DIURNAL MIGRATION IN THREE SPECIES OF ROTIFERS IN SUNFISH LAKE, ONTARIO

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ABSTRACT

The pattern of diurnal migration in three species of rotifers has been studied from six 24-hr samples obtained in different months to cover a wide range of seasonal conditions. Velocities and amplitude of vertical migration were calculated for the three species.

The same species can show nocturnal upward migration at one season and the reverse at another. There are differences in vertical movements during ice cover. There is some indication that different species exhibit diurnal migration keeping different zonation.

INTRODUCTION

Diurnal migration of zooplankton in lakes and oceans is a well-documented phenomenon, particularly for cladocerans and copepods. This study was undertaken in Sunfish Lake, Waterloo, Ontario, to obtain information of a more detailed nature than hitherto available on the diurnal migration of rotifers. Ten species of planktonic rotifers have been recorded from this lake, but only three occurred with sufficient frequency for this investigation: *Polyarthra vulgaris* Carlin, *Keratella quadrata* Muller, and *Filinia terminalis* Skorikow. This work was supported by National Research Council of Canada Grant A3478 to Dr. C. H. Fernando.

MATERIALS AND METHODS

Sunfish Lake has an area of 9 ha and a mean depth of 10.4 m. The lake is meromictic and the monimolimnion is below the 13-m level; all data are for the mixolimnion only. The maximum depth is 19 m; samples were collected from a fixed station indicated by a buoy at this depth in June, July, and August 1967 and February, March, and April 1968—months chosen to cover a wide range of seasonal conditions. Collections were started at 0800 hours and repeated every 6 hr till 0800 the next day (Fig. 1).

Water samples were collected at 1, 3, 6, 9, 12, and 13 m with a Kemmerer sampler. For each depth, 2-liter samples of water were taken in polyethylene bottles to the laboratory, filtered through a plankton net (No. 25 bolting silk), and the plankton concentrate preserved in 5% formaldehyde. Total numbers of each species of rotifer were counted in chambers with parallel lines under a microscope.

Two sets of samples (February and March) were collected under ice cover. A small slab of ice was cut out and the water samples collected within about 15 min; in another 15 min the temperature and oxygen readings were recorded (E.I.L. Model 15 A dissolved oxygen meter). Such quick sampling prevented both freezing of the sampler and prolonged illumination. Immediately after sampling, the ice slab was replaced and then lifted for subsequent samplings. In February there was no snow on top of the ice, but in March there was 13 cm of snow. The ice on both occasions was 40–50 cm thick.

The method for depicting the diurnal migration of zooplankton of Worthington (1931) was followed (Fig. 2). The lines plotted represent the migrations of the average individual; times of sunset and sunrise are also indicated. The maximum velocity of vertical movement for each species has been calculated from these figures.

Pyrheliometer readings (from the weather station of the University of Guelph) for the different times of collection are given in Table 1.

