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Seasonal distribution and vertical migration of planktonic rotifers in two lakes in Eastern Canada

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With 10 figures in the text

The most significant contributions on the seasonal succession of rotifers in temperate regions are Ahlstrom (1934) and Carlin (1943). Recently Pejler (1957) and Amren (1964) from Sweden and Gilyarov (1965) from Russia provided additional information on the seasonal and vertical distribution of planktonic rotifers. However, the literature on the diurnal migration of rotifers is scanty. No published data exists on the diurnal migration of rotifers covering the different seasons. This paper is an attempt to give quantitative data on seasonal distribution of rotifers in two lakes in Ontario and to present a general pattern of diurnal migration of three species from one of these lakes.

Materials and methods

Sunfish and Paradise Lakes are located within a radius of 20 kilometers from the University of Waterloo. Sunfish Lake is meromictic, has an area of 9 ha and a maximum depth of 19 m. The monimolimnion was from 13 m. Paradise Lake with an area of 7 ha has a maximum depth of 6 m. Water samples were collected weekly (weather permitting) with a Kemmerer sampler from fixed stations every 2 m up to 13 m in Sunfish Lake and 1, 2, 4 and 6 m in Paradise Lake. Two litres of water from each depth were taken back to the laboratory in polyethylene bottles. The samples were concentrated with a plankton net made of Bolting Silk No. 25 and were preserved in 5 % formaldehyde. The total number of each species of rotifer was enumerated in counting chambers under a stereoscopic microscope. The number of each species was then calculated per litre. A few samples were collected during ice cover. The temperature and oxygen were recorded by the E. I. L. Model 15 A Dissolved Oxygen Meter for each depth. The observations were begun in the fall of 1966 and continued until the fall of 1967, but in Sunfish Lake sampling was continued until February 1968. Collections were more regular from Sunfish Lake.

The diurnal variations among rotifers were studied in Sunfish Lake on six days between June 1967 and April 1968. For each 24 hour study, samples were collected at 8 a. m. on one morning and continued until 8 a. m. the next day. The frequency of sampling was every six hours at 1, 3, 6, 9, 12, and 13 m.

Observations

Temperature and oxygen conditions

In Sunfish Lake the temperature (Fig. 1) was uniform from the surface to 13 m from the end of November until early December. Thermal stratification was fully established from the end of May until the middle of September and the lake was in circulation by the end of October. A metalimnetic oxygen maximum around 200 percent saturation was noted for about two weeks in early June (Fig. 2). Oxygen values were generally above the saturation point in the metalimnion. Oxygen was completely depleted from 7—13 m by the end of October.

The temperature and oxygen in Paradise Lake are shown in Fig. 3. Low oxygen values were noted at 6 m from early August until the middle of September.

Seasonal distribution of rotifers

The total number of species recorded from Sunfish Lake was 10 and from Paradise Lake 21. However some of the species appeared in only one or two samples and are not taken into account. Also the few males encountered during the course of the present study are not enumerated due to the problem of accurate identification. The distribution of the more important species are described.

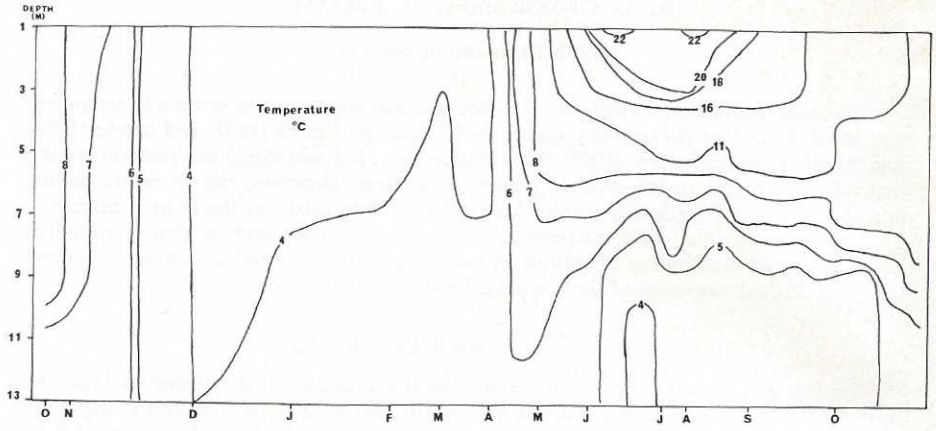

Fig. 1. Isothermal variations in Sunfish Lake: October 1966 — October 1967.

