

Summer Mid-Day-Night Composition and Abundance of Zooplankton from Lake Ikeda, Japan

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ABSTRAK

Variasi tengah-hari dan tengah-malam dalam komposisi dan kelimpahan himpunan zooplankton utama dalam Tasik Ikeda, sebuah tasik kawah telah dianalisis semasa musim panas 1986. Protozoa menjuzuki lebih 70% daripada keseluruhan populasi zooplankton dan adalah yang paling melimpah diikuti oleh rotifera (12%), kopepoda (8%) dan kladosera (7%). Kecuali kopepoda dan sebilangan kecil rotifera, kebanyakan zooplankton lain didapati dengan agak lebih sedikit kelimpahan pada waktu malam. Kelimpahan keseluruhan zooplankton paling tinggi didapati pada bermulanya musim panas tetapi beransur berkurangan pada hujung musim panas. Komposisi spesies paling tinggi pada awal musim panas, kekal sehingga pertengahan musim panas tetapi beransur berkurangan dan jarang terdapat spesies pada hujung musim panas, malah beberapa spesies lain jarang didapati atau langsung tidak terdapat dalam sampel.

ABSTRACT

Variations between midday and midnight in the species composition and abundance of the main zooplankton assemblage of Lake Ikeda, a crater-lake were analyzed during the summer of 1986. The protozoans, comprising more than 70% of the whole zooplankton population were the most abundant followed by the rotifers (12%), copepods (8%) and cladocerans (7%). Except for the copepods and a few rotifers, most of the other zooplankton were evident at a slightly higher abundance at night. Total zooplankton abundance was highest during early summer but decreased gradually until the end of summer. Species composition was highest in early summer, and persisted until the middle of summer but gradually decreased with rare occurrences of some species at the end of summer, where some species were either rarely sampled or entirely absent from the samples.

INTRODUCTION

Zooplankton study is important as it could provide ways to predict and increase the productivity of lakes (Borgmann *et al.* 1984; Morgan *et al.* 1978). The aim of this study was to compare the summer midday and midnight compositions of the zooplankton in Lake Ikeda. This lake is a crater-lake situated at the southwestern edge of Kyushu island. One of the earliest researchers to work on this lake was Miyakita (1928). He focussed most of his works on the benthos as-

pect of this lake. Other well-noted researchers were Yoshimura (1930), Mizuno (1963) and Murayama and Saisho (1967). All these researchers dealt with the overall plankton composition of this lake. So far, no in-depth study on the midday and midnight zooplankton composition and abundance in the summer months, (which are the most reproductive months of the year) has been done on this lake. This study will focus on the midday and midnight zooplankton composition and abundance in summer. The months

involved were June, July, August and September (See Fig. 2). These four months were the ones with higher temperatures compared to the rest of the months. August and September were the two months with the highest temperatures. The summer months were chosen for this study because most of the species present in this lake appeared in high abundance compared with the other months. In the other seasons, they were found to be of much less abundance and some species were totally absent from the plankton.

Study Site Description

Lake Ikeda is located in Kagoshima Prefecture, Japan at 31°14'N, 130°34'E and is 88m above sea level (Fig. 1). It is a crater-lake situated at the southwestern edge of Kyushu Island, Japan. The mean depth is 135m and the deepest point is at 233m. With a water volume of 1.47 X 10⁹m³ it has a residence time of 1.7 per year. It has a surface area of 11 km² and a shoreline length of 15 km. For its size, it is very deep and is surrounded by steep slopes except on its northwestern side. It was formed as a crater-lake during the pyroclastic eruption of the Ibusuki Volcanic Group, which occurred around 4,000 years ago. Together with the neighbouring cone-shaped Mt. Kaimon on its southern side, it offers one of the most scenic spots to the southern Kyushu tourist zone, that of the Kirishima-Yaku National Park.

