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NOTE

Physicochemical Features of Rivers and Lakes in Pantanal Wetland

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ABSTRACT

The Pantanal is one of the largest wetland in the world, and its located almost in the central part of South America. Preliminary studies on the chemical features of waters were carried out in July, 1983 in Rio Paraguai and its tributaries in southern Pantanal, and in January, 1986 for some lakes near Porto Jofre and a river in northern Pantanal. The former showed an extremely oligotrophic character and the latter a eutrophic character, while the nitrogen seemed to be the limiting nutrient rather than phosphorus in both waters. The oxygen deficiency in water seemed rather common throughout the area studied in spite of the difference in water temperature and the organic matter contents.

Key words : dissolved oxygen, nutrient, organic matter, Pantanal wetland

INTRODUCTION

The Pantanal is one of the largest wetlands in the world. The major part belongs to Brazil, and the minor parts to Bolivia and Paraguay. The Pantanal is located almost in the central part of South America, but the average altitude is only 130 m or so. This would be the major reason for the formation of such a huge wetland having an area of about 200,000 km^2.

The Pantanal seems to be an indispensable water system to understand the limnological and ecological feature of South America, but, our knowledge of this water system remains quite limited. On the general feature of this wetland, there is only a small volume of monograph which was recently published by POR (1995). The Pantanal is not a simple wetland, but composed of a shallow interconnecting complex of lakes, flood plains, swamps and inundated depressions.

As an approach to understand the Pantanal water system, preliminary research was carried out at first in July, 1983, along the Rio Paraguai and its tributaries, by research ship from Corumba. The second research project was undertaken in January, 1986, in the northern part of the Pantanal, for some small lakes near Porto Jofre and a river Rio Cuiabá.

This study was undertaken to obtain preliminary knowledge of the physicochemical features of the water in this vast wetland, such as the distribution of the optical feature of water, water temperature, pH, dissolved and particulate constituents in waters as a basis to understand the biological production and biogeochemical metabolism of the water system.

MATERIALS AND METHODS

Areas studied

In 1983, from July 25 to 30, in the dry season, research of several days was carried out in the southern part of Pantanal, by using a ship "Apapore", which was kindly offered from the State of Mato Grosso do Sul. During the cruise from Corumbá, Mato Grosso do Sul, to the midstream region of the Rio Paraguai, the observation and sampling were carried out at six stations (Stas. P1 to P6) in this river and at two stations (Stas. M1 and M2) in the Rio Miranda, one station (Sta. T1) in the Rio Taquari and one station (Sta. A1) in the Rio Aboral, respectively. These three rivers are rather small tributaries of the Rio Paraguai (Fig. 1).

In 1986, from January 5 to 7, a brief study was undertaken in the northern Pantanal near Porto Jofre, Mato Grosso, locating at the end of road Trans Pantaneira Highway, and along the Rio Cuiabá (Fig. 1). Generally, in this region, January is the middle of the rainy seaon, so we expected that the Pantanal would be covered with water. In 1986, however, probably due to the abnormal climatic condition, the water level seemed to be still low, as if in the dry season. Therefore, the data obtained during this research would not be representative of the water bodies in this season, but they give some idea of the limnological characteristics of the studied area.

Three small lakes (Stas. L1 to L3) and the Rio Cuiabá (Sta. C1), a tributary of the Rio Paraguai, were studied. In the lakes studied, Lake 2 (Sta. L2) is a shallow lake near the hotel at Porto Jofre and connected with the Rio Cuiabá by a small channel. The maximum depth was about 1.2 m and has about 200 m length and 100 m width, respectively. The lake was fringed by the free floating plant, *Eichhornia crassipes* and the emergent plant, *Eichhornia azurea* : at the eastern end of the lake, the water surface was covered by several species of emergent plants, Cyperaceae and Gramineae. Some shallow part, of the lake bottom having the depth of 50 to 60 cm were covered by a submerged plant, *Utricularia.* The lake is located in a small livestock farm.

The other two lakes, Lake 1 (Sta. L1) and Lake 3 (Sta. L3), were small water bodies locating along the road of Trans Pantaneira, and were traversed by wooden bridges. Both lakes seemed to be a part of the stream when the water level was high. The depth of lakes was 3.5 m and 4.3 m, respectively, when measured from the bridges. In Lake 3, two thirds of the water surface was covered by the emergent plant, *Eichhornia azurea,* and the water flowed slowly beneath this plant community.