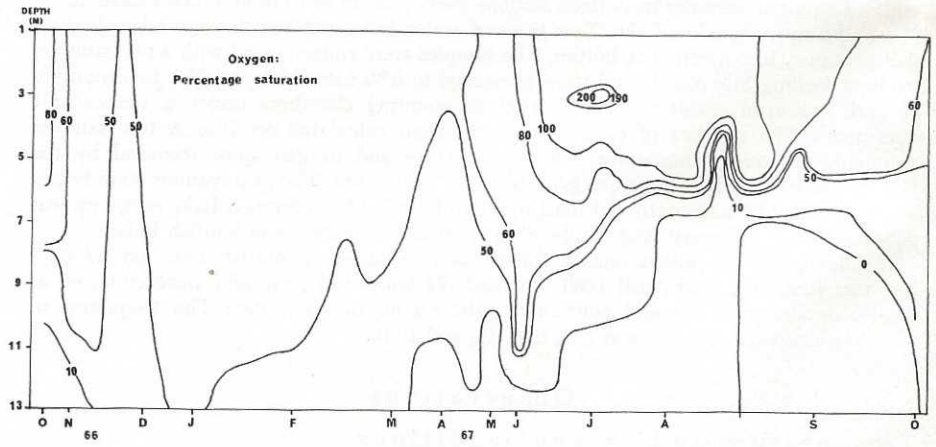

Fig. 2. Isopleths of percentage saturation of dissolved oxygen in Sunfish Lake: October 1966 — October 1967.

Species common to both lakes

Keratella canadensis Berzins (Figs. 4 and 5)

K. canadensis is a species appearing early in winter. By the end of March, before the break up of the ice, the species disappeared. The population was distributed mainly in the top layers and the periods of abundance were similar in both the lakes.

Keratella quadrata (Müller) (Figs. 4 and 5)

This species was present from November onwards in both lakes. In Sunfish Lake the population increased from January until April and then declined. The population was again high by the end of May. From June they were present only in the hypolimnion. By the end of August they disappeared. In Paradise Lake also a similar trend was noted.

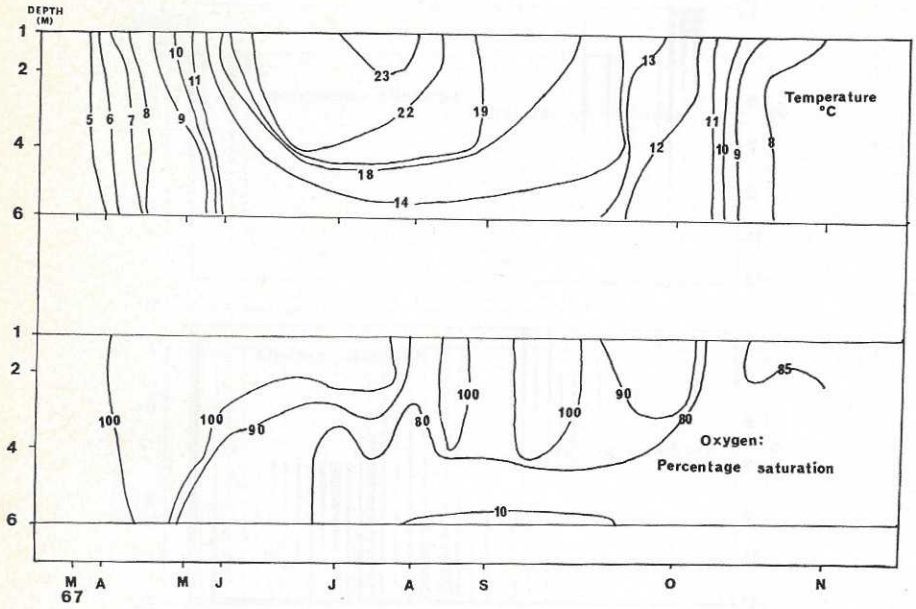

Fig. 3. Isothermal variations and Isopleths of percentage saturation of dissolved oxygen in Paradise Lake: March 1967 — November 1967.