MATERIAL AND METHODS

Field Sampling Methods

Midday and midnight zooplankton specimens were taken at a fixed Station 4 in the summer of 1986 during the months of June, July, August and September. Midday abundance was taken at around noon (1200hrs) and midnight abundance samples were taken at around midnight (2400hrs). Station 4 was chosen because it was the most accessible station in terms of its nearness to research facilities and also that of safety. The others (stations 1,2 and 3) were too far away and considered unsafe especially during night samplings.

Zooplankton samples were collected using a 24 cm diameter Kitahara net (NXX13) by vertical net hauls from a depth of 30 m to the surface at a constant speed of 0.5ms⁻¹. Six replicate samples (ca. 250 ml each) were obtained from Station 4 on each sampling occasion. The samples were preserved with cool sucrose formalin technique (Haney and Prepas 1978) in order to avoid carapace distortion and loss of eggs especially from the brood chamber of adult cladocerans. Surface temperature and dissolved oxygen concentration were measured with a Yellow-Springs Instrument model 57 probe. Water transparency was measured with a 30 cm diameter white Secchi Disc. Measurements were taken from November 1985 to November 1986. Analy-

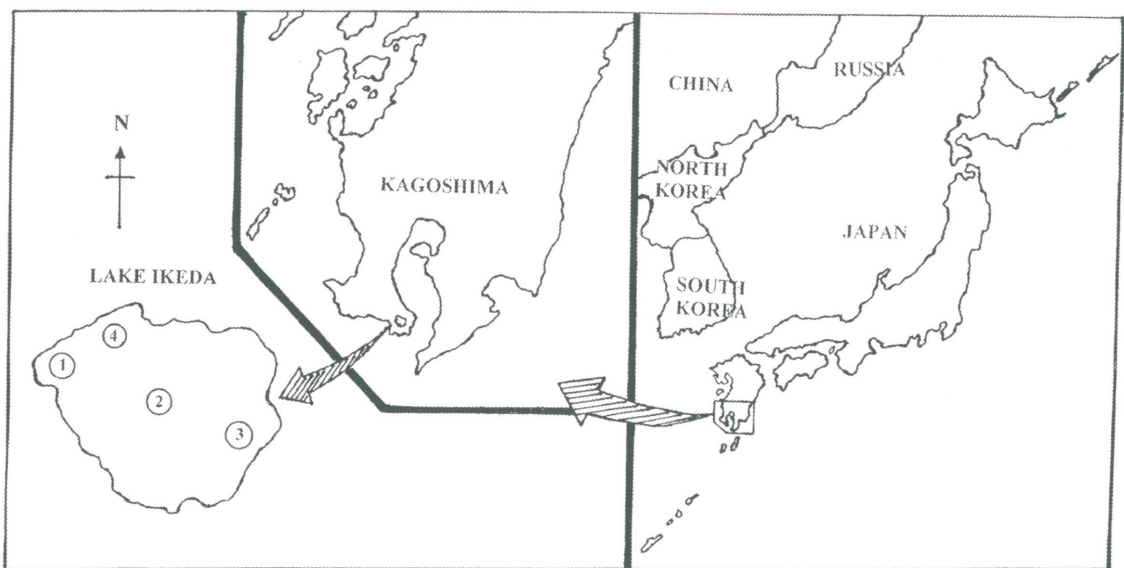


Fig. 1. Locations of Station 4 in Lake Ikeda

TABLE 1

Midday and midnight abundance (mean number/litre \pm standard deviation) of different Protozoa species at station 4 during the summer of 1986 taken by vertical hauls from a depth of 30m to the surface

TAXA	Month			
	June Day(Night)	July Day(Night)	Aug Day(Night)	Sep Day(Night)
PROTOZOA	Numbers/Litre \pm Standard deviation			
<i>Peridinium bipes</i>	3.5 \pm 0.5(2.4 \pm 0.4)	16.0 \pm 5.2(77.3 \pm 10.4)	r(r)	-(-)
<i>Ceratium hirundinella</i>	433 \pm 20.3(590.6 \pm 22.4)	116.0 \pm 12.5(46.3 \pm 6.3)	7.3 \pm 0.5(8.5 \pm 1.0)	r(1.4 \pm 0.3)
<i>Carchesium polypinum</i>	18.8 \pm 7.9(19.1 \pm 10.2)	1.5 \pm 0.3(2.5 \pm 0.5)	-(-)	-(-)

