplankton distribution in these three oxbow lakes is probably due to the difference of environmental conditions such as water quality and physical conditions such as moprphological conditions. The relationship between some water quality and phytoplankton density was discussed.

Introduction

An oxbow lake is a backwater of the main channel remaining in communication with the main river and lentic, having many of the characteristic of floodpalin lagoons. There are usually rich nutrients, giving rise to phytoplankton blooms. Therefore an oxbow lake has an important role as a feeding site for river fishes. Some studies reported that phytoplankton are more abundant in backwater or oxbow lake and scarce in the river system (Welcome, 1979). The oxbow lake receives the water from the main river so that the condition of water quality, flora and fauna has also relationship to the condition of the main river. There are many types of oxbow lakes in central Kalimantan based on the morphology and channels connecting to the main river. The oxbow lakes in Central Kalimantan are of ecological and economical value for local people, since the oxbow lakes of the major rivers such as the Kahayan River are important fishing ground for local fisheries. Study from an ecological viewpoint of these types of aquatic system in this area is still limited. While to manage these types of aquatic systems, a data base on their limnological condition is essential.

The present study analyzes the distribution of phytoplankton in some oxbow lakes of the Kahayan River system (Fig. 1). We compare phytoplankton densities and compositions at five sampling sites for each lake including inside the lake and river segment that have influence on the water in the lake.

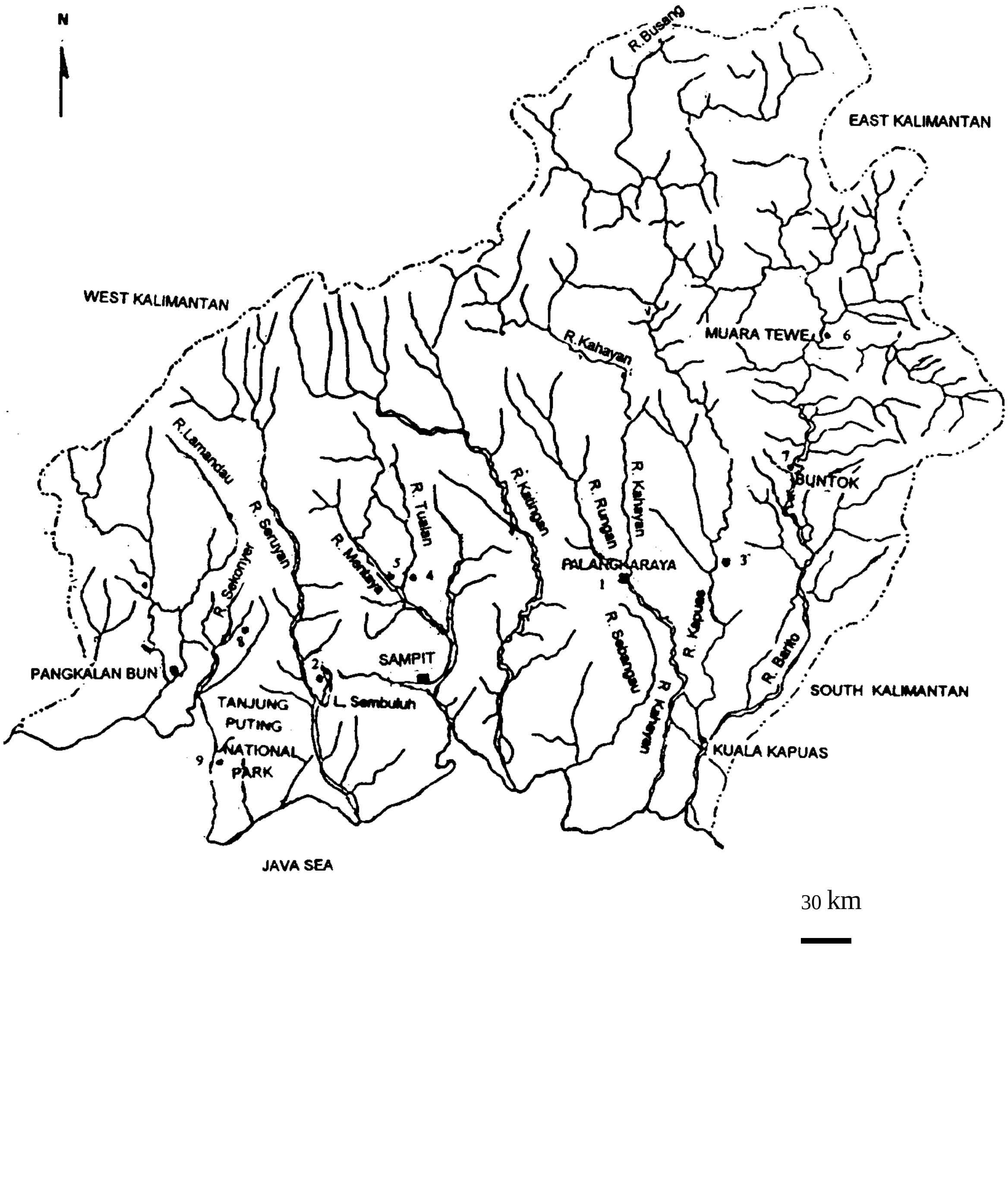


Fig. 1. Position of phytoplankton sampling sites in inland water of Central Kalimantan

Materials and Methods

Study was conducted in Lake Lutan (Fig. 2), Takapan (Fig. 3) and Rengas (Fig. 4). The morphological, physical and chemical condition at each sampling site were presented in Table 1. Lake Lutan is the lowermost part of these three oxbow lakes in the Kahayan River system and receives the water from the main river or Kahayan River. Lake Takapan is the middle of these three oxbow lakes and receives the water from the Kahayan Rriver and its tributaries. And Lake Rengas is the uppermost part of these three oxbow lakes in the Kahayan River system, receives the water from the Rungan River or the tributary of the Kahayan River.

Samples were taken from some habitat types (Table 2) in 1996 and 1997. To have representative data, the data was collected both water quality and phytoplankton at least four or five time at sampling site. Temperature, conductivity, transparency, depth, pH, dissolved oxygen were measured *in situ* using Horiba U-10 instrument. While other parameters like nutrients were analyzed in the laboratory. Phytoplankton samples were collected by composite from surface water to the bottom and passing 30 l of water through a plankton net number 25 (40 µm mesh opening) then fixed in 1% Lugol's solution for taxonomical studies. The algal taxon was identified according to Presscott (1970), Scott and Prescott (1961). Quantitative analyses of phytoplankton were performed using modified Lackey drop microtransec method (Anonymous, 1977). Species diversity was calculated according to Shannon and Weaver (Odum, 1971). Correlation analysis between phytoplankton and water quality parameters was performed using a statistical software Microsta.

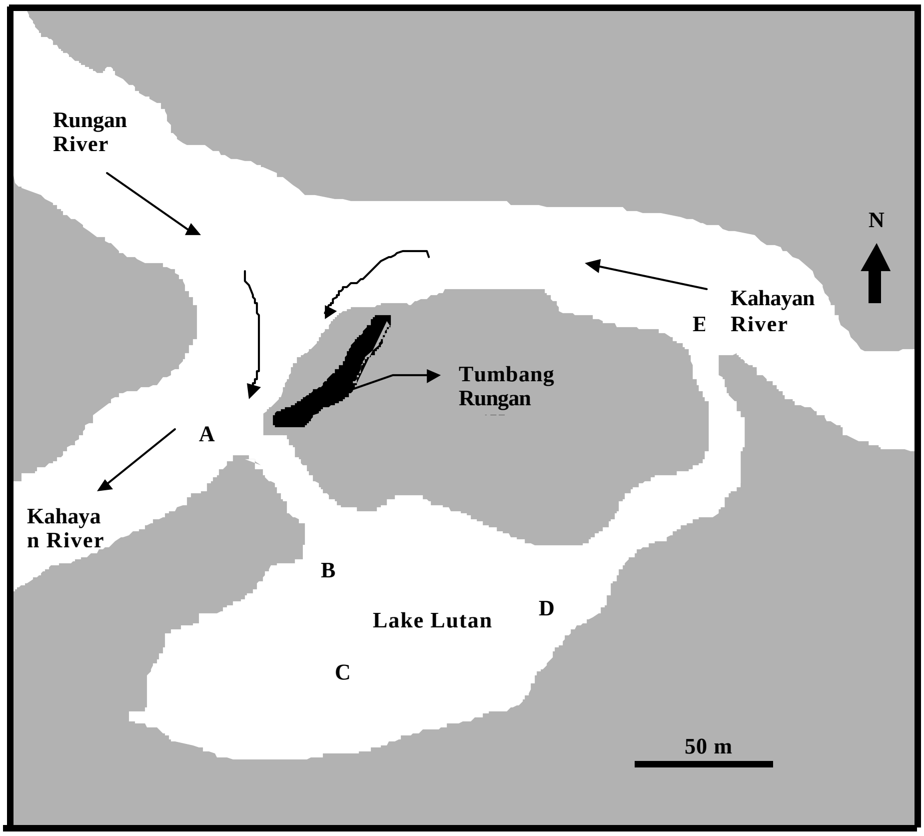


Fig. 2. Sampling sites in Lake Lutan

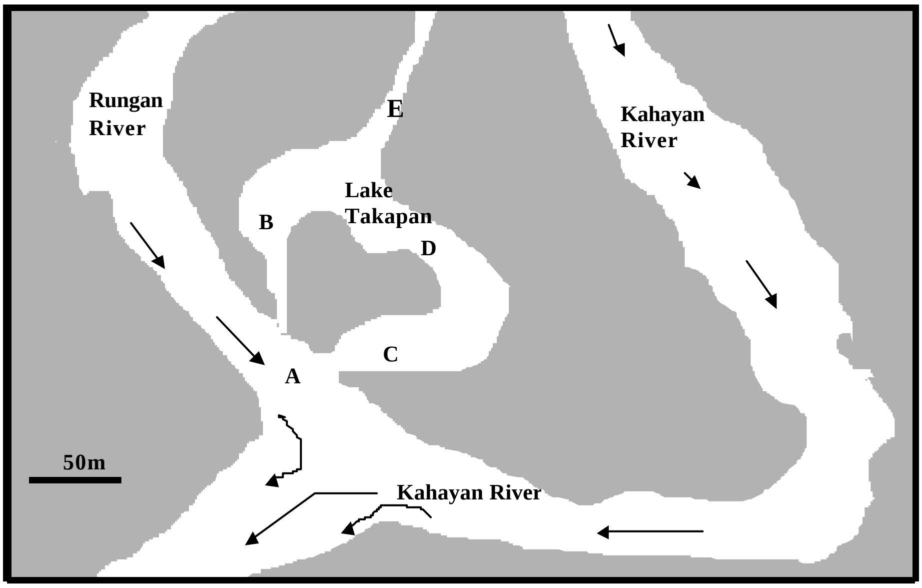


Fig. 3. Sampling sites in Lake Takapan

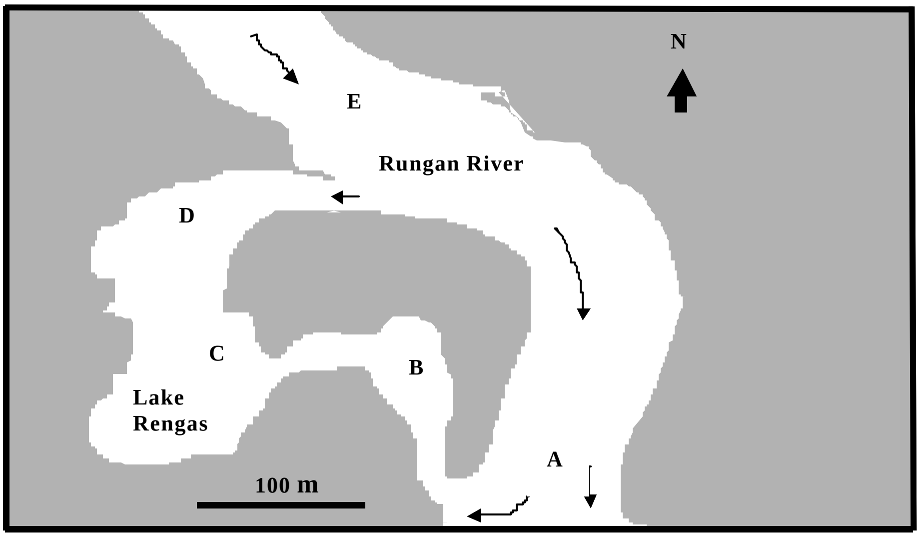


Fig. 4. Sampling sites in Lake Rengas

Table 1. The morphometric features of Lakes Lutan, Takapan and Rengas.

Parameters	Lutan	Takapan	Rengas
Maximum area (ha)	7.0	50.4	35
Maximum depth (m) (pelagic)	5.02	7.0	7.0
Transparancy (cm) (average)	35.20	40.71	35.36
Turbidity (NTU) (average)	84.02	22.13	72.42

Table 2. Description of physical condition of sampling sites.

No	Lake	Code of site	Description of sampling site
1.	Lutan	A	Kahayan River segment, in front of downstream inlet channel of lake Lutan.
		B	Part of Lake Lutan system, in front of downstream connecting channel
		C	Middle of Lake Lutan
		D	Part of Lake Lutan system, in front of the mouth of upstream connecting channel.
		E	Kahayan River segment, in front of upstream inlet channel of Lake Lutan.
2	Takapan	A	Rungan River segment, at the mouth of inlet of lake
		B	Part of the Lake Takapan system, near the northern inlet
		C	Part of the Lake Takapan system, near the southern inlet.
		D	Middle of the lake
		E	Right junction of another inlet stream, flooded grass land, part of riparian system of Lake Takapan.
3	Rengas	A	Rungan River segment, in front of down stream inlet channel.
		B	A segment of down stream connecting channel of Lake Rengas
		C	Middle of the lake
		D	A segment of upstream connecting channel of Lake Rengas.
		E	Rungan River segment, in front of upstream inlet channel of Lake Rengas.

Results and Discussion.

Physico-chemical parameters at three oxbow lakes were presented in Fig. 5. The result showed that generally water temperature in the lake (sites B, C and D) either Lake Lutan, Takapan or Rengas is higher than in river habitat (sites A and E). It is probably due to shading by riparian vegetation along the river that cause the water temperature in the river habitat lower than in the lake system. While the dissolved oxygen (DO) content in these three oxbow lakes show that the value of oxygen content in river habitat is generally higher than in the lake system. It may be due to water current. The same pattern is also observed for conductivity and pH that generally value of these parameters in river habitat are higher than in lake system except conductivity value of Lake Rengas is higher in the middle of the lake. While the nutrient contents such as nitrate, nitrite, ammonia, total N and total P showed in variation condition at each sampling site. For example nitrite value in Lake Lutan and Rengas is higher in lake systems than in river habitats. While the highest value of total N in Rengas and Lake Lutan is the middle of the lake or at site C (Hartoto and Awalina, 1999; Yustiawati and Hartoto, 1999).

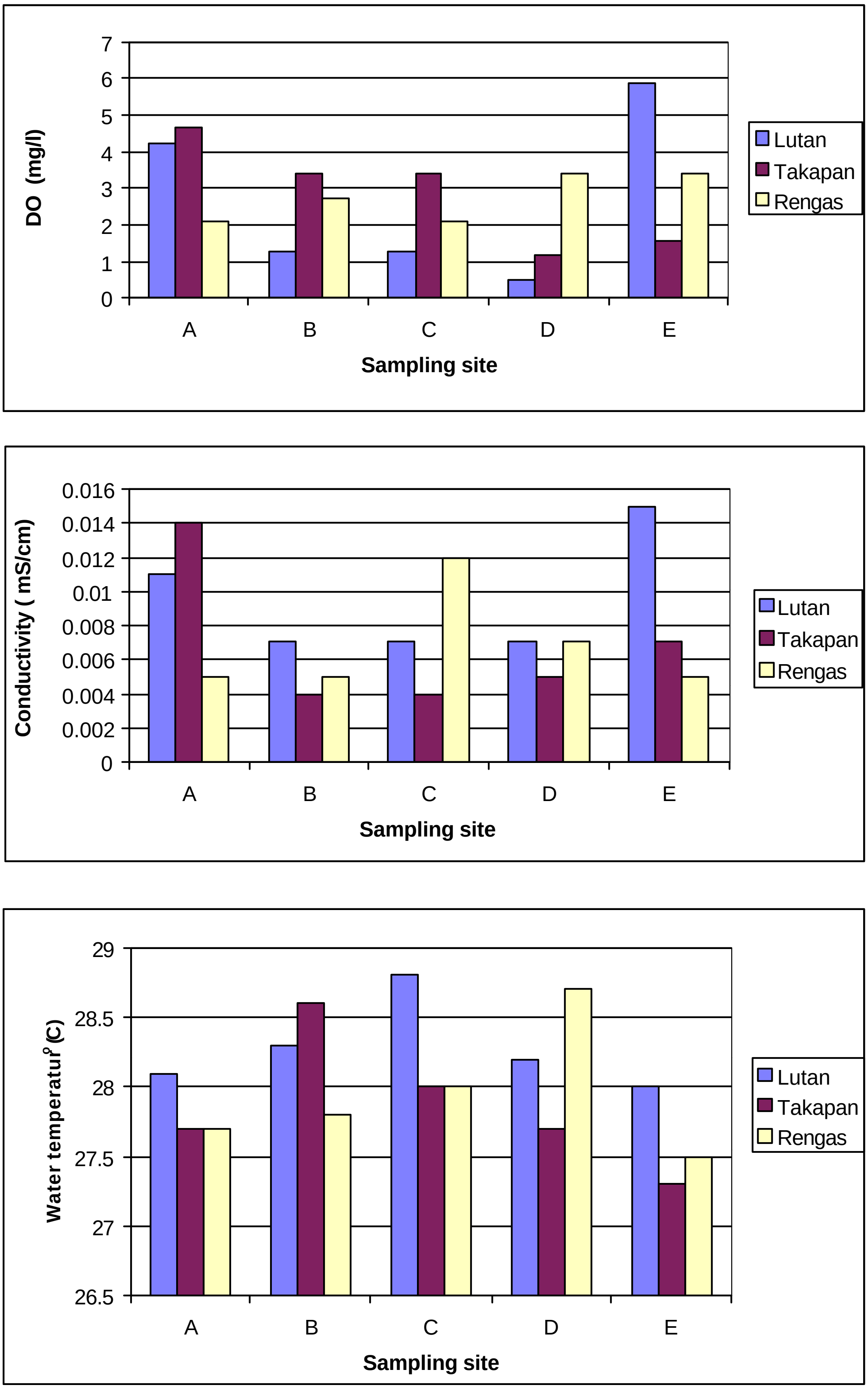
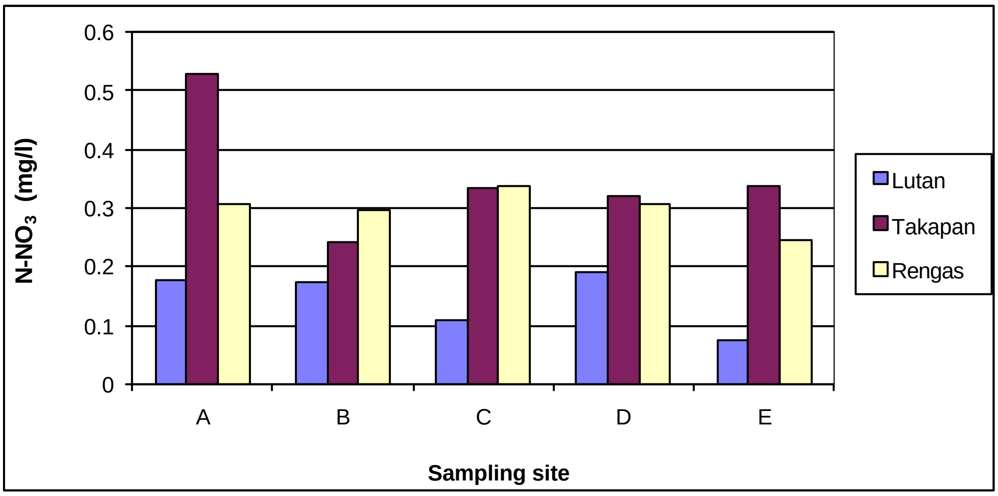
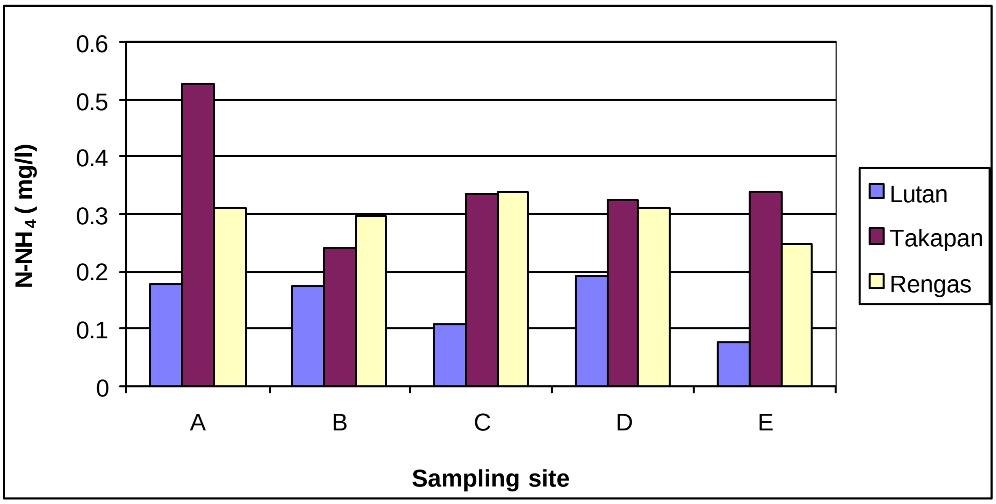


Fig. 5. Water quality of Lakes Lutan, Takapan and Rengas





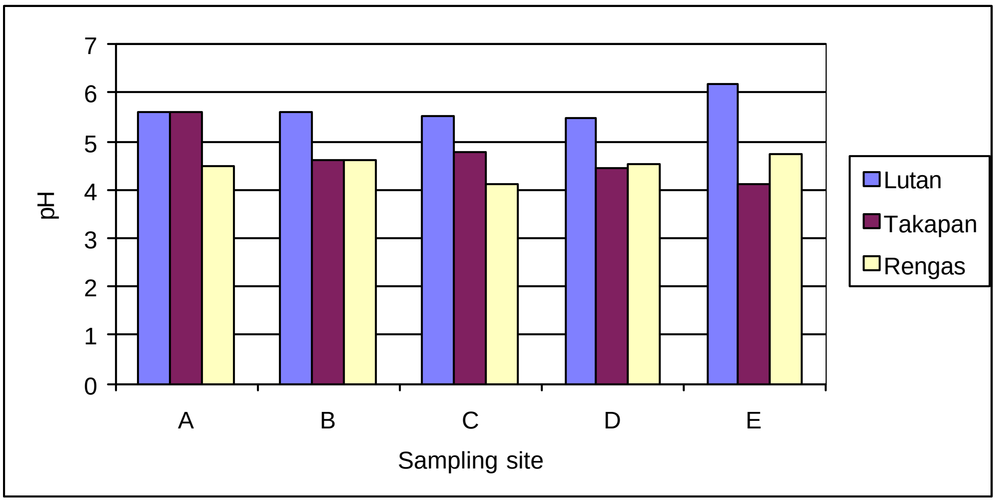
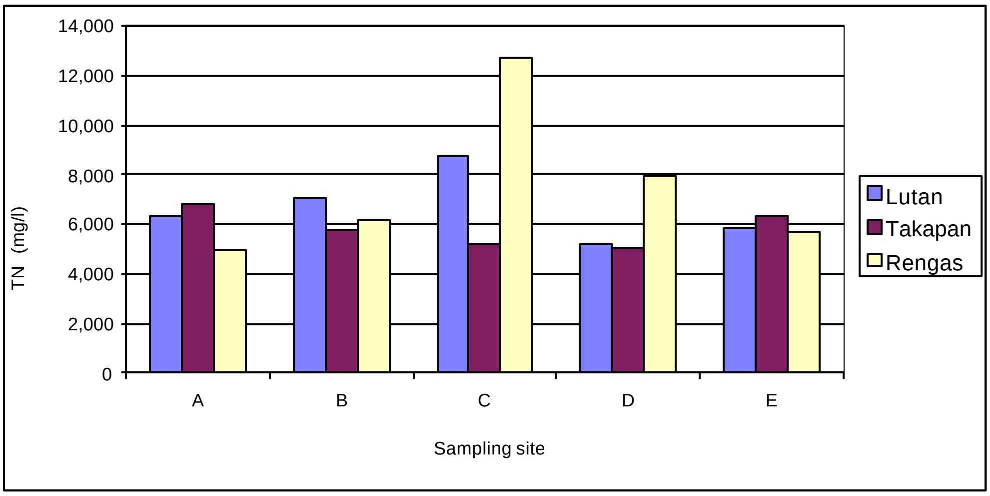
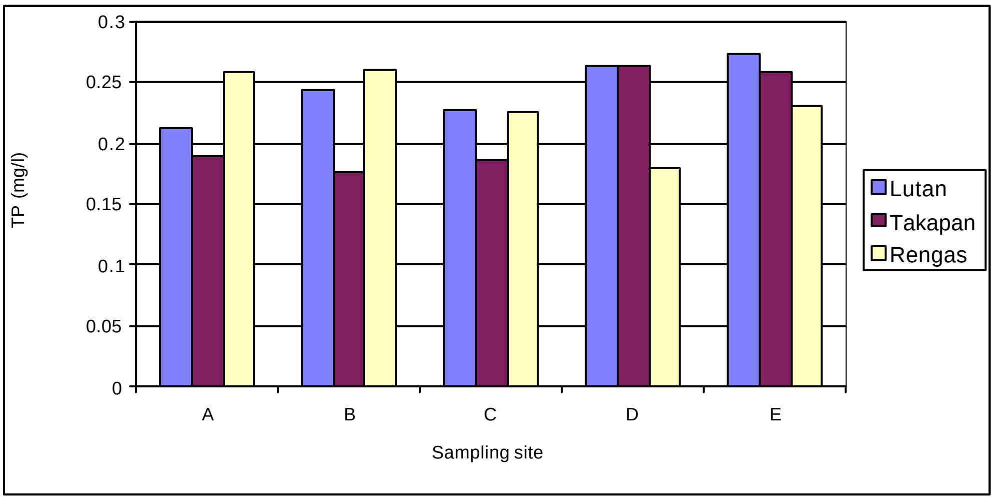


Fig. 5. Water quality of Lakes Lutan, Takapan and Rengas (continued)





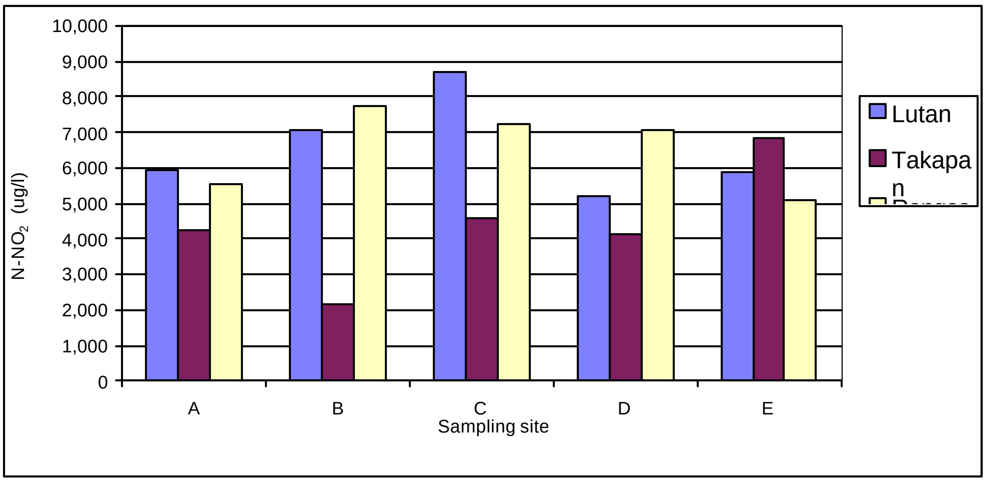


Fig. 5. Water quality of Lakes Lutan, Takapan and Rengus (continued)

Tabel 3. Average density (individuals/l) of phytoplankton in Lake Lutan

Taxon group	Sampling site				
	River habitat		Pelagic / oxbow lake system		River habitat
	A	B	C	D	E
CHRYSOPHYTA					
Actinocyclus	46	-	9	-	23
Asteronella	152	-	-	-	28
Cyclotela	-	-	-	-	8
Diatoma	56	-	29	-	28
Eunotia	-	5	-	-	5
Fragilaria		-	23	-	55
Gomphonema	-	-	-	-	5
Meridion	6	-	-	-	-
Navicula	34	42	92	-	89
Pinnularia	9	-	-	-	-
Surirella	24	-	9	20	9
Synedra	51	-	28	7	58
CHLOROPHYTA					
Ankistrodesmus	189	14	5	-	14
Basicladia	5	48	69	-	19
Chlamidomonas	-	7	345	-	-
Cladophora	94	-	9	7	154
Closterium	266	55	75	25	58
Cosmarium	-	14	97	10	5
Desmidium	5	7	5	-	9
Dermatophyton	5	-	-	-	9
Euastrum	5	-	-	-	-
Genicularia	19	-	-	-	-
Gloeocystis	-	-	-	-	5
Gonatozygon	50	28	106	41	18
Ichthyocercus	-	7	-	-	-
Kirchneriella	-	14	-	-	-
Micrasterias	-	7	-	-	-
Oedogonium	5	-	-	-	-
Pediastrum	6	-	-	-	-
Penium	6	-	-	-	-
Pleurotaenium	5	20	65	20	-
Rhizoclonium	-	28	-	14	-
Sphaerocystis	-	-	-	-	5
Scenedesmus	6	-	-	-	-
Spirogyra	5	14	14	52	16
Tetraedron	-	-	-	-	8
Trochisia	30	28	733	176	35
Ulotrix	22	7	18	-	14
Zygnema	-	-	-	7	-
CYANOPHYTA					
Anabaena	18	46	32	-	-
Aphanocapsa	-	20	-	7	-
Aphanizomenon	-	14	-	-	-
Coelosphaerium	-	7	-	-	-
Hapalosiphon	-	62	-	-	-

Table 3 (continued)

Taxon group	A	B	C	D	E
Lyngbya	-	-	5	-	-
Microcystis	-	35	18	-	5
Nodularia	-	-	5	-	-
Nostoc	5	-	-	-	-
Oscillatoria	33	35	18	41	23
Rivularia	-	-	-	-	5
Spilurina	37	14	18	-	5
EUGLENOPHYTA					
Euglena	55	14	221	-	61
Phacus	-	-	414	-	8
Trachelomonas	-	7	990	14	-
Total number (individuals/l)	1249	599	3495	441	746
Index of diversity	0.871	1.068	0.697	0.539	0.959

Table 4. Average density (individuals/l) of phytoplankton in Lake Takapan

Taxon goup	Sampling site				
	River habitat		Pelagic/ oxbow lake system		River bahitat
	A	B	C	D	E
CHRYSOPHYTA					
Cyclotela	0	5	0	0	0
Cymbella	35	0	0	0	35
Diatoma	-	-	52	-	-
Eunotia	35	15	41	-	-
Fragilaria	84	0	41	0	0
Gomphonema	-	-	21	-	-
Meridion	118	-	-	-	-
Navicula	308	11	38	17	83
Synedra	851	-	414	-	-
Surirella	49	-	-	17	-
Tabellaria	278	36	392	-	276
CHLOROPHYTA					
Actinastrum	64	-	-	-	-
Bambusina	-	-	5	-	-
Characium	-	-	293	-	-
Cladophora	35	-	-	-	-
Closterium	428	106	64	-	110
Cosmarium	-	52	10	-	-
Crucigenia	-	15	34	-	-
Desmidium	-	-	5	-	-
Dictyospaerium	23	-	-	-	23
Excentrospharea	-	31	17	55	-
Gonatozygon	35	54	28	10	55
Hyalotheca	-	-	10	-	-
Oedogonium	35	-	-	-	-
Oocystis	-	283	-	-	-
Ophiocytium	-	7	-	-	-

Table 4 (continued)

Taxon group	A	B	C	D	E
Pediastrum	-	-	-	-	28
Quadrigula	-	-	35	-	-
Scenedesmus	-	15	-	-	62
Spirogyra	511	11	41	7	-
Staurastrum	26	-	10	19	-
Trochisia	241	5	133	-	55
Ulotrix	135	25	31	-	-
Stigonema	-	15	5	-	-
Xantidium	23	-	-	-	-
CYANOPHYTA					
Anabaena	-	111	22	10	78
Aphanocapsa	-	-	52	-	28
Chroococcus	-	-	-	-	469
Dicothtrix	-	70	37	14	-
Lyngbya	35	-	-	-	-
Microcystis	69	-	-	-	138
Nostoc	-	10	33	-	-
Oscillatoria	-	16	33	-	-
EUGLENOPHYTA					
Euglena	76	11	67	-	5
Phacus	35	-	-	-	28
Trachelomonas	-	-	17	10	7
PYRROPHYTA					
Glenodinium	-	-	14	-	-
Peridinium	23	-	-	-	7
Total number (individuals/l)	3337	904	1995	149	1487
Index of diversity	0.824	0.687	0.902	0.563	0.666

Table 5. Average density (individuals/l) of phytoplankton in Lake Rengas.