Keratella cochlearis (Gosse) (Figs. 4 and 5)

K. cochlearis is a cold stenotherm. In Sunfish Lake the maximum population was seen in the top 5 m on January 25. The species was otherwise uniformly distributed. With the warming up of the lake, the population decreased and was less uniform in their vertical distribution. With the onset of thermal stratification in June, the forms were found only in the hypolimnion. They disappeared in August.

In Paradise Lake, the number of individuals/litre was much higher than in Sunfish Lake. From March until the middle of May the population was scanty but this was followed by a considerable increase until the middle of June. This species was absent from July until September. By November there was a more uniform vertical distribution.

Keratella hiemalis Carlin (Figs. 6 and 7)

In Sunfish Lake, this species a cold stenotherm, was absent from 1—3 m till early March. But the population was at its maximum in February and March and

from March until the middle of April was uniformly distributed at all depths. With the onset of high temperatures in May, the species moved to the cold hypolimnion and continued until the end of August. With the depletion of oxygen by the end of August, the population disappeared. In Paradise Lake the maximum population was in winter and early spring and thereafter the species was not available.

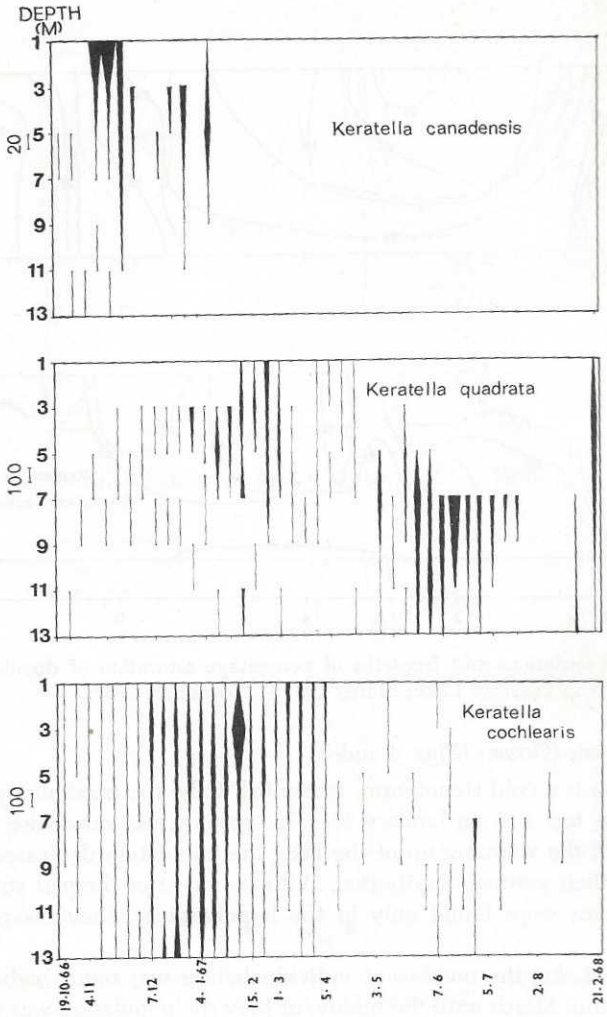

Fig. 4. Seasonal distribution of *Keratella canadensis*, *K. quadrata*, and *K. cochlearis* in Sunfish Lake.

Polyarthra vulgaris Carlin (Figs. 6 and 7)

P. vulgaris attained high populations for about two weeks in May and was present at all depths in Sunfish Lake. With the thermocline formation, individuals were found only in the hypolimnion. The population, however, moved up and was

found in large numbers above 7 m by the middle of August. With this last maximum, the forms disappeared. In Paradise Lake *P. vulgaris* was found in large numbers at all depths from April until May. The population was present in the summer months also down to the 6 m level. The second major pulse with very high densities between 4—6 m was observed at the end of August and early September. It was uniformly distributed from top to bottom thereafter.