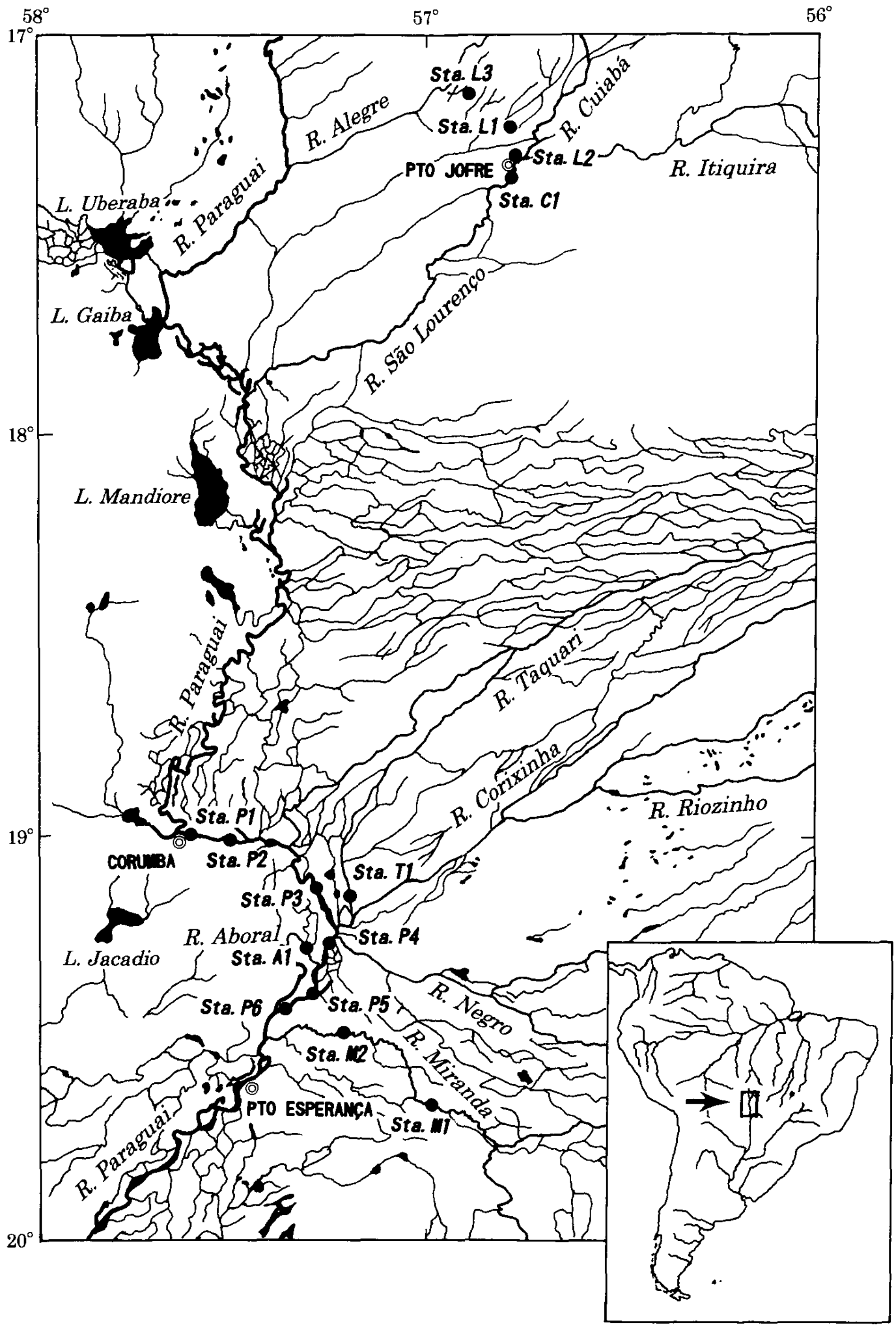

Fig. 1. Location of the sampling stations in the studied area of the Pantanal water system in July, 1983 and January, 1986.