Taxon goup	Sampling site				
	River habitat		Pelagic/ oxbow lake system		River habitat
	A	B	C	D	E
CHRYSOPHYTA					
Actinocyclus	5	-	-	14	-
Asteronella	24	124	-	156	-
Centritractus	20	-	-	-	-
Cyclotela	7	25	-	41	-
Cymbella	-	5	-	-	7
Diatoma	58	-	-	-	-
Eunotia	20	58	20	-	-
Fragilaria		20	-	-	-
Melosira	-	5	-	-	-
Meridion	-	20	-	-	-
Navicula	7	72	-	7	-
Surirella	7	11	-	7	-
Synedra	25	-	-	7	-
Tabelaria	118	43	-	7	55

Table 5 (continued)

Taxon group	A	B	C	D	E
CHLOROPHYTA					
Ankistrodesmus	39	-	-	27	-
Basicladia	59	-	-	7	-
Cladophora	-	-	89	-	-
Chlamydomonas	-	5	55	-	20
Closterium	311	381	30	346	255
Cosmarium	6	-	30	-	-
Desmidium	-	9	-	28	-
Echinosphaerela	20	-	-	-	-
Gonatozygon	166	9	-	89	-
Kirchneriella	20	-	89	205	50
Microspora	-	-	-	82	-
Oedogonium	-	20	35	574	30
Oocystis	-	-	-	7	-
Pediastrum	20	-	30	-	61
Rhizoclonium	-	-	146	7	-
Staurastrum	20	-	7	20	-
Spirogyra	9	23	-	7	27
Stigeoclonium	-	-	-	82	-
Trochisia	87	63	-	20	-
Ulotrix	43	54	87	110	124
CYANOPHYTA					
Anabaena	680	31	-	30	491
Aphanocapsa	-	-	-	41	-
Asterocystis	-	-	-	-	207
Chroococcus	-	6	-	-	20
Holopedium	-	5	-	-	-
Lyngbya	-	5	48	-	41
Microcystis	98	20	-	-	386
Nodularia	-	6	-	-	-
Nostoc	32	6	-	144	991
Oscillatoria	114	7	20	-	27
Spilurina	20	13	-	-	-
EUGLENOPHYTA					
Euglena	57	13	7	30	7
Trachelomonas	36	-	-	-	-
PYRROPHYTA					
Peridinium	20	-	-	-	-
Total number (individuals/l)	2948	1026	693	2095	2799
Index of diversity	0.674	0.771	0.719	0.768	0.597

The composition and the density of phytoplankton at each site sampling of Lake Lutan, Takapan and Rungan are presented in Tables 3, 4 and 5. While the total density toxonomical group is presented in Fig. 6. In Lake Lutan , Euglenophyta were found at higher density with *Trachelomonas* as the dominant species. Correlation analysis showed that Euglenophyta had positive correlation with the water temperature (Table 6). The highest density was found in pelagic zone that was also high of water temperature.

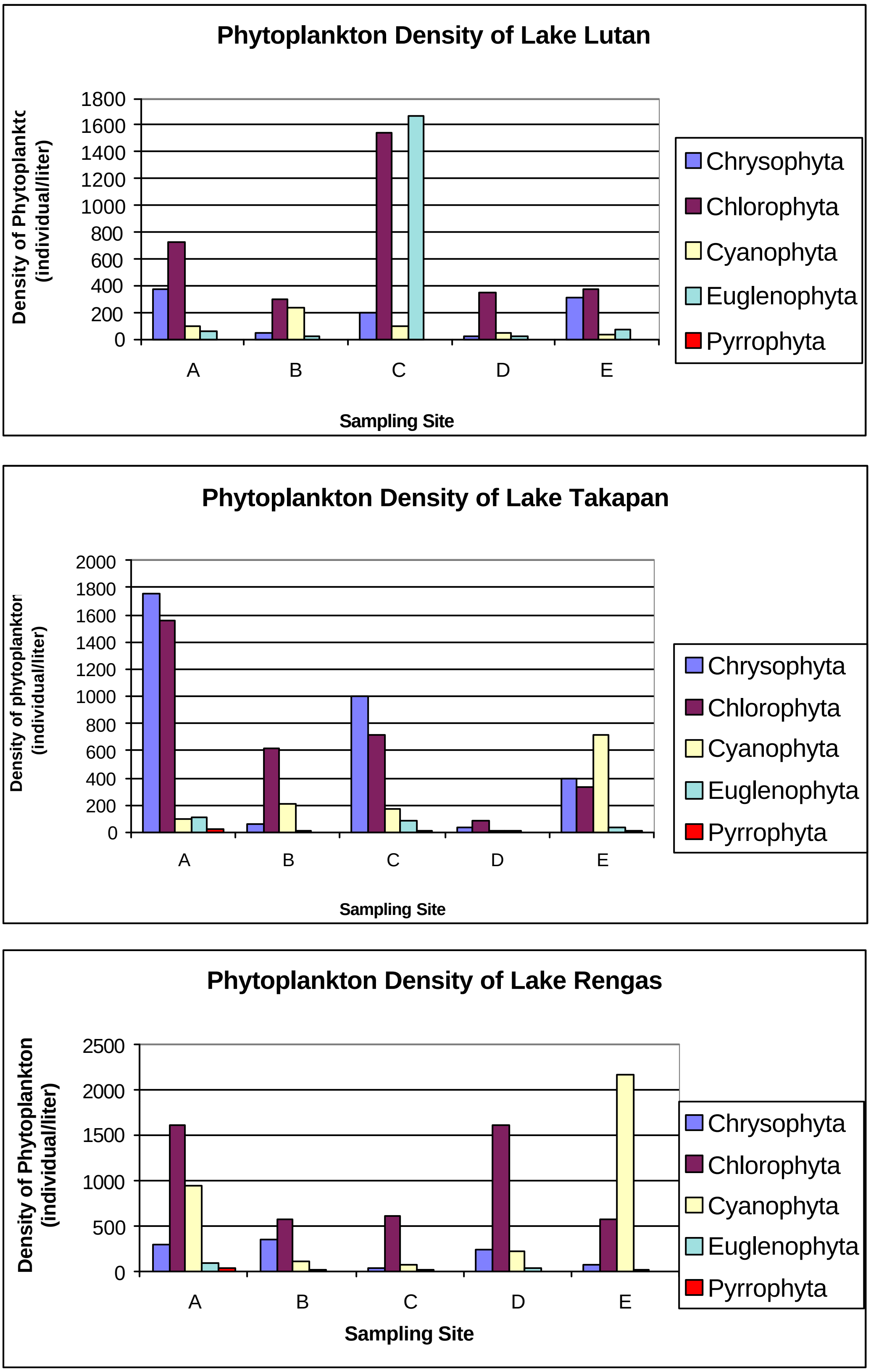


Fig. 6. Phytoplankton density of Lakes Lutan, Takapan and Rengas

Table 6. Regression analysis of phytoplankton and water quality parameters

Phytoplankton versus water quality	Equation of regression analysis	R and F values
1. Lake Lutan		
Cyanophyta vs. N-NO_3	Cyano= -73.517 + 211.96 N-NO_3	R = 0.930, F =170.8*
Euglenophyta vs. WT (water temperature)	Eugleno= -60672.8 + 2158.35 WT	R = 0.922, F = 17.18
Cyanophyta vs. N-NO_2	Cyano = 5362.25 - 714.01N-NO_2	R = 0.922, F = 17.23*
2. Lake Takapan		
Chrysophyta vs. N-NH_4	Chryso = -1524.24 + 6163.96 N-NH_4	R = 0.890, F = 11.43*
Chlorophyta vs. pH	Chloro = 917.60 - 360.74 pH	R = 0.925, F = 17.98*
Diversity vs. N-NO_3	Diversity = -0.4246 + 1.1872 N-NO_3	R = 0.890, F = 11.43*
3. Lake Rengas		
Euglenophyta vs. WT	Eugleno = 2.5646 + 0.3278 WT	R = 0.989, F =144.6*
Diversity vs. N-NO_2	Diversity = -3.8904 + 14.768 N-NO_2	R = 0.929, F =19.00*

* $P<0.05$

Euglenophyta shows preference for high pH value (5.5 to 6.1) and is frequently associated with nutrient rich sites (Round, 1981; Mataloni and Tell, 1996). The water quality analysis shows that Lake Lutan has higher values of pH and nutrients especially nitrite than in Lake Takapan and Lake Rengas (Fig. 5). The high density of phytoplankton in Lake Lutan was found in the pelagic zone. The high density of Chrysophyta was found in river habitat or the Kahayan River segment.

In Lake Takapan, Chrysophyta were found in higher density with *Synedra* as the dominant species. The higher density of Chrysophyta was found in river habitat or the Kahayan River segment (site A). Study on African river reported that the main river was inhabited mainly desmids and diatoms (Welcome, 1979). It may be due to turbulence, some species like heavy desmids and diatoms can be resuspended in the river habitat. At site C as a part of the Lake Takapan also has higher density of Chrysophyta than two others sites (sites B and D). Site C is near the Kahayan River segment and received the water directly from the Kahayan River segment. Correlation and regression analyses show that Chrysophyta in Lake Takapan has positive correlation with ammonia (N-NH_4). Species from group of Chlorophyta is dominated by *Closterium* and *spirogyra* that were also high in the Kahayan River segment (site A). *Closterium* is a group from desmid that was reported mostly inhabited river habitat.

In Lake Rengas the dominant phytoplankton is some species from Cyanophyta group, such as *Anabaena* and *Nostoc.* The other species which show high densitiy are *Closterium* and *Oedogonium,* a group of Chlorophyta. The high density of Cyanophyta was observed in river habitat or segment of the Rungan Rver (sites A and C). In this way there is no significant correlation between the density of Cyanophyta and water quality parameters, although a study Mataloni and Guilermo (1995) have reported that Cyanophyceae show a preference for lower pH. In Lake Rengas the average value of pH is lower than Lakes Lutan and Takapan (Fig. 5).

Based on the total density of phytoplankton for each taxonomical group in these three lakes (Fig. 6), in Lake Lutan the highest density of phytoplankton was found at the middle of the lake while in Lake Takapan and Lake Rengas the highest density of phytoplankton were found in the river habitat or segment of the Kahayan and Rungan Rivers. This is due probably to the differences of morphology and water quality. Lake Lutan is shallower than other two lakes, which cause the faster nutrient turnover.

The diversity index value of phytoplankton in lake Lutan, Takapan and Lake Rengas are not difference clearly between oxbow lake system and river habitat.

Conclusion

Dominant phytoplankton differed between Lakes Lutan, Takapan and Rengas. The dominant phytoplankton were Euglenophyta in Lake Rengas, Chrysophyta in Lake Takapan and Cyanophyta in Lake Rengas. It seemed that the water quality condition exerted an impact on the composition of phytoplankton, which was shown by correlation analyses of water quality and each group of these phytoplankton.

Based on the total density of phytoplankton, their distribution differed within lakes and rivers. The highest density of phytoplankton was observed in the pelagic zone in Lake Lutan while in Lakes Takapan and Rengas the highest density was observed in the river habitat. It was due probably to the differences of geomorphology and water quality condition.

References

Anonymous, 1975. *Standard Methods for the Examination of Water and Waste Water. 14th edn*. APHA-AWWA-WCR, 1-193 pp.

Goldman, C. R. and Horne, A.J. 1983. *Limnology*. McGraw-Hill, London-Mexico-Sidney, 464 pp.

Hartoto, D.I. and Awalina.1999. Nitrogen fractions variation in some oxbow lakes of Central Kalimantan. *Paper presented as Poster on Seminar on Limnological Research Activities 1998/1999, Research and Development Center for Limnology, Indonesian Institute of Sciences, Cibinong, 13 April 1999I*, 19 pp.

Mataloni, G. and Tell, G. 1996. Comparative analysis of the phytoplankton communities of a plat bag from Tierra del Fuego (Argentina). *Hydrobiologia*, 325: 101-112.

Odum, E.P. 1971. *Fundamentals of Ecology. 3rd edn*. W.B. Sounders, Philadelphia 574 pp.

Prescott, G. W. 1963. *The Freshwater Algae*, W.M. Brown Company Publisher, 347 pp.

Round, F.E. 1981. *The Ecology of Algae*. Cambridge University Press, London-New York-Melbourne-Sydney, 653 pp.

Scott, A. M. and Prescott, G.W. 1961. *Indonesian Desmid*. Hydrobiologia. XVII. Acta Hydrobiologica Hydrographica et Trostistologica. Dr. W. Junk, Den Haag, 123 pp.

Welcome, R.L. 1979. *Fisheries Ecology of Floodplain Rivers*. Longman, London-New York, 317 pp.

Yustiawati and Hartoto, D. I. 1999. Phosphorus nutrient fingerprints of some inland water types in Central Kalimantan. *Paper presented as Poster on Seminar on Limnological Research Activities 1998/1999, Research and Development Center for Limnology, Indonesian Institute of Sciences, Cibinong, 13 April 1999*, 23 pp.

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Seasonal Changes of Phytoplankton Species in Relation to Environmental Factors in an Oxbow Lake of Central Kalimantan, Indonesia

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Abstract

Dystrophic lakes are distributed widely in tropical region and it is generally assumed that desmids and diatoms are dominant and have low biomass. In the present study, phytoplankton and its vertical composition were observed and their biomasses were estimated in Lake Sabuah, Central Kalimantan, Indonesia during 8 May to 22 July 1999. Dominant species were *Cryptomonas* spp. and *Chlamydomonas* sp. from 8 May until 8 July and the density of *Chlamydomonas* sp. increased markedly. During the period from 8 to 22 July, densities of *Tabellaria* sp., *Synedra* sp. and *Gymnodinium* spp. increased. Total biomass of the phytoplankton ranged widely from 0.4 to 65.8 mgC/m^3 throughout the observation period. Biomass percentages of *Cryptomonas* spp. and *Chlamydomonas* sp. changed from 9.5% to 83.5% in the surface water during the observation period and the total biomass increased simultaneously with the dynamics. Biomasses of *Synedra* sp. and *Tabellaria* sp., which increased remarkably on 22 July, were 33.6% in the surface water. Most phytoplankton cells were distributed in the top 1.0 m of the water column throughout the observation period. Thus, vertical profile of phytoplankton agreed well with the depth of euphotic zone of 0.8-1.49 m.

Introduction

The knowledge of aquatic organisms in Indonesia is still poor although there is information on the Mahakam River system in Kalimantan, the Musi River system and some lakes in Sumatra (Mizuno, 1980), attached algae in 5 lakes in Sumatra (Watanabe, 1987), a review on meteorology, hydrology, geographical features and aquatic systems of Indonesia (Rasi *et al.,* 1999), biological features of some lakes in Kalimantan (Sulastri, 1998). These studies didn’t focus much on the succession of phytoplankton species, their biomass and vertical distribution, based on long-term surveys.

Dystrophic lakes are distributed widely in tropical region and it is generally assumed that desmids and diatoms are dominant in these lakes and have low biomass or density (Mizuno, 1980; Vegas-Vilarrúbia, 1995; Sulastri *et al*., in press). In the meanwhile, there are a few studies which reports that flagellates appeared in certain lakes (Croome, 1988; Jorgen, 1998). In the past studies in Indonesia, phytoplankton samplings might have been conducted mainly with plankton net. Because of that, there were some cases in which small flagellates were possibly dropped out of the samples.

In the present study, phytoplankton and its vertical composition were observed using a sedimentation chamber and their biomasses were estimated.

Study site

Surveys were conducted at Lake Sabuah that is located in the Kahayan River system in Central Kalimantan, Indonesia. Samples were taken at the centeral part (2°3’19”S, 113°56’37”E) of the lake (Fig. 1). The lake lies ca. 15 km north from Palangkaraya, the capital city of Central Kalimantan, and has 0.61 km^2 surface area. This oxbow lake is connected to the Kahayan River via small channels. When the water level that is influenced mainly by precipitation is low, inflow from the Kahayan River decreases. Water color of the river is yellowish brown, whereas that of Lake Sabuah is black.

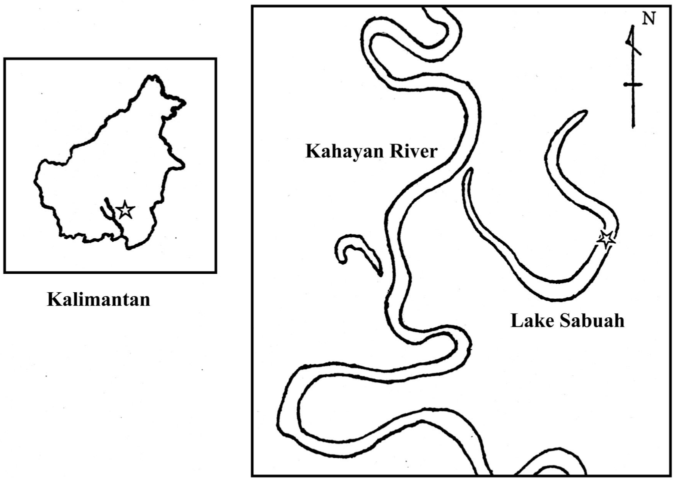

Fig. 1. Lake Sabuah in Central Kalimantan.

Methods

Surveys were conducted at the central part of Lake Sabuah on 8 and 22 May, 8 June and 8 and 22 July 1999. Water depth was measured with an echo sounder (Furuno, Japan). Water temperature and concentration of dissolved oxygen were measured in situ with a DO meter (YSI Model 55, Yellow Springs Instruments, USA) at every 0.5 m from surface to bottom. Quantum flux density was measured at water depth of 0, 0.5, 1.0, and 1.5 m with an underwater quantum sensor (LI192S, LI-COR, USA) and as a reference an abovewater quantum sensor (LI190S, LI-COR, USA) equipped with a data logger (LI-6000, LI-COR, USA). Water samples were taken from 6 depths (0, 0.5, 1.0, 2.0, 4.0, 8.0 m) using a 2-l Van-Dorn water sampler. Specific conductivity (SC) and pH were measured for the sampled water with a combined pH-SC meter (ES-14, Horiba, Japan).

Subsamples of lake water were taken to analyze phytoplankton, chlorophyll *a* and particulate organic carbon (POC).

For the analysis of phytoplankton species, 150-500 ml of lake water was sampled in a 500-ml polyethylene bottle and fixed with 1% Lugol's iodine solution. After phytoplankton were sedimented and concentrated in the laboratory, the supernatant was removed by siphoning. The sediments and some water were poured into 50-ml polyethylene bottle. Identification and enumeration of phytoplankton species were conducted using a Utermöhl chamber (20 ml) with inverted microscope (Nikon TMS, Japan). The length and width of predominant species were measured and the volume was calculated after Miyai *et al.* (1988). Thereafter, carbon content of the cell was calculated using a formula by Strathmann (1967). Biomass of predominant species was determined by multiplying cell density by carbon contents.

For the analysis of chlorophyll *a*, 100-400 ml of the water was passed through a grass fiber filter (Whatman GF/F, not precombusted). The filter was placed in a 15-ml polypropylene centrifuge tube with 8 ml of pure methanol. After that, this tube was wrapped with aluminum foil and stored in a freezer until analysis. Later the tube was centrifuged at 3000 rpm for 20 min and absorbance of the supernatant was determined at 750 nm and 664 nm with a spectrophotometer (DU-65, Beckman, USA). Chlorophyll *a* concentration was calculated after Marker *et al*. (1980).

A subsample of 100-300 ml of the lake water was passed through a Whatman GF/F glass-fiber filter precombusted at 450°C for 3 h to analyze POC concentration. The filter was wrapped with aluminum foil and stored in a freezer until analysis. The filter was ground to powder and analyzed with an elemental analysis system (Vario EL, Germany).

Results

Environmental factors

Water depth changed from 8.9 to 10.8 m in the sampling period and it became the shallowest on 8 June 1999: the maximum difference of water depth was about 2.0 m during the observation period (Fig. 2).

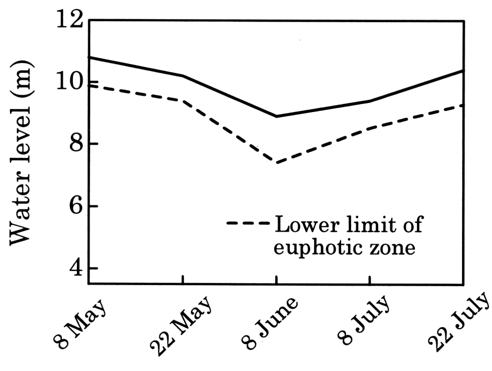

Fig. 2. Temporal changes of water level (m) and the depth of euphotic zone at the center of Lake Sabuah from 8 May to 22 June 1999.

Water temperature varied from 28.6 to 31.2°C in the surface water (0 m depth) and was the lowest on 22 July 1999. A distinct stratification was observed (1.3-3.6°C/m) within the top 1 m depth. Below 2 m depth, temperature gradient in the water column was small (Fig. 3a). Dissolved oxygen (DO) concentration changed from 1.34 to 4.60 mg/l in the surface water. The concentration was lowest on 8 June 1999. Except a slightly higher value on 22 July, DO concentration was less than 1.0 mg/l under the depth of 1.5 m. On 22 July, there were 2 DO peaks vertically in the water column (Fig. 3c). Specific conductivity (EC) varied from 2.47 to 4.27 mS/m in the surface water. The value was the highest on 8 June. The values decreased as it reached deeper sites in the column on 22 May and 8 June 1999. On other days, there were 2 peaks vertically in the water column. Especially the values were over 5.00 at the depth of 4.0 and 8.0m on 8 June (Fig. 3d).

Chlorophyll *a* concentration in the surface water ranged from 2.1 to 19.0 μg/l during the observation period. The concentration was highest on 8 July and on every sampling occasion the value decreased vertically to deeper depths (Fig. 4a). Concentrations of particulate organic carbon (POC) and particulate organic nitrogen (PON) in the surface water ranged from 0.78 to 1.92 mg/l and from 0.10 to 0.88 mg/l, respectively. Dynamic patterns of POC and PON were similar (Fig. 4b, c).

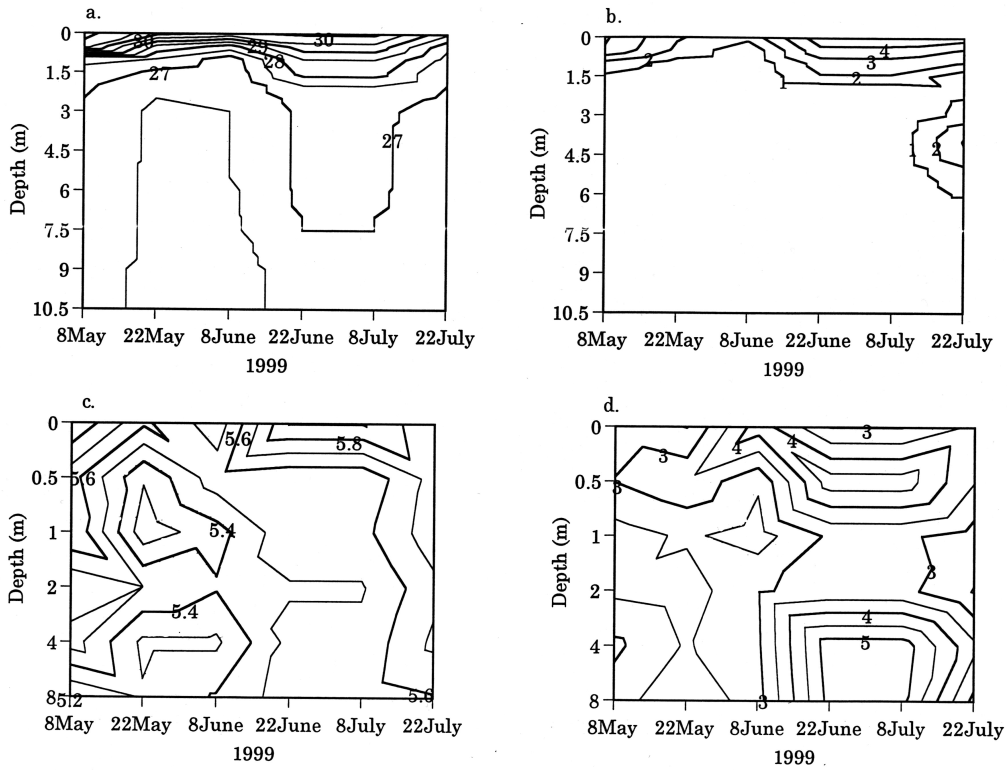

Fig. 3. Depth-time isopleths of environmental factors in Lake Sabuah from 8 May to 22 June 1999. a: water temperature (°C); b: dissolved oxygen concentration (mg/l); c: pH; d: specific conductivity (mS/m).

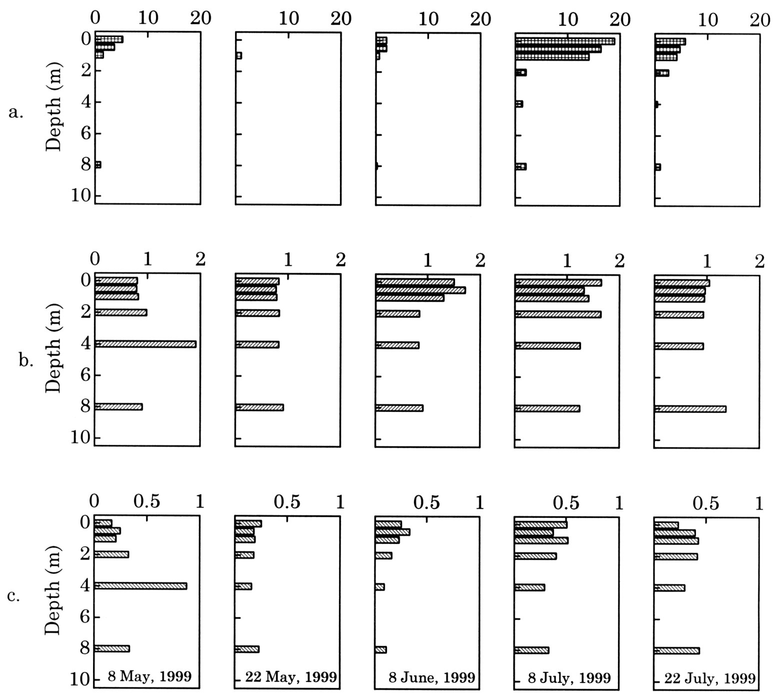

Fig. 4. Depth profile of concentration of (a) chlorophyll *a* (μg/l), (b) POC (mg/l) and (c) PON (mg/l) in Lake Sabuah from 8 May to 22 June 1999.

Phytoplankton

Phytoplankton taxa appeared were mainly *Chroococcus* spp. (Cyanophyceae), *Tabellaria* sp., *Synedra* sp. (both Bacillariophyceae), *Gymnodinium* spp. (Dinophyceae), *Cryptomonas* spp. (Cryptophyceae), *Phacus* sp., *Trachelomonas* sp. (both Euglenophyceae) and *Chlamydomonas* sp. (Chlorophyceae). Dominant species were *Cryptomonas* spp. and *Chlamydomonas* sp. from 8 May until 8 July and the density of *Chlamydomonas* sp. increased markedly (Fig. 5a, b). Individual numbers of *Trachelomonas* sp. were stable throughout the time (Fig. 5c). *Chroococcus* spp. showed 3 different patterns of vertical profile throughout the sampling period: appearing only in the bottom layer, only in the surface layer and appearing both in the bottom and surface layers (Fig. 5d). During the period from 8 to 22 July, densities of *Tabellaria* sp., *Synedra* sp. and *Gymnodinium* spp. increased (Fig. 5e, f and g). *Phacus* sp. appeared only on 7 July with Its cell density was maximum at the depth of 1.0 m (Fig. 5h).