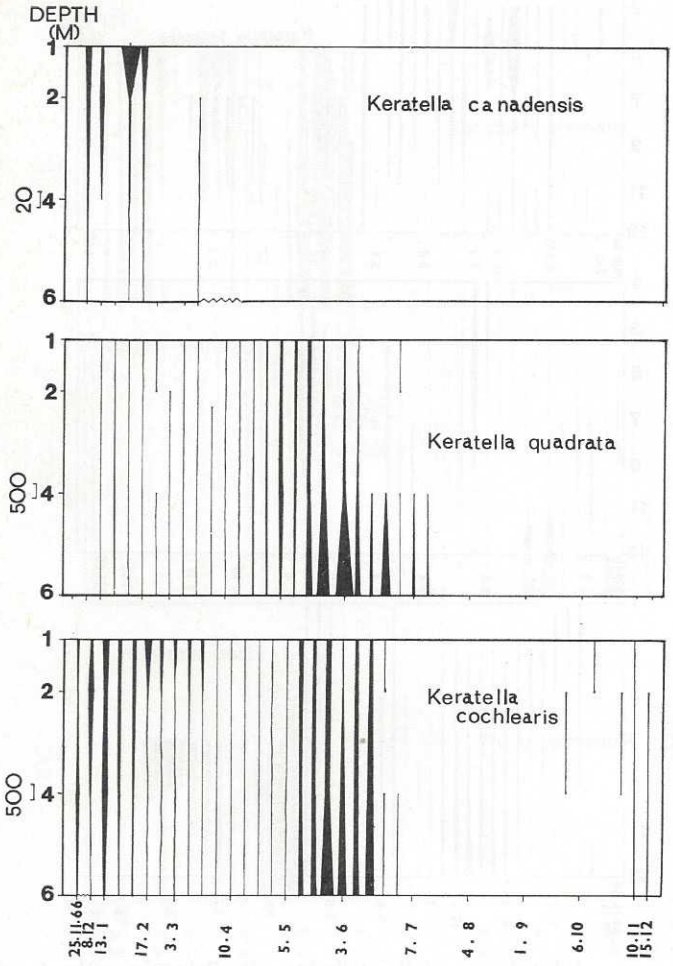

Fig. 5. Seasonal distribution of *Keratella canadensis, K. quadrata* and *K. cochlearis* in Paradise Lake.

Filinia terminalis Plate (Fig. 6 and 7)

This form was somewhat uniformly distributed in Sunfish Lake until May with a high population at 13 m in January. In summer the species moved down and was present in large numbers in the hypolimnion. With the autumnal circulation

the population disappeared. In Paradise Lake, *F. terminalis* was present from November until the middle of May with a major pulse in the last two weeks of April. Since then it appeared sporadically in low numbers and was not present from early August.

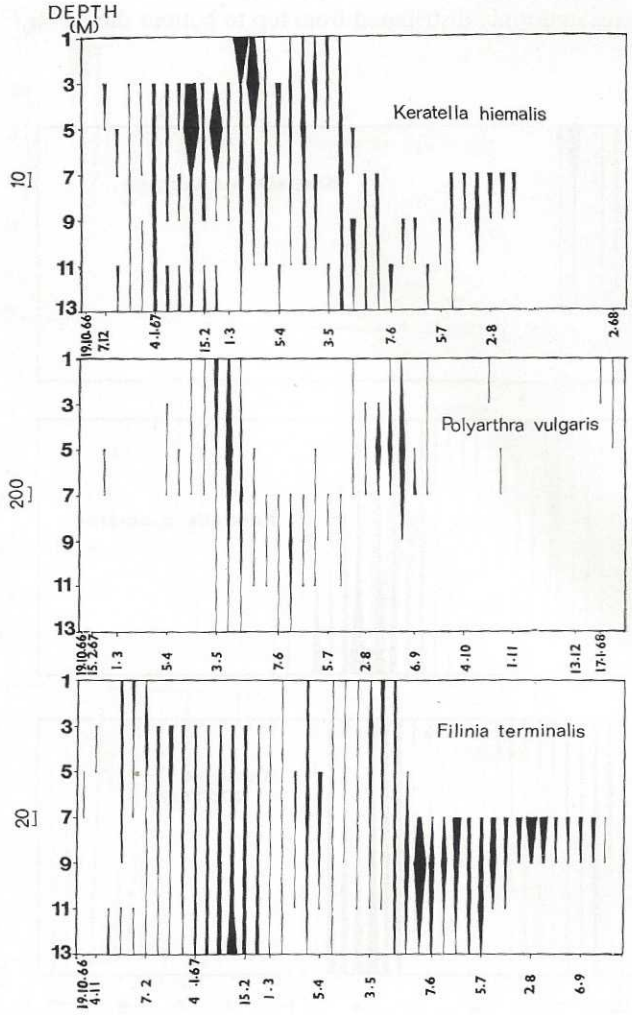

Fig. 6. Seasonal distribution of *Keratella hiemalis, Polyarthra vulgaris* and *Filinia terminalis* in Sunfish Lake.