PHYSICAL AND CHEMICAL CONDITIONS

The Secchi disc transparency of the lake varied between 3.4–4.0 m during summer

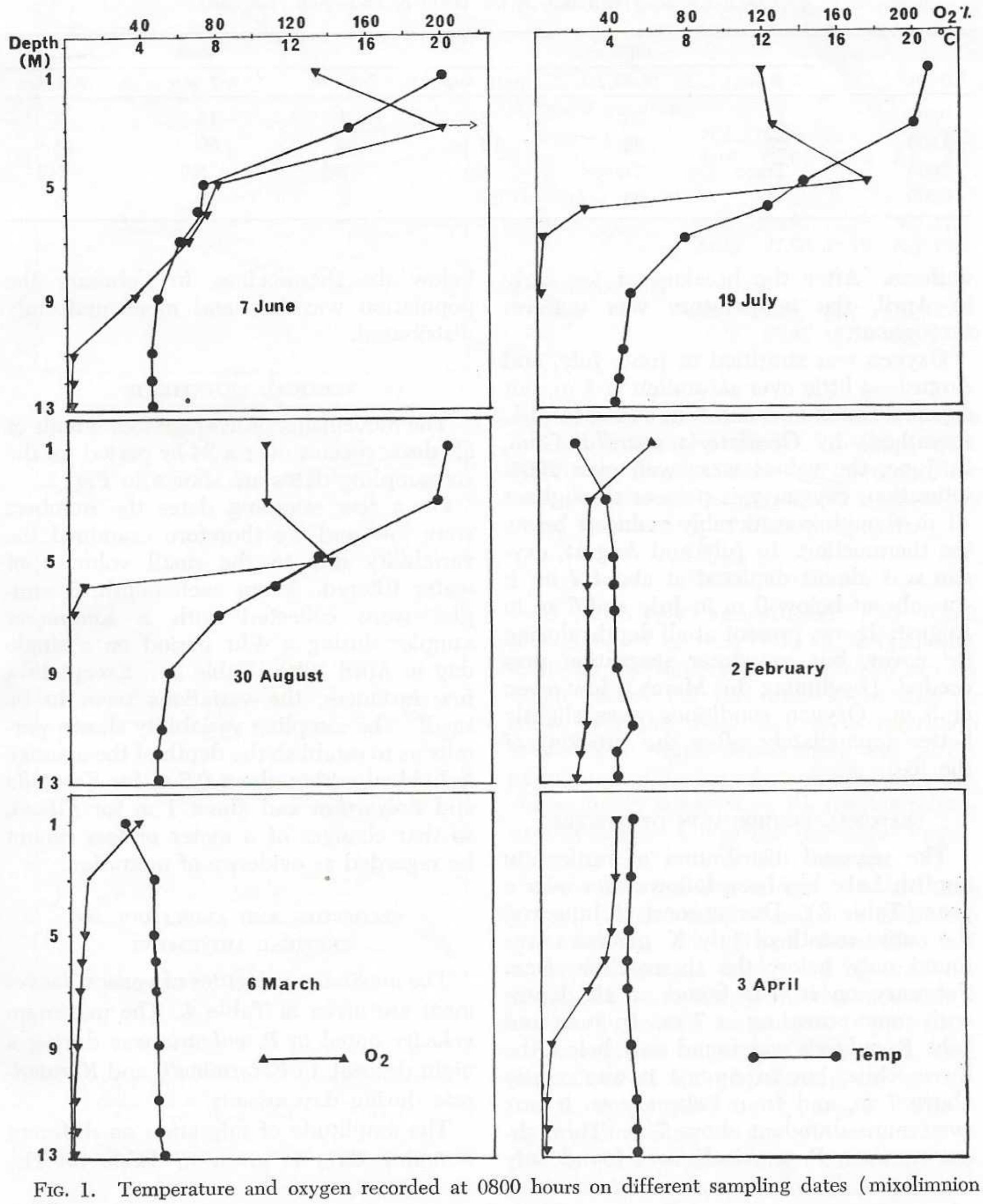

FIG. 1. Temperature and oxygen recorded at 0800 hours on different sampling dates (mixolimnion only).

stratification and 2.0–2.5 m during spring overturn. The temperature and oxygen readings taken at frequent depths at the 0800 sampling are plotted in Fig. 1. The lake was thermally stratified during June, July, and August. In February and March there was a slight inverse stratification; below 3 m the temperature was relatively

TABLE 1. *Solar radiation at the times of collection (cal/cm²)*

Hours	1967			1968		
	7–8 Jun	19–20 Jul	30–31 Aug	7–8 Feb	6–7 Mar	3–4 Apr
0800	11	34	2	5	16	6
1400	20	38	18	40	60	13
2000	Trace	Trace	Nil	Nil	Nil	Nil
0800	4	26	32	2	35	6

uniform. After the breakup of ice early in April, the temperature was uniform throughout.

Oxygen was stratified in June, July, and August—a little over saturation at 1 m, but supersaturated at 3 and 5 m owing to photosynthesis by *Oscillatoria agardhii* Gum. In June, the values were well over 200% saturation; oxygen was present throughout 13 m though considerably reduced below the thermocline. In July and August, oxygen was almost depleted at about 7 m; it was absent below 9 m in July and 7 m in August. It was present at all depths during ice cover, but as winter stagnation proceeded (beginning in March) low even at 3 m. Oxygen conditions were slightly better immediately after the breakup of the ice.