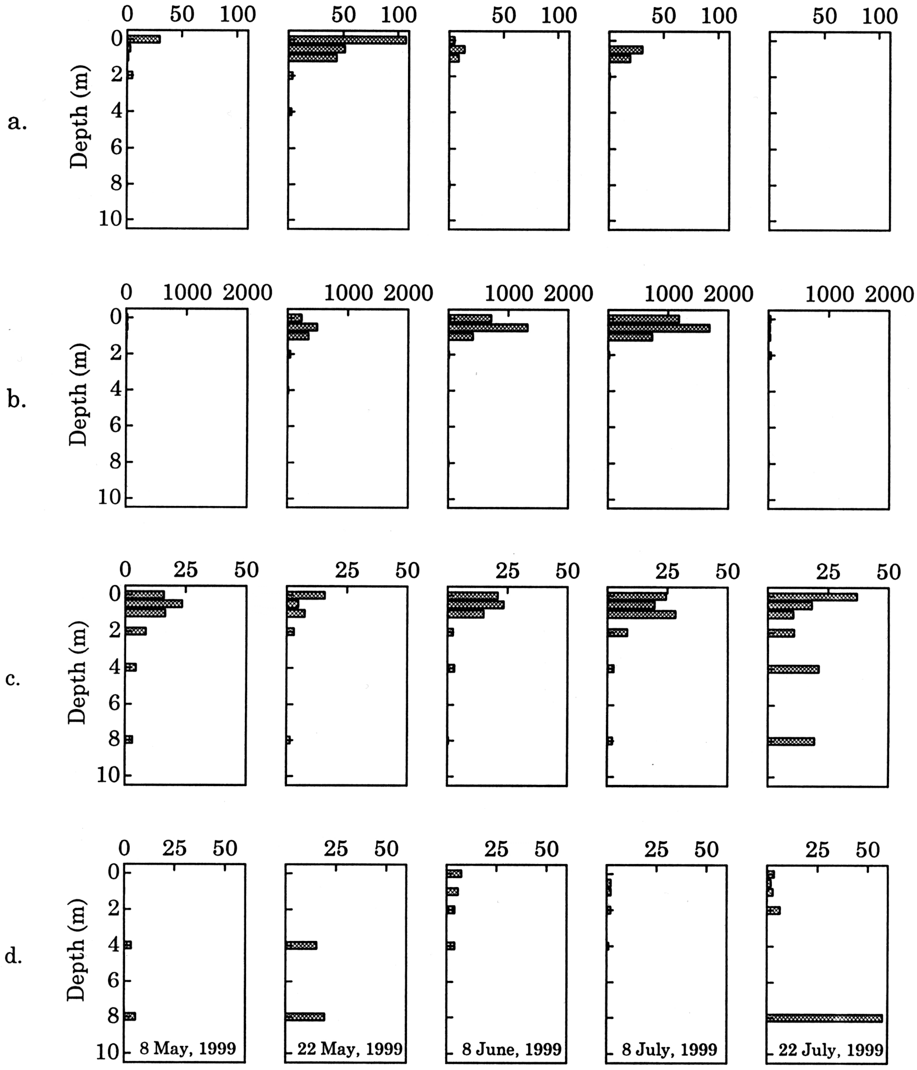

Fig. 5. Vertical distributions of phytoplankton in Lake Sabuah (inds./ml).
a: *Cryptomonas* spp.; b: *Chlamydomonas* sp.; c: *Trachelomonas* sp.; d: *Chroococcus* spp.; e: *Tabellaria* sp.; f: *Synedra* sp.; g: *Gymnodinium* spp.; h: *Phacus* sp.

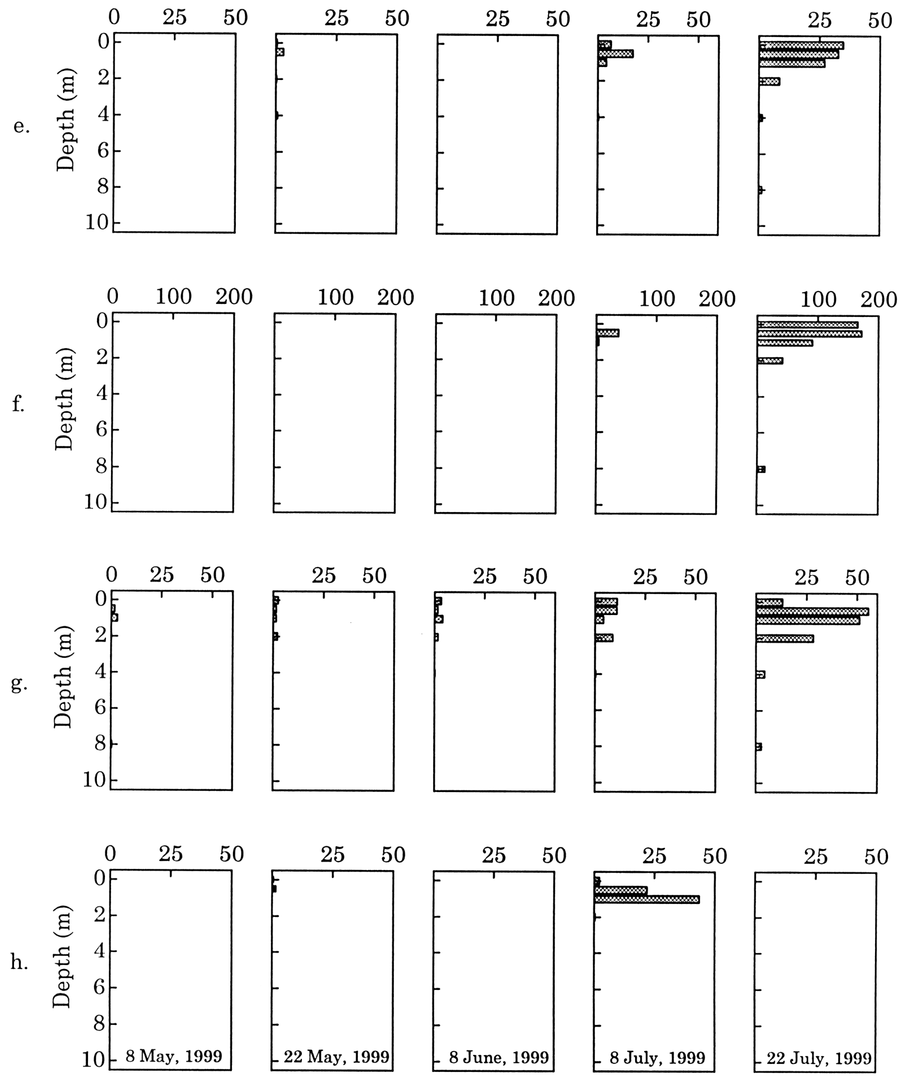

Fig. 5. (continued).

Average lengths of phytoplankton cells were 76.6-106.3 µm for *Tabellaria* sp., 46.6-49.1 µm for *Synedra* sp., 13.3-17.9 µm for *Gymnodinium* spp., 16.7-24.1 µm for *Cryptomonas* spp., 30.3 µm for *Phacus* sp., 11.6-16.0 µm for *Trachelomonas* sp. and 8.8-12.0 µm for *Chlamydomonas* sp. Thus, *Tabellaria* sp., *Synedra* sp., *Cryptomonas* spp. and *Phacus* sp. were categorized as microplankton and *Gymnodinium* spp., *Trachelomonas* sp. and *Chlamydomonas* sp. were categorized as nanoplankton. Average cell volumes were 396.4-728.1 µm^3 for *Tabellaria* sp., 48.2µm ^{3} for *Synedra* sp., 436.8-1605.0 µm ^{3} for *Gymnodinium* spp., 498.1-1113.4 µm^3 for *Cryptomonas* spp., 6462.0 µm^3 for *Phacus* sp., 575.4-1335.3 µm^3 for *Trachelomonas* sp. and 92.0-199.1 µm^3 for *Chlamydomonas* sp. (Fig. 6).

Total biomass of the phytoplankton ranged widely from 0.4 to 65.8 mgC/m^3 and the values were high in the surface layer (0-1.0 m depth) throughout the observation period. The biomass fluctuation in the surface water was influenced mainly by the dynamics of density of *Chlamydomonas* sp.: as the density became maximum (1693 inds./ml) at the depth of 0.5 m on 8 July, the value of biomass reached maximum(65.8 mgC/m^3) (Fig. 7).

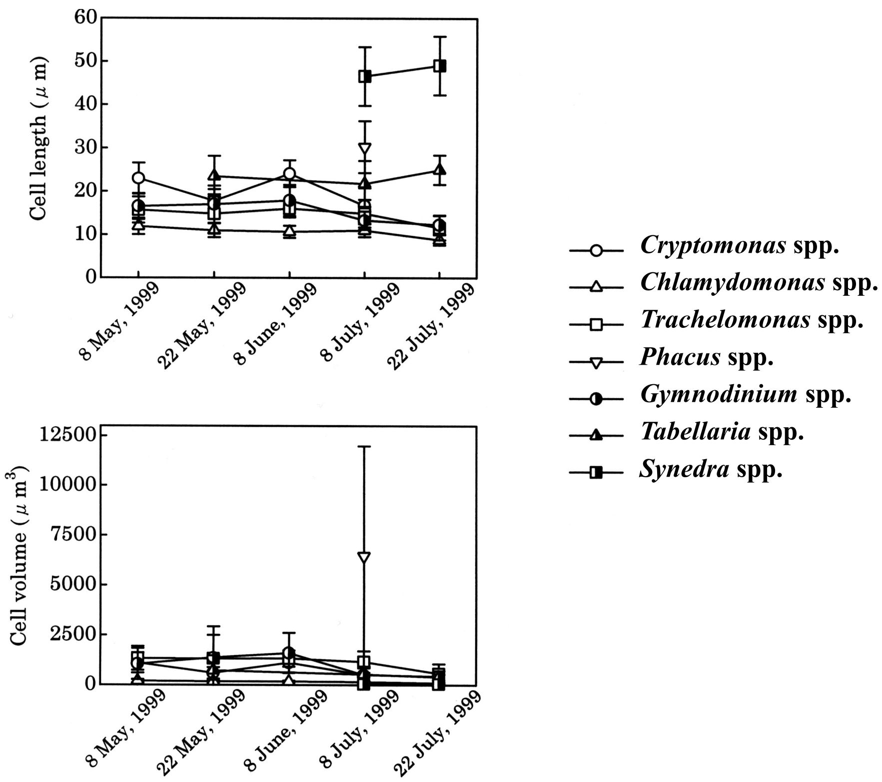

Fig. 6. Temporal changes of length (μm) and volume (μm^3) of phytoplankton cells in Lake Sabuah. A vertical bar indicates standard deviation.

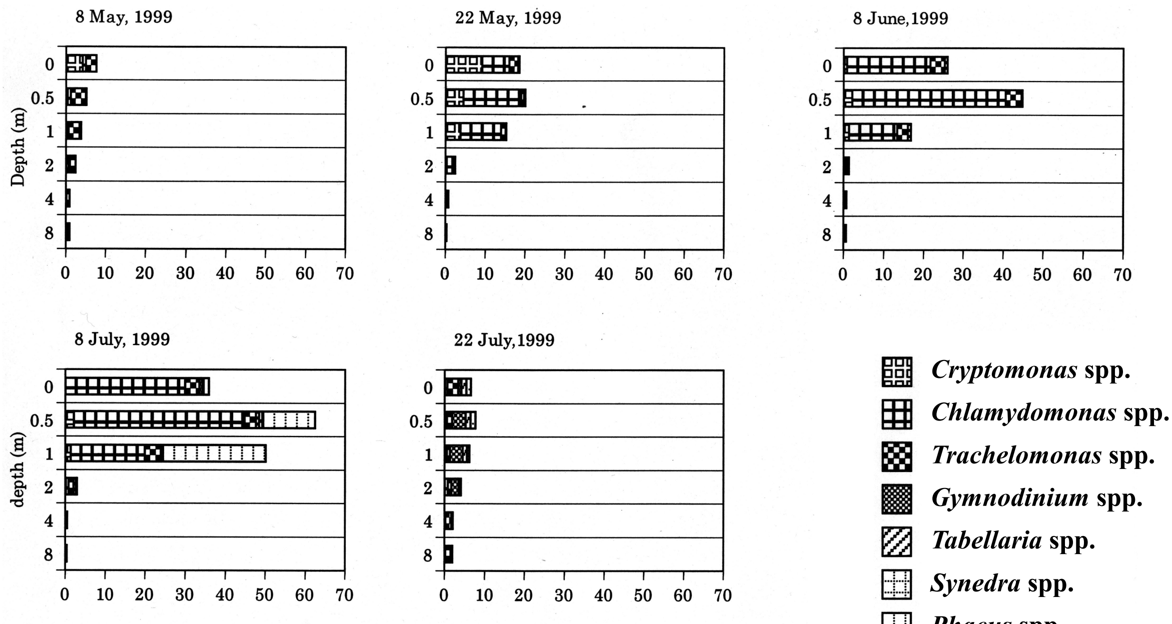

Fig. 7. Depth profile of biomass (mgC/m^3) of dominant phytoplankton species.

Percentage compositions of phytoplankton taxa in terms of biomass are shown in Fig. 8. Percentage of *Cryptomonas* spp. and *Chlamydomonas* sp. biomass changed from 9.5% to 83.5% in the surface water during the observation period. Particularly it reached 93.9% at 0.5 m depth on 22 May. Biomass of *Trachelomonas* sp. occupied constant proportion throughout the water column from 8 May to 8 June. It became larger in the bottom layers on 8 and 22 June. Biomass of *Chroococcus* spp. tended to occupy large proportions in bottom layers. Biomass percentage of *Phacus* sp. was 53.2% at 1.0 m depth on 8 June. Biomasses of *Synedra* sp. and *Tabellaria* sp., which increased remarkably on 22 July, were 33.6% in the surface water (Fig. 8).

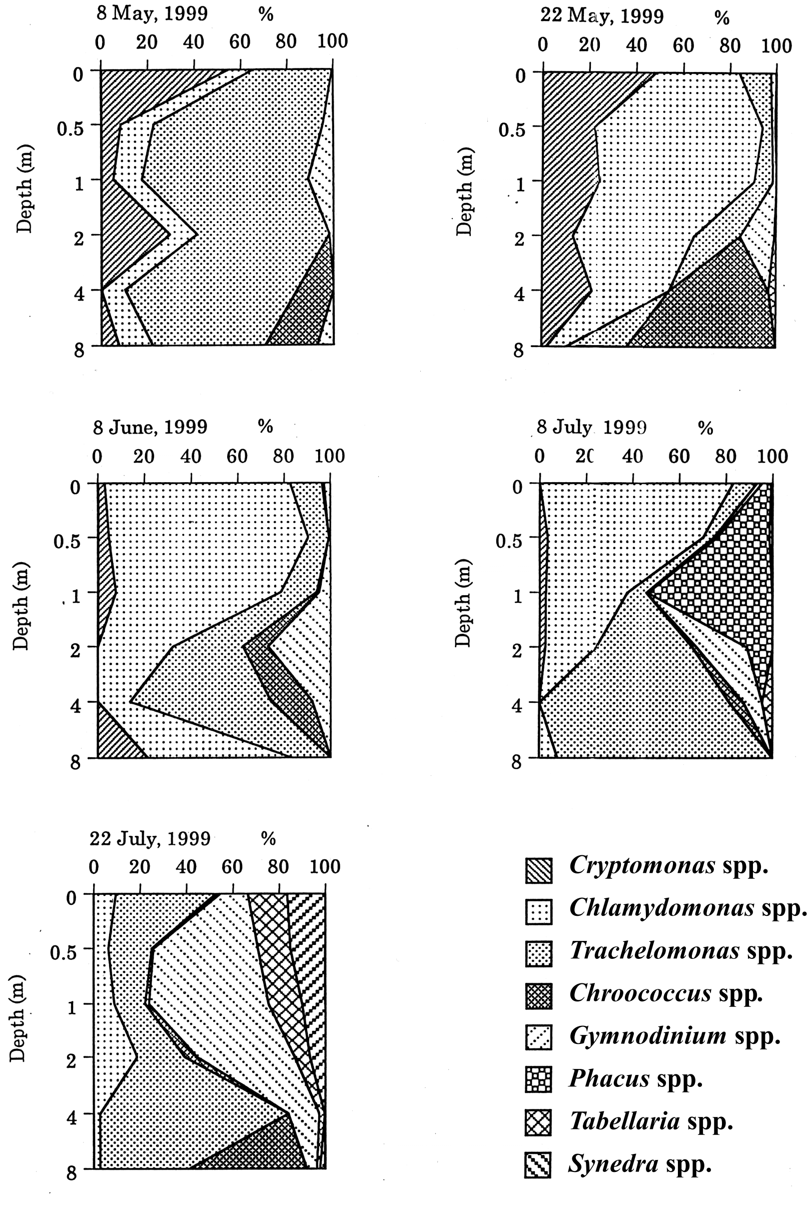

Fig. 8. Percentage composition of dominant phytoplankton species in terms of biomass from 8 May to 22 June 1999.

Discussion

In dystrophic lakes, low pH, amounts of ions and humic substances affect phytoplankton. Humic substances absorb light quanta and bind with ion and phosphorus, which regulate light and nutrient availability of phytoplankton (Wetzel, 1990). The conditions and large fluctuation of water level, which are unique in tropical region, regulate occurrence pattern of phytoplankton species. In the present survey, the water level fluctuated widely and became shallowest on 8 June. The features of other environmental factors were very low DO concentrations, relatively acidic water as shown by pH and very low specific conductivity.

Flagellates were dominant and its individual number increased markedly before 8 June, whereas diatoms and dinoflagellates were dominant thereafter. When carbon contents of each phytoplankton were applied to obtain the amount of biomass, total biomass increased simultaneously with increasing flagellates' cell number. The percentage fraction in total phytoplankton biomass was 90.3% (0.5 m, 8 June). Even when the densities of diatoms increased, their proportion to the total biomass of phytoplankton was only 33.6% (0m, 22 June). This was due to the fact that their volumes were small and that the carbon contents were smaller than other phytoplankton. Biomass of *Chroococcus* spp. tended to occupy higher proportion among the phytoplankton biomass in the bottom layer.

A heavy precipitation (ca. 115 mm/d) was observed on 20 June at a meteorological station in the campus of the University of Palangkaraya (02°12'55"S, 113°54'00"E) (Takahashi, 2000). Therefore it was not clear that which factor (water level change or large precipitation) strongly affected the succession of phytoplankton. The depth of euphotic zone was the deepest on 8 June when the water depth was shallowest, which might be caused by lesser inflow from the main stream, the Kahayan River. After the heavy precipitation, the depth of euphotic zone decreased to 0.88 m. This might be caused by the increased water inflow from the Kahayan River, which carried dissolved and particulate organic substances from the watershed into the lake.

Flagellates which have motile ability and diatoms which sink slowly due to their slender needle-like shapes may be able to stay longer in the euphotic zone. The present study revealed that these algae became dominant in a humic oxbow lake in Kalimantan. However phytoplankton species that have been reported from Indonesian freshwaters were mainly desmids and diatoms (Sulastri, in press). Flagellates will also be found in other aquatic systems in the further study observing plankton for the intact water. More detailed and long-term phytoplankton research as well as the quantitative and qualitative survey of attached algae are necessary to elucidate how hydrological conditions and humic substances affect phytoplankton population.

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References

Croome, R.L. and Tyler, P.A. 1988. Phytoflagellates and their ecology in Tasmanian polyhumic lakes. *Hydrobiologia*, 161, 245-253.

Fittkau, E.J., Irmler, U., Junk, J.W., Reiss, F. and Schmidt, G.W. 1975. Productivity, biomass, and population dynamics in Amazonian water bodies. *Amazonian Aquatic Systems*. pp 289-311. Springer-Verlag, New York.

Hirose, H. and Yamagishi, T. 1977. Illustrations of the Japanese Fresh-Water Algae. . Uchida Rokakuho Publishing (in Japanese).

Kristiansen, J. and Menezes, M. 1998. Silica-scaled Chrysophytes from an Amazonian flood-plain lake, Mussura Lake, northern Brazil. *Arch. Hydrobiol*., *Algological Studies*, 90: 97-118.

Lehmusluoto, P., Machbub, B., Terangna, N., Achmad, F., Boer, L., Timotius, K.H. and Goeltenboth, F. 1999. Limnology in Indonesia from the legacy of the past to the prospects for the future. In: Wetzel, R.G. and Gopal, B. (eds.), *Limnology in Developing Countries*, International Association for Limnology, pp 119-234.

Miyai, H., Mitsuzaki, K., Ogawa, K. and Sugihara, T. 1988 A simple method for the estimation of phytoplankton biomass based on cell morphology. *Bull. Plankton Soc. Jpn*., 35: 121-126 (in Japanese).

Mizuno, T. 1980. *Lakes and Forests in Southeast Asia*. Tokai University Press, Tokyo, 232 pp. (in Japanese).

Nakano, K., Watanabe, T. and Usman, R. 1987. A fundamental study of overall conservation of terrestrial and freshwater ecosystems in a montane region of Western Sumatra: Vegetation, land-use, and water quality. *Memoirs of the Kagoshima University Research Center for the South Pacific*, 8: 87-124.

Sulastri, Hartoto, D.I. and Sarnita, A. (in press) Comparative analysis of phytoplankton community in some inland habitat Central Kalimantan, Indonesia. *In: Proceedings of the International Symposium on Ecosystems in Borneo.*

Strathmann, R.R. 1967. Estimating the organic carbon content of phytoplankton from cell volume or plasma volume. *Limnol. Oceanogr*.,12: 411-418.

Takaashi, H. 2000. Meteorological data at the weather station in University of Palangka Raya. *Environmental Conservation and Land Use Management of Wetland Ecosystem in Southeast Asia, Annual Report for April 1999-March 2000*, Graduate School of Environmental Earth Science of Hokkaido University, pp. 100-106.

Takamura, N., Ishikawa, Y., Mikami, H., Mikami, H., Fujita, Y., Higuchi, S., Murase, H., Yamanaka, S., Nan-jyo, Y., Igari, T. and Fukushima, T. 1996. Abundance of bacteria, picophytoplankton, nanoflagellates and ciliates in relation to chlorophyll *a* and nutrient concentrations in 34 Japanese waters. *Jpn. J. Limnol*., 57: 245-259.

Vegas-Vilarrúbia, T. 1995. Distribution of the phytoplankton from the Guri Reservoir (Venezuela). *Hydrobiologia*, 310: 33-46.

Wetzel, R.G. 1990. Land-water interfaces: Metabolic and limnological regulators. *Verh. Internat. Verein. Limnol.*, 24: 6-24.

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pp. 423-435 (2000)

Effects of Artificial Mixing of Surface and Bottom Waters and Lime Treatment on the Abundance and Primary Productivity of Phytoplankton in Lake Sabuah

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Abstract

The objective of this research was to find out the effect of artificial turn over on primary productivity and abundance of phytoplankton in Lake Sabuah. Experiment was conducted in situ by constructing a series of transparent plastic bag-type enclosures for incubation of mixed bottom and surface water mass. These plastic enclosures were fixed to 2 floating rafts. The experimental design applied was complete randomize design (CRD) with one independent variable, percentage of bottom water to the total volume (500 l) of mixture of surface and bottom waters (0 %, 25%, 50%, and 75%) with 3 replications. Dependent variables were net primary productivity (NPP) and abundance of phytoplankton. A similar experiment was performed in which water's pH was increased to about 7 using limestone ($CaCO_3$), as comparative experiment to the acid lake.

The artificial mixing of bottom water into surface layer water significantly increased the primary productivity of phytoplankton in both non-lime (F = 24.65) and lime (F = 7.79) treatments. Phytoplankton abundance was not affected significantly by the artificial mixing of bottom and surface waters. However, the average phytoplankton abundance on days 1 to 3 after the start of incubation was higher than the initial abundance at all the levels of mixing rates. The significant difference of dependent variables with different levels of mixing rates was attributed to the close relation between mixing rate and phosphorous concentration during incubation.

Introduction

Lake Sabuah is an oxbow lake, which has low pH and quite high concentrations of iron (Fe) and orthophosphate (PO_4-P) in the bottom water. According to Torang (1995) and Buchar (1998) productivity of phytoplankton in this lake is low (oligotrophic). Consequently, a research is needed to find out new information about how to increase productivity of phytoplankton in Lake Sabuah and to know the potential of it growth under artificial turn over or controlled conditions. Phytoplankton are important natural food due to their ability to synthesize inorganic matters to organic ones through photosynthetic mechanism.

Phytoplankton are microscopic plants that suspend in the water column. The production rate is primarily a function of light intensity, nutrient and temperature. In addition, the primary limiting nutrient for phytoplankton is phosphorous (in the form of PO_4-P) (Goldman and Horne, 1983). A study conducted in 49 lakes of the United States has shown that phosphorous is limiting phytoplankton growth in 35 lakes, while nitrogen in 8 lakes (Miller *et al*., 1974 in Boyd, 1990).

The precipitation of phosphate is controlled by redox potential and pH, and a pure sodium phosphate solution will precipitate as iron phosphate ($FePO_4$) upon an introduction of iron. This process can be shown to vary with the oxygen level and pH of the water (Goldman and Horne, 1983). In the epilimnion, if the pH is low and the oxygen concentration is quite high, phosphate is easily reacting with Fe, Al, and Ca forming chemical compounds, and slowly sink to the hypolimnion because of the heavy weights of the compounds. Under the oxygen-depleted (anoxic) condition in the bottom area, the chemical compounds of phosphorous metal-alkali (Fe, Al, and Ca) are separated by producing the soluble phosphorous (Wetzel, 1983). The anoxic condition around the bottom area is called "phosphorous trap" (Jorgensen and Vollenweider, 1989). Moreover, in the presence of stratified water column, phosphate is trapped in the hypolimnion. Thus, phosphorous is not available for primary production of phytoplankton in the epilimnion. It becomes available if a physical-process turnover occurs, which, however, rarely happens in the tropical region.

In an aquatic system management the turnover process may be caused artificially. Movement of the bottom water mass to the surface layer also cause a direct movement of abundant orthophosphate to the layer. In the present research, we examined the effect of artifitial mixing of bottom water into surface water on the abundance and primary productivity of phytoplankton in Sabuah Lake. The abundance and primary productivity of phytoplankton was predicted to increase under adequate light intensity and higher PO_4-P concentrations, the latter of which would be caused by such mixing treatment.

Since the pH of Lake Sabuah is originally low, a similar experiment was performed in which water's pH was increased to about 7 using limestone ($CaCO_3$) as comparative experiment to that in the acid lake. Conversely, the neutral-pH would be expected to give probability to phytoplankton growth.

The objective of this research was to clarify the effect of artificial mixing of bottom water into surface water and a lime treatment to primary productivity and abundance of phytoplankton in Lake Sabuah. It was expected to give information on the method of enhancing phytoplankton productivity in the oligotrophic Lake Sabuah and some other lakes with similar characteristics in the catchment area of the Kahayan River.

Methods

Study site and time

The study site was located in Lake Sabuah, Tuwung Baru Village, Central Kahayan District, Kapuas Regency of Central Kalimantan Province, about 17 km from Palangkaraya (Fig. 1).

Research was conducted about 4 months from February until May 1999. Primary productivity was measured by incubating lake water in situ as long as 6 h per day from 9:00 A.M. to 15:00 P.M. Lake water and plankton samples were collected at 9:00 A.M. for the analysis of chemical parameters and identification of plankton in the laboratory.

Experimental design

Field design

The experiment was conducted by constructing a series of transparent plastic (thickness = 0.35 mm) bag-type enclosures for incubation of mixed bottom and surface waters. A total of these 24 enclosures each having an opening area of 0.864 m^2 (enforced by wooden frame of 1.44 m $\times$ 0.6 m) and 1 m depth were fixed to 2 floating rafts, where each length and width was 8 $\times$ 5 m. Each of floating raft held 12 enclosures (Fig. 2).

Factor design

The experimental design applied was complete randomize design (CRD) with one independent variable: percentage of bottom water to the mixed volume of the bottom and surface waters, i.e., 0% (A, control), 25%(B), 50%(C) and 75%(D) of 500 l of lake water, with 3 replications. Dependent variables were net primary productivity (NPP) and abundance of phytoplankton.

Bottom water was introduced into each enclosure with an electric pump fitted with PVC pipe. The bottom end of the PVC pipe for water intake was set at 25-50 cm above lake bottom. The bottom water was mixed with the surface water in the enclosures according to the fixed mixing rates. After the mixing initial values of physic-chemical parameters and variables were measured.

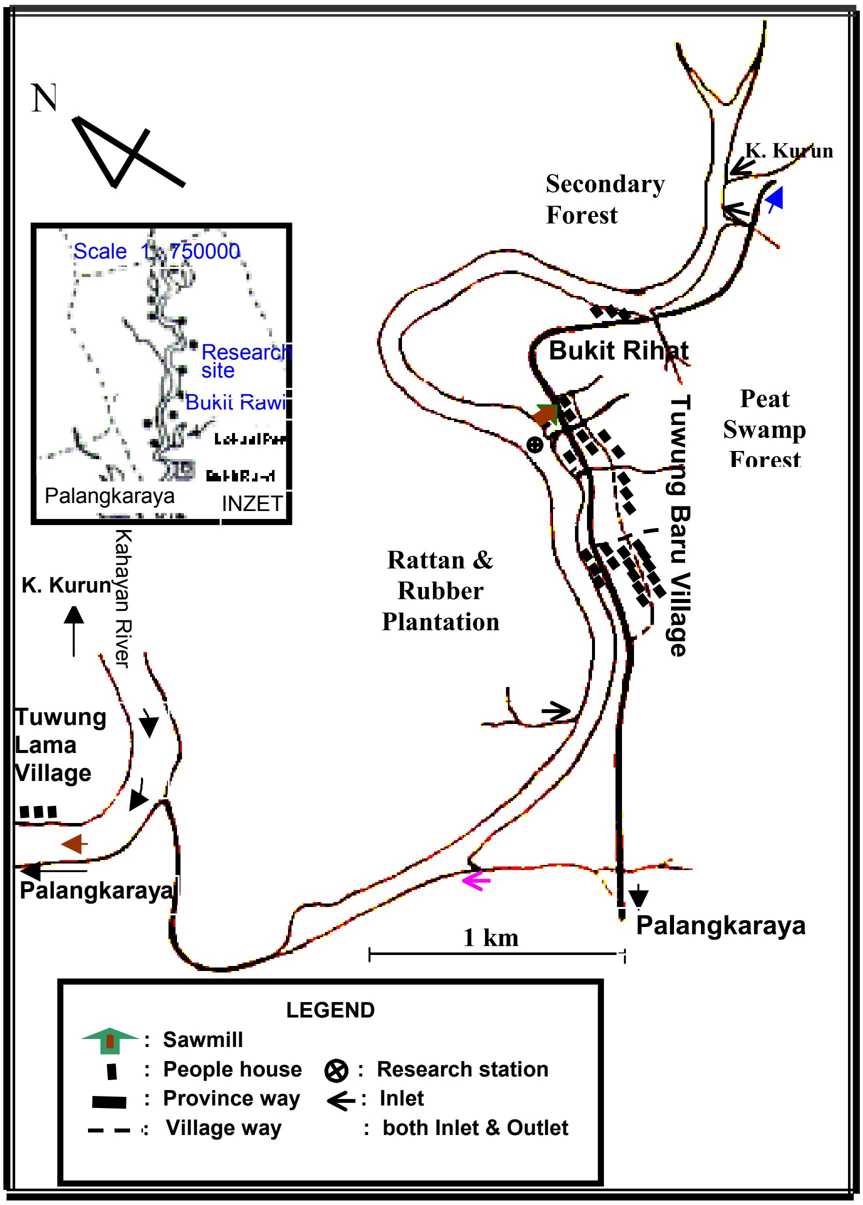

Fig. 1. Map of Lake Sabuah showing research station.