Species present only in Paradise Lake

Keratella crassa AHLSTROM (Fig. 8)

The species made its appearance in June and continued until September below 2 m. From October until the middle of December, the population had a

uniform vertical distribution. *K. crassa* was numerically low throughout and its numbers never exceeded 10/litre.

Polyarthra euryptera Wierzejski (Fig. 8)

This species was present by the end of April and attained a high population by early May and occurred at all depths. By the beginning of June, the population dwindled and it finally disappeared.

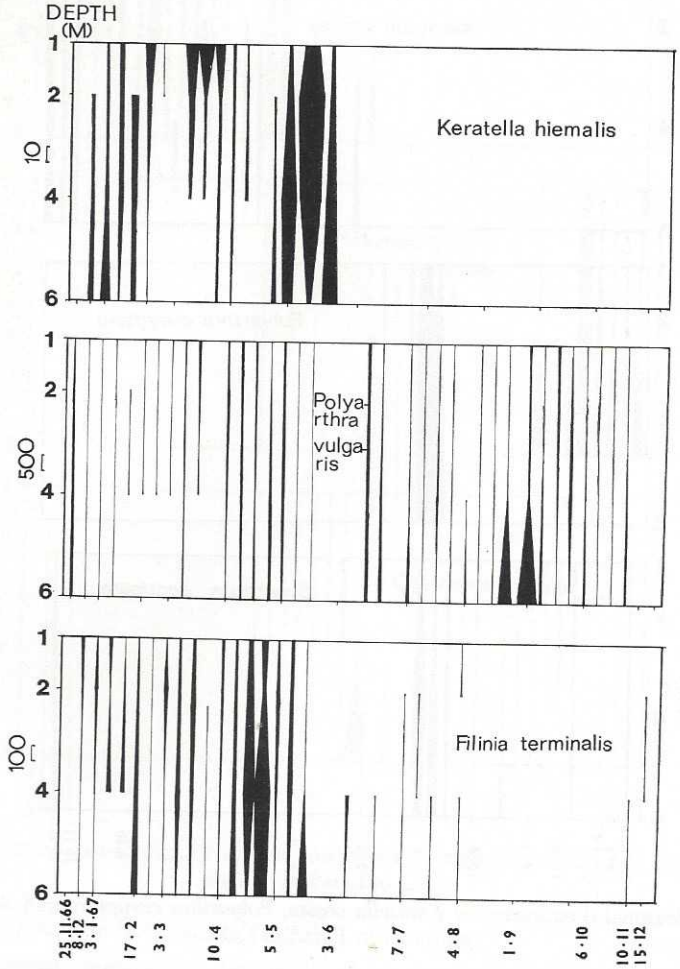

Fig. 7. Seasonal distribution of *Keratella hiemalis, Polyarthra vulgaris* and *Filinia terminalis* in Paradise Lake.

Synchaeta pectinata Ehrenberg (Fig. 8)

Whenever present, *S. pectinata* showed uniform distribution. A pronounced early summer maximum was noted but by June the forms disappeared. In autumn it was present in moderate numbers.

Asplanchna girodi DE GUERNE (Fig. 9)

Though not present in large numbers, *A. girodi* occurred throughout the winter and early summer with a uniform distribution. This species was absent from the end of June.