METHODS

The techniques employed for the research in 1983 were as follows. Water samples were collected from the surface layer, then used for the measurement of pH, electric conductivity and silicate determination. The residual water samples were immediately filtered through glass fiber filters (Whatman, GF/C) which were free of organic matter by ignition at 450 °C. Then the filters and filtrates were stored at −20 °C in a deep freezer before chemical analyses in the laboratory. The sample for the determination of silicate was filtered through a paper filter (Toyo, No.5C) and stored in a refrigerator.

Water temperature were taken with a Tohodentan thermistor-thermometer (type ET-5). The pH was measured with a Horiba pH meter (type H-7). Electric conductivity with a Yokogawa Pocket Conductivity Meter (Model SC-51), and was equated to the value at 18 °C. Dissolved oxygen was measured by a portable oxygen meter (Electronic Instruments Ltd. Model 1520 and 1521).

Ammonia was determined by the method of SAGI (1966), nitrite after BENDSCHNEIDER and ROBINSON (1952), nitrate after ELLIOTT and PORTER (1971) and phosphate after MURPHY and RILEY (1962). Urea was determined using the method described by NEWELL *et al.* (1967) with a slight modification, dissolved organic carbon (DOC) by MENZEL and VACCARO (1964), dissolved organic nitrogen (DON) by MITAMURA (1994), and dissolved organic phosphorus (DOP) by MENZEL and CORWIN (1965). Particulate carbon (PC) and nitrogen (PN) were determined with a Yanagimoto CHN Corder (Type MT-3) and particulate phosphorous (PP) by the method described by MENZEL and CORWIN (1965) after digestion with perchloric and nitric acid. Chlorophyll-*a* was determined using the method described by LORENZEN (1967).

In 1986, there were minor changes in the techniques employed for the research, as shown below. Water samples in three lakes were collected with a VAN DORN type sampler from the surface to bottom layer. Nitrate was determined by the method of WOOD *et al.* (1967). Underwater light intensity was determined with a waterproof silicone photocell illuminometer (Model T 1M for underwater, Minolta).

RESULTS

1. Rio Paraguai and Rio Miranda

General physicochemical features

General physico-chemical features of the rivers are summarized in Table 1. The river waters were rather transparent except in the Rio Taquari. The transparency (Secchi disk depth) ranged from 0.7 m to 3.1 m, and the extinction coefficient ranged from 0.6 to 2.4 m^{-1}. Water temperature ranged from 19 to 20 °C.

Table 1. General physicochemical characteristics of rivers in southern Pantanal.

Water system	Station	Tr. (m)	Extinc.Coef. (m^{-1})	W.T. (°C)	DO (%)	pH	E.C. ($\mu S\ cm^{-1}$)	Silicate ($mg\ Si\ l^{-1}$)
Rio Paraguai	P1					7.3	39	4.5
Rio Paraguai	P2	1.7	1.51	20	70	7.2	44	5.2
Rio Paraguai	P3	2.0	1.21	20	72	7.0	41	4.8
Rio Paraguai	P4	1.9	1.20	20	76	7.0	42	5.7
Rio Paraguai	P5	2.7	1.12	19	76	7.0	39	5.4
Rio Paraguai	P6	2.0	1.03	19	75	7.3	39	5.5
Rio Miranda	M1	2.2	0.79	20	57	7.6	129	7.5
Rio Miranda	M2	3.0	0.83	20	50	6.8	128	6.0
Rio Taquari	T1	0.7	2.44	19	73	7.1	25	3.6
Rio Aboral	A1	3.1	0.62	19	89	7.3	29	6.3

The pH value ranged from 6.8 to 7.6. It was interesting to note that the water samples were undersaturated with dissolved oxygen at all stations. As can be seen in Fig. 2, conductivity was considerably different in each river. High values were observed at Stas. M1 and M2 in the Rio Miranda (129 and 128 $\mu S\ cm^{-1}$) and low values were recorded at Sta. T1 in the Rio Taquari (25 $\mu S\ cm^{-1}$) and Sta. A1 in the Rio Aboral (25 $\mu S\ cm^{-1}$), a small channel in the marsh. The conductivity in the Rio Paraguai ranged from 39 to 44 $\mu S\ cm^{-1}$. This variation in conductivity seems to be caused by the geological differences of their watershed, though there is almost no appreciable difference in the physiognomy. These values are low compared with those generally observed in the rivers of Japan having the character of soft water.