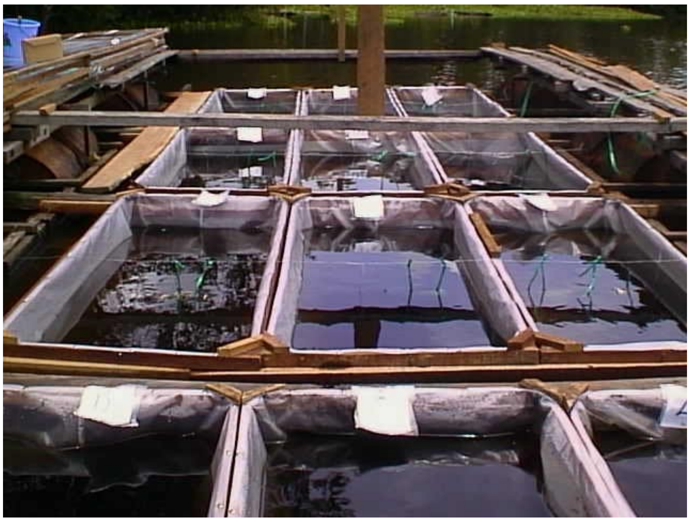

Fig. 2. Transparent plastic enclosures fixed to floating rafts.

The comparative treatment with lime ($CaCO_3$) was conducted after mixing process. In the preliminary lime treatment, mixing rate was fixed at 50% (B).

Physico-chemical parameters

Physico-chemical parameters were measured in the field or analyzed in the laboratory. The parameters and the methods of measurements or analysis are shown in Table 1. Initial parameters were taken for pH, DO, iron, PO_4-P, and plankton abundance.

Table 1. Methods of measurement or analysis of physico-chemical parameters.

No.	Parameter	Equipment /Method	Experiment
1.	Temperature	Thermometer/Expansion	Supporting
2.	Transparency	Secchi disk/Visual	Supporting
3.	Light intensity	Lux meter/Potensiometer	Supporting
4.	pH	.pH meter/Potentiometer	Supporting
5.	Free-CO_2	Titrimetric/ Sodium carbonate	Supporting
6.	DO	Test-kit and DO meter/Winkler	Main/ Supporting
7.	Iron (Fe)	AAS/Phenentroline	Supporting
8.	Orthophosphate (PO_4-P)	Spectrophotometer/Stannous chloride	Main
9.	Nitrate (NO_3-N)	Spectrophotometer/Brucine	Supporting
10.	Ammonia (NH_3-N)	Spectrophotometer/Nesslerization	Supporting

Primary productivity

Net primary productivity (NPP, mgC m^{-3} h^{-1}) was measured using the oxygen method (Wetzel and Likens, 1979), in which net photosynthetic activity per unit volume per time interval (period) was obtained by the concentration of oxygen in the light bottle

(*LB*, ppm) minus the concentration in the initial bottle (*IB*, ppm) as follows:

$$\text{NPP} = \frac{[(O_2, LB) - (O_2, IB)] \cdot (1000)}{(PQ) \cdot (t)}$$

where t is incubation time (6 h); *PQ,* photosynthetic quotient (=1.2) (Strickland and Parsons 1968) and 1000, the conversion factor from liter to m^3.

Phytoplankton abundance

The phytoplankton samples was concentrated using centrifuge or centrifugation method (Throndsen, 1978). Phytoplankton in each concentrated sample of 3 ml were counted and identified under microscope. Phytoplankton cell density was determined using the Hardy's formula:

$$N = n \cdot \left(\frac{S}{a} \right) \cdot \left(\frac{1}{V} \right)$$

where N is the amount of phytoplankton (cells l^{-1}); n, the number of phytoplankton counted (cells); S, the volume of concentrated sample (=3 ml); a, the volume of a drop sample counted and identified under microscope (φ 0.05 ml); V, the total volume of sample centrifuged (=2 l) (Hardy, 1939).

Data analyses

Statistical analyses were ANOVA for dependent variables and regression-correlation for chemical parameters in relation to the factor (independent variable). If ANOVA result tended to show significant difference at 95% probability level (α=0.05), a polynomial regression analysis was performed. Computer programs used were SPPS and Minitab for Windows.

Results and Discussion

Preliminary experiment

Lime adjusting

For 50% (B) of mixing rate, 37.24 mg l^{-1} of $CaCO_3$ was required to increase water's pH of each enclosure to about 7. Physico-chemical parameters at first day of preliminary experiment are shown in Table 2.

Table 2. Physico-chemical parameters of bottom and surface water mass in the preliminary experiment.

Parameters	Bottom	Surface	Mixing rate of 50%	
			Non Lime	Lime
Temperature (^oC)	25.5	27.1	26.1	26.5
pH	5.67	6.26	5.61	5.76
DO (ppm)	0.00	3.7	-	-
Orthophosphate (PO_4-P) (ppm)	0.098	0.047	-	-
Iron (Fe) (ppm)	0.393	0.091	-	-

Day of monitoring
Growth of phytoplankton was not directly increased after the artificial mixing. However, they were passing the adaptation phase from no optimum light, temperature and nutrient under the natural condition. Further, from the preliminary experiment the abundance of phytoplankton was shown to increase. Indeed, it was fixed on the 3rd day after mixing as primary (main) monitoring and the NPP and abundance of phytoplankton were measured.

Treatment
Pre monitoring
Physico-chemical parameters
Artificial mixing of bottom and surface mass was done at 6:30 to 16:00 of D(-2), continued to liming and sampling of plankton. Amount of lime (calcite) added to 0% (A) to 75%(D) was 13.72, 16.38, 17.37 and 19.02 g, respectively. Data for physico-chemical parametera are shown in Table 3. The difference were significant (bottom > surface) for all parameters particularly orthophosphate and iron, while the dissolved oxygen (DO) was vice versa.

Table 3. Physico-chemical parameters for bottom and surface waters.

Parameters	Bottom	Surface
Temperature (^oC)	25.4 – 28.3	29.2 – 36.8
pH	5.46	6.14
DO (ppm)	0.46	3.72
Free-CO_2 (ppm)	19.97	10.98
Orthophosphate (PO_4-P) (ppm)	0.114	0.056
Iron (Fe) (ppm)	0.383	0.089

There was no correlation between water temperature and the mixing rate of bottom and surface waters (Fig. 3a). The pH, in particular on D (-2), showed significant correlation with the mixing rate. The pH decreased with increasing percentage of bottom water in the mixed water mass (Fig. 3b), due to the lower pH of bottom water than that of surface (see Table 3). However, no significant correlation was found for D (-1) and D (0) probably because of the buffer process within the enclosures.

Orthophosphate and iron concentrations of D (-2) to D (0) tended to increase with increasing percentage of bottom water in the mixed water mass (Figs. 3c, d). The correlation coefficient ranged between 0.86 and 0.99 (mostly significant except for orthophosphate (NL) at D (0), which was - 0.22) (Table 4).

Phytoplankton abundance
The phytoplankton abundances in the surface and bottom waters at the research station were 57 and 80 cells l^{-1}, respectively. The average abundance of phytoplankton in the present study (74 cells l^{-1}; Table 5) was higher than the reported values of 1.968 cells l^{-1} (Torang, 1985) and 2.356 cells l^{-1} (Buchar, 1998) in this lake (average of 5 stations). The difference was probably caused by difference in sampling times (or seasons): Torang and Buchar sampled in August to November (rainy season).

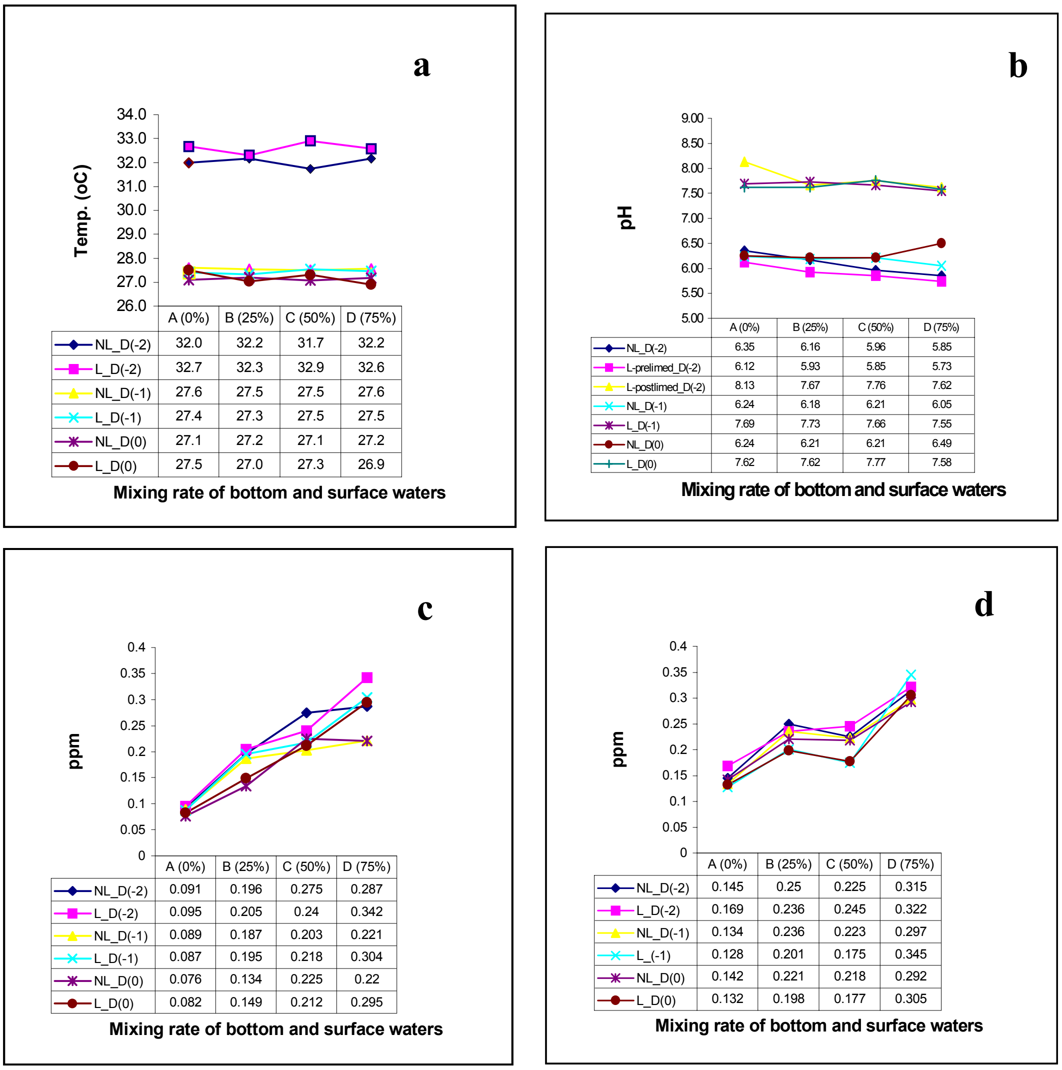

Fig. 3. Physico-chemical parameters of D (-1) to D (0) for non-lime (NL) and lime (L) treatments. a: Temperature; b: pH; c: Orthophosphate; d: Iron.

Table 4. Correlation of orthophosphate and iron (Y) to percentage of bottom water to mixed surface and bottom waters (X) in the pre monitoring.

Date/day		Parameters (Y)	Correlation coefficient	Equation
24-3-99/ D (-2)	NL	Iron (Fe)	0.89	Y = 0.16 + 0.0019X
		PO_4-P	0.95*	Y = 0.11 + 0.0027X
	L	Iron (Fe)	0.96*	Y = 0.17 + 0.0019X
		PO_4-P	0.98*	Y = 0.10 + 0.0031X
25-3-99/ D (-1)	NL	Iron (Fe)	0.91	Y = 0.15 + 0.0019X
		PO_4-P	0.90	Y = 0.11 + 0.0016X
	L	Iron (Fe)	0.86	Y = 0.12 + 0.0025X
		PO_4-P	0.97*	Y = 0.10 + 0.0027X
26-3-99/ D (0)	NL	Iron (Fe)	0.94	Y = 0.15 + 0.0018X
		PO_4-P	-0.22	Y = 13.63 – 0.1334X
	L	Iron (Fe)	0.87	Y = 0.13 + 0.002X
		PO_4-P	0.99**	Y = 0.08 + 0.0028X

**P<0.01 ; * P<0.05; ; NL = Non-lime treatment; L = Lime treatment.

Table 5. Average of initial phytoplankton and zooplankton abundances.

Treatment	Phytoplankton (cells l^{-1})		Zooplankton (cells l^{-1})	
	Non Lime	Lime	Non Lime	Lime
A (0%)	67	63	3	7
B (25%)	60	73	13	13
C (50%)	80	83	17	17
D (75%)	83	83	20	30

Main monitoring

Physico-chemical parameters

Physico-chemical parameters on D (1) to D (3) correlated with the mixing rate of surface and bottom waters. Light is a main source of energy, and temperature as a controlling factor: these are not affected by the mixing rate of surface and bottom waters. Therefore phosphorous was probably increased by increasing percentage of the bottom water in the mixture of surface and bottom waters. On the other hand, nitrogen (N) was not increased significantly. Iron concentration increased significantly since it served as a controller of solubility of orthophosphate (Fig. 4a, b).

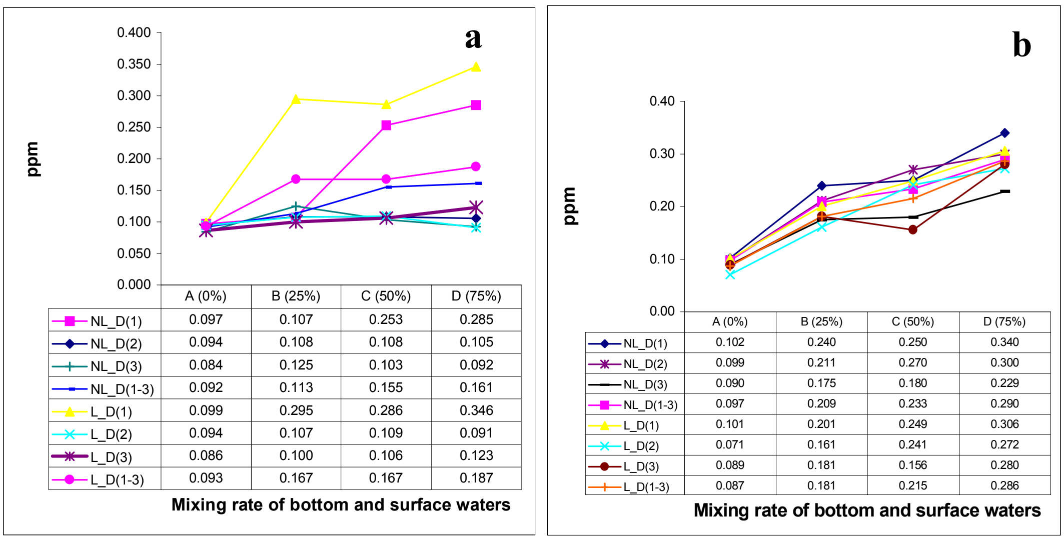

Fig. 4. Physico-chemical parameters of D (1) to D (3) for non-lime (NL) and lime (L) treatments. a: Orthophosphate; b: Iron.

Phosphorous (absorbed in the form of PO_4-P) in fresh water is more limiting than nitrogen (absorbed in the form of ammonia, nitrate and N_2) for phytoplankton due to their immobility.

Most data for phosphate and iron concentrations of D (1) to D (3) in non-lime (NL) treatment showed significant correlation with the mixing rate of surface and bottom waters. However, by the lime treatment, the correlation became insignificant (iron = linear correlation; phosphate = quadratic), indicating that a reaction might have occurred among lime, orthophosphate and iron. Because of the difference in their concentrations (iron > orthophosphate), iron was still linear whereas orthophosphate had already been quadratic up to D (3) (Fig. 4a, b).

Table 6. Correlation between orthophosphate and iron (Y) and Percentage of mixed bottom and surface water (X) in the main experiment.

Date/day		Parameters (Y)	Correlation coefficient	Equation
27-3-99/ D (1)	NL	Fe	0.95*	$Y = 0.12 + 0.0029X$
		PO_4-P	0.94	$Y = 0.079 + 0.0028X$
	L	Fe	0.98*	$Y = 0.11 + 0.0027X$
		PO_4-P	0.87	$Y = 0.14 + 0.003X$
28-3-99/ D (2)	NL	Fe	0.96*	$Y = 0.10 + 0.0051X – 3.0x10^{-5}X^2$
		PO_4-P	0.97*	$Y = 0.094 + 0.0006X – 7.0x10^{-6}X^2$
	L	Fe	0.98*	$Y = 0.084 + 0.0027X$
		PO_4-P	0.99**	$Y = 0.093 + 0.0009X – 1.0x10^{-5}X^2$
29-3-99/ D (3)	NL	Fe	0.94	$Y = 0.10 + 0.002X$
		PO_4-P	0.84	$Y = 0.09 + 0.0016X – 2.0x10^{-5-}X^2$
	L	Fe	0.89	$Y = 0.09 + 0.002X$
		PO_4-P	0.98*	$Y = 0.086 + 0.0005X$
Avg. of D(1) to D(3)	NL	Fe	0.96*	$Y = 0.12 + 0.0024X$
		PO_4-P	0.97*	$Y = 0.093 + 0.001X$
	L	Fe	0.86	$Y = 0.12 – 0.007 + 0.0002X^2$
		PO_4-P	0.88	$Y = 0.097 + 0.0027X – 2.0x10^{-5}X^2$

* P<0.05; ** P<0.01; NL = Non-lime treatment; L = Lime treatment.

Net primary productivity (NPP) of phytoplankton

Artificial mixing of the bottom and surface water mass increased NPP that is shown by ANOVA of D (1) – D (3) for non-lime (F = 24.65) and lime (F = 7.79) treatments (Table 7).

Table 7. Analysis of variance for percentage (%) of bottom water to the mixture of surface and bottom waters and primary productivity (NPP).

Time of day	F-value		Polynomials	
	NL	L	NL	L
D1	1.89	33.06*	-	L
D2	9.48*	13.28*	L	Q
D3	15.20*	0.58	L	-
D1 – D3	24.65*	7.79*	L	L

* P < 0.05; L = linear; Q = quadratic; NL = Non-lime treatment; L = Lime treatment

A linear correlation was observed up to 75% of mixed water mass with r^2 >0.8 (Figs. 5a, b). The significant effect of mixing of water mass on NPP was caused by increasing of orthophosphate from 0% to 75% of mixing rate, with correlation coefficient of 0.84 – 0.99 for non-lime treatment and 0.87 – 0.99 for lime treatment.

According to Schindler (1978) maximum biomass is particularly limited by phosphorous supply in temperate lakes, conversely by nitrogen in marine systems. Thus, there is a significant correlation between phytoplankton biomass and phosphorous (Anderson *et al.* 1978) or phytoplankton biomass is affected by concentration of phosphorous in most of the lakes (Heyman and Lundgren, 1988).

In a tropical lake, Lago do Castanho, phosphate concentration in the hypolimnion is 0 to 0.46 g l^{-1} (higher in the bottom), and commonly decrease in the epilimnion after turn over due to high rates of phytoplankton photosynthesis (Payne, 1986).

Under natural condition, turbulence (turn over) may increase trophic status because of the movement of sediment containing high concentration of phosphorous which will become available for the growth of phytoplankton in the epilimnion (Schubel, 1968; Anderson, 1972, 1978 *in* Peters and Cattaneo, 1984).

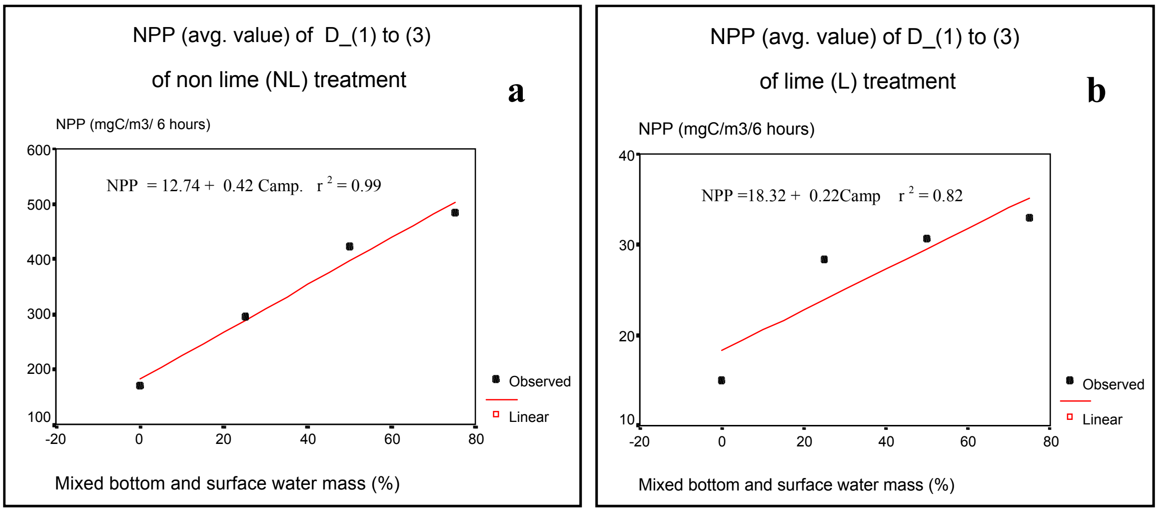

Fig. 5. Net primary productivity (NPP) averaged for D (1) to D (3) in relation to mixing rate of surface and bottom waters. a: non-lime (NL) treatment; b: lime (L) treatment.

Abundance of phytoplankton

A total of 30 phytoplankton genera were found consisting of 4 classes, viz. Bacillariophyceae (9 genera), Chlorophyceae (19 genera), Cyanophyceae (1 genus) and Eulenophyceae (1 genus). The dominant genus was *Tabellaria*.

Based on the ANOVA, the phytoplankton abundance was not significantly affected by the artificial mixing of bottom and surface waters (Table 8). However, the average phytoplankton abundance for 5 days of incubation was higher than the initial values at each level of mixing (Table 9). The significant correlation between dependent and independent variables was caused by a close relation between the levels of artificial mixing and the concentrations of phosphorous during incubation.

Both non-lime (NL) and lime (L) treatments caused high difference of abundance of phytoplankton as compared with the initial abundance (columns 6 and 7 in Table 9). Phytoplankton abundance increased up to the 3rd day of monitoring (D (3)) particularly for the mixing rate of 25% (B), 50% (C) and 75% (D).

Table 8. Analysis of variance for percentage (%) of bottom water to the mixture of surface and bottom waters and phytoplankton abundance.

Time of Day	F-value		Polynomials	
	NL	L	NL	L
D1	1.68	0.47	-	-
D2	4.12*	5.74*	-	L
D3	0.35	9.05*	-	Q
Avg. of D1– D3	0.08	1.19	-	-

* $P<0.05$; L = linear; Q = quadratic; NL = Non Lime treatment; L = Lime treatment

Table 9. Comparison of phytoplankton abundance between initial value and the average of D (1) to D (3).

Treatment	Abundance of phytoplankton (cell l^{-1})					
	Initial (after mixing)		Avg. of D1 to D3		Avg. of D1toD3 – initial	
	Non Lime (NL)	Lime (L)	Non Lime (NL)	Lime (L)	Non Lime (NL)	Lime (L)
1	2	3	4	5	6	7
A (0%)	67	63	357	257	290	149
B (25%)	60	73	341	246	281	173
C (50%)	80	83	335	251	171	168
D (75%)	83	83	326	214	131	131

The fact that the phytoplankton abundance did not differ significantly between non-lime and lime treatments (ANOVA) was not caused by insufficient nutrient (PO_4-P) but possibly by grazing of zoopankton during incubation (Figs. 6a, b). It is also supported by the correlation coefficient between phyto- and zooplankton of –0.733 (NL) and 0.121 (L) and the regression in Figs. 7a and b. The dominant zooplankton species identified in the present study were cyclopoid copepods which are reported as phytoplankton feeder (Pennak, 1978; Lewis, 1979; Goldman and Horne, 1983).

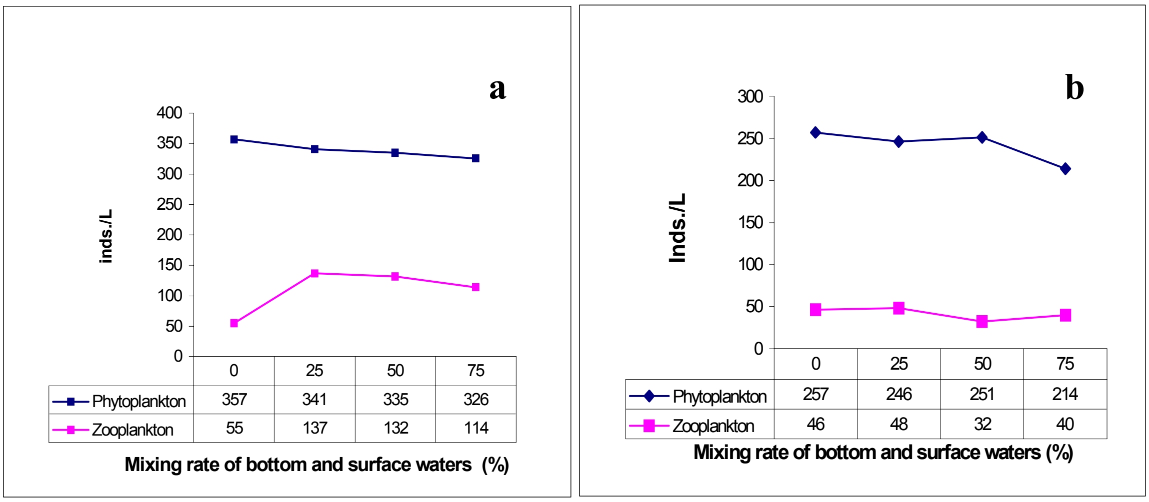

Fig. 6. Phytoplankton and zooplankton abundances averaged for D (1) to D (3) in relation to mixing rate of surface and bottom waters. a: non-lime (NL) treatment; b: lime (L) treatment.

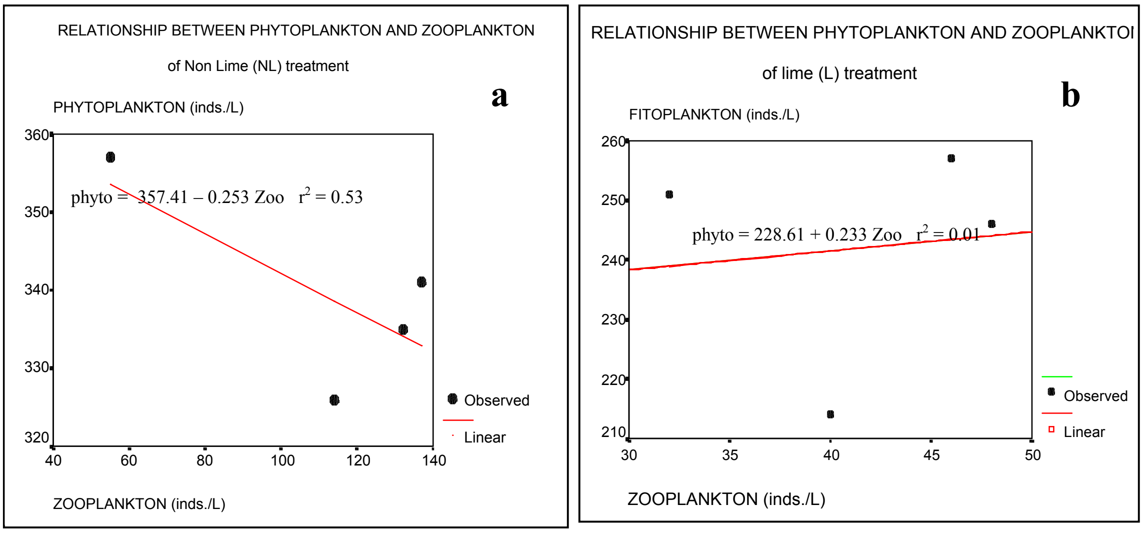

Fig. 7. Realtionship between phytoplankton and zooplankton abundances. a: non-lime (NL) treatment; b: lime (L) treatment.

Conclusion

According to the result, there can be concluded that artificially turn over of water mass from the bottom to the surface layer with different percentage of mixing may increase nutrient concentration, especially orthophosphate, so it could be able to support the increasing of primary productivity and abundance of phytoplankton within the surface water which is adequate of light.

References

Anderson, G., Berggren, H., Cronberg, C. and Gelin, C. 1978. Effect of planktivorous and bentivorous fish on organisms and water chemistry in eutrophic lakes. *Hydrobiologia*, 59: 9-15.

Boyd, C. E. 1990. *Water Quality in Ponds for Aquaculture*. Alabama Agricultural Experimental Station, Auburn University, Alabama. USA.

Buchar, T. 1998. Bioekologi Komunitas Ikan di Danau Sabuah. Tesis, Program Pascasarjana, Institut Pertanian Bogor (IPB), Bogor. Tidak dipublikasikan.

Cole, G. A. 1983. *Textbook of Limnology. 3rd edn.* Waveland Press Inc, New York, USA.

Connel, W. Des and Miller, G. J. 1995. Kimia dan Ekotoksikologi Pencemaran (alih bahasa : Yanti Koestor). Penerbit Universitas Indonesia, Jakarta.

Goldman, C.R. and Horne, A. J. 1983. *Limnology*. McGraw-Hill, New York. USA.

Heyman, U, and Lundgren, A. 1988. Phytoplankton biomass and production in relation to phosphorous: some conclusion from field study. *Hydrobiogia*, 170: 211 – 227.

Jorgensen, S.E and Vollenweider, R. A. 1989. Guidelines of Lake Management. Principles of Lake Management Vol. 1. International Lake Environment Committee, United Nations Environmental Program, Shiga. Japan.

Lewis, W. M. Jr. 1979. *Zooplankton Community Analysis: Studies on A Tropical System*. Springer-Verlag, New York, USA.

Payne, A. I. 1986. *The Ecology of Tropical Lakes and Rivers*. John Willey and Sons, Chichester, New York, Toronto, Brisbane, Singapore.

Pennak, R.W. 1978. *Fresh Water Invertebrates of the United States*. Jhon Wiley and Sons. Canada.

Peter, R.H., and Cuttaneo, A. 1984. The effect of turbulence on phosphorous supply in a shallow bay of Lake Memphremagog. *Ver. Internat. Verein. Limnol*., 22:185 – 189.

Schildler, D. W. 1978. Factors regulating phytoplankton production and standing crop in the world's freshwater. *Limnology and Oceanography*., 23: 86 – 93.

Strickland, J. D. H. and Parsons, T. R. 1968. *A Practical Handbook of Sea Water Analysis*. *Bull. Fish. Res. Bd*., Canada.

Torang, I. 1995. Hubungan Antara Iluminasi dengan Kelimpahan dan Komposisi Jenis Fitoplankton. Tesis, Program Pascasarjana, Institut Pertanian Bogor (IPB), Bogor. Tidak dipublikasi.

Wetzel, R. G. and Likens, G. E. 1979. Limnological Analyses. W.B. Sauders Company, Philadelphia, London, Torronto.