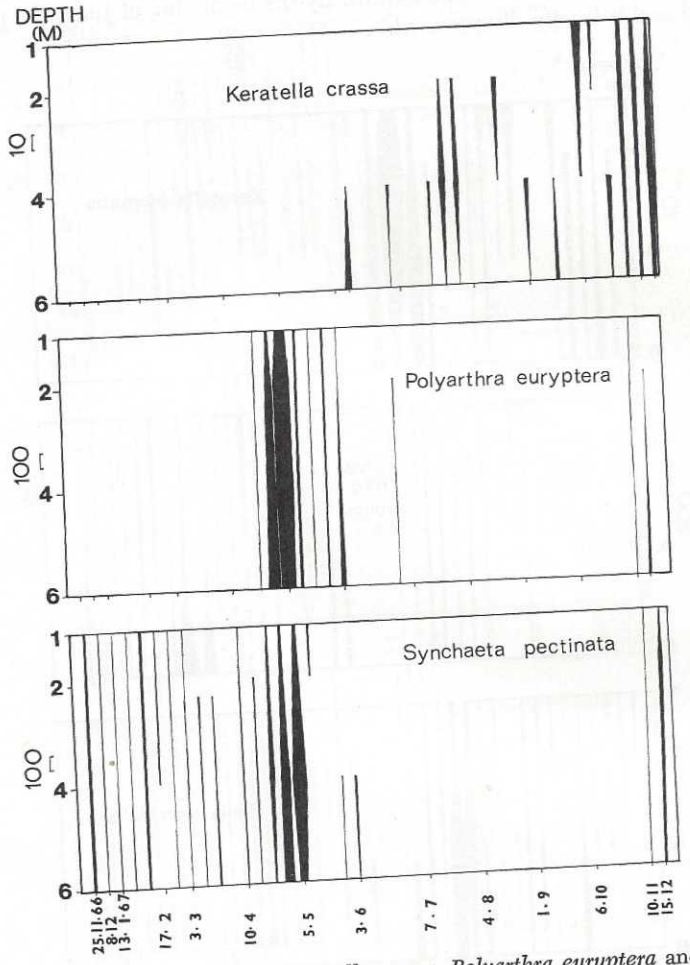

Fig. 8. Seasonal distribution of *Keratella crassa, Polyarthra euryptera* and *Synchaeta pectinata* in Paradise Lake.

Pompholyx sulcata HUDSON (Fig. 9)

After an initial appearance in May, this species came back only in September and showed a maximum in autumn.

Gastropus stylifer IMHOF (Fig. 9)

This species was present only from May and in the top 4 m, but became uniformly distributed at all depths by the middle of June. The population persisted

till the end of July between 4—6 m. This species appeared to be a typical summer form.

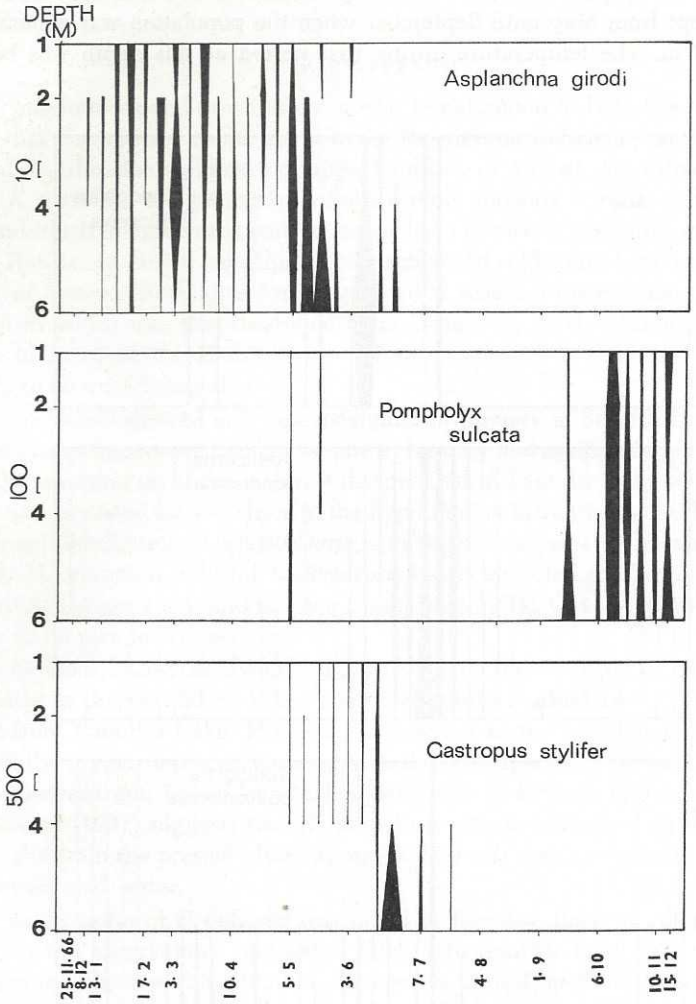

Fig. 9. Seasonal distribution of *Asplanchna girodi*, *Pompholyx sulcata* and *Gastropus stylifer* in Paradise Lake.