Nutrients

The concentrations of ammonia ranged from 1.4 to 1.9 $\mu g\ N\ l^{-1}$; those of nitrite were 2.5 to 3.4 $\mu g\ N\ l^{-1}$ and nitrate ranged from 2.6 to 3.3 $\mu g\ N\ l^{-1}$. The phosphate concentrations ranged from 7.0 to 9.8 $\mu g\ P\ l^{-1}$. The nitrogen and phosphorous nutrients were low and showed no appreciable differences among the stations. The concentration of silicate ranged from 3.6 to 7.5 mg Si l^{-1}, and was high in the Rio Miranda and low in the Rio Taquari. The ratio of dissolved inorganic nitrogen (DIN ; taken as the sum of ammonia, nitrite, and nitrate) to phosphate was calculated as 0.8 to 1.1.

Dissolved organic matter

The distribution of DOC, DON, DOP and urea concentration is shown in Fig. 3. The DOC concentration ranged from 530 to 1050 $\mu g\ C\ l^{-1}$. DOC was high in the Rio Paraguai and low in the Rio Aboral and Rio Taquari. DON ranged from 155 to 282 $\mu g\ N\ l^{-1}$ with a similar tendency noted in the distribution of DOC. The DOP concentration ranged from 4.0 to 7.9 $\mu g\ P\ l^{-1}$. The ratio of DOC to DON was calculated as 3.4 to 4.6, with high ratios recorded in the Rio Miranda. The DOC/DOP and DON/DOP ratios ranged from 120 to 210 and 30 to 60, respectively. Urea ranged from 0.15

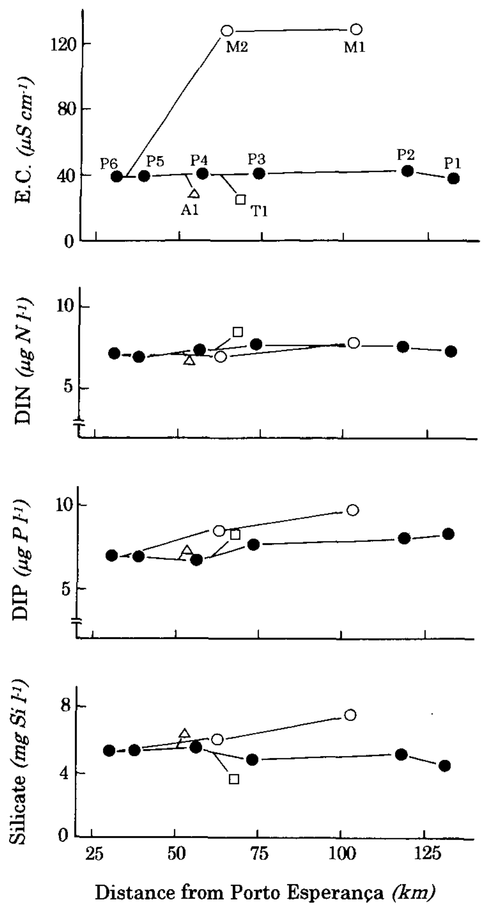

Fig. 2. Distribution of electric conductivity (K_{18}), dissolved inorganic nitrogen (DIN) ; as the sum of ammonium, nitrite, nitrate, phosphate (DIP) and silicate concentration.