Wetzel, R. G. 1983. Limnology. Second edition. CBS College Publishing, New York, USA.

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Turnover Rate of Aquatic Macrophytes in the Irrigation Ponds around Lake Shinji and Lake Nakaumi, Japan

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Abstract

This study was conducted to evaluate the temporal changes of the species composition of aquatic macrophytes and environmental variables in the irrigation ponds around Lake Shinji and Lake Nakaumi, Shimane Prefecture, Japan, during a relatively long period of time by comparing the data taken in 1980's and in1990's. The results compared showed a drastic change in species composition in each pond and almost all the taxa exhibited appearance/disappearance patterns without significant environmental change during the period. Mean turnover rate of dominant 11 taxa, which showed more than 10% frequency of occurrence in 1980's, was estimated as 35.2%.

Introduction

It is reported that there exist hundreds of thousands irrigation ponds in Japan and most of these ponds are artificial developed during sixteenth and nineteenth centuries with the development of rice field. During 1980s, the author studied the relation between aquatic macrophyte composition and water variables of 149 irrigation ponds around Lake Shinji and Lake Nakaumi and showed that (1) the macrophytes can be divided into 4 or 5 groups by using Detrended Correspondence Analysis (DCA) and chi-square test and (2) such variables as pH, electric conductivity, alkalinity, Ca, Mg, Na, K have significant relation with aquatic macrophyte composition while other variables (transparency, chlorophyll a content, reactive-P, total P, COD, Fe and ignition loss of bottom soil) have not (Kunii, 1991).

Lakes and ponds can be conceptualized as islands (Keddy, 1979; Browne, 1981), and it is very important to know the temporal changes in aquatic macrophyte composition in terms of the conservation and management of aquatic macrophytes. Ten years after this study, the author thus conducted to evaluate the temporal changes of the species composition of aquatic macrophytes and environmental variables in the irrigation ponds.

Site and Methods

Present study was conducted at the irrigation ponds around Lake Shinji and Lake Nakaumi, Shimane Prefecture, Japan. Forty-five and 46 ponds, which were visited in 1984 and 1986, respectively, were visited again in the growth period of 1994 and 1996, respectively, and presence/absence data on each macrophyte were recorded and several environmental variables were measured in the field and/or analysed in the laboratory (cf. Table 2). For the detailed description of the study site and measurement, refer Kunii (1991). From these two time different data sets, comparisons were made to evaluate the temporal changes of the species composition of aquatic macrophytes and environmental variables. Here the author used turnover rate to express the dynamic equilibrium or the community stability of the macrophytes in ponds in terms of the island biogeography (see Diamond, 1969; Browne, 1981).

Results and Discussion

Of the 37 species found in 1980s, 4 species (*Sparganium fallax*, *Vallisneria asiatica*, *Myriophyllum verticillatum* and *Eichhornia crassipes*) could not be found, while 2 species (*Potamogeton maackianus* and *Elodea nuttallii*) were newly found in 1990s (Table 1). As a result, total number of taxa found was 37 and 35 and average number of taxa per pond was 3.9 and 3.4, respectively, in 1980s and in 1990s.

Table 1. Temporal changes in floristic composition between 1980s and 1990s in 91 irrigation ponds, Shimane, Japan.

Plant name	1984+1986		Newly found	Not found	Difference	1994+1996	
	No. ponds found	Frequency (%)				No. ponds found	Frequency (%)
Trapa spp.	51	56.0	6	-9	-3	48	53.9
Utricularia spp.	34	37.4	8	-13	-5	29	32.6
Potamogeton octandrus	35	38.5	4	-16	-12	23	25.8
Nymphaea tetragona	27	29.7	2	-9	-7	20	22.5
Brasenia schreberi	21	23.1	0	-4	-4	17	19.1
Ceratophyllum demersum	15	16.5	6	-5	1	16	18.0
Potamogeton fryeri	18	19.8	3	-7	-4	14	15.7
Lemna paucicostata	5	5.5	9	-2	7	12	13.5
Hydrilla verticillata	14	15.4	2	-5	-3	11	12.4
Spirodela polyrhiza	8	8.8	4	-1	3	11	12.4
Najas minor	15	16.5	6	-11	-5	10	11.2
Myriophyllum oguraense	19	20.9	0	-10	-10	9	10.1
Ottelia alismoides	4	4.4	5	-1	4	8	9.0
Egeria densa	2	2.2	4	0	4	6	6.7
Myriophyllum ussuriense	7	7.7	1	-4	-3	4	4.5
Eleocharis sp.	7	7.7	3	-6	-3	4	4.5
Potamogeton distinctus	5	5.5	0	-1	-1	4	4.5
Nymphoides indica	5	5.5	0	-1	-1	4	4.5
Nymphaea cv.	4	4.4	0	0	0	4	4.5
Blyxa echinosperma	7	7.7	1	-5	-4	3	3.4
Najas graminea	6	6.6	2	-5	-3	3	3.4
Limnophylla sessiliflora	2	2.2	1	0	1	3	3.4
Nuphar japonica	2	2.2	3	-2	1	3	3.4
Nitella spp.	17	18.7	1	-16	-15	2	2.2
Nelumbo nucifera	3	3.3	0	-1	-1	2	2.2
Chara spp.	3	3.3	2	-3	-1	2	2.2
Potamogeton oxyphyllus	1	1.1	2	-1	1	2	2.2
Ricciocarpus natans	1	1.1	2	-1	1	2	2.2
Potamogeton maackianus	0	0	2	0	2	2	2.2
Elodea nuttallii	0	0	2	0	2	2	2.2
Potamogeton crispus	5	5.5	0	-4	-4	1	1.1
Najas japonica	2	2.2	1	-2	-1	1	1.1
Blyxa japonica	2	2.2	1	-1	0	1	1.1
Isoetes japonica	2	2.2	1	-2	-1	1	1.1
Hydrocharis dubia	1	1.1	0	0	0	1	1.1
Sparganium fallax	2	2.2	0	-2	-2	0	0
Vallisneria asiatica	1	1.1	0	-1	-1	0	0
Myriophyllum verticillatum	1	1.1	0	-1	-1	0	0
Eichhornia crassipes	1	1.1	0	-1	-1	0	0
Total no. of taxa found	37					35	
Average no. of taxa per pond	3.9					3.4	

Almost all the taxa (37 out of 39 taxa) showed appearance/disappearance pattern (Fig. 1) and only *Nymphaea* cv. and *Hydrocharis dubia* showed no temporal change. While *Utricularia* spp., *Potamogeton octandrus*, *Najas minor* and *Myriophyllum oguraense* decreased drastically, *Lemna paucicostata* increased markedly. Mean turnover rate of dominant 11 taxa, which showed more than 10% frequency of occurrence in 1980s, was estimated as 35.2% (Fig. 2) without significant environmental changes (Table 2).

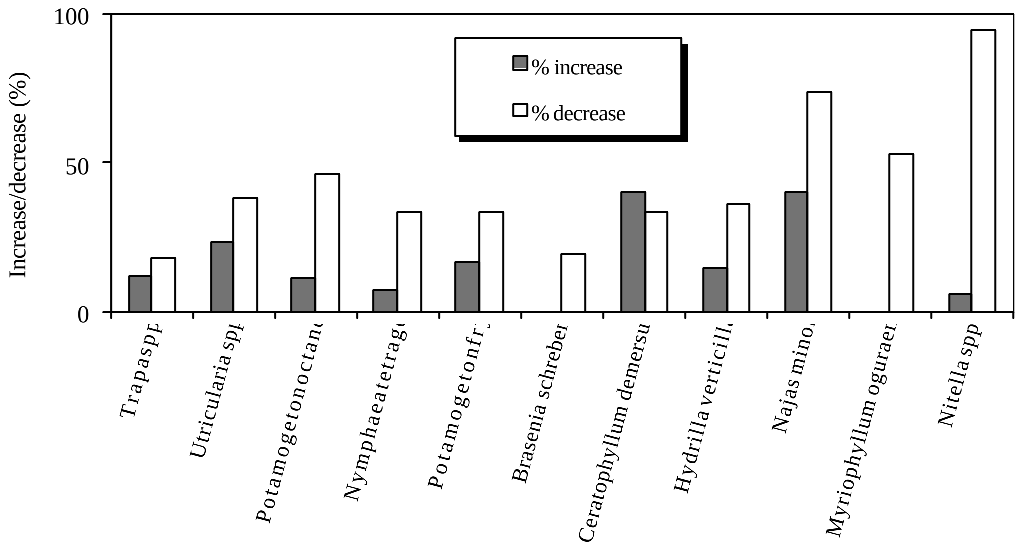

Fig. 1. Percent increace/decrease of dominant aquatic macrophytes during 10 yeas.

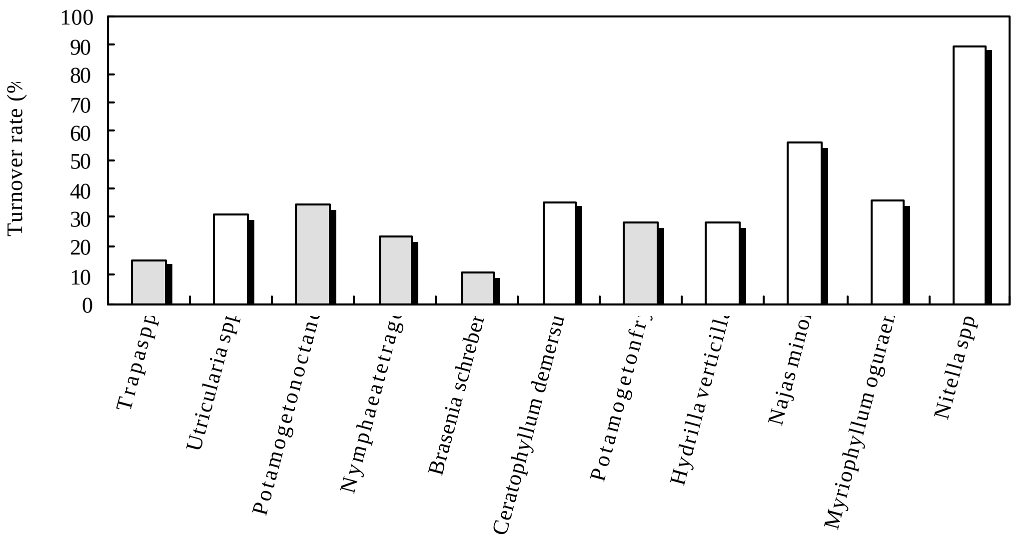

Fig. 2. Turnover rate of dominant aquatic macrophytes during 10 years.
Hatched bars indicate floating-leaved and free-floating macrophytes.

Table 2. Comparison of some environmental variables between 1980s and 1990s.

Variables	Years	Sample No.	Max.	Min.	Mean	S.D.	*t*-test
Water depth	1980s	77	6	0.3	1.9	0.95	
(m)	1990s	82	5.65	0.02	1.67	1.05	
Transparency	1980s	76	3	0.3	1.14	0.57	***
(m)	1990s	78	2.4	0.02	0.89	0.44	
pH	1980s	89	9.1	4.5	6.67	0.58	
	1990s	89	8.8	4.8	6.63	0.76	
E.C.	1980s	89	329	15	107	52.9	**
(ìS/cm)	1990s	89	553	34	133.96	80.66	
COD	1980s	89	22.12	3.16	11.02	4.46	***
($KMnO_4$ mg/l)	1990s	89	37.79	2.57	14.49	7.22	
PO_4-P	1980s	85	80.2	0	2.65	8.79	
(ìg/l)	1990s	89	178.34	0	8.19	28.75	
Alkalinity	1980s	89	2.19	0	0.39	0.31	
(meq/l)	1990s	89	11.4	0.03	0.56	1.22	
Chl.a	1980s	83	163.07	0.58	14.45	21.31	*
(ìg/l)	1990s	88	526.94	0.67	32.89	71.97	
Ignition loss	1980s	43	50.9	1.99	9.3	9.01	***
(%)	1990s	70	27.45	7.1	15.04	4.52	
Na	1980s	90	25.46	0	11.13	5.07	
(mg/l)	1990s	89	41.21	4.13	11.34	5.02	
K	1980s	91	5.7	0.23	1.85	1.03	
(mg/l)	1990s	89	6.67	0.15	1.69	1.03	
Ca	1980s	90	30.09	0.29	4.52	4.08	**
(mg/l)	1990s	89	41.29	0.54	6.66	6.49	
Mg	1980s	89	14.15	0.15	3.24	2.35	
(mg/l)	1990s	89	15.06	0.49	3.79	2.99	
Mn	1980s	90	1.16	0.01	0.17	0.18	
(mg/l)	1990s	89	2.24	0	0.15	0.34	
Fe	1980s	90	1.72	0	0.45	0.36	
(mg/l)	1990s	89	5.91	0	0.31	0.75	
T-P	1980s	44	0.031	0.006	0.015	0.006	
(mg/l)	1990s	89	0.418	0.001	0.034	0.058	
T-N	1980s	-	-	-	-	-	
(mg/l)	1990s	89	0.56	0	0.06	0.1	
DOC	1980s	-	-	-	-	-	
(mg/l)	1990s	89	6.74	0.12	1.45	1.23	
Al	1980s	-	-	-	-	-	
(mg/l)	1990s	89	14.28	0.65	3.9	2.39	

*, P<0.05; **, P<0.01; ***, P<0.001

Temporal changes in aquatic macrophyte flora have also been observed in other regions in Japan (e.g. Nakamura, 1992; Shimoda, 1995; Kadono, 1998). Several possibilities concerning about the appearance/disappearance pattern of the aquatic macrophytes can be proposed; the artifact caused by overlooking of some plant species in each investigation, the change of environmental factors (e.g. eutrophication), the autogenous factor such as occasional germination of buried seeds/propagules, the allogenous factor such as seeds/propagules transportation by birds and so on.

Lakes and ponds can be conceptualized as islands (Keddy, 1979; Browne, 1981), and each population in each pond may be recognized as local population while that in whole study area as metapopulation (Hanski, 1999). In terms of the conservation and management of aquatic macrophytes in the ponds, further studies and analyses are needed.

References

Browne, R. A. 1981. Lakes as islands: biogeographic distribution, turnover rates, and species composition in the lakes of central New York. *Journal of Biogeography*, **8**:75-83.

Diamond, J. M. 1969. Avifaunal equilibria and species turnover rates on the Channel Islands of California. *Zoology*, **64**:57-63.

Hanski, I. 1999. *Metapopulation Ecology*. Oxford University Press. 313p.

Kadono, Y. 1998. Present status of wetland flora in Japan, with special reference to aquatic macrophytes. In: Peng, C. I. and Lowry, P. P. (eds.), *Rare, Threatened, and Endangered Floras of Asia and the Pacific Rim*. Institute of Botany, Academia Sinica Monograph Series No.16. pp.27-36.

Keddy, P. A. 1976. Lakes as islands: the distributional ecology of two aquatic plants, *Lemna minor* L. and *L. trisulca* L. *Ecology*, **57**:353-359.

Kunii. H. 1991. Aquatic macrophyte composition in relation to environmental factors of irrigation ponds around Lake Shinji, Shimane, Japan. *Vegetatio*, **97**:137-148.

Nakamura, T. 1992. The present state of aquatic plants of irrigation reservoirs in Sakai City, Osaka Pref. *Bulletin of the Water Plant Society of Japan*, **48**:24-27 (in Japanese).

Shimoda, M. 1995. Changes in aquatic vegetation and environment in irrigation ponds in the Saijo Basin, Hiroshima Prefecture, Japan. *Vegetation Science*, **11**:23-40 (in Japanese with English Abstract).

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A Preliminary Study on the Dynamics of Zooplankton Community in Two Humic Lakes of Central Kalimantan

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Abstract
A 5 months study on zooplankton abundance was carried out in two humic oxbow lakes, Sabuah undergoing permanent isolation from the main river with occasional connection during high water level season and Tundai being open to the main river at both ends. Zooplankton abundance was higher in Lake Tundai than in Lake Sabuah. In both lakes, the highest peak occurred in May when the zooplankton community was dominated by copepod nauplii. In Lake Tundai, abundance of copepod nauplii was higher near inlet compared with the central area. Cladocerans and adult copepods were rare in Lake Sabuah, whereas in Lake Tundai cladocerans were the dominant group during August-September or low water level season. The difference in zooplankton communities was possibly caused by the difference in carbon concentrations (TC and DOC) induced by the different hydrological processes between the two oxbow lakes.
Key words: zooplankton, humic oxbow lake, hydrological condition, water quality

Introduction

Although the knowledge of the structural components of tropical lakes and reservoir has expanded greatly over the past three decades, research on freshwater ecosystems in this region has mainly been directed toward describing species (Nilssen, 1984). This is also true for zooplankton community. For example: in tropical Asia, a comprehensive knowledge of systematic and distributions is available at least in half the country of the area (Dussart *et al.*, 1984) and the reviews on species and size composition of tropical freshwater zooplankton in Southeast Asia have been well documented (Fernando, 1980; Lai and Fernando, 1980; Fernando and Ponyi, 1981; Idris and Fernando, 1981; Lim and Fernando, 1985). In Indonesia, however, zooplankton information is still not adequate enough (Lesmuluoto *et al.*, 1999) and its seasonal variation is little known.

Most information on the population dynamics of subtropical and tropical zooplankton is only available from studies conducted in American and African lakes. In most tropical lakes studied, zooplankton has a maximum abundance during period of July to December (Wyngaard, 1982; Twombly, 1983; Mangestou and Fernando, 1991), although the population peak period does not follow this phenomenon among different zooplankton taxa such as observed from two different lakes of North Ethiopia (Wodajo and Belay, 1984). Various factors have been argued to induce the pattern of seasonal abundance of tropical zooplankton, i.e., food availability, predation pressure and coupling of hydrological events in the lake. More studies are needed to verify this typical phenomenon and identify factors controlling population dynamics of tropical zooplankton.

The main objective of the present study was to examine the seasonal dynamics of zooplankton community in two humic lakes with different hydrological conditions to discuss possible mechanism underlying the changes of zoolankton abundance.

Study Sites

The two subject lakes of the present study are located along the Kahayan River near Palangka Raya, the capital city of Central Kalimantan - Indonesia (Fig. 1). Lake Sabuah (2°3'19"S; 113°56'37"E) is an oxbow lake located in ca. 15 km north of Palangka Raya city. The surface area of the lake is approximately 1.2 km^2. The lake undergoes permanent isolation from the Kahayan River during most period of the year and only occasionally connected with the river during high water level season. In rainy season the deepest point can be up to 14 m. Previous study indicated that this lake has a poor vertical mixing, the depth of euphotic zone is 0.76 m at the centre of the lake and the dissolved oxygen concentrations are very low under this euphotic depth, indicating that plankton and fish may inhabit the top 1 m of the lake water column (Iwakuma *et al.*, 2000).

Lake Tundai (2°12'30"S; 114°00'37"E), is also an oxbow lake located ca. 10 km south of Palangka Raya city. Unlike Lake Sabuah, Lake Tundai is still open at both ends to the Kahayan River. A small tributary river namely the Jengahen River also flows into this lake. The surface area of the lake is approximately 2.8 km^2 and the maximum depth of 11 m at the centre of the lake. An earlier observation on the limnological features of this lake indicated that in December the depth of euphotic zone in the northern inlet part was 0.88 m, and the dissolved oxygen concentration in the surface layer was lower near the inlet than that at the centre of the lake (Iwakuma *et al.*, 1999).

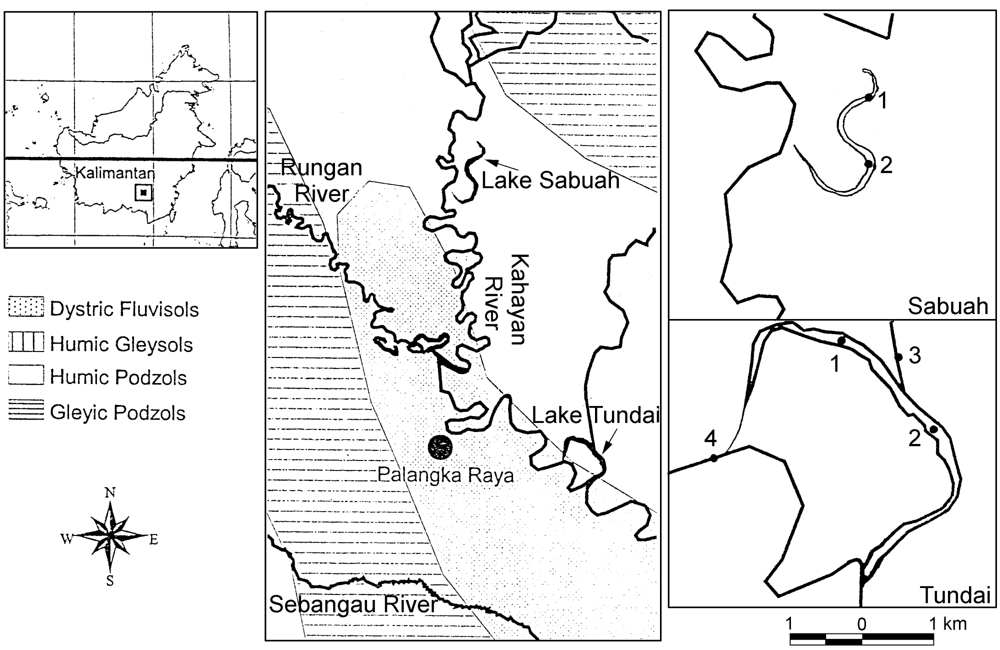

Fig. 1. Map of study sites in Lake Sabuah and Lake Tundai.
Lake Sabuah 1: Station near inlet; 2: Centre;
Lake Tundai 1: Station near inlet; 2: Centre; 3: Jengahen River; 4: Kahayan River.

Material and Methods

Observation and sample collection were made during May-September 1999. Field measurement and sample collection were performed in two stations: near inlet and centre of both lakes. Observation and water sample collection were also performed for the Kahayan and Jengahen Rivers that connected to the Lake Tundai.

Environmental factors were measured monthly. Lake water level was measured using a water level gauge, set up at the shoreline near the centre of both lakes. Water temperature and dissolved oxygen concentration were measured in situ with a platinum resistor thermometer and an oxygen probe (YSI Model 55, Yellow Springs Instruments, USA). The measurement was made at 0.25 m and 0.5 m intervals from the surface to 1 m depth and from 1 m to the bottom. Specific conductivity and pH were measured at 0.5 m intervals with probes (HORIBA, Japan).

Water sample was collected at 0.5 m depth with a 3-l Van-Dorn water sampler for total carbon (TC) and dissolved organic carbon (DOC) analysis. For DOC analysis, a subsample of 500 ml of the water was passed through a glass fibre filter (Whatman GF/F). TC and DOC were determined for unfiltered and filtered waters, respectively, with a TOC analyser (TOC-500, Shimadzu, Japan).

Zooplankton were collected at the water surface of the stations near inlet and centre of the lake. Samples were collected using a 10-l plastic bucket. Twenty such collections (200 l) of surface water were filtered through a 40-µm mesh plankton net and zooplankton were preserved in 4% sugar formalin solution. In the laboratory, three separate 1-ml sub samples were counted in a grid-marked counting slide at 50× magnification and an average count was taken, following the procedure described by Eaton *et al.* (1995). Zooplankton were classified into five different groups: rotifers, cladocerans, copepod nauplii, copepodids, and adult copepods.

Results

Lake Sabuah

Environmental factors

During the period of study, there was a considerable change of lake water level. The water level was high in May and June, then decreased sharply in July and it remained relatively stable at the lowest level until September. The difference between the highest and lowest water levels was 2.86 m (Fig. 2.)

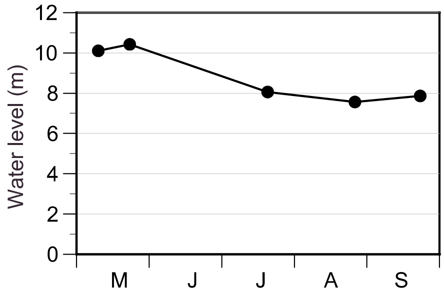

Fig. 2. Temporal change of water level in Lake Sabuah.

Water temperature was stratified at both stations and decreased sharply within the top 2 m depth. At both stations, dissolved oxygen (DO) concentrations increased with decreasing water level. DO concentrations decreased sharply within the top 2 m depth to less than 1mg/l, which coincided with the stratification of water temperature. The surface pH value varied between 4.9-6.2 at the station neat inlet and between 5.6-6.0 at the centre of the lake. During low water level season, pH values increased slightly at the station near the inlet, whereas such values were relatively stable at the centre of the lake. Specific conductivity (SC) fluctuated between 1.5-5.9 mS/m at the station neat inlet and between 2.5-6.5 mS/m at the centre of the lake (Fig. 3).

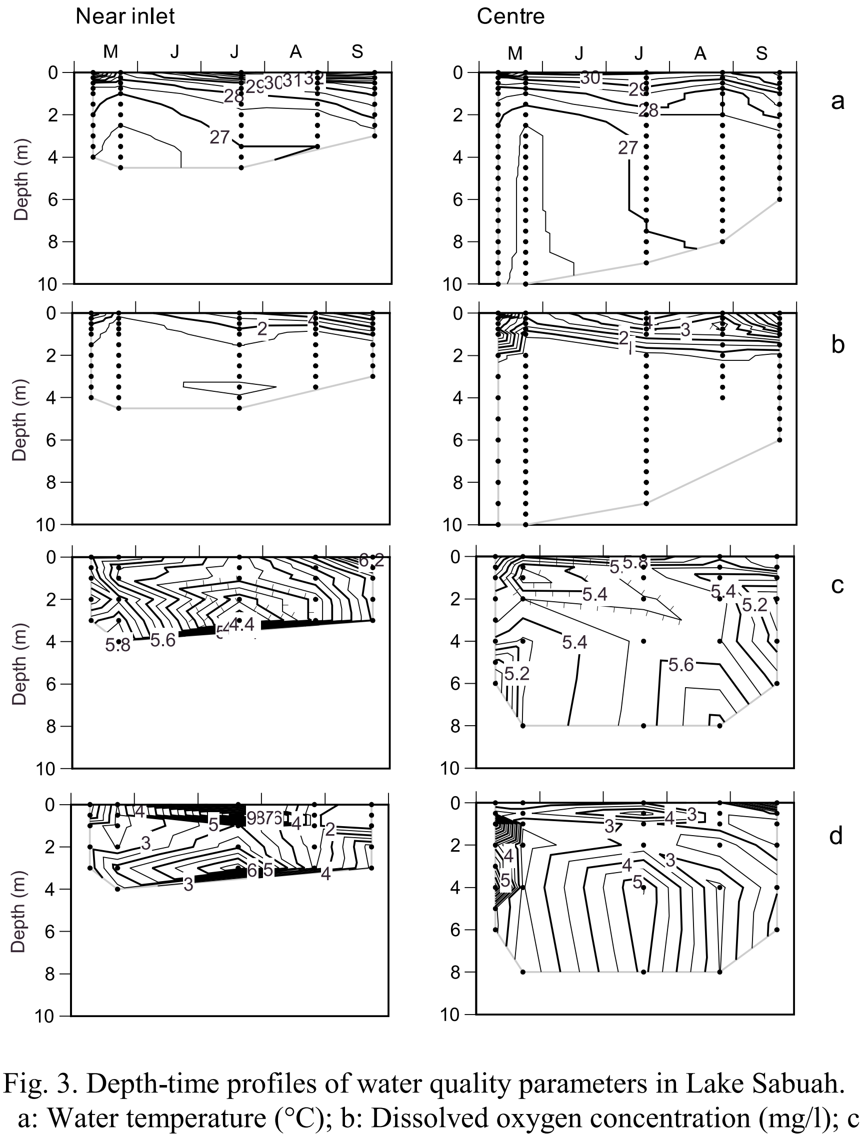

Fig. 3. Depth-time profiles of water quality parameters in Lake Sabuah.
a: Water temperature (°C); b: Dissolved oxygen concentration (mg/l); c: pH;
d: Specific conductivity (mS/m).

Total carbon (TC) and dissolved organic carbon (DOC) concentrations in the surface water fluctuated between 11.2-19.1 mg/l and 6.3-14.9 mg/l, respectively, at the station near inlet and between 7.6-17.9 mg/l and 4.4-13.6 mg/l, respectively, at the centre of the lake. The values were lowest in July (Fig. 4).

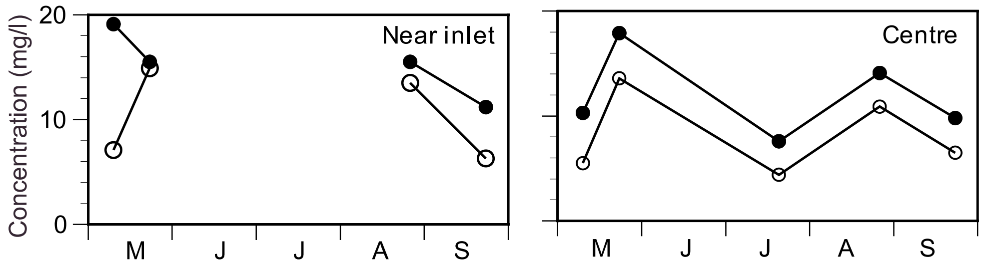

Fig. 4. Temporal changes of total carbon (TC, solid circle) and dissolve organic carbon (DOC, open circle) concentrations in the surface water of lake Sabuah.

Zooplankton abundance

In general, total zooplankton density in Lake Sabuah was low with the maximum density of 6.5 individuals/l occurred during May at the station near inlet of the lake. Copepod nauplii was the dominant zooplankton group in this period. At the centre, the abundance of zooplankton community was extremely low throughout the study period. Cladocerans were nearly absent from the surface water of the lake (Table 1).

Table 1. Zooplankton abundance in Lake Sabuah (individuals/l).

	Sampling date				
	9 May	22 May	18 July	23 August	19 September
Near inlet					
Rotifers	0.56	-	-	-	0
Cladocerans	0	-	-	-	0
Copepod nauplii	5.83	-	-	-	0
Copepodids	0	-	-	-	0.03
Adult copepod	0.1	-	-	-	0
Total	6.49	-	-	-	0.03
Centre					
Rotifers	0.46	-	0.03	-	0
Cladocerans	0	-	0	-	0
Copepod nauplii	0.4	-	0.17	-	0
Copepodids	0	-	0	-	0.03
Adult copepod	0	-	0	-	0.03
Total	0.86	-	0.20	-	0.06

- : No data

Lake Tundai

Environmental factors

During the observed period, the water level of Lake Tundai decreased continuously. The difference between the maximum and minimum water levels was 3.3 m (Fig. 5).

Water temperature decreased sharply with depth in the top 1 m of the water column at both stations but the stratification was destabilized in July at the station near inlet. Surface water temperature increased with the decrease in water level in Aygust-September. DO concentration increased with decreasing water level from May to September as with Lake Sabuah. However in contrast to Lake Sabuah, stratification of DO was not clear within the water column of Lake Tundai. The pH values decreased with the decrease of water level: the surface pH values decreased from 5.9 to 4.0 at the station near inlet and from 4.2 to 4.0 at the centre of the lake. SC values increased with decreasing water level from May to September. The range of SC values in the surface water were 2.7-6.9 mS/m and 3.5-7.8 mS/m for the station near inlet and the centre of the lake, respectively (Fig.6).