TABLE 2

Midday and midnight abundance (mean numbers/litre \pm standard deviation) of different Rotifera species at Station 4 during the summer of 1986 taken by vertical hauls from a depth of 30m to the surface

TAXA	Month			
	June Day(Night)	July Day(Night)	Aug Day(Night)	Sep Day(Night)
ROTIFERA	Numbers/Litre \pm standard deviation			
<i>Colochilus unicornis</i>	6.6 \pm 0.8(4.4 \pm 0.4)	r(r)	15.9 \pm 3.2(23.9 \pm 5.6)	r(r)
<i>Polyerthra eurypetra</i>	2.1 \pm 0.4(5.9 \pm 0.3)	11.3 \pm 4.3(4.1 \pm 1.2)	r(r)	-(-)
<i>Polyartha trigla</i>	1.2 \pm 0.2(7.2 \pm 0.9)	4.2 \pm 1.2(2.6 \pm 0.5)	r(r)	r(2.1 \pm 0.6)
<i>Asplanchna priodonta</i>	10.7 \pm 3.7(21.1 \pm 5.5)	-(-)	r(r)	r(1.3 \pm 0.4)
<i>Ploesoma truncatum</i>	8.6 \pm 2.2(14.5 \pm 4.5)	r(r)	r(r)	3.2 \pm 0.9(2.5 \pm 0.8)
<i>Trichocerca cylindrica</i>	r(r)	r(1.3 \pm 0.4)	r(r)	r(r)
<i>Conochiloides coenabasis</i>	-(-)	6.3 \pm 1.4(4.6 \pm 0.9)	r(1.0 \pm 0.3)	r(-)
<i>Conochiloides natans</i>	r(r)	2.9 \pm 0.8(r)	2.8 \pm 0.3(12.2 \pm 4.7)	r(2.0 \pm 0.3)
<i>Hexarthra mira</i>	3.3 \pm 0.5(17.4 \pm 5.2)	-(-)	r(r)	r(r)
<i>Keratella cochlearis</i>	-(-)	r(-)	-(-)	-(-)
<i>Keratella valga</i>	-(-)	-(-)	1.5 \pm 0.3(12.2 \pm 4.7)	r(2.0 \pm 0.3)

TABLE 3

Midday and midnight abundance (mean numbers/litre \pm standard deviation) of different Copepoda species at Station 4 during the summer of 1986 taken by vertical hauls from a depth of 30m to the surface

TAXA	Month			
	June Day(Night)	July Day(Night)	Aug Day(Night)	Sep Day(Night)
COPEPODA	Numbers/Litre \pm standard deviation			
<i>Thermocyclops hyalinus</i>	12.3 \pm 3.3(4.0 \pm 0.4)	12.7 \pm 3.2(12.1 \pm 2.5)	3.6 \pm 0.5(5.8 \pm 1.5)	2.4 \pm 0.3(5.4 \pm 0.8)
<i>Mesocyclops sp.</i>	r(r)	r(r)	-(-)	-(-)
<i>Nauplii</i>	4.3 \pm 1.5(7.5 \pm 2.0)	21.6 \pm 5.5(25.5 \pm 5.9)	12.4 \pm 3.1(15.5 \pm 4.0)	2.8 \pm 0.7(2.5 \pm 0.5)

TABLE 4

Midday and midnight abundance (mean numbers/litre ± standard deviation) of different Cladocera at Station 4 during the summer of 1986 taken by vertical hauls from a depth of 30m to the surface