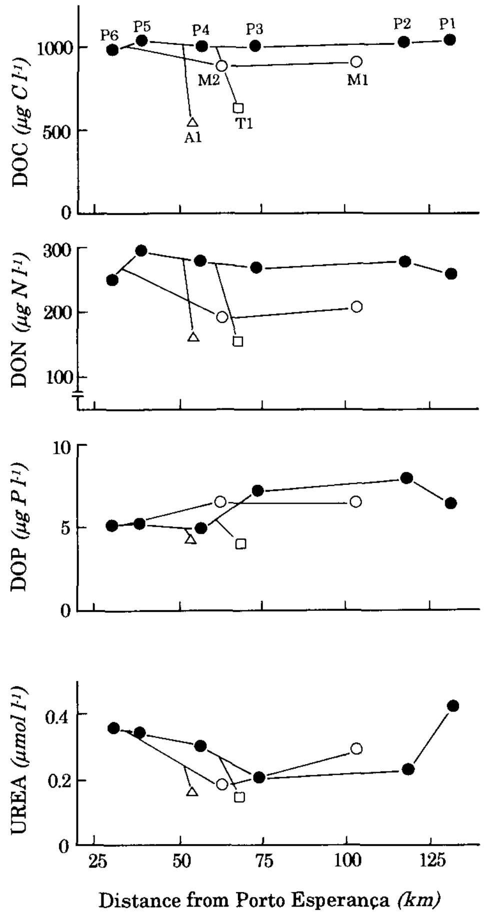

Fig. 3. Distribution of dissolved organic carbon (DOC), nitrogen (DON), phosphorus (DOP) and urea concentration.

to 0.42 μmol l^{-1}, and low concentrations were recorded in the Rio Taquari and Rio Aboral.

Particulate matter

The distributions of PC, PN, PP and chlorophyll-*a* are shown in Fig. 4. PC levels varied within the range of 140 to 430 μg C l^{-1}, with the highest value recorded in the Rio Taquari. PN ranged from 18 to 46 μg N l^{-1} and PP was 2.4 to 9.2 μg P l^{-1}. The amounts in the present study were low compared with those generally obtained in freshwater lakes. The PP level in the Rio Taquari showed a much higher value than those recorded at other stations.

Chlorophyll-*a* levels ranged from 0.8 to 3.9 μg chl.*a* l^{-1}, with low values recorded in the Rio Miranda. The PC, PN, PP and chlorophyll-*a* levels exhibited a decreasing tendency as samples were taken lower in the course

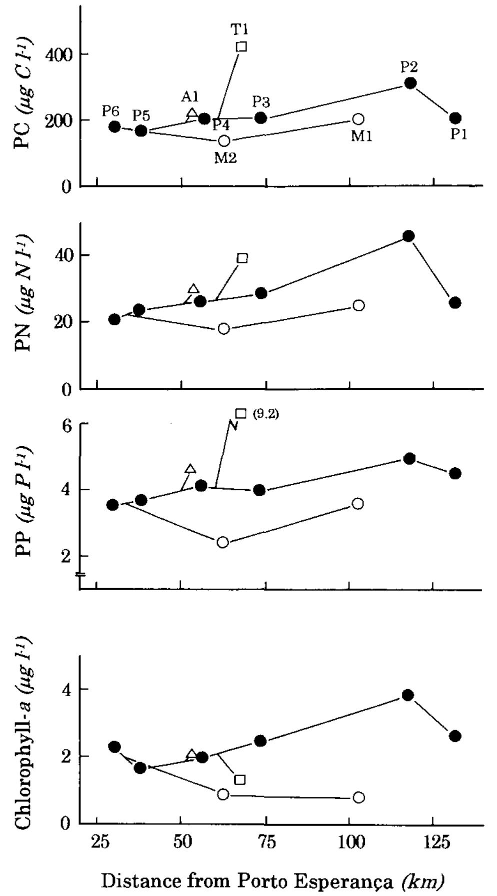

Fig. 4. Distribution of particulate carbon (PC), nitrogen (PN), phosphorus (PP) and chlorophyll-*a* amount.

of the Rio Paraguai. The ratio of PC to chlorophyll-*a* was calculated as 77 to 156, with the exception of high values recorded at two Stas. M1 and T1. This indicates that the particulate matter in this area is mainly composed of phytoplankton.

2. Small lakes and river near Porto Jofre

General physicochemical features

General physico-chemical features of the lakes and river are summarized in Table 2. The water of each lake seemed to have the color of so-called "black water" and Lake 2 was turbid by the silt. The transparency of lakes ranged from 0.40 to 0.86 m, and the extinction coefficient ranged from 3.0 to 9.3 m^{-1}. Water temperature ranged from 27.0 to 31.0 °C probably changed depending on the time of sampling.

Conductivity was generally low from 44 to 52 $\mu S\ cm^{-1}$ in the Lake 1 and Lake 3, and the lowest value of 25 $\mu S\ cm^{-1}$ was obtained in the Lake 2. The latter value is comparable with that of the Rio Cuiabá, 26 $\mu S\ cm^{-1}$. The pH

Table 2. General physicochemical characteristics of lakes and river near Porto Jofre.