SEASONAL DISTRIBUTION OF SPECIES

The seasonal distribution of rotifers in Sunfish Lake has been followed for over a year (Table 2). During most of June and the entire month of July *K. quadrata* was found only below the thermocline; from February on it was found at all depths with some crowding at 7 m. In June and July, *P. vulgaris* was found only below the thermocline, but in August it was mostly above 7 m, and from February on it was even more abundant above 7 m. Throughout summer, *F. terminalis* was found only below the thermocline; in February the population was low and more uniformly distributed.

VERTICAL MOVEMENTS

The movements of average individuals of all three species over a 24-hr period on the six sampling dates are shown in Fig. 2.

On a few sampling dates the numbers were low and we therefore examined the variability due to the small volumes of water filtered. From each depth, 5 samples were collected with a Kemmerer sampler during a 4-hr period on a single day in April 1969 (Table 3). Except in a few instances, the variations seem to be small. The sampling variability shown permits us to establish the depth of the average individual within about 0.5 m for *Keratella* and *Polyarthra* and about 1 m for *Filinia*, so that changes of a meter or less cannot be regarded as evidence of migration.

VELOCITIES AND AMPLITUDE OF VERTICAL MOVEMENT

The maximum velocities of vertical movement are given in Table 4. The maximum velocity noted in *P. vulgaris* was during a night descent, in *F. terminalis* and *K. quadrata* during day ascents.

The amplitude of migration on different sampling days is given in Table 5. The

TABLE 2. *Maximum population densities (per liter) of the three species*

	Jun	Jul	Aug	Feb	Mar	Apr
Keratella quadrata	5.5	100.5	—	—	28.5	62
Polyarthra vulgaris	5.5	11	58	6	84.5	100.5
Filinia terminalis	171	223	194.5	—	—	5

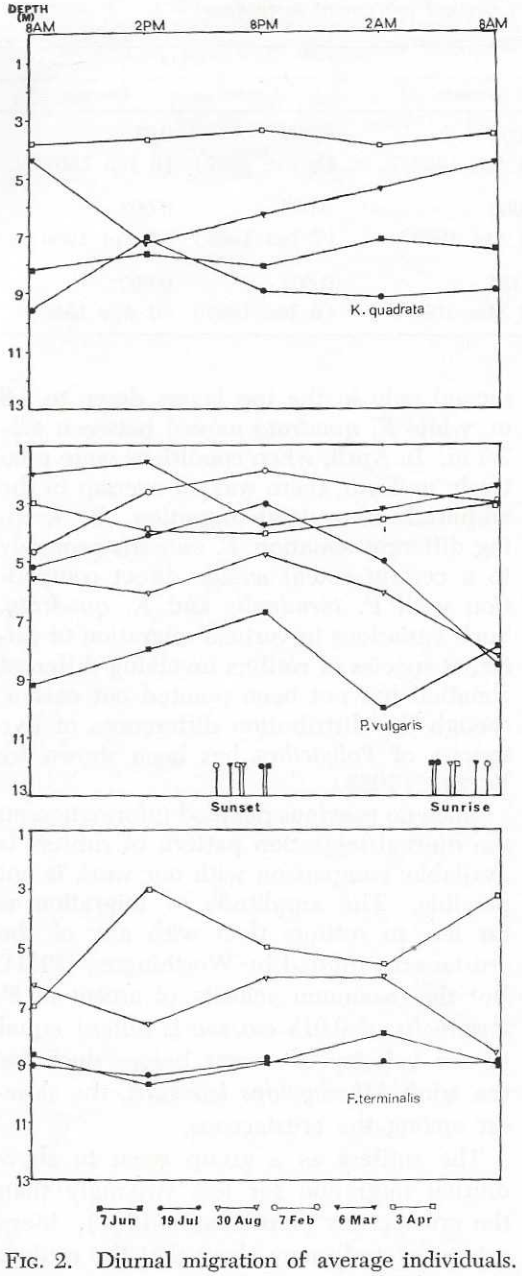

FIG. 2. Diurnal migration of average individuals.