TAXA	Month			
	June Day(Night)	July Day(Night)	Aug Day(Night)	Sep Day(Night)
CLADOCERA	Numbers/Litre±standard deviation			
<i>Diaphanosoma brachyurum</i>	-(-)	2.9±0.3(8.5±0.8)	1.2±0.3(2.2±0.4)	r(r)
<i>Bosmina longirostris</i>	2.8±0.2(6.0±0.3)	13.6±3.4(40.6±4.5)	9.1±2.1(10.2±2.4)	4.7±0.4(5.0±0.5)
<i>Ceriodaphnia reticulata</i>	2.9±0.3(2.0±0.2)	3.3±0.4(2.8±0.3)	4.0±0.5(4.3±0.5)	r(r)
<i>Bosminopsis deitersi</i>	4.4±0.9(8.4±1.4)	r(r)	r(-)	r(r)
<i>Alona guttata</i>	r(r)	r(-)	r(-)	r(r)
<i>Holopedium gibberum</i>	-(-)	-(-)	r(r)	r(-)
<i>Monospilus distar</i>	r(r)	r(r)	r(r)	r(-)
<i>Daphnia pulex</i>	r(r)	-(-)	-(-)	-(-)

sis of data was done using the SAS statistical package.

RESULTS

Physical-chemical Parameters

Fluctuations in surface temperature, dissolved oxygen and transparency for Station 4 are shown in Fig. 2. Surface water temperature ranges from 10°C to 30°C, with an average of 19.8°C. The

hottest month was August while the coldest was February. The four hottest months were June, July, August and September. These were the months chosen to represent the months of summer in this study. Dissolved oxygen ranges from 8.1 to 12.2 mg/L with an average of 9.2 mg/L. Transparency ranges from 4.8 to 9.2 m with an average of 6.3 m. Transparency decreased from spring to summer but increased from autumn to winter.

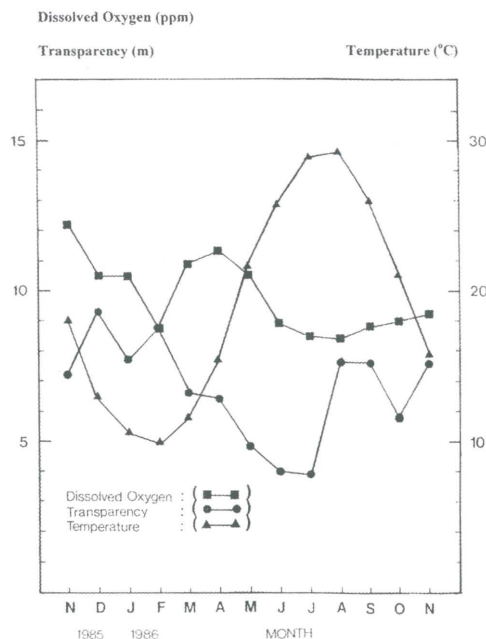


Fig. 2. Fluctuations in dissolved oxygen (ppm), transparency (m) and surface temperature (°C) at Station 4 in Lake Ikeda from November 1985 to November 1986

Composition and Abundance

The midday and midnight composition and abundance of Protozoa, Rotifera, Copepoda and Cladocera are shown in Tables 1,2,3 and 4 respectively.

Protozoa

Three species of Protozoa were present in Lake Ikeda. They are *Peridinium bipes* (Stein 1883), *Ceratium hirundinella* (O.F. Muller 1882) and *Carchesium polypinum* (Ehrenberg 1830). *Peridinium bipes*'s abundance was highest in July (Day: 16.0 ± 5.2 individuals/litre; Night: 77.3 ± 10.4 individuals/litre) and after that it quickly disappeared from the plankton. Comparing each summer month, *Ceratium hirundinella* was the most abundant species with a maximum in June (Day: 433 ± 25.3 individuals/litre; Night: 590.6 ± 22.4 individuals/litre) and was also found to be less in abundance in July (Day: 116 ± 12.5 individuals/litre; Night: 46.3 ± 6.3 individuals/litre) and diminished drastically the next month (Day: 7.3 ± 1.8 individuals/litre; Night: 8.5 ± 1.2 individuals/litre) (Student's t-test, $P < 0.05$). It continued to decrease at the end of the summer month of September. *Carchesium polypinum* was most abundant in June (Day: 18.8 ± 7.9 individuals/litre; Night: 19.1 ± 10.2 individuals/litre) and decreased further in July (Day: 1.5 ± 0.3 individuals/litre; Night: 2.5 ± 0.5 individuals/litre) (Student's t-test, $P < 0.05$) and was absent in August and September.