Conochilus unicornis Rousselet (Fig. 10)

C. unicornis appeared by the middle of May and continued till early September. A prominent summer maximum was noted on June 16 with the maximum numbers at 4 m. In late summer there was a more uniform vertical distribution.

Kellicottia longispina (Kellicot) (Fig. 10).

This is a perennial species distributed at all depths. From early May till early June, the population was at its highest. The maximum numbers were observed at 6 m on May 5.

Kellicottia bostoniensis (ROUSSELET) Fig. 10)

As in *K. longispina* this species is also perennial having, similar vertical distribution except from May until September when the population was generally between 4—6 m. The temperature during that period at this depth was between 12—14° C.

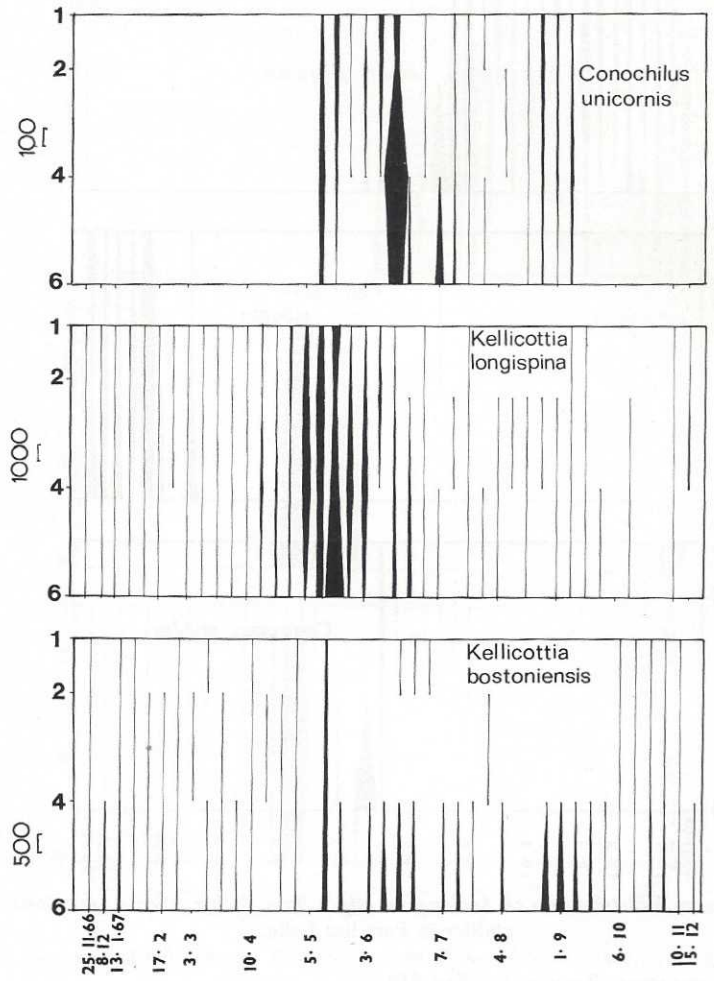

Fig. 10. Seasonal distribution of *Conochilus unicornis, Kellicottia longispina* and *K. bostoniensis* in Paradise Lake.

Diurnal migration

Only 3 species, *Keratella quadrata, Polyarthra vulgaris* and *Filinia terminalis* were available in sufficient numbers to study the diurnal migration. *K. quadrata* showed a clear cut migration in February and a reverse migration in March. *P. vulgaris* exhibited nocturnal migration in June, July, August and February and

reverse migration in March and April. Similar migration was seen in the case of *F. terminalis*. *K. quadrata* populations were neglegible in August and *F. terminalis* in February.

Discussion

K. quadrata moved down to the cooler hypolimnion in both the lakes. But it seems that the species could not tolerate the oxygen deficiency at the close of thermal stratification and hence disappears in July or August. According to CARLIN (1943) *K. quadrata* is a perennial species usually showing a maximum in May or June and this is in agreement with what has been observed in Sunfish and Paradise Lakes. But BEACH (1960) calls this species a rare and cold water form in the Ocquecoc River System. Nothing is known about the seasonal distribution of *Keratella canadensis* which was first described from Canada in 1954. This species is very similar to *K. quadrata*. If this is a valid species, which is doubtful, the species appears to be a cold stenotherm.