Water system	Station	Tr. (m)	Extinc.Coef. (m^{-1})	Depth (m)	W.T. (°C)	DO (%)	pH	E.C. ($\mu S\ cm^{-1}$)
Lake 1	L1	0.9	3.04	0	29	31	5.4	44
				1	28	7		
				2	28	5		
				3	27	5		
				3.5	27	4	5.5	52
Lake 2	L2	0.4	9.33	0	31	83	5.4	25
				0.25	30	68		
				0.5	30	67		
				0.7	29	34		
Lake 3	L3	0.7		0	28	15	5.7	51
				0.5	28	12		
				1	28	9		
				2	28	8		
				3	28	6	5.7	52
				4	28	5		
				4.3	28	4		
Rio Cuiabá	C1			0	31		6.2	26

values were generally low, ranging from 5.4 to 5.7, probably due to the influence of humic substance in blackwater. In the Rio Cuiabá, pH was 6.2. Dissolved oxygen content was also very low even at the surface in two lakes, the Lake 1 and 3, 2.4 (31%) and 1.2 mg $O_2\ l^{-1}$ (15%), respectively, and 0.3 $mgO_2\ l^{-1}$ in both lakes near the bottom. In Lake 2, higher values of 6.2 (83%) and 2.6 mg $O_2\ l^{-1}$ (34%) were observed at the surface and near the bottom, respectively, probably because of the circulation by the wind.

Table 3. Concentrations of nutrients in lakes and river near Porto Jofre.

Water system	Depth (m)	Ammonia	Nitrite ($\mu g\ N\ l^{-1}$)	Nitrate	Phosphate ($\mu g\ P\ l^{-1}$)	Silicate ($mg\ Si\ l^{-1}$)
Lake 1	0	14	1.3	4.3	10	6.2
	3.5	47	3.2	5.6	12	7.0
Lake 2	0	14	1.5	3.1	10	10.4
Lake 3	0	20	2.3	3.5	14	6.7
	3	10	2.4	3.9	13	6.6
Rio Cuiabá	0	20	1.7	6.9	12	6.2

Nutrients

In the three lakes shown in Table 3, the ammonium, nitrite, and nitrate concentrations of surface water ranged from 14 to 20, 1.3 to 2.3 and 3.1 to 4.3 $\mu g\ N\ l^{-1}$ respectively, while slightly higher values, 20, 1.7 and 6.9 $\mu g\ N\ l^{-1}$, respectively, were obtained in the Rio Cuiabá. The phosphate concentration ranged from 10 to 14 $\mu g\ P\ l^{-1}$ including the Rio Cuiabá. The silicate concentration was also rather high and ranged from 6.2 to 10.4

Table 4. Concentration of dissolved organic carbon (DOC), nitrogen (DON), phosphorus (DOP) and urea in lakes and river near Porto Jofre.

Water system	Depth (m)	DOC (μg C l^{-1})	DON (μg N l^{-1})	DOP (μg P l^{-1})	Urea (μmol l^{-1})
Lake 1	0	1770	220	18	0.53
	3.5	1810	250	20	0.65
Lake 2	0	4860	550	64	0.66
Lake 3	0	2220	310	29	0.91
	3	2240	320	28	1.11
Rio Cuiabá	0	1400	210	25	0.63

mg Si l^{-1}. The ratio of DIN to phosphate of surface water was calculated as 1.8 to 2.0 in the lakes and 2.3 in the Rio Cuiabá.

Dissolved organic matter

The distribution of DOC, DON and DOP and urea concentrations is shown in Table 4. DOC and DON were lowest in the Rio Cuiabá, at 1400 μg C l^{-1} and 210 μg N l^{-1}, respectively, and highest in Lake 2, at 4860 μg C l^{-1} and 550 μg N l^{-1}, respectively. DOP was also high in Lake 2, at 64 μg P l^{-1}, and ranged from 18 to 29 μg P l^{-1} in other waters. The ratio of DOC to DON was calculated as 6.7 to 8.8. The DOC/DOP and DON/DOP ratios ranged from 56 to 100 and 8.4 to 12.7, respectively. The ratios were lowest in the Rio Cuiabá. Urea ranged from 0.53 to 1.11 μmol l^{-1}, and the percentage of carbon in DOC was calculated as 0.16 to 0.59% and that of urea nitrogen in DON from 3.3 to 9.7%.