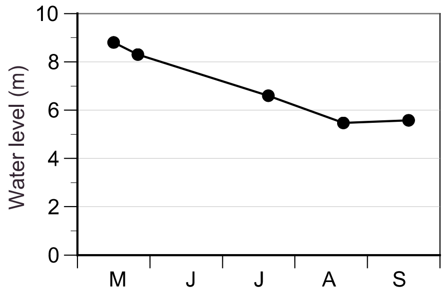

Fig. 5. Temporal change of water level in Lake Tundai.

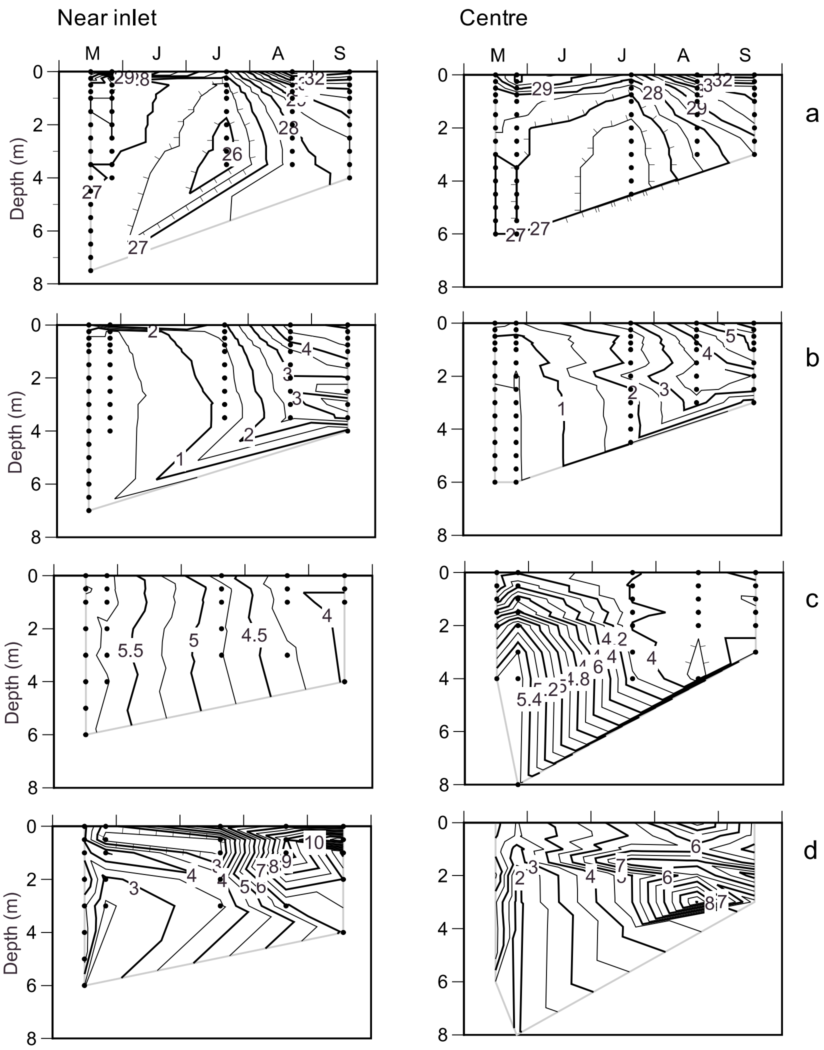

Fig. 6. Depth-time profiles of water quality parameters in Lake Tundai.
a: Water temperature (°C); b: Dissolved oxygen concentration (mg/l).c: pH;
d: Specific conductivity (mS/m).

TC and DOC concentrations also increased with the decrease of water level. At the station near inlet TC concentrations increased from 4.5 to 46.4 mg/l and DOC from 4.1 to 39.4 mg/l. At the centre of the lake, these values were relatively higher than the station near inlet varying between 31.1-44.5 mg/l for TC and 23.9-41.1 mg/l for DOC. The values also tended to increase with decreasing water level (Fig. 7).

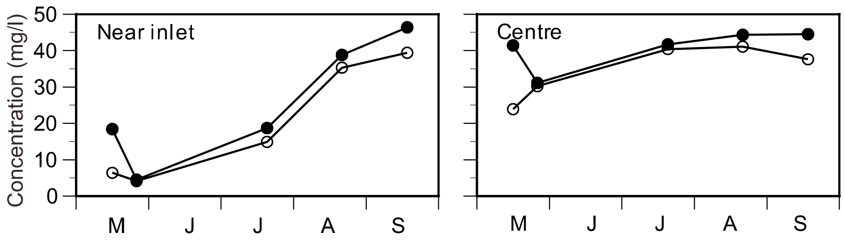

Fig. 7. Temporal changes of total carbon (TC, solid circle) and dissolve organic carbon (DOC, open circle) concentrations in the surface water of lake Tundai.

Water quality parameters changed considerably due to the influence of the Kahayan River that was connected to the lake both in upstream and downstream part of the lake, and also by a tributary river namely the Jengahen River that was connected continuously to the lake. These two rivers were different in their chemical characteristics. The Kahayan River was characterised by neutral pH and low TC and DOC, whereas the Jengahen River was characterised by low pH, and high TC and DOC. In high water level season the Kahayan River affected the water quality of Lake Tundai, whereas in low water level season, the lake water was controlled by the Jengahen River (Fig. 8).

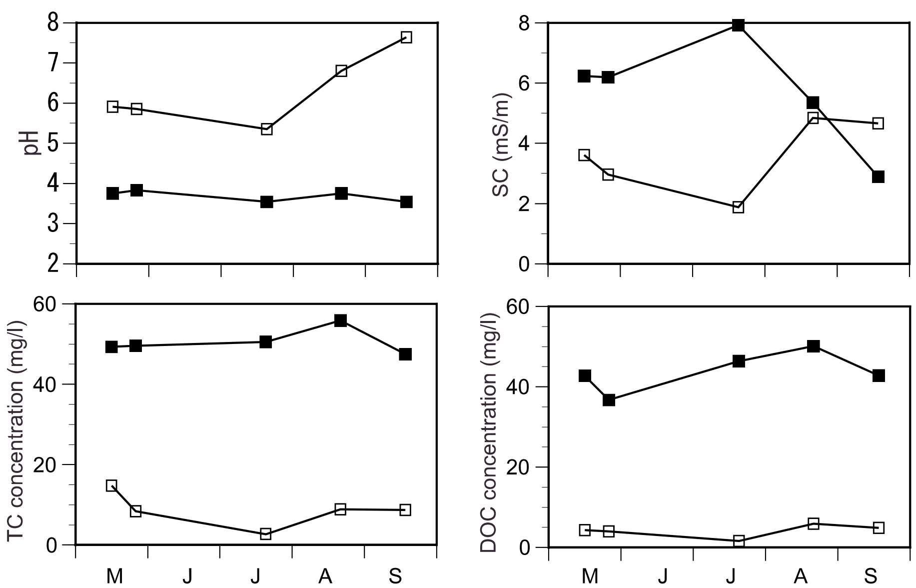

Fig. 8. Water quality of the Kahayan (open square) and the Jengahen Rivers (solid square).

Zooplankton abundance

The temporal patterns of total zooplankton abundance were similar between the station near inlet and centre of the lake. At both stations high total zooplankton densities occurred similarly in May and August. However there were different patterns for the temporal dynamics among main groups of zooplankters. In May, copepod nauplii was dominant at the station near inlet, whereas rotifers dominated the centre of the lake. In August, however, rotifers became the dominant zooplankton at the station near inlet, whereas at the centre the cladocerans became predominant, and in September this group was the only zooplankton inhabiting the water surface at the centre of the lake. Adult copepods were very rare at both stations (Table 2).

Table 2. Zooplankton abundance in Lake Tundai (individuals/l).

	Sampling date				
	14 May	22 May	18 June	23 August	19 September
Near inlet					
Rotifers	4.67	0.83	-	18.40	0.00
Cladoceran	3.17	0.07	-	1.47	1.00
Copepod nauplii	9.83	0.53	-	2.23	0.07
Copepodids	7.83	0.07	-	0.13	0.07
Adult copepods	0.17	0.03	-	0.07	0.13
Total	25.67	1.53	-	22.30	1.27
Centre					
Rotifers	14.00	4.67	-	2.20	0.00
Cladoceran	1.17	0.33	-	21.33	13.67
Copepod nauplii	1.50	1.00	-	0.07	0.00
Copepodids	5.33	0.00	-	0.07	0.00
Adult copepods	0.83	0.33	-	0.13	0.00
Total	22.83	6.33	-	23.80	13.67

- : No data

Discussion

In both Lake Sabuah and Lake Tundai the maximum zooplankton densities occurred in May at the station near inlet when the water level was high. However, the densities were considerably different. In Lake Sabuah the total zooplankton density was 6.49 individuals/l, whereas in Lake Tundai the maximum density was 25.65 individuals/l.

Another interesting finding was the occurrence and seasonal dynamics of rotifers and cladocerans in both lakes. In Lake Sabuah, these two groups were very rare and cladocerans were totally absent during low water period. In Lake Tundai, on the other hand, rotifers were very abundant, but their seasonal dynamics at both stations were oppositely different. At the station near inlet, rotifers tend to increase, whereas at the centre they tended to decline with the decrease of water level. Cladocerans were relatively stable at low densities at the station near inlet, but they increased considerably during low water level season at the centre.

The different abundance and seasonal dynamics of zooplankton community in Lakes Sabuah and Tundai may be explained by the following mechanisms.

The decrease of water level affected the water quality differently in both lakes. Since there is no influx river to Lake Sabuah, the decrease of water level might lead to the exposure of littoral zone and then increase the transparency especially in the near inlet of the lake. This, in turn, would affect the depth of light penetration into the water column and increase the difference between water temperatures and oxygen concentrations at the surface and 1 m depth. There was no clear effect of decreasing water level with the changing of pH values, SC, TC and DOC concentrations in this lake. However, by judging from the low TC and DOC concentrations, the low abundance of zooplankton in this lake in September might be related with the low supply of carbon (TC and DOC) from surrounding area of the lake due to the decrease of water level.

In Lake Tundai the hydrological mechanisms was slightly different. Due to its open connection with the Kahayan River and also by receiving water from the Jengahen River, the water quality of Lake Tundai was greatly affected by the contribution of water discharge from both rivers. During high water level season, water from the Kahayan River enters the lake from two different channels. During this period, the water quality at the station near inlet of the lake was greatly affected by the Kahayan River. As a result, the pH values were much higher and TC and DOC concentrations were much lower at the station near inlet than at the centre. When the inflow water from the Kahayan River decreased, the inlet channel dried up and the station near inlet was influenced mainly by the Jengahen River. This led to the decrease of pH and increase of EC, DO, TC and DOC at both stations near inlet and centre of the lake.

In lakes with significant allochthonous input of humic substances, two conceptually separate food chains come together: Jones (1992) described that in this combined food chain, phytoplankton and bacteria can be viewed as occupying the same trophic level which serve to mobilise, and to make available to higher trophic levels, energy which is otherwise unavailable, whether in a physical form (light) or a chemical form (dissolved organic matter, DOM). Many workers have reported several evidences that DOC is the main source of carbon for bacteria in humic lakes. Hessen (1992) observed that allochthonous DOC accounted for almost 90% of the carbon required to support bacterial growth in a small humic lake of Norway. This finding was supported by the laboratory culture experiment by Arvola and Tulonen (1998) who reported that the growth rates, cell numbers, and biomass of bacteria were substantially higher in the presence of DOM than in culture without DOM.

Many other workers also reported the linkages between organic carbon and zooplankton growth. In their earlier work, Hessen *et al.* (1990) reported that most of the carbon biomass of zooplankton was derived from detritus and bacteria, while phytoplankton accounted only for a minor fraction. The most recent work on this concept was done by Thouvenot *et al.* (1999) who observed that metazoan zooplankton especially cladocerans appeared to be the main consumers of bacteria.

In the present study we found that, over the whole study period, the TC and DOC concentrations in Lake Sabuah were considerably lower than that in Lake Tundai. Therefore, one possible factor that influenced the abundance of zooplankton community was the carbon (TC and DOC) concentration in both lakes.

The difference in physiological adaptations among zooplankton groups to the changing of water quality may affect the zooplankton community. Rotifers (*Keratella*, *Polyarthra*) are often abundant in acidified lakes (Brönmark and Hansson, 1998), whereas a study in a eutrophic lake of Germany indicated that two *Daphnia* species could have different resistance to low oxygen concentration due to the difference in their ability in producing Haemoglobin (Sell, 1998). Judging from the above information, the successful colonization of rotifers at the statoin near inlet and cladocerans at the centre of Lake Tundai during low water level season, might be also induced by this physiological adaptation. Of course other factors such as food availability, predation pressure and competition among zooplankton should also be taken into account as factors affecting the seasonal dynamics of rotifers and cladocerans.

In conclusion, the present study showed that the difference in zooplankton abundance between Lake Sabuah and Lake Tundai could be attributed to the difference in carbon concentrations, e.g. TC and DOC, as an important source of energy in humic oxbow lakes. Hydrological conditions regulated the allochthonous input of carbon to these oxbow lakes resulting in different levels of carbon concentrations.

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References

Arvola, L. and Tulonen, T. 1998. Effects of allochthonous dissolved organic matter and inorganic nutrients on the growth of bacteria and algae from a highly humic lake. *Environt. Intern.,* **24:** 509-520.

Brönmark, C. and Hansson, L. A. 1998. *The Biology of Lakes and Ponds*, Oxford University Press, Oxford.

Dussart, B. H., Fernando, C. H., Tundisi, T. M. and Shiel, R. J. 1984. A review of systematics, distribution and ecology of tropical freshwater zooplankton. *Hydrobiologia*, **113:** 77-91.

Eaton, A. D., Clesceri, L. S. and Greenberg, A. E. 1995. *Standard Methods for the Examination of Water and Wastewater*, 19th edn. American Public health Association, Washington.

Fernando, C. H. 1980. The species and size composition of tropical freshwater zooplankton with special reference to the oriental region (South East Asia). *Int. Revue ges. Hydrobiol*, **65:** 411-426.

Fernando, C. H. and Ponyi, J. E. 1981. The freeliving freshwater Cyclopoid Copepoda (Crustacea) of Malaysia and Singapore. *Hydrobiologia*, **78:** 113-123.

Hessen, D .O., Andersen, T. and Lyche, A. 1990. Carbon metabolism in a humic lake: Pool sizes and cycling through zooplankton. *Limnol. Oceanogr.,* **35:** 84-99

Hessen, D .O. 1992. Dissolved organic carbon in a humic lake: effects on bacterial production and respiration. *Hydrobiologia*, **229**: 115-123.

Idris, B. A. and Fernando, C. H. 1981. Cladocera of Malaysia and Singapore with new records, redescriptions, and remarks on some species. *Hydrobiologia*, **77:** 233-256.

Iwakuma, T., Hehanussa, P. E. et al. 1999. Aquatic ecosystems in Central Kalimantan (FY1998). In: *Environmental Conservation and Land Use Management o Wetland Ecosystems in Southeast Asia: Annual Report for April 1998-March 1999*. Hokkaido University and RDC for Biology-LIPI, pp. 165-189.

Iwakuma, T. I. Ohtaka, A., Hartoto, D. I., Limin, S. H., Torang, I., Jaya, S. and Tanaka, N. 2000. Preliminary study on limnological features of lakes and rivers in the peat swamp area of Central Kalimantan. *Rep. Suwa Hydrobiol*., **12**: 81-88.

Jones, R. I. 1992. The influence of humic substances on lacustrine planktonic food chains. *Hydrobiologia*, **229:** 73-91.

Lai, H. C. and Fernando, C. H. 1980. Zoogeographical distribution of Southeast Asian freshwater Calanoida. *Hydrobiologia*, **74:** 53-66.

Lehmusluoto, P., Machbub, B., Terengna, N., Ahmad, F., Boer, L., Brahmana, S. S., Setiadji, B., Priadie, B., Timostius, K. H. and Goeltenboth, F. 1999. *Limnology in Indonesia - From the legacy of the past to the prospect for the future*. In Wetesel, R. G. and Gopal, B. Limnology in Developing Countries. Vol. 2. International Publications, New Delhi.

Lim, R. P. and Fernando, C. H. 1985. A review of Malaysian freshwater Copepoda with notes on new records and little known species. *Hydrobiologia*, **128:** 71-89.

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

Nilssen, J. P. 1984. Tropical lakes - functional ecology and future development: The need for a process-orientated approach. *Hydrobiologia*, **113:** 231-242.

Wodajo, K. K. and Belay, A. 1984. Species composition and seasonal abundance of zooplankton in two Ethiopian Rift Valley lakes - Lake Abiata and Langano. *Hydrobiologia*, **113:** 129-136.

Sell,A. F. 1998. Adaptation to oxygen deficiency: Contrasting patterns of haemoglobin synthesis in two coexisting *Dhapnia* species. *Comp. Bioch. And Physiol. - Part A: Mol. & Integ. Physiol.,* **120:** 119-125.

Thouvenot, A., Richardot, M., Debroas, D., and Devaux, J. 1999. Bacteriovory of metazooplankton, ciliates and flagellates in a newly flooded reservoir. *J. Plankton Res.,* **21:** 1659-1679.

Twombly, S. 1983 Seasonal and short term fluctuations in zooplankton abundance in tropical Lake Malawi. *Limnol. Oceanogr.,* **28:** 1214-1224.

Wyngaard, G. A., Elmore, J. L. and Cowell, B. C. 1982. Dynamics of a subtropical plankton community, with emphasis on the copepod *Mesocyclops edax*. *Hydrobiologia*, **89:** 39-48.

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Bogor, Indonesia, 22-23 November 1999
Hokkaido University & Indonesian Institute of Sciences
pp. 455-470 (2000)

Diel and Seasonal Feeding Activities of Fishes in an Oxbow Lake of Central Kalimantan, Indonesia

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Abstract

In Central Kalimantan, there are abundant fish species, which may be playing important roles in freshwater ecosystems. Food habit and the changes of diel and seasonal feeding activities of fishes were studied to elucidate their functional roles in a tropical lake ecosystem and to demonstrate how the fish communities are maintained. A total of 31 species of fishes were collected with gill nets, a scoop net (selambau), cast nets in Lake Tundai (lat. 2°12'30"S and long. 114°0'34"E, surface area 0.65 km^2), an oxbow lake along the Kahayan River, in September 1998 or low water level season and in April-May 1999 or high water level season. *Cyclocheilichthys apogon* ware caught during 1500 to 1800 including sunset and during 0300 to 0600 including sunrise in low water level season and caught at daytime in high water level season. They fed on Chironomidae larvae preferably in high water level season. *Mystus nemurus* and *Mystus nigriceps* ware caught during nighttime or around 1800 and 0600. They fed on fishes in low water level season. The ratio of Chironomidae larvae among the stomach contents of 2 *Mystus* species increased in high water level season. *Trichogaster leerii* were caught abundantly during 1500 to 1800 and during 0300 to 0600. They fed on filamentous algae and detritus in high water level season. The ecology of fishes and interaction with the environment are discussed.

Introduction

A large amount of fish catch has been reported for tropical peatswamp areas in Central Kalimantan, indicating that the abundance and production of fish species are also large in this region (Hartoto, 2000). These fishes are, without doubt, playing important roles in freshwater ecosystems and have large impacts on them (Horne and Goldman, 1994; Lampert and Sommer, 1997).

Freshwater environments in peatswamp areas of Central Kalimantan are characterized by high concentrations of dissolved organic matters which are the cause of brown water, low transparency and subsequent very low dissolved oxygen concentration (Iwakuma *et al.*, 1999).The ecological information on ecosystem function especially on the maintenance mechanism of fish communities is not always true for tropical waters although there have been some intensive studies on fish community structure (Ng and Kelvin; 1992; Peter *et al.*, 1994; Zakaria-Ismail and Lim, 1995), effect of food contents (Khan *et al.*, 1996), impacts of introduced animals on aquatic ecosystems (Ng *et al.*, 1993). The purpose of the present study was to analyze the food habit and the changes of diel and seasonal feeding activities of fishes to elucidate their functional roles in a lake ecosystem and to demonstrate how the fish communities are maintained.

Study Area

Many oxbow lakes are located along the rivers flowing through tropical peatswamp areas in Central Kalimantan, Indonesia. Lake Tundai is a long and slender oxbow lake (lat. 2°12'30"S and long. 114°0'34"E, surface area 0.65 km^2) still connected to the Kahayan River 20 km downstream of Palangka Raya City. We caught fishes in Lake Tundai (Fig. 1). The lake outlet at the southern tip is wide and deep enough to pass through easily by boat even in the low water level season. In high water level season, i.e., November-April, the forest surrounding the lake is inundated widely. Several channels where only a small boat can pass through are connecting the lake to the Kahayan River and another river. Water coming through these channels also inundates the forests. In low water level season, lake water is concentrated in the lake basin. The maximum observed fluctuation of water level was 3.4 m during September 1998-June 1999 (S. Gumiri, unpublished data). Since the water color is deep brown, the transparency in this lake is about 50 cm (R. Komatsu, unpublished data).

On the left bank of the lake, there is a village which is connected to other villages only by waterway. Observations and sampling were made near the village.

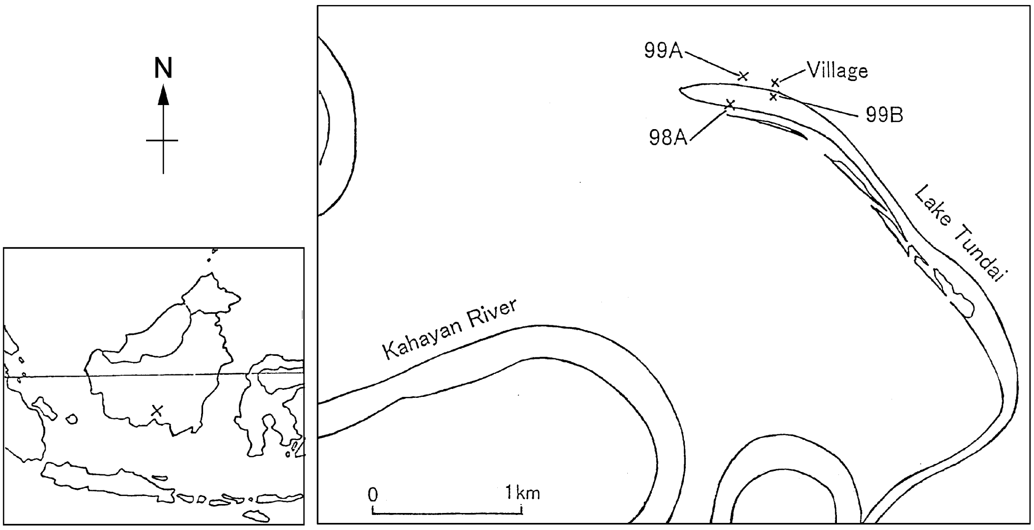

Fig. 1. Lake Tundai showing the location of sampling sites. Gill nets were set at site 98A along the right bank of the lake in September 1998. A scoop net (selambau), which we lent in April 1999, was set by local fisherman at site 99A in the flooded forest. Fishes were also collected with cast nets at site 99B in front of a village in May 1999.

Methods

Freshwater fishes were caught in Lake Tundai in September 1998, when it was near the end of low water level season and April-May 1999, when it was near the end of high water level season.

In September 1998, fishes ware caught with three gill nets of different depths and mesh sizes: 18 m long × 2 m deep with 50-mm opening mesh, 18 m long × 2 m deep with 2.5-mm opening mesh and 18 m long × 1.8 m deep with 1.5-mm opening mesh. Nets were set in parallel at Site 98A of the lake each extending from littoral zone to pelagic zone. The site was located near a forest and therefore some wood debris were on the muddy bottom sediment. Since the water depth at this site was 0 m to ca. 2.3 m. almost all the lower ends of the nets touched the bottom. We set the nets at 1200 on 18 September 1998 and collected fishes 9 times every 3 h until 1500 on the following day.

In April and May 1999, we used a traditional big scoop net (selambau) ca. 10 m long × 5m wide with 2” mesh opening at Site 99A. The 3 sides of the net were submerged to the bottom before each sampling occasion, left for 2-3 h and the net was pulled up quickly above the water to collect fish. The site was located alongside a watercourse for timber transportation from the marginal flooded forest to the lake during a high water level season. Water depth was ca. 2 m to 3 m and the bottom was covered with many wood and plant debris. We collected fishes 10 times at 1600 and 1800 on 29 April and thereafter every 3 h until 1740 on the following day. During 6-7 May we used 2 gill nets of different dimensions and mesh sizes: 11 m long × 1.5 m with 0.5” opening mesh and 18 m long × 2 m deep with 50-mm opening mesh. The nets were set at Site 99A at 1300 on 6 May 1999 and fishes were collected 9 times every 3 h from 1500 until 1500 on the following day. In addition, we collected fishes with cast nets in front of the village we stayed (Site 99B). Depth of water was between 0m to ca. 2.5m for this sampling. The bottom sediment was mud and the water surface was covered by many artificial materials, e.g., pillars of houses, floating huts, small boats etc. Fishes were collected 4 times at 1800 on 6 May and 0000, 0600, and 1200 on 7 May 1999. Each sampling was completed within 30 min During 25-26 May 1999 fishes were collected again at Site 99B with the cast nets. We caught fishes 8 times every 3 h from 1200 on 25 May until 0900 on 26 May. Similarly, each sampling was completed within 30 min Additional samplings using the cast net and gill nets were made off the village, pelagic zone and in the flooded marginal forest.

Fishes were killed with an excess amount of anesthesia MS222 (ethyl-3-aminobenzoate methanesulfonic acid salt) to avoid the vomiting of stomach contents soon after they were caught. And they were fixed and preserved in 10% formalin solution. To fix their internal organs and gut contents, 10% formalin solution was injected into the abdomen soon after they were killed. Total length, standard length, wet body weight and the wet weights of stomach and intestine contents of each individual were measured in the laboratory and ratio of stomach contents weight to body weight, i.e., 100 × stomach content weight (g) / body weight (g), were calculated. The quantitative analyses of the contents of gut were made according to a points method (Hynes, 1950). Stomach contents were identified under binocular microscope of 10-40 × magnification as fishes, prawns, Chironomidae, Anisoptera, Trichoptera, Hemiptera, insects other than them, unidentified insects, litter, algae, detritus and others. When sand or mud was found in gut contents, it was classified as detritus. Average ratio of each food items of stomach contents found from each species to body weight were calculated.

All the statistical analysis was performed using a statistical software (StatView, Hulinks Inc.).

Results

Diel patterns of number of fish caught with nets

In the present study we caught 504 individuals belonging to 14 species in September 1998, and 1115 individuals belonging to 26 species in April-May 1999 from Lake Tundai (Table 1).

Table 1. List of fishes caught in Lake Tundai with gill nets, cast nets and a scoop net.

Species	Number of individuals	
	September 98	April and May 99
Cyclocheilichthys apogon	13	111
Leptoburbus hoevenii	10	27
Luciosoma trinema		6
Osteochilus melanopleura	15	76
Osteochilus microcephalus		1
Osteochilus pentalineatus		5
Osteochilus schlegelii	10	
Osteochilus triporos		250
Parackela spp.		12
Puntius lineatus		48
Rasbora sp.1		61
Rasbora spp.		40
Thynnichthys polylepis		4
Mystus nemurus	20	14
Mystus nigriceps	33	10
Kryptopterus apogon		10
Kryptopterus limpok		12
Kryptopterus sp.1		9
Kryptopterus spp.	3	116
Ompok sp.	1	
Wallago leerii	1	
Pseudentropius brachypopterus		35
Pangasius nasutus		5
Clarias meladerma		1
Parambassis macrolepis		1
Nandus nebulosus	1	
Pristolepis grooti	15	3
Helostoma temminckii	39	10
Trichogaster leerii	339	224
Trichogaster trichopterus	4	18
Macrognathus aculeatus		6
Total	504	1115

Diel patterns of number of individuals caught with gill nets in Sep 1998 or low water level season was bimodal having peaks at the time interval 1500-1800 which included sunset and at the interval 0300-0600 which included sunrise. In these time intervals many species were also caught. Some differences were recognized in the diel patterns of number of individuals trapped among fish species. The patterns for dominant species are as follows: *Osteochilus melanopleura* was caught only during daytime, *Mystus nemurus* was caught mainly at the intervals 1500 to1800 and 0300 to 0600 and most individuals of *Mystus nigriceps* were caught at the same time intervals as *M. nemurus*. *Helostoma temminckii* was caught mainly at time interval 0300-0600.

Number of *Trichogaster leerii* caught was highest and they were caught mainly at intervals 1500-1800 and 0300-0600. Though the total number of *Cyclocheilichthys apogon* collected was not so large, they seemed to be caught mainly at intervals 1500-1800 and 0300-0600 (Fig. 2). A complete list of species collected at each sampling time interval with the gill nets is shown in Appendix 1.

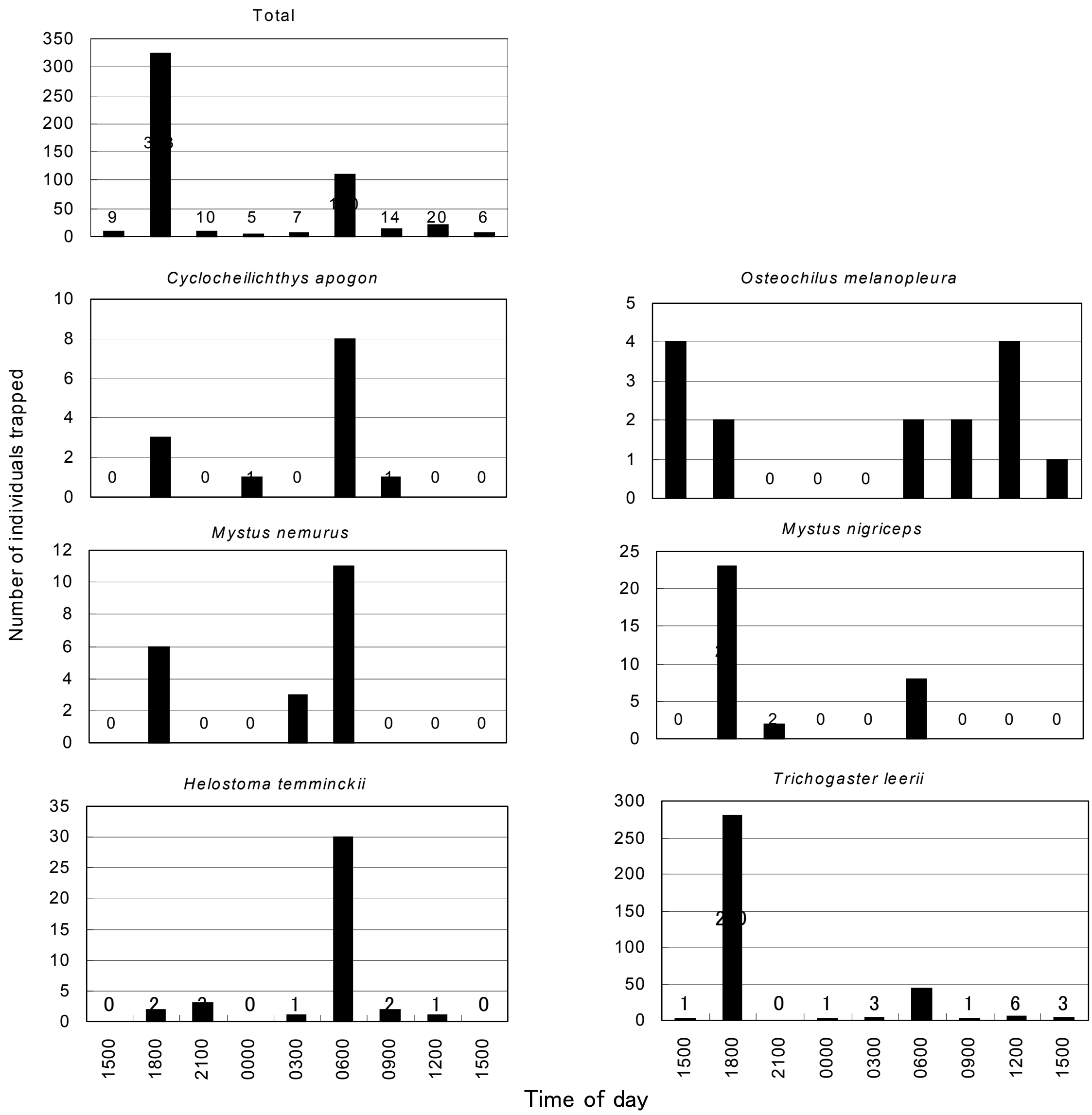

Fig. 2. Number of individuals caught with gill nets at site 98A in low water level season at several sampling occasions during 1200 of 18 September to 1500 of 19 September 1998. A figure by the column indicates number of individuals caught at each sampling time.