K. cochlearis showed only one maximum in January in Sunfish Lake while in Paradise Lake there were two peaks, one in January and another in May and June. With the warming up of the water, it disappeared in Paradise Lake while a sparse population persisted for sometime in the hypolimnion in Sunfish Lake. This pattern of seasonal distribution of *K. cochlearis* is different from what is known about the species. An autumnal pulse of *K. cochlearis* has been noted in Terwilliger's Pond in Ohio (AHLSTROM 1934) and in Lake Erie (DAVIS 1954). CARLIN (1943) found this species to be rare in winter.

K. hiemalis, known as a winter and early spring species (CARLIN 1943) behaves differently in the two lakes. When the temperature reached 14—15° C, it disappeared from Paradise Lake. However, it survived in the hypolimnion in Sunfish Lake till the oxygen depletion came in August. Other species of the genus *Keratella*, like *K. quadrata*, and *K. cochlearis* also coexist with *K. hiemalis* in the hypolimnion. HUTCHINSON (1967) suggests that *K. hiemalis* is able to withstand an oxygen deficiency. But from the present observations, *K. hiemalis* does not seem to be tolerant of deoxygenated water.

A major pulse of *P. vulgaris* was noted in Paradise Lake in autumn. This is similar to the observations of CARLIN (1943). In Sunfish Lake with the oxygen depletion in August and September, the species moved up from the hypolimnion. It is of interest to find that *P. vulgaris* was the only species that survived the oxygen deficiency in the hypolimnion by its movement to the top layers.

C. unicornis, *G. stylifer*, *P. euryptera* and *K. crassa*, recorded only from Paradise Lake, are found to be summer species. According to CARLIN (1943) *C. unicornis* is a perennial form. *P. sulcata* another known summer form, reached a maximum in October in Paradise Lake. In the Motala Lake System, CARLIN (1943) found the species to be maximal in August.

K. longispina and *K. bostoniensis* are perennial species, the latter known only from North America. Both species showed uniform vertical distribution except that *K. bostoniensis* remained between 4—6 m from June till October. The two species showed their maxima differently *K. longispina* showed its maximum from May till July at all depths while *K. bostoniensis* had a period of maximum abundance lasting

from May till September. The latter species was restricted to the hypolimnion except on one occasion in May. GILYAROV (1965) reported the occurrence of *K. longispina* between 2—4 m in Bolshoe Lake, Russia, which has a maximum depth of 5 m. He has quoted a few instances of this species moving down to the hypolimnion and rising to the top layers after the thermal stratification. According to CAMPBELL (1941) *K. longispina* is restricted to the epilimnion and *K. bostoniensis* to the hypolimnion in Douglas Lake in Michigan. It may be pointed out that in these cases thermal stratification has produced niches for the two species as has been shown in the case of *Polyarthra* spp. reported by BERZINS (1958). From the present study, it was noted that the periods of abundance of the two species do not overlap for most of the time. Also, *K. bostoniensis*, during thermal stratification, was found only in the hypolimnion while a thin population of *K. canadensis* existed at all depths.

From the present study it is concluded that the seasonal distribution of planktonic rotifers could vary considerably in different lakes and need not be synchronous.

The diurnal variations studied, with reference to the three species, point out that there is always some kind of vertical movement but generally a nocturnal migration during a 24 hour period. There are changes in the diurnal migration pattern of the three species in relation to the seasonal differences in temperature, oxygen and light regimes. The information on this phenomenon in rotifers is very meagre and the few published accounts are based on observations during one 24 hour period. Consequently the rotifers that are studied are said to show nocturnal, reverse or sometimes no migration.

Acknowledgement

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Discussion

EDMONDSON: This material seems very well suited to an analysis of population dynamics by the egg ratio method. Do you plan to do it?

FERNANDO: The material is available and such a study is envisaged.

RUTTNER-KOLISKO: Have you ever found males or resting eggs of *Keratella hiemalis* in your biotops?

FERNANDO: We have not kept records on the males and resting eggs since the counting involved considerable difficulties if males were to be identified.