The Protozoa was the most abundant zooplankton and it comprised more than 70% of the total zooplankton found in Lake Ikeda. In June, *Peridinium bipes* had a higher abundance during midday but in July the reverse was found to be true. *Ceratium hirundinella* was most abundant at midnight in June, but in July the midday sample had a higher abundance compared with the midnight sample ($P < 0.05$). However in August and September, there was no significant difference between the midnight and the midday sample ($P > 0.05$). This was also true of *Carchesium polypinum* ($P > 0.05$).

Rotifera

Altogether, 11 species of Rotifers were present in Lake Ikeda. They are *Conochiloides unicornis* (Rouselet 1892), *Polyerthra euryptera* (Wierzejski 1893), *Polyerthra trigla* (Schreyer 1921), *Asplanchna priodonta* (Gosse 1850), *Ploesoma truncatum* (Levander 1894), *Trichocerca cylindrical* (Imhof

1891), *Conochiloides coenobasis* (Skorikov 1914), *Conochiloides natans* (Voigt 1904), *Hexarthra mira* (Hudson 1871), *Keratella cochlearis* (Gosse 1851) and *Keratella valga* (Ehrenberg 1834).

The most abundant rotifer was *Conochilus unicornis* (with a maximum in August) (Day: 15.9 ± 3.2 individuals/litre; Night: 23.9 ± 5.6 individuals/litre) followed by *Asplanchna priodonta* (with a maximum in June) (Day: 10.7 ± 3.7 individuals/litre; Night: 21.1 ± 5.5 individuals/litre). The most abundant rotifers found in June were *Ploesoma truncatum* (Day: 8.6 ± 2.2 individuals/litre; Night: 14.5 ± 4.5 individuals/litre) and *Hexarthra mira* (Day: 3.3 ± 0.5 individuals/litre; Night: 17.4 ± 5.2 individuals/litre). *Trichocerca cylindrical* (Day: rare; Night: 1.3 ± 0.4 individuals/litre), and *Conochiloides coenobasis* were most abundant in July (Day: 6.3 ± 1.4 individuals/litre; Night: 4.6 ± 0.9 individuals/litre) and *Conochiloides natans* both in July (Day: 2.9 ± 0.8 individuals/litre; Night: rare) and August (Day: 2.8 ± 0.7 individuals/litre; Night: 12.2 ± 4.7 individuals/litre) while *Keratella valga* (Day: 1.5 ± 0.3 individuals/litre; Night: 12.2 ± 4.7 individuals/litre) in August. From the end of September onwards, most of the rotifers were diminishing in abundance. *P. euryptera*, *P. trigla*, *A. priodonta*, *P. truncatum*, *H. mira* and *K. valga* occurred at much higher abundance at midnight compared with midday (Students' t-test, $P < 0.05$).

The rotifers made up about 12% of the total zooplankton abundance. Except for *Conochiloides coenobasis*, generally all the other rotifers occurred at a much higher abundance at midnight compared with midday. However in July, *Polyerthra euryptera* and *Polyerthra trigla* had a higher abundance during the midday compared with midnight ($P < 0.05$). The reverse was true for both species in June, i.e. midnight was more abundant than midday ($P < 0.05$).

Copepoda

Only two species of Copepods were found in Lake Ikeda. The two species were *Thermocyclops hyalinus* (Rehberg 1880) and *Mesocyclops* sp. Both belonged to the cyclopoids. *Thermocyclops hyalinus* occurred in almost equal numbers during the day in June (12.3 ± 3.3 individuals/litre) and July (12.7 ± 3.2 individuals/litre) ($P > 0.05$) but at night the July samples (12.1 ± 2.5 individuals/litre) showed a higher abundance compared with the June samples (4.0 ± 1.2 individuals/litre) ($P < 0.05$). *Mesocyclops* sp. was rarely seen in

June and July and was absent in August and September. Apart from that, nauplii of both species were present in the samples.