Diel pattern of number of individuals caught by scoop net (selambau) in April 1999 or high water level season was unimodal having single peak at 0600 which was due to the catch of predominant *Osteochilus melanopleura.* As for other species, although distinct peaks like in Sepember 1998 were not found, some different patterns were found. *Cyclocheilichthys apogon* and *Leptoburbus hoevenii* were caught only at daytime. A large number of *Osteochilus melanopleura* were caught at 0600. Unlike September 1998, *Mystus nemurus* and *Mystus nigriceps* were not abundunt but they were caught mainly during nighttime or around the sunrise at 0600. Only a small number of *Kryptopterus apogon* were caught mainly during nighttime. Other *Kryptopterus* spp. could not be collected enough to detect diel pattern. Furthermore because it was difficult to identify them correctly to species. The number of *Helostoma* *temminkii* was also small but there was a pattern that they were caught mainly during daytime. Similarly *Trichogaster leerii* were caught only during daytime (Fig. 3). A complete list of species collected at each sampling time with the scoop net is shown in Appendix 2.

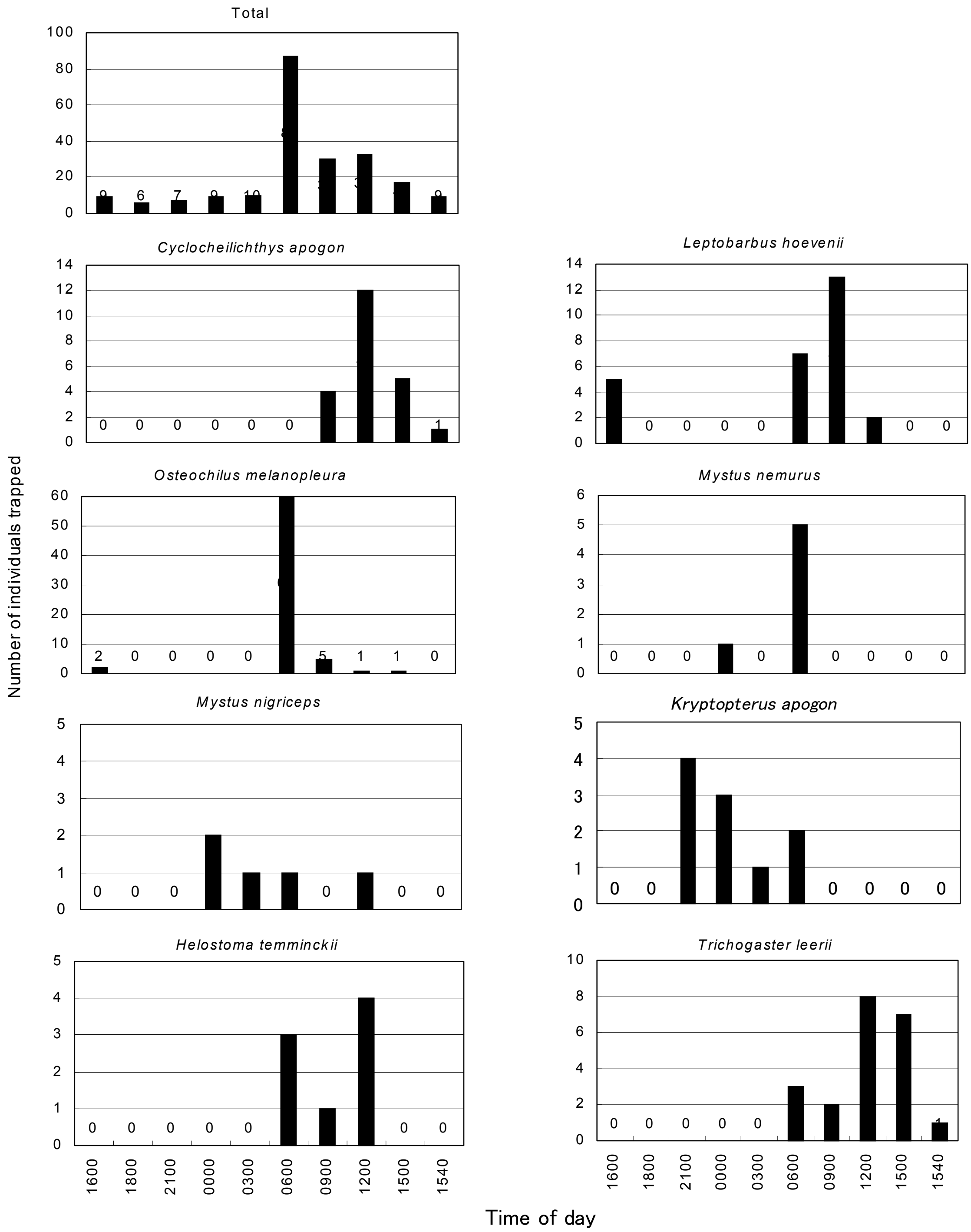

Fig. 3. Number of individuals caught with a scoop net (selambau) at site 99A in high water level season at several sampling times during 1600 of 29 April to 1740 of 30 April 1999. A figure by the column indicates number of individuals caught at each sampling time.

Fig. 4 shows the number of individuals caught by 2 gill nets in May 1999, or high water level season. Except for 1 individual of *Clarias meladerma* and *Macrognathus aculeatus*, all the fishes were caught with the gill net of smaller mesh size (0.5”). The sample consisted of small individuals of *Osteochilus triporos, Puntius lineatus, Rasbora spp.,* etc., of which *Osteochilus triporos* was most abundant (Appendix 3). They were not caught during nighttime but only during daytime.

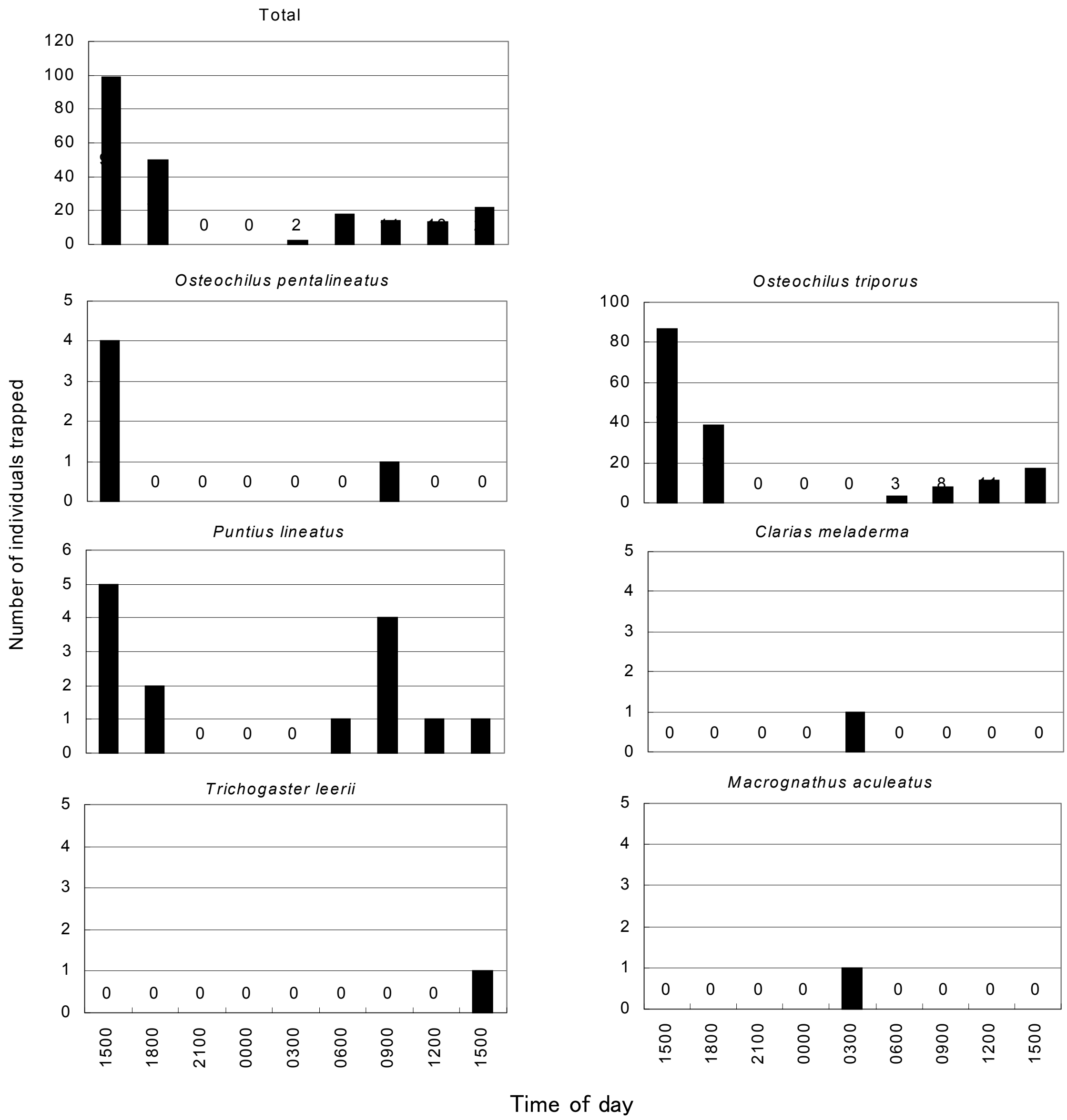

Fig. 4. Number of individuals caught with gill nets at site 99A in high water level season at several sampling times during 1200 of 6 May to 1500 of 7 May 1998. A figure by the column indicates number of individuals caught at each sampling time.

Stomach contents

All samples were caught with gill nets in September 1998. Some individuals had presumably been alive being trapped in the gill nets to a maximum of 3 h. This might have caused the stomachs of some individuals become empty. Individuals with empty stomachs therefore could not be judged that stomach contents had already been digested, vomited or empty from the beginning. Fortunately, stomachs of most individuals of *Mystus nemurus* and *Mystus nigriceps* were not empty. *M. nemurus* fed mainly on small fishes, with small amount of shrimps, aquatic insects, etc. *M. nigriceps* fed also on small fishes, aquatic insects (Hemiptera and Anisoptera larvae), etc. Since the samples collected with a scoop net (selambau) and cast nets in April-May 1999 were fixed immediately after the collection, percentage of stomach contents, food items and their average composition were calculated. Relatively many individuals of *Cyclocheilichthys apogon* were collected with a scoop net and cast nets both during daytime and nighttime. Many head capsules of Chironomidae larvae were found from their stomach contents. Many lumps of protein were also found, which seemed to be the remains of Chironomidae larvae crushed with the fish's pharyngeal teeth. Other items were small amount of aquatic insects, algae, etc. (Table 2).

Table 2. Food items found from the stomachs of *Cyclocheilichthys apogon*, *Mystus nemurus*, *Mystus nigriceps* and *Trichogaster leerii*. Average of ratio of each food items in stomach to body weight.

Food items	*Cyclocheilichthys apogon*	*Mystus nemurus*		*Mystus nigriceps*		*Trichogaster leerii*
	High water level season	Low water level season	High water level season	Low water level season	High water level season	High water level season
Fishes		2.98	0.93	0.24	0.32	
Prawns		0.064				
Chironomidae larvae	0.044		0.372	0.0078	0.824	0.0003
Chironomidae pupae			0.0028		0.024	
Ceratopogonidae larvae						0.0038
Anisoptera larvae		0.044	0.044	0.028	0.035	
Trichoptera larvae			0.0067		0.0079	
Hemiptera adalts			0.016	0.024	0.0010	
Insects (all stages)	0.004		0.090	0.024	0.032	
Unidentified invertebrates	0.132					
Animals			0.099	0.029	0.037	
Attatched algae	0.0002					0.088
Higher plants	0.0039					
Detritus						0.105
Others	0.015	0.051	0.035	0.046	0.101	0.010
Total	0.1991	3.139	1.5955	0.3988	1.3819	0.2071

Since almost all individuals of *Mystus nemurus* and *Mystus nigriceps* were caught around sunrise and nighttime, it was difficult to construct a figure of diel change in percentage of stomach contents for these species. Therefore the information on food items and their ratio of each food items to body weight are shown in Table 2. A large amount of Chironomidae larvae were found with small fishes from the stomach of *Mystus nemurus*. Some other aquatic insects, e.g., Anisoptera larvae and Trichoptera larvae were also found. Likewise most of the stomach contents of *Mystus nigriceps* were Chironomidae larvae which were dwelling the lake bottom. A small amount of other aquatic insects were also found. *Trichogaster leerii* were caught mainly during daytime except for around at 0300.

The ratio of stomach contents weight to body weight did not show any distinct diel pattern: some fish had some contents in their stomach both during daytime and nighttime. However the value for daytime seemed to be higher than that for nighttime. At least individuals that had empty stomach were caught only at nighttime.

The fact that the stomach contents of *T. leerii* included sand and mud suggested that this species was detritus feeders. Many filamentous algae mainly *Zygonema* were also found from the stomach of *T. leerii*. During the nighttime, they were caught only at 0300 but almost all of their stomachs were empty. Except for some individuals caught around 0600 whose stomachs were empty, all the individuals caught during daytime had some contents in their stomachs (Fig. 5).

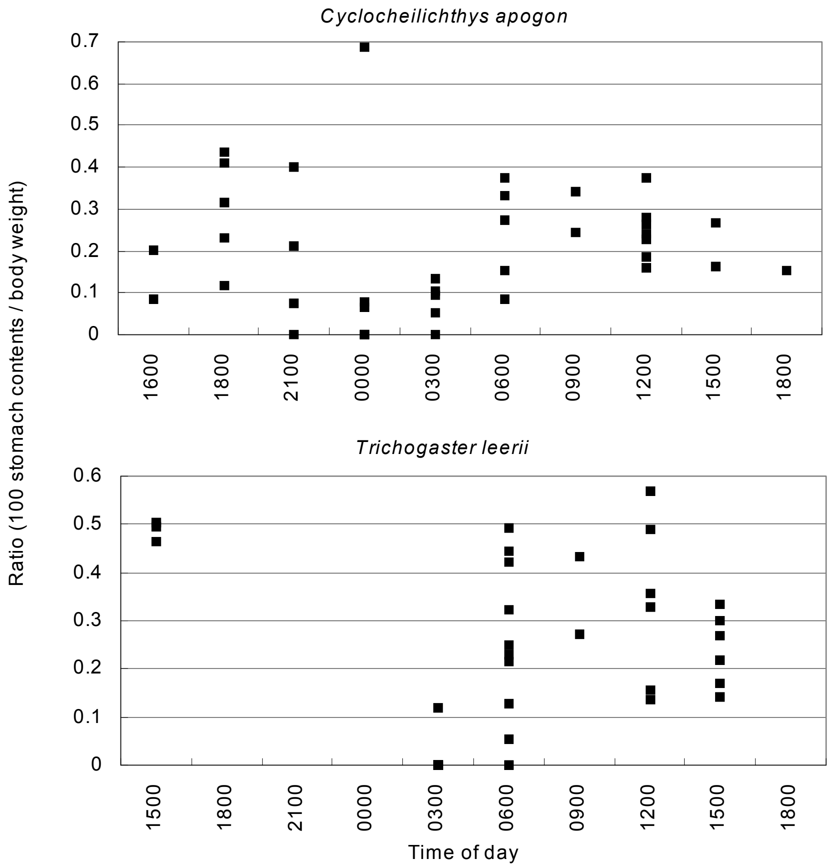

Fig. 5. Diel changes in the ratio of stomach contents weight to body weight for *Cyclocheilichthys apogon* and *Trichogaster leerii*.

Discussion

A total of 31 species or taxa of fishes were caught from Lake Tundai in September 1998 and April-May 1999. For some taxa, individuals large enough for correct identification were not caught. There were species for which it was too difficult to investigate their gut contents. In the present study, we discussed on 4 dominant species, i.e., *Cyclocheilichthys apogon, Mystus nemurus, Mystus nigriceps* and *Trichogaster leerii*.

C. apogon belongs to Cyprinidae. In general, Cyprinidae fishes vary widely in their behavior, e.g., diurnal or nocturnal activity, which made them fit to respective environments. Similarly they have also various food habits, e.g., carnivorous, herbivorous or omnivorous habits. Let us first compare the number of individuals caught during a 24-h period between low water level season in September 1998 and high water level season in April 1999. *C. apogon* were caught mainly during 1500-1800 and 0300-0600 including sunset and sunrise in low water level season. In high water level season, however, they were caught during daytime. They seemed to have crepuscular activity in low water level season andchange their behavior to diurnal in high water level season. Shiraishi et al. (1972) have studied freshwater fishes in Lake Bera using gill nets. They caught *C. apogon*, which is regarded as nocturnal in low water level season but its diel activity is not clear in high water level season. Maybe this fish have different behavior in other regions, or they moved actively also around sunset and sunrise and caught by gill net for nighttime.

Chironomdae larvae seemed to be eaten preferably by fishes during the high water level season. Furthermore the food item, unidentified invertebrates, seemed to consist mainly of crushed Chironomdae larvae, since fish of Cyprinidae crush their foods with their pharyngeal teeth. Therefore the main food item seems to be Chironomdae larvae during this season. This seemed to agree well with the result of Yap (1988). However this fish species is considered as a detritivore (Tan, 1972) or a carnivore (Inger & Chin, 1962). So they seemed to be able to change their food item according to the environmental condition. Also in this lake, they fed mainly on detritus in low water level season (T. Buchar, personal communication). *C. apogon* in lake Tundai may change their food items according to the seasons.

From the several 24-h observations during high water level season (29-30 April, 7-8 May, and 25-26 May 1999), feeding activity of fishes measured by the percentage of stomach content seems to decrease during nighttime. Although there was no significant difference in stomach contents among sampling times (Kruskal-Wallis test, $P>0.5$), a significant difference was detected between daytime (1500, 1800, 0600, 0900, 1200) and nighttime (2100, 0000, 0300) (Mann-Whitney U-test, $P=0.0007$). Individuals that had empty stomach were only caught at nighttime. Therefore they seem to feed more actively during daytime than nighttime in high water level season. Their diel activity reflected their feeding activity. Why they change their diel activity in low water level season remain unsolved although there are some plausible reasons such as change of food items, presence of predators, etc.

Mystus nemurus and *M. nigriceps* belong to Bagridae. In general, Bagridae fish are nocturnal and carnivorous. From the result of number of individuals caught by gill nets and a scoop net, they also seemed nocturnal or crepuscular. The main food items of *M. nemurus* were fishes in low water level season, but in high water level season, Chironomidae larvae became important food item rank with fishes. Ratio of fishes was still large, but most of it was due to amount of only 1 individual. The food items of *M.*

nigriceps were also fishes and some aquatic insects in low water level season, but in high water level season, their main food item was almost completely changed to Chironomidae larvae, a few number of which were found in low water level season. Comparing these 2 species, *M. nemurus* had stronger tendency of piscivory as is pointed out by Hartoto (in press). Why they switch their food items between high and low water level seasons? Lake water is concentrated in the narrow space in low water level season as compared with high water level season. Of cause fishes are also concentrated in this narrow space which may enhance the predation by piscivores or increase of food for piscivores. In fact that, In high water level season, at first we set the gill nets used in low water level season, but only small number of fishes ware caught. For reason, it is thought that density of fish was decreased in high water level season. Whether the availability of chironomid larvae as food items decreased or not in low water level season remain unsolved. Further studies are necessary on population dynamics Chironomidae larvae.

Trichogaster leerii belongs to Belontiidae. Individuals *T. leerii* were caught mainly during 1500-1800 and 0300-0600 which include sunset and sunrise, respectively, in low water level season. Especially during 1500-1800, a large number of them were caught. In high water level season, they were caught during daytime. Therefore they seem to have diurnal or crepuscular behavior. In fact they were observed during daytime when they were swimming in school in the pelagic zone of lake and they could be caught there. And when only one time we could catch them during nighttime, they made school and didn't move. So it is thought that they swim actively in school during daytime and rest in the littoral zone during nighttime. Maybe clear peaks in low water level season were made because they were caught when they moved actively in the littoral zone before or after resting in a big school. Fishes caught during three 24-h periods in high water level season, there is only one group of samples caught during nighttime. However almost all of their stomachs were empty and their percentage of stomach contents weight were different significantly in each sampling time (Kruskal-Wallis test, P=0.0001) and between daytime and nighttime (Mann-Whitney U-test, P<0.0001). Therefore it is thought that they have high activity in daytime including feeding behavior. They fed on filamentous algae like *Zygnema* and detritus. Some Ceratopogonidae larvae were found with filamentous algae, but they seemed to be eaten by chance. These filamentous algae might have been distributed in the littoral zone (Kusakabe *et al.*, 2000) and there are some more fish species feed on filamentous algae like *T. leerii*. Further study on the littoral zone is necessary.

It is clear that chironomid larvae are important food item for several fishes, e.g., *C. apogon, M. nemurus, M. nigriceps*, to maintain their population at least high water level season. However the food item most frequently appeared more *M. nemurus* and *M. nigriceps* were small fishes and other aquatic insects in low water level season. Possible reason is that it is difficult to prey upon small fishes in high water level season. In general, fishes spawn during high water level season in flooded forests. Piscivores like *M. nemurus* cannot prey fishes including their own juveniles easily. So it is thought that high water level season is also important for hatched juvenile fishes to avoid menace of predation and grow up. On the other hand, it is thought that low water level season is more important than high water level season for the piscivorous fishes. Because small prey fishes that hatched in high water level season are concentrated and prey condition become better than high water level season. For *C. apogon* high water level season maybe better than low water level season. Also in low water level season, they feed mainly on detritus (T. Buchar, personal communication), which itself is not a good food item (Lemke and Bowen, 1998). High water level season when they feed on Chironomidae larvae seem to be better than low water level season. Moreover there is no benefit about food condition for them like piscivorous fishes in low water level season. And maybe competition in same species for prey is decreased in high water level season. *T. leerii* seemed to feed on also filamentous algae in low water level season (T. Buchar, personal communication). So high water level season is also better for them because there seems to be same benefits to *C. apogon* except for difference of food items. Eventually it is thought that not only forest around the lake but also phenomenon to repeat the flooding in the forest and disperse of lake in high water level season and decrease and concentration of the water in low water level season is important to maintain fish community and ecosystem.

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References

Hartoto, D. I. 2000. An overview of some limnological parameters and management satus of fishery reserve in Central Kalimantan. *Rep. Suwa Hydrobiol. Sta., Shinshu Univ.* 12: 49-74.

Horne , A. J. and Goldman, C. R. 1994. *Limnology, 2nd edn*. McGraw-Hill, New York.

Hynes, H. B. N. 1950. The food of fresh-water sticklebacks (*Gasterosteus aculeatu* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. Journal of Animal Ecology. 36-58

Inger, R. F. and Chin, P. K. 1962. The freshwater fishes of North Borneo. Fieldiana Zoology, 45. Chicago Natural Museum, 268 pp.

Iwakuma, T., Hehanussa, P. E. *et al.* 1999. Aquatic ecosystems in Central Kalimantan (FY 1998). In: *Environmental Conservation and Land Use Management of Wetland Ecosystem in Southeast Asia. Annual Report for April 1998-March 1999*, Hokkaido University and RDC for Biology-LIPI, 165-189

Khan-M.-S., Ang, K.-J. and Ambak, M.-A. 1996. The effect of varying dietary protein level on the growth, food conversion, protein utilization and body composition of tropical catfish *Mystus nemurus* (C. and V.) cultured in static pond water system. *Aquatic Research*, 27: 823-829

Kusakabe, K., Iwakuma, T. and Sulastri. 2000. Biomass and abundance of phytoplankton in a tropical oxbow lake. In: *Proceedings of the International Symposium on Tropical Peatlands, Bogor, Indonesia, 22-24 November 1999*, pp. 413-422.

Lampert, L. and Sommer, U. 1997. *Limnoecology: The Ecology of Lakes and Streams*. Oxford Univ. Press, New York-Oxford.

Lemke, M. J. and Bowen, S. H. 1998. The nutritional value of organic detrital aggregate in the diet of fathead minnows. *Freshwater Biol*., 39, 447-453

Ng, P. K. L. and Lim, K. K. P. 1992. The conservation status of the Nee Soon freshwater swamp forest of Singapore. *Aquatic Conservation: Marine and Freshwater Ecosystem*, 2: 225-226

Ng, P. K. L., Chou, L. M. and Lam, T. J. 1993. The status and impact of introduced freshwater animals in Singapore. *Biol. Conserv.*, 64: 19-24.

Ng, P. K. L., Tay, J. B. and Lim, K. K. P. 1994. Diversity and conservation of blackwater fishes in Peninsular Malaysia, particulary in the North Selangor peat swamp forest. *Hydrobiologia*, 285: 203-218

Shiraishi, Y., Mizuno, N., Nagai, M., Yoshimi, M. and Nishiyama, K. 1972. Studies on the diel activity and feeding habit of fishes at Lake Bera, Malaysia. *Jpn. J. Ichthyol*., 19: 295-306 (in Japanese).

Tan, L. W. 1972. Studies on the feeding biology of *Pristolepis fasciatus* Bleeker and *Cyclocheilichthys apogon* Valenciennes. B. Sc. (Hons) Thesis, Zoology Division, Sch. Biol. Sc., University of Malaya, Kuala Lumper, Malaysia, 57pp.

Yap, S.-Y. 1988. Food resource utilization partitioning of fifteen fish species at Bukit Merah Reservoir, Malaysia. *Hydrobiologia*, 157: 143-160

Zakaria-Ismail, M and Lim, K-K-P., 1995 The fish fauna of Tasik Temengor and its tributaries south of Banding, Hulu Perak, Malaysia. *Malayan Nature Journal*, 48: 319-332.

Appendix 1. The time of sampling and number of fishes caught with gill nets at site 98A in low water level season during 1200 of 18 September to 1500 of 19 September 1998.

from 1200 to 1500	
Species	No.
Leptobarbus hoevenii	1
Osteochilus melanopleura	4
Osteochilus schlegelii	1
Pristolepis grooti	2
Trichogaster leerii	1

from 1500 to 1800	
Species	
Cyclocheilichthys apogon	3
Helostoma temminckii	2
Osteochilus melanopleura	2
Pristolepis grooti	3
Trichogaster leerii	280
Kryptopterus sp.	2
Mystus nemurus	6
Mystus nigriceps	23
Nandus nebulosus	1
Ompok sp.	1

from 1800 to 2100	
Species	No.
Leptobarbus hoevenii	5
Helostoma temminckii	3
Mystus nigriceps	2

from 2100 to 0000	
Species	No.
Cyclocheilichthys apogon	1
Leptobarbus hoevenii	1
Trichogaster leerii	1
Trichogaster trichopterus	1
Kryptopterus sp.	1

from 0000 to 0300	
Species	No.
Helostoma temminckii	1
Trichogaster leerii	3
Mystus nemurus	3

from 0300 to 0600	
Species	No.
Cyclocheilichthys apogon	8
Osteochilus melanopleura	2
Helostoma temminckii	30
Pristolepis grooti	3
Trichogasterr leerii	44
Trichogaster trichopterus	3
Mystus nemurus	11
Mystus nigriceps	8
Wallago leerii	1

from 0600 to 0900	
Species	No.
Cyclocheilichthys apogon	1
Leptobarbus hoevenii	1
Osteochilus melanopleura	2
Osteochilus schlegelii	2
Helostoma temminckii	2
Pristolepis grooti	5
Trichogaster leerii	1

from 0900 to 1200	
Species	No.
Leptobarbus hoevenii	2
Osteochilus melanopleura	4
Osteochilus schlegelii	5
Helostoma temminckii	1
Pristolepis grooti	2
Trichogaster leerii	6

from 1200 to 1500	
Species	No.
Osteochilus melanopleura	1
Osteochilus schlegelii	2
Trichogaster leerii	3

Appendix 2. The time of sampling and number of fishes caught with a scoop net (selambau) at site 99A in high water level season during 1600 of 29 April to 1740 of 30 April 1999.