Table 5. Concentrations of particulate carbon (PC), nitrogen (PC), phosphorus (PP) and chlorophyll-*a* in lakes and river near Porto Jofre.

Water system	Depth (m)	PC (μg C l^{-1})	PN (μg N l^{-1})	PP (μg P l^{-1})	Chl. *a* (μg chl.*a* l^{-1})
Lake 1	0	1820	180	19	4.3
	3.5	1590	160	15	3.7
Lake 2	0	2700	310	43	9.0
Lake 3	0	1370	120	16	1.8
	3	1460	130	22	2.1
Rio Cuiabá	0	2140	210	12	4.6

Particulate matter

Chlorophyll-*a*, PC, PN and PP values were summarized in Table 5. Chlorophyll-*a* ranged from 1.8 to 9.0 μg chl.*a* l^{-1} and was highest in the Lake 2. PC values ranged from 1370 to 2700 μg C l^{-1}, PN from 120 to 310 μg N l^{-1}, and PP from 12 to 43 μg P l^{-1}. All of the highest values were found in Lake 2. The Rio Cuiabá also showed higher values except for PP. The present results showed that the organic matter contents are very high in Lake 2, which is located in a livestock farm, though the chlorophyll-*a* concentration was not so high.

DISCUSSION

Recently, from 1991 to 1993, HECKMAN (1994) studied the seasonal changes in physical and chemical parameters at six stations in northern part of Pantanal wetland, ranging from the neighboring area of Poconé, located about 100 km south and southwest of Cuiabá, to south about 60 km along the Trans Pantaneira Highway. In his research, five stations were small rivers and one station was a low-lying site which deepened during the highway construction.

The seasonal changes in chemical features of water at all stations showed a similar pattern. The prime factor that seems to determine the times at which the change occur is the elevation of the particular area, which determines whether and how early in the dry season the various water bodies completely dry up and how early in the rainy season they will be flooded.

The conductivity remained generally low in the region, but relatively high values are reached during the late dry and early rainy seasons (100 to 200 $\mu S\ cm^{-1}$). In contrast, during the high water period from February through April, the conductivity remains at a minimum (30 to 60 $\mu S\ cm^{-1}$). Our data on the conductivity, obtained in January 1986 near Porto Jofre, at the end of the Trans Pantaneira Highway, are similar to those in high water period, though the water level seemed to be still low. The pH values of the small lakes near Porto Jofre were about 5.4 to 5.7, and that of the Rio Cuiabá, 6.2, was lower than those obtained in the Rio Paraguai and its tributaries, 7.0 to 7.2. HECKMAN (1994) measured the seasonal changes in the pH and dissolved oxygen at the stations along the Trans Pantaneira Highway in February 1992. The daily change of pH was between 6.2 and 6.6, and that of dissolved oxygen, between 1.3 and 5.0 mg $O_2\ l^{-1}$. The lowest values of both pH and dissolved oxygen were obtained during 4:00 to 6:00 and the highest values from 12:00 to 15:00. These pH and dissolved oxygen levels are not so low as our data obtained near Porto Jofre, but the tendency was similar.

The values of nitrogenous nutrients as well as the phosphate and silicate concentrations in waters near Porto Jofre were considerably higher than those observed in the Rio Paraguai and its tributaries except for the nitrite level. It is interesting that in all of the water bodies near Porto Jofre, the ammonium concentration was high in nitrogenous nutrients. The ratio of DIN to phosphate in Rio Paraguai and its tributaries, 0.8 to 1.1, and those in waters near Porto Jofre, 1.8 to 2.3, suggest that the growth of phytoplankton and periphyton populations in the Pantanal Water System is considerably influenced by the levels of nitrogenous nutrients, though the limitation of nitrogenous nutrients is more severe in the Rio Paraguai and its tributaries. The DIN to phosphate ratios obtained for the surface water in the Rio Doce Lakes in Minas Gerais ranged from 23 to 76, suggesting the limitation of primary production by phosphorus (MITAMURA and HINO, 1992).