Altogether the copepods comprise 8% of the total number of zooplankton. The cyclopoids together with their nauplii were present throughout all the summer months. Nauplii of both genera were counted together as they could not be easily separated and distinguished. The copepods' abundance was higher during early summer (June) but was not significantly different in July, August and September. In the early summer month of June, more copepods were present during the midday compared with midnight. As for the nauplii, there was no significant difference in abundance between midday and midnight in all the summer months.

Cladocera

Altogether, in this study, eight species of Cladoceras were found to inhabit Lake Ikeda. They were *Diaphanosoma brachyurum* (Lieven 1848), *Bosmina longirostris* (O.F.Muller 1785), *Ceriodaphnia reticulata* (Jurine 1820), *Bosminopsis deitersi* (Richard 1895), *Alona guttata* (Sars 1862), *Daphnia pulex* (O.F.Muller 1785), *Monospilus distar* (Sars 1862) and *Holopedium gibberum* (Zaddach 1855).

The most abundant cladoceran was *Bosmina longirostris* which occurred in all the summer months of June, July, August and September. It was the most abundant in July (Day: 13.6 ± 3.4 individuals/litre; Night: 40.6 ± 4.8 individuals/litre) and then decreased in August (Day: 9.1 ± 3.2 individuals/litre; Night: 10.2 ± 3.9 individuals/litre) ($P < 0.05$). *Diaphanosoma brachyurum* was absent from the samples in June but suddenly appeared with a maximum abundance in July (Day: 2.9 ± 0.3 individuals/litre; Night: 8.5 ± 1.7 individuals/litre) and started to decrease in August (Day: 1.2 ± 0.5 individuals/litre; Night: 2.2 ± 0.9 individuals/litre) ($P < 0.05$) and further still in September where it rarely appeared. *Ceriodaphnia reticulata* was present from June (Day: 2.9 ± 0.6 individuals/litre; Night: 2.0 ± 0.3 individuals/litre), July (Day: 3.3 ± 0.7 individuals/litre; Night: 2.8 ± 0.5 individuals/litre) and until August (Day: 4.0 ± 0.6 individuals/litre; Night: 4.3 ± 0.6 individuals/litre) but almost disappeared from the plankton in September. There was no significant difference in abundance among all the four months ($P > 0.05$). *Bosminopsis deitersi* could only be sampled in

June (Day: 4.4 ± 1.3 individuals/litre; Night 8.4 ± 2.2 individuals/litre) and then became too few in number in July and by September it had disappeared. *Alona guttata* was present but too few in number to be of much significance in its abundance. *Holopedium gibberum*, *Monospilus distar* and *Daphnia pulex* are three new colonizers of Lake Ikeda.

Altogether the Cladoceras comprises 7% of the whole zooplankton abundance. Although *Ceriodaphnia reticulata* occurred in higher abundance during the midday as compared to midnight, it was not statistically significant (Students' t-test, $P > 0.05$). On the other hand, more of *Diaphanosoma brachyurum*, *Bosmina longirostris*, and *Bosminopsis deitersi* were significantly more at midnight compared with midday (Students' t-test, $P < 0.05$).

DISCUSSION

Most of the zooplankton species sampled in this lake during the summer months were also inhabitants of other natural lakes and artificial impoundments in Japan (Miura and Cai 1990; Hanazato and Nohara 1992). Comprising about 70% of the whole zooplankton's abundance, the protozoa appeared to play an important role in the zooplankton community of this lake. They could represent an important trophic link between microheterotrophic production and invertebrate predators (Porter *et al.* 1979). They may hold a key role in nutrient regeneration due to their high specific rates of phosphorous excretion (Pace and Orcutt 1981). Future research on these protozoans could help to elucidate processes such as energy flow and nutrient regeneration in this lake.