1600	
Species	No.
Leptoburbus hoevenii	5
Osteochilus melanopleura	2
Rasbora sp.	1
Kryptopterus sp.	1

1800	
Species	No.
Kryptopterus spp.	3
Pangasius masutus	3

2100	
Species	No.
Kryptopterus apogon	4
Kryptopterus sp.	1
Pangasius masutus	1
Macrognathus aculeatus	1

0000	
Species	No.
Mystus nemurus	1
Mystus nigriceps	2
Kryptopterus apogon	3
Kryptopterus limpok	1
Kryptopterus spp.	2

0300	
Species	No.
Mystus nigriceps	1
Kryptopterus apogon	1
Kryptopterus limpok	3
Kryptopterus spp.	2
Pangasius masutus	1
Macrognathus aculeatus	2

0600	
Species	No.
Leptoburbus hoevenii	7
Osteochilus melanopleura	60
Mystus nemurus	5
Mystus nigriceps	1
Kryptopterus apogon	2
Kryptopterus spp.	4
Helostoma temminckii	3
Trichogaster leerii	3
Macrognathus aculeatus	2

0900	
Species	No.
Cyclocheilichthys apogon	4
Leptoburbus hoevenii	13
Luciosoma trinema	1
Osteochilus melanopleura	5
Osteochilus triporos	2
Pristolepis grooti	1
Helostoma temminckii	1
Trichogaster leerii	2
Trichogaster trichopterus	1

1200	
Species	No.
Cyclocheilichthys apogon	12
Leptoburbus hoevenii	2
Luciosoma trinema	3
Osteochilus melanopleura	1
Osteochilus triporos	1
Parackela sp.	1
Mystus nigriceps	1
Helostoma temminckii	4
Trichogaster leerii	8

1500	
Species	No.
Cyclocheilichthys apogon	5
Luciosoma trinema	2
Osteochilus melanopleura	1
Osteochilus triporos	2
Trichogaster leerii	7

1740	
Species	No.
Cyclocheilichthys apogon	1
Kryptopterus spp.	2
Pseudentropius brachypopterus	5
Trichogaster leerii	1

Appendix 3. The time of sampling and number of fishes caught with gill nets at site 99A in high water level season during 1500 of 6 May to 1500 of 7 May 1999.

from 1200 to 1500	
Species	No.
Osteochilus pentalineatus	4
Osteochilus triporos	87
Puntius lineatus	5
Rasbora spp.	1
Unknown	2

from 1500 to 1800	
Species	No.
Osteochilus triporos	39
Puntius lineatus	2
Rasbora spp.	3
Kryptopterus spp.	3
Pseudentropius brachypopterus	2
Unknown	1

from 1800 to 2100
No fishes

from 2100 to 0000
No fishes

from 0000 to 0300	
Species	No.
Clarias meladerma	1
Macrognathus aculeatus	1

from 0300 to 0600	
Species	No.
Osteochilus triporos	3
Puntius lineatus	1
Rasbora sp.	1
Kryptopterus spp	13

from 0600 to 0900	
Species	No.
Osteochilus pentalineatus	1
Osteochilus triporos	8
Puntius lineatus	4
Rasbora spp.	1

from 0900 to 1200	
Species	No.
Osteochilus triporos	11
Puntius lineatus	1
Rasbora sp.	1

from 1200 to 1500	
Species	No.
Osteochilus triporos	17
Puntius lineatus	1
Rasbora spp.	3
Trichogaster leerii	1

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Concept for Sustainable Development of Local Fish Resource in Central Kalimantan

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Abstract

In Central Kalimantan, the total area of inland waters is approximately 2,267,800 ha. Most of these resources have long been recognized as important habitats for local freshwater fishes. These freshwater fishes are of high important for the local people as the main source of protein and the source of income for local fisherman. However, various human activities carried out in the waters body such as transportation, deforestation and illegally fishing practices have threaten these freshwater ecosystems. Local people have been affected by this habitat destruction.

Peat swamp is the dominant freshwater habitat in Central Kalimantan. This water body is characterized by a high water level fluctuation, browning water color, low transparency and low pH values. These special features lead to the specific characteristics of organisms including local fishes that occupy the habitat. Any environmental change such as the changing of microclimate, will affect the sustainability of this unique ecosystem.

In order to maintain local fish habitat, a management practice should be applied in Central Kalimantan. This could be done by formulating a government policy that can manage the exploitation of water resources in this region. The establishment of a conservation area will also be useful in maintaining local fish biodiversity. For this need, the local people have agreed to allocate their land at the upstream of the Sebangau River to be developed as the local fish conservation area. There is also a possibility to develop similar conservation area in other region of Central Kalimantan.

It is recommended that this sustainable development concept could be supported by establishing a research collaboration program among scientists either locally or internationally.

Key words: Local fish, aquatic resource, conservation, sustainable development.

Introduction

Total area of Central Kalimantan province is 1,538,280,000 ha where inland water covers approximately 2,267,800 ha. This inland water consists of 323,500, 132,800 and 1,811,500 ha of rivers, lakes and swamps respectively (Anonymous, 1994). The huge areas of freshwater ecosystems indicate that this province has a high potential for the development of fisheries resources.

Traditionally, indigenous peoples of Central Kalimantan fulfill their need for protein by consuming local fishes caught from inland waters. For most people in this region, local freshwater fishes are more preferable than marine or introduced fishes. In order to maintain the sustainability of their need for local fish, local people apply traditional ways of maintaining the environment. For example, they always use simple and selective equipment for catching the fishes and they avoid to overexploiting their natural resources.

However, since few years ago there have been changes of inland waters condition in this region. The increase of population due to the immigration program lead to the increase of human invasion to the natural resources as well as to the local people in this region. Various human activities either in the water body or in the catchment area of the water body have deteriorated the water quality and reducing the water production including local fishes. As a consequence, local people lost their natural resources either as a source of their food or the source of their income. Unfortunately, no one cares about this condition.

Environmental Condition

A. Spread of Environment

In the past, Central Kalimantan was covered by a dense tropical rain forest. People could easily collected good quality, high and big trees just from their surrounding forest. Many big rivers such as the Barito, Kapuas, Kahayan, Katingan, Mantaya, Pambuang, Kumai, Lamandau and Jelai flow from northern to southern part of the province. These rivers were always clear and unpolluted. At that time, the people of Central Kalimantan was very proud of these rivers due to its function in supporting their life such as for transportation, drinking water as well as the place where they can go for catching fishes.

At present, however, the condition has changed dramatically. Rivers discharge fluctuated considerably. During dry season the upstream villages could not be reached by water transportation, whereas during wet season flooding will occur in the area down stream of the rivers. River water is always turbid throughout the year and the local fishes have been hard to find in the river. This condition was caused by the change of the natural environment due to the two different causes: natural and man-made. The natural change usually occur slowly and in relatively small scale, whereas the man-made change could be massive and out of control. Now, huge area of bare land occur in Central Kalimantan due to the over exploitation of forest resources. One of extreme example could be seen in Bukit Batu area, 35 km from Palangka Raya City to the west. In the past this area was covered with a dense forest. Due to the over exploitation, the vegetation now has disappeared, and the area is completely open without any single big tree left. Other effects of deforestation practice are the lowering of ground water level and the increase of surface run-off or decreasing the infiltration of rainfall to the ground. During last ten years there has been an indication that microclimate has also changed in this region (based on Schmidt and Ferguson Climatic type).

There have been many environmental impacts of deforestation practice and climate change in this region. The worse forest fire in 1997 was an example. During the fire, all area was polluted by haze and smog for several months. Other impact occurred in disturbed peat swamp forest is the lowering of ground surface (subsidence). This impact is usually caused by the drainage of natural peatland for other purposes such as its conversion for public settlement or agricultural land. Such impact do not occur in a naturally peat swamp forest. This natural ecosystem usually support the existence of a high biodiversity either aquatic or terrestrial organisms including local fishes that are consumed by the local people. Therefore, the economical value of the lost of this natural ecosystem could not be counted precisely.

B. Water Properties

The properties of a water body are influenced by both allochthonous and autochthonous factors. In other word, the present status of a water body reflects the present environmental condition both inside and surroundings of the water body. Therefore, any changing of environmental condition surround a specific water body will lead to the changing of the properties of such water body. Followings are the general properties of water bodies in Central Kalimantan.

1. Physical water properties

a. Water flow

Inland waters could be categorized into two different types: running water (lotic) and stagnant water (lentic). The ecological natures of these two are also different.

The general feature of peatland water in Central Kalimantan is the changing from a running water during rainy season to become a stagnant water in the dry season. During high water level many puddles occur in a peatland area. These puddles especially shallow water will be dried out with the decrease of ground water level during dry season. Another feature is the occurrence of various size of oxbow lakes along the river systems. These lakes also undergo the switch from lotic water during rainy season to become lentic water during dry season. In order word, during rainy season this water body possesses river system characteristics, whereas in dry season a lake characteristics will become apparent.

b. Water color

Water color of inland peat waters always brown visual color. This color is influenced by the present of organic compounds soluble in the water (Matling, 1995). Therefore, this color is not an apparent color, means it can be reduced by filtering process. For example, the value of a natural peatland water could be reduced from 549 to 65 unit PtCo by filtering the water with ash and charcoal (Matling, 1995).

According to Cole (1983), the water color can be affected by dissolved organic matters as humic acid (humic substance) released from soil, peat, or sediment. After the oxidation of peat in dry season, the peat will be washed and washed into the water streams during rainy season, hence the water color will be affected to become browning in color. Due to their surrounding area, many oxbow lakes in Central Kalimantan have water color same as peat water. Similar color also occurs in several rivers such as the Kapuas and Sabangau rivers. There is also a black water color in this region such as in the Mantangai River (a tributary of the Kapuas River).

c. Transparency

In general, water transparency in Central Kalimantan is relative low. For example in Kahayan River during August 1999 the transparency ranged only between 19.0 and 29.5 cm. This is due to the water color and turbidity. The major causes of water turbidity are the opening of catchment areas and gold mining activities either in the river body or its catchment area. From field observation conducted in April 1999, there were 1,904 units of gold mining in Kahayan water body spread out from Tumbang Miri village at the upstream to Palangka Raya city at the downstream. Each unit could dig up 5-10 m^3 river sediment, resulting approximately 14,280 m^3 along the Kahayan River weekly.

The water color in peat swamp area is slightly different. In this water body the color is mainly influenced by the release of organic substance from peatland. Water transparency could be up to 42.5 cm as measured in a natural peat swamp area (Matling 1999), and between 37.5 and 42.5 cm in Lake Sabuah which is affected by peat water from its surrounding area (Yulistatie, 1999).

d. Water temperature

Fluctuation of water temperatures in shallow waters are higher than those in deep waters. The temperature measured for inland peatland waters around Palangkaraya ranges between 24.9-37.9°C (Matling, 1999). The variance in temperature value is possibly due to the fact that it was measured only in surface water between 1200-1500PM. The depth of this natural peatland water ranged between 0.03-0.54 m. In deeper water such as in Lake Sabuah (12.5 m depth), water temperature ranged between 27.5-30.3°C (Yulistatie, 1999). Both types of water undergo similar process that changes from stagnant waters during dry season to be stream waters in rainy season. In the river body, on the other hand, the fluctuation of water temperature is not high. For example water temperature of the Kahayan River (Palangka Raya) in March and April 1999 ranged between 26.0-29.5°C (Indarti, 1999). This river water temperature is relatively constant throughout the year, as indicated by the values that ranged from 26.4-28.8°C in the same location in the Kahayan River during September 1999.

2. Chemical properties

a. pH

Generally, the freshwaters in low land area of Central Kalimantan have low pH values (Roberts, 1989). In Kahayan River, for example, the pH values ranged between 6.03-6.98 and in Lake Sabuah such values ranged from 5.69-6.05 (Torang, 1996). Under turn over mixing between bottom and surface waters in Lake Sabuah, the pH values ranged from 5.76-6.99 (Yulistatie,1999). These values are much higher compared with peatland waters collected from puddles around Palangka Raya, that ranged from 3.60-4.97 (Matling, 1999) and 3.42-4.41 (Resistensi, 1998). Although the pH values are very low, many local fishes could be found easily in these puddles. Therefore, the unique feature of local fishes in Central Kalimantan is their ability to adapt and grow in acidic waters.

b. Dissolved oxygen

Due to the decomposition of organic matters, the concentration of dissolved oxygen in peatland waters of Central Kalimantan is usually very low. In 1996, for example, the concentration in Lake Sabuah ranged from 3.86-4.79 ppm (Torang, 1996), whereas in 1999 such concentration ranged between 2.99 and 3.66 ppm (Yulistatie, 1999). At the bottom of the lake, the concentration decreased considerably up to 0.1 ppm. In he surface waters of puddles around Palangka Raya, the concentration ranged from 0.14 to 6.39 ppm (Matling, 1999).

Local fishes can adapt very well to this low concentration of dissolved oxygen. Their physiological adaptation to this hard environment is indicated by the presence of labyrinth on their breeding organ system.

Biotic Condition

A. Community of Fishes

Fish communities were studied in both Lake Sabuah during period of July to November 1996, and in Lake Tundai from March to August 1999. The identification of fish species was performed according to Weber and Beaufort (1916), Saanin (1984), Affandi *et al*. (1992) and Kottelat *et al*. (1993). In Lake Sabuah, local fishes consist of 5 orders, 17 families and 48 species (Table 1), whereas in Lake Tundai, collected fishes belong to 6 orders, 18 families and 44 species (Table 2).

Table 1. Fish species compositions at each location of Lake Sabuah from July to November 1996.

Order	Family	Species	Common name	Station I	Station II	Station III	Station IV
Cypriniformes	Cyprinidae	*Cyclocheilicthys apogon*	Puhing	+	+	+	-
		Oteochilus melanopleura	Kalabau	-	+	-	-
		Labiobarbus ocellatus	Masau	+	+	+	-
		Pontiopliter waandersi	Sanggang	-	+	-	-
		Parachela oxygastroides	Lalang	-	+	-	-
		Rasbora argyrotaenia	Seluang bulu	+	+	+	-
		Lebtobarbus hoeveni	Jelawat	+	+	-	-
		Thynnicthys thynnoides	Menangin	+	+	+	-
		Osteochilus hasselty	Nilem	+	+	-	-
		Thynnicthys polylepis	Mentukan	+	-	-	-
		Luciosoma trinema	Johar	-	+	-	-
		Barbicthys laevis	Kumkum	+	+	-	-
		Barbodes schwanefeldi	Salap	-	+	-	-
		Hampala macrolepidota	Adungan	+	+	-	-
		Osteochilus triporos	Banta	+	+	-	-
		Osteochilus pentalineatus	Tembayuk	+	+	-	-
		Osteochilus waandersi	Umpan-umpan	-	+	+	-
		Puntius binotatus	Bunter	-	+	-	-
		Rohteichthys microlepis	Kenali	+	+	-	-
	Cobitidae	*Botia macracanthus*	Ikan macan	-	+	-	-
		Botia hymenophysa	Langli	-	+	-	-
Perciformes	Mascembalidae	*Macrognathus aculeatus*	Joli	-	+	-	-
	Belontidae	*Trichogaster leeri*	Sepat iju	+	+	-	-
		Trichogaster trichopterus	Sepat rawa	+	+	-	-
		Belondidae hasselti	Kapar	-	+	-	+
	Chandidae	*Parambasis wolffi*	Ikan Kaca	+	+	-	-
	Chanidae	*Channa pleuropthalmus*	Kerandang	+	+	-	-
		Channa melanopterus	Kehung	-	+	-	-
		Channa striata	Gabus	-	+	-	+
		Channa micropeltes	Toman	+	+	-	-
	Anabantidae	*Anabas testudineus*	Betok	-	+	-	-
	Helostomatidae	*Helostoma temmincki*	Tambakan	+	+	-	-
	Osphronemidae	*Osphronemus goramy*	Gurami	+	+	-	-
	Luciocephalidae	*Luciocephalus pulcher*	Tumbu ramer	-	+	-	-
	Pristolepididae	*Pritolepsis grooti*	Patung	+	+	-	-
Siluriformes	Siluridae	*Kryptopterus micronema*	Lais junggang	+	+	+	+
		Kryptopterus apogon	Lais timah	-	+	+	+
		Kryptopterus schilbeides	Lais puith	-	+	-	+
		Kryptopterus kryptopterus	Lais tunggul	+	+	+	-
	Bagridae	*Mystus nigriceps*	Sanggiringan	+	+	+	+
		Mystus micracanthus	Baung	+	+	+	+
		Bagrichthys micranodus	Hinur	-	+	-	+
	Claridae	*Clarias batrachus*	Lele	-	+	-	-
	Schilbidae	*Pseudotropius brachypopterus*	Nuanjang	-	+	-	-
		Pseudotropius moolenburghae	Ikan riu	-	+	-	-
Plegtognathy	Tetraodontidae	*Tetraodon immaculatus*	Buntel pinnag	-	+	-	-
		Tetraodon reticularis	Buntel kelapa	-	+	-	-
Osteoglossiformes	Notopteridae	*Notopterus borneensis*	Belida	+	+	-	-

+ : existing - : none

B. Food Habit of Several Fish Species

The food habits of several fish species was analysed by referring to the Index of Preponderance (Natarajan and Jhingran, 1963; Effendie, 1979), whereas the stomach contents was identified according to Edmondson (1963) and Prescott (1970). The structure of fish community in Lake Sabuah and Lake Tundai was dominated by carnivorous fishes (Buchar, 1997, 1999), as presented in Table 3.

Table 2. Fish species compositions at each location of Lake Tundai from March to August 1999.

Order	Family	Species	Common name	Station I	Station II	Station III
Cypriniformes	Cyrinidae	*Osteochilus pentalineatus*	Tembayuk	+	+	-
		Osteochilus triporos	Banta	+	-	+
		Osteochilus melanopleura	Kalabau	+	+	+
		Rasbora sp.	Saluang kahui	+	-	-
		Rasbora argyrotaenia	Saluang balu	+	+	+
		Cyclocheilicthys apogon	Puhing	+	+	+
		Cyclocheilicthys heteronema	Sabuluh	+	-	-
		Cyclocheilicthys jantochir	Puhing kahui	-	+	-
		Thynnicthys thynnoides	Menangin	+	-	+
		Parachela oxygastroides	Lalang	+	-	-
		Lebtobarbus hoeveni	Jelawat	+	+	+
		Labiobarbus ocellatus	Masau	+	-	-
		Luciosoma trinema	Seluang juara	+	+	+
		Puntius lineatus	Lauk tundai	+	-	-
		Puntiopliter waandersi	Sanggang	+	+	-
Perciformes	Belontidae	*Trichogaster leeri*	Sepat hijau	+	+	+
		Trichogaster tricopterus	Sepat rawa	+	-	+
		Belontidae hasellti	Kapar	+	-	-
	Chandidae	*Parambasis wolffi*	Ikan kaca	+	+	+
	Chanidae	*Channa pleuropthalmus*	Kerandang	-	-	+
	Anabantidae	*Anabas testudineus*	Betok	+	-	-
	Helostomatidae	*Helostoma temmencki*	Tambakan	+	+	+
	Luciocephalidae	*Luciocephalus pulcher*	Tumbu ramer	+	-	-
	Pritolepididae	*Pristolepis grooti*	Patung	+	+	-
	Nandidae	*Nandus nebolusus*	Tatawun	+	+	-
	Mascembalidae	*Macrognathus aculeatus*	Joli	+	-	-
Siluriformes	Siluridae	*Kryptopterus palembangensis*	Lais baji	+	+	+
		Kryptopterus apogon	Lais junggang	+	-	-
		Kryptopterus macrocephalus	Lais hitam	+	-	-
		Kryptopterus limpok	Lais kerak	+	-	-
		Kryptopterus sp.	Lais nipah	+	-	-
		Kryptopterus parvanalis	Lais bamban	+	+	+
		Kryptopterus schilbeides	Lais putih	-	-	+
		Ompok hypophthalmus	Lais Bantut	+	-	-
		Wallogo leeri	Tapah	+	-	-
	Pangsidae	*Pangasius micronema*	Lawang	+	+	+
	Bagiridae	*Mystus nigriceps*	Sanggiringan	+	+	+
		Mystus nemurus	Baung	+	+	+
	Claridae	*Clarias meladerma*	Lele	+	-	-
	Schilbidae	*Pseudotropius brachypopterus*	Ikan riu	+	-	-
Plegtognathi	Tetraodontidae	*Tetraodon reticularis*	Buntel kelapa	+	-	-
		Tetraodon immaculatus	Buntel pinang	-	+	-
Osteoglossiformes	Notopteridae	*Notopterus borneensis*	Belida	+	-	-
Ostariophysi	Doiichthyidae	*Doiichthys novae*	Sapapirang	-	-	+

+ : existing,   - : none

Table 3. Food habit and tropic level status of several fish.

Species	Groups of food									Tropic level status
	Aquatic plant	Gastropoda	Nematoda	Insecta	Plankton	Detritus	Fishes	Crustacea (shrimp)	Insect larvae	
Osteochilus pentalineatus	A	-	-	-	M	S	-	-	-	H
Oteochilus triporos	A	-	-	-	M	S	-	-	-	H
Oteochilus melanopleura	S	-	-	-	M	A	-	-	-	H
Rasbora sp.	-	-	A	M	M	S	-	-	-	C
Rasbora argyrotaenia	-	-	A	S	M	A	-	-	S	C
Cyclochheilicthys apogon	S	-	-	-	S	M	-	-	-	O
Cyclochheilicthys heteronema	S	-	-	-	S	M	-	-	-	D
Cyclochheilicthys jantochir	A	-	-	-	S	M	-	-	-	D
Thynnicthys thynnoides	S	-	-	-	M	A	-	-	-	H
Parachela oxygastroides	-	-	A	M	S	-	-	-	S	C
Lebtobarbus hoeveni	M	-	-	A	M	S	-	-	-	H
Labiobarbus ocellatus	-	-	-	-	M	S	-	-	A	H
Luciosoma trinema	-	A	-	S	M	A	-	-	-	C
Puntius lineatus	-	-	-	A	S	M	-	-	A	D
Puntiopliter waandersi	S	-	-	-	M	A	-	-	A	O
Trichogaster leeri	S	-	-	-	M	A	-	-	-	H
Trichogaster tricopterus	S	-	-	-	M	A	-	-	-	H
Belontidae hasellti	-	-	A	A	M	S	-	-	-	C
Parambasis wolfii	-	A	-	S	M	-	S	-	-	C
Channa pleuropthalmus	-	A	-	-	-	S	M	A	A	Pr
Channa melanopterus	-	-	-	A	-	S	M	-	-	Pr
Channa striata	-	-	-	A	-	S	M	A	-	Pr
Channa micropeltes	-	A	-	-	-	-	M	S	-	Pr
Anabas testudineus	-	-	S	A	M	S	-	-	A	C
Helostoma temmincki	S	-	-	-	M	A	-	-	-	H
Luciocephalus pulcher	-	-	S	A	M	-	-	-	A	C
Pristolepis grooti	-	-	A	A	M	S	-	-	S	C
Nandus nebolusus	-	-	A	A	M		-	-	-	C
Macrognathus aculeatus	-	-	A	M	S	A	-	-	-	C
Kryptopterus palembangensis	-	-	A	S	S	-	M	-	A	C
Kryptopterus apogon	-	A	A	-	S	-	M	-	-	C
Kryptopterus macrocephalus	-	-	A	A	M	S	-	-	-	C
Kryptopterus limpok	-	-	-	A	M	S	A	-	-	C
Kryptopterus sp.	-	A	-	A	M	-	S	-	-	C
Kryptopterus parvanalis	-	-	-	-	S	S	M	A	-	C
Kryptopterus hypophthalmus	-	A	-	A	M	S	-	-	-	C
Wallago leeri	-	A	-	-	-	-	M	S	-	Pr
Pangasius micronemus	A	-	-	-	S	M	-	-	-	O
Mystus nigriceps	-	-	-	-	S	S	M	A	-	C
Mystus nemurus	-	-	-	A	-	S	M	A	-	Pr
Pseudotropius brachypopterus	-	-	-	-	M	S	-	-	A	C
Tetraodon reticularis	-	-	-	S	M	A	A	-	-	C
Tetraodon immaculatus	-	-	-	S	M	A	-	-	A	C
Notopterus boornensis	-	A	-	-	-	S	M	A	-	C
Osphronemos goramy	S	-	-	A	M	S	-	-	-	H
Barbodes schwanenfeldii	A	-	A	-	M	S	-	-	-	O
Barbichthys laevis	A	-	-	-	S	M	-	-	-	D
Osteochilus hasselti	A	-	A	-	S	M	-	-	-	D

Remarks: M = Main food (index of preponderance) (IP = 30%)
S = Supplement food (IP = 5 - 25%)
A = Added food (IP = 5%)
H = Herbivore
D = Detrivore
O = Omnivore
C = Carnivore
Pr= Predator

Concept for Sustainable Development

A. Establishment of Conservation Area

Having described water properties and its existing aquatic organisms, we can understand the relationship between various human activities and the deterioration of water quality in Central Kalimantan. It is urgently necessary to consider the establishment of conservation areas in order to sustain the natural resources in the region.

The establishment of the areas should be based on the result of a scientific ecological research. For this purpose, it is important to select undisturbed, safe and ecologically suitable areas. Two areas have been identified to be appropriate for conservation areas in Central Kalimantan. The first area located in the upstream of Sebangau River that is suitable for local fish conservation, and the second area is in the upstream of the Kahayan River (Sirat River and Lake Saribu) which is good for crocodile conservation (Tim Peneliti PPLH Unpar, 1999). There might be also other suitable sites in other part of the province.

This concept of the establishment of conservation area should be adapted to the ecological potential of the area. The most important priority should be addressed to protect the existence of the original organisms in the region. The introduction of new species from outsides should be avoided. A feasibility study and the formulation of a government regulation will be important steps in establishing the area. In addition, this idea should be also introduced to the local people in order to develop their awareness of the important of their natural resources in supporting human life.

B. Research Concepts

As described previously, the sustainable concept should be based on the result of a scientific research. The research should be organized in a such a way, hence any short and small scale ecological researches could be integrated in broader concept and goals of long term research period with the main purpose to improve prosperity of people especially local community in Central Kalimantan. It is necessary to develop further a research institution that can manage and organize such research activities. The present CIMTROP that has long experience in ecological research, should be utilized, improved further and facilitated in order to achieve this sustainable development concept.

Conclusions

1. The continuously rapid environmental change in Central Kalimantan should be paid attention to.
2. There is a need for an action to protect the natural resources and to prevent its rapid man-made deterioration.
3. Indigenous peoples of Central Kalimantan prefer local freshwater fish instead of sea fish and introduced fish for their consumption.
4. The sustainable development of resources of local fish by conserving their natural habitat could improve the prosperity of local people in Central Kalimantan.
5. The fish communities in Lake Sabuah and Lake Tundai are dominated by the family Cyprinidae, with the tropic level status dominated by carnivorous fishes.

References

Affandi, R., Sjafei, D.S., Rahardjo, M.F. and Sulistiono. 1992. *Iktiologi, Suatu Pedoman Kerja Laboratorium*. Departemen Pendidikan dan Kebudayaan Dirjen Pendidikan Tinggi PAU Ilmu Hayat IPB-Bogor. 344 pp.

Ampera, C. 1990. Pengaruh Faktor-faktor Produksi terhadap Pendapatan Petani dan Usahatana Kacang Panjang (*Vigna ungviculala*) di WKPP Banturung Kecamatan Bukit Batu Tangkiling. Fakultas Non Gelar Teknolgi Universitas Palangkaraya (Thesis).

Anonymous. 1994. *Laporan Tahunan 1993*. Dinas Perikanan Propinsi Daerah Tingkat I Kalimantan Tengah. Palangkaraya.

Buchar, T. 1997. Bio-ekologi Komunitas ikan di danau Sabuah, Kabupaten Kapuas Propinsi Kalimantan Tengah. Tesis Pascasarjana. Institut Pertanian Bogor, 108 pp (MSc. thesis).

Buchar, T. 1997. Kebiasaan Makan dan Relung makanan komunitas ikan di danau Sabuah. Fak. Pertanian Jurusan Perikanan, Universitas Palangkaraya. 81 pp.

Buchar, T. 1999. Iktiofauna di danau Tundai Kodya Palangka Raya, Kalimantan Tengah. Fak. Pertanian Jurusan Perikanan, Universitas Palangkaraya. (in press).

Cole, G.A. 1983. *Textbook of Limnology*. Waveland Press, Illinois, USA.

Colwell, R.K. and Futuyama, D.J. 1971. On the measurement of niche breadth and overlap. *Ecology*, 52: 567-576.

Effendie, M.I. 1979. *Metoda Biologi Perikanan*. Yayasan Dwi Sri Bogor, 112 pp.

Edmonson, W.T. 1963. *Fresh Water Biology*. *2nd edn*. John Wiley and Sons, New York, 1248 pp.

Indarti, 1999. Pembesaran Benih Ikan Patin (*Pangasius* sp.) dalam Karamba di sungai Kahayan Pahandut Seberang Kecamatan Pahandut Kotamadya Palangkaraya. Jurusan Perikanan Fakultas Pertanian Universitas Palangkaraya (Thesis).

Kottelat, M., Whitten, J.A., Kartikasari, S.N. and Wirjoatmojo. 1993. *Ikan Air Tawar Indonesia Bagian Barat dan Sulawesi*. Edisi Dwibahasa Inggeris-Indonesia. Periplus Edition. Indonesia. 293 pp.

Lukas. 1997. Pengamatan Waktu dan Jenis Ikan yang Tertangkap dengan Pukat Kantong (Tabing) di Muara Danau Rigei Kelurahan Tumbang Tahai Kecamatan Bukit Batu. Jurusan Perikanan Fakultas Pertanian Universitas Palangkaraya (Thesis).

Matling. 1995. Penggunaan Arang dan Abu dalam Perbaikan Kualitas Fisik dan Kimia Air Gambut untuk Media Tumbuh Fitoplankton. Program Pascasarjana Institut Pertanian Bogor (MSc thesis).

Matling. 1999. Laporan Hasil Pengamatan Terhadap Kualitas Air Rawa Gambut Pedalaman di Sekitar Palangkaraya. Jurusan Perikanan Fakultas Pertanian Universitas Palangkaraya.

Natarajan, A.V and Jhingran, A.G. 1961. Index of preponderance, a method of grading the food elements in the stomach of fishes. *Ind. J. Fish.*, 8 (1): 54-59.

Prescott, G. W. 1970. *The Fresh Water Algae. 2nd edn*. Wm. C. Brown Company Publishers. 348 pp.

Purnamalita, 1997. Pengamatan Kegiatan Penangkapan Ikan yang Dilakukan oleh Nelayan di Danau Rigei Kelurahan Tumbang Tahai Kecamatan Bukit Batu. Jurusan Perikanan Fakultas Pertanian Universitas Palangkaraya (Thesis).

Resistensi, M.D., 1998. Hubungan Curah Hujan dengan Kualitas Air Permukaan Rawa Gambut Pedalaman di Kecamatan Pahandut Kotamadya Palangkarayan. Jurusan

Perikanan Fakultas Pertanian Universitas Palangkaraya (Thesis).

Roberts, T.R. 1989. *The Freshwater Fishes of Westrn Borneo (Kalimantan Barat Indonesia)*. California Academy of Sciences, San Francisco.

Saanin, H. 1984. *Taksonomi dan Kunci Identifikasi Ikan*. Cetakan ke dua. Jilid I dan II. Binacipta. Bandung. 520 pp.

Tim Peneliti PPLH Unpar, 1999. Laporan Hasil Survey Buaya di Sei Sirat Kapuas Hulu. Pusat PPLH Universitas Palangkaraya.

Torang, I. 1996. Hubungan Antara Illuminasi dengan Kelimpahan dan Komposisi Jenis Fitoplankton. Program Pasacasarjana Institut Pertanian Bogor (MSc thesis).

Yulistatie. 1999. Pengaruh Percampuran Massa Air Dasar dan Massa Air Permukaan Terhadap Kelimpahan Fitoplankton di Perairan Danau Sabuah. Jurusan Perikanan Fakultas Pertanian Universitas Palangkaraya (Thesis).

Weber, M and De Beaufort. 1916. *Fishes of Indo-Australian Archipelago. Vol. I-X*. E.J. Brill Ltd., Leiden. Holland.