All of the values of dissolved organic matter, DOC, DON and DOP, in waters near Porto Jofre were very high compared with those in the Rio Paraguai and its tributaries, and also higher than those in the Rio Doce Lakes except DON. All of these values in water near Porto Jofre are comparable with those in Lake Biwa (MITAMURA and SAIJO, 1981), a deep mesotrophic lake. The ratio of DOC to DON in waters near Porto Jofre was higher than those in the Rio Paraguai and the Rio Doce Lakes, suggesting the influence of humic substances. The DOC/DOP and DON/DOP ratios in waters near Porto Jofre were much lower than those in the Rio Paraguai and Rio Doce Lakes, respectively. The major reason for such large differences is the high DOP contents of water in waters near Porto Jofre.

The urea concentrations in the waters near Porto Jofre were higher than those in the Rio Paraguai and in the Rio Doce Lakes (MITAMURA *et al.*, 1995), but comparable with those in Lake Biwa (MITAMURA and SAIJO, 1981). Information on the distribution of urea in river water is extremely limited. The urea concentrations in the present study were considerably lower than those measured in a polluted river in Japan by OGURA *et al.* (1975) and in the Han River, Korea by MITAMURA *et al.* (1994). Urea is one of the important compounds which serves as a nitrogen source for phytoplankton in natural waters (EPPLEY *et al.*, 1971 ; MCCARTHY *et al.*, 1982 ; MITAMURA and SAIJO, 1986). In Pantanal, in the Rio Paraguai and in the waters near Porto Jofre, the contribution of urea nitrogen in nitrogenous nutrient (taken as the sum of DIN and urea) was found to be very high (33 to 62%). This suggests that urea plays a significant role as a nitrogen source for phytoplankton also in the Pantanal water system.

The PC, PN and PP values in waters near Porto Jofre were higher than those in the Rio Paraguai and its tributaries, and comparable with those in the Rio Doce Lakes. The PC/PN ratios in waters near Porto Jofre are similar to those in the Rio Paraguai and its tributaries and in the Rio Doce Lakes. The PC/PP and PN/PP ratios in the waters near Porto Jofre were higher than those in the Rio Paraguai and its tributaries and lower than those in the Rio Doce Lakes. This also seems to indicate that in the waters near Porto Jofre, the nitrogen is the limiting parameter, rather than phosphorous, regulating the growth of phytoplankton and periphyton populations. The Rio Paraguai and its tributaries seem to have an extremely oligotrophic character.

The nutrients and organic matter contents of water in the Rio Cuiabá are much higher than those in Rio Paraguai and its tributaries in the southern Pantanal.

CONCLUSION

Though our research were limited to two areas in the Pantanal wetland, one is the small lakes and river near Porto Jofre in northern Pantanal, another is the Rio Paraguai and its tributaries in southern Pantanal, the former showed a eutrophic character and the latter an extremely oligotrophic character, while the nitrogen seemed to be the limiting nutrient in both water systems.

The oxygen deficiency in water seemed rather common throughout the area studied in spite of the difference in water temperature and the organic matter contents. POR (1995) suggested that after the first rains in the spring, the spill-off from the alluvial land carries much decomposing vegetable matter as a consequence, oxygen is low, and pH is slightly acidic. However, it seems probable that there are no permanently acidic "blackwaters" in the Pantanal system.

Water pollution by livestock farms was observed near Porto Jofre. Considering a rapid growing of the livestock farm, it seems highly probable that in a large part of the Pantanal the water pollution and other destruction of the natural environment is caused by this source. This presents a serious problem for the conservation of one of the largest wetlands in the world with a high diversity of flora and fauna.

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パンタナル大湿原の河川，湖沼の物理化学的性状

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摘　　要

パンタナルは南米大陸のほぼ中央に位置する世界最大の湿原であるが，それに関する科学的知見はきわめて不足している。われわれは 1983 年 7 月にパンタナル南部のパラグアイ川とその支流，1986 年 1 月にパンタナル北部のポルトジョフリ付近の小湖群ならびにクイアバ川について，水の化学的性状を中心に調査を行った。パラグアイ川とその支流はきわめて貧栄養的であり，ポルトジョフリ付近の湖と川は富栄養的であった。これらの水系では，基礎生産の制限因子はリンでなく窒素であると考えられた。また，水温も異なり，水中の有機物量にも顕著なちがいが認められたにもかかわらず，両水域ともに一般に溶存酸素飽和度は低かった。