In Lake Ikeda, the rotifers were more diverse when compared with the other zooplankton community. They were comparable to other lakes in Japan (Miura and Cai 1990; Hanazato and Nohara 1992). The rotifers were considered opportunists (Allan 1976). Its population rises and falls according to its tolerance of environmental conditions. Their total biomass is usually low but this is compensated by a short generation time, thus a fast renewal of population (Hutchinson 1967). After *Polyerthra euryptera*, *Asplanchna priodonta* was the most abundant rotifer. Apart from its ability to suppress other rotifers, especially *K. cochlearis* (Hoffmann 1983; Sarma 1993), it can also consume algae and small crustacean species, especially small

Bosminidae (Matveeva 1989; Hutchinson 1967) and *Peridinium* (Pourriot 1965). However, in Lake Ikeda, its density crashed immediately after its peak in June. What could have happened is that it could have migrated down to lower water layers at some periods of the day especially during midday, where it can find higher rotifer densities to consume (Vasconceles 1994). Welch (1935) suggested that prey and predation principles are the most important factors involved in diurnal migration of zooplankton. During the day time, the zooplankters descend to the bottom water to hide themselves from their predators and ascend upwards during night hours. Hutchinson (1967) reported that the pattern of zooplanktonic migration may be due to the result of interspecific competition, whereby species dominant during night hours were generally fewer in number during the day. In fact he went on further to state that the interpretation of zooplankton dynamics is impossible without considering the historic, biotic and competitive factors. In the future, it would be interesting to follow the fluctuations in density of rotifers and relate it to more detailed environmental parameters. Physical and chemical properties of the water may limit the occurrence of some species (Elliot 1977; Ruttner-Kolisko 1977; Herzig 1987), but phytoplankton availability (Gilbert and Bogdan 1984; Herzig 1987), competition and predation (Dumont 1977; Hoffmann 1983; Gilbert and Stemberger 1984) are also important.

For the copepods, a significant difference was found in *T. hyalinus* which occurred at higher abundance in June during midday compared with midnight. The rest were not significantly different. The rest are either too few to be sampled or not present in the samples. The species composition of Copepods in Lake Ikeda is similar to other tropical or subtropical lakes (Fernando 1980a,b). In Lake Ikeda, they are represented by only two genera, *Thermocyclops hyalinus* and *Mesocyclops* sp.

Eutrophication is known to affect the specific composition of the zooplankton by altering the environment which could lead to changes in the phytoplankton composition. This in turn could promote the changes in the quantity and quality of available food for the zooplankton (Sandecz 1984). During this study, three species of Cladoceras that were never reported to be present in this lake were encountered in the samples. They were *Daphnia pulex*, *Holopedium*

gibberum and *Monospilus distar*. However, their abundance was too low to be of much significance to the overall zooplankton's abundance. Although they were very few in number, they were nevertheless present. Prior to this report there was no record of their presence (Miyakita 1928; Yoshimura 1930; Mizuno 1963 and Murayama and Saisho 1967). What could have happened is that they could have been introduced from elsewhere together with fish released into Lake Ikeda for stocking purposes. Altogether, this study has managed to detect the presence of eight genera of Cladoceras living in Lake Ikeda. The degree of eutrophication of a lake is closely associated with the zooplankton community, and in an eutrophic environment, the cyclopoid copepods and the cladocerans are dominant (Bradshaw 1964; Patalas 1972; Hillbricht-Ilkowska and Weglenska 1970). It seems that Lake Ikeda is heading towards an eutrophic environment with the continued increase in abundance of cyclopoid copepods and cladocerans compared with previous studies done on this lake by Murayama and Saisho (1967). The presence of *Bosmina longirostris* and *Diaphanosoma brachyurum* in high abundance is usually also associated with an eutrophic environment as *Diaphanosoma* sp. is well adapted to eutrophic environments (Sendacz 1984). This finding is supported by Zago (1974) who reported that with the eutrophication of the Americana Reservoir, *Diaphanosoma* sp. replaced *Daphnia gessneri* as the dominant species of cladocera. Future research on this lake will involve a more in-depth analysis of each zooplankton species together with more detailed measurements of physical-chemical parameters coupled with *in situ* experiment-based analysis in order to elucidate each species' role in the ecology of this lake in its path towards eutrophication.

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