TABLE 3. *Mean numbers of rotifers per liter at each depth (m) ± SD*

	1	3	6	9	12
Keratella quadrata					
Mean	6.2	192.0	54.8	7.0	2.2
SD	0.08	67.67	16.54	5.2	1.3
Polyarthra vulgaris					
Mean	81.0	383.8	17.2	5.0	17.2
SD	29.95	37.45	11.18	6.3	13.8
Filinia terminalis					
Mean	2.4	72.2	67.6	29.2	17.2
SD	1.34	25.46	15.04	12.8	13.86

greatest movement was that of *P. vulgaris* in July—5.6 m. In all three species of rotifers, the movements were just below the thermocline in June and within the thermocline in July and August. During ice cover, *P. vulgaris* showed movements in the top layers, with a maximum descent of 4.8 m, while *K. quadrata* moved between 4.3 and 7.3 m. After ice breakup, their amplitude of migration was more or less uniform, though *F. terminalis* seemed to move a little deeper than the others.

DISCUSSION

In June, July, and August, *P. vulgaris* moved upward from 0800 till 2000 hours, as it did in February, although the sun set much earlier (at this time there was no snow over the ice). A reverse migration was seen in March when there was 13 cm of snow over the ice. A similar pattern was shown by *F. terminalis* with reverse migration in April. A clearcut nocturnal migration was not seen in *K. quadrata.* These rotifers therefore can migrate upward nocturnally at one season and reverse at another season. The rotifers show nocturnal upward migration during ice cover if the ice is free from snow, but the movements seem to be erratic when snow is present.

Some of the migratory movements seem anomalous as the populations do not return to the original depth (e.g., *P. vulgaris* in July and August and *F. terminalis* in April). The peculiar migration of *P. vulgaris* in August may be attributed to the differences in light intensity at 0800 on the two successive days (Table 1). However, this cannot explain the migration of *P. vulgaris* in July and *F. terminalis* in April. In these cases, the population may not have been sufficiently dense to warrant any conclusions.

TABLE 4. *Velocities (cm/sec) of vertical movement in rotifers*

	Day		Night	
	Ascent	Descent	Ascent	Descent
Polyarthra vulgaris	0.006 (7 Jun 1967)	0.005 (3 Apr 1968)	0.007 (8 Jun 1967)	0.01 (8 Jun 1967)
Filinia terminalis	0.018 (3 Apr 1968)	0.009 (3 Apr 1968)	0.005 (7 Jun 1967)	0.003 (4 Apr 1968)
Keratella quadrata	0.01 (19 Jul 1967)	0.014 (6 Mar 1968)	0.004 (8 Jun 1967)	0.003 (3 Apr 1968)

All these species show some kind of vertical movement during the 24-hr period, and we conclude that these are mainly nocturnal migrations. Information on this phenomenon in rotifers is meager. What is known is from single sets of observations during one 24-hr period for a species. Consequently the rotifers are said to show nocturnal, reverse, or sometimes no migration (Ruttner 1937; Kikuchi 1930; Pennak 1944; Kubicek 1964). Some data for *P. vulgaris* and *K. quadrata* are available and according to Pennak (1944), who studied the diurnal variations of zooplankton in five lakes in Colorado, *K. quadrata* showed a well-defined reverse migration on one of the lakes. No migration by *P. trigla* (*P. vulgaris*) was shown in any of his lakes.

The amplitude of vertical migration of our rotifers is interesting. In June, their movements were almost within the same range. But in July, *P. vulgaris* moved over a wider range (from 3.0–8.6 m) while the other two species were restricted to 7.1–9.6 m. Similar patterns were noted in August. In winter, during ice cover, *P. vulgaris* moved only in the top layers down to 4.8 m, while *K. quadrata* moved between 4.3–7.3 m. In April, when conditions were relatively uniform, there was an overlap in the amplitude of vertical migration. By keeping different zonation, *P. vulgaris* probably to a certain extent avoids direct competition with *F. terminalis* and *K. quadrata.* Such variations in vertical migration of different species of rotifers involving different zonation has not been pointed out earlier, though the distribution differences of five species of *Polyarthra* has been shown by Berzins (1958).

TABLE 5. *Amplitude (in m) of vertical migration in rotifers*

Date	*Polyarthra vulgaris*	*Filinia terminalis*	*Keratella quadrata*
7–8 Jun 1967	7–10	8.0–9.7	7.4–8.4
19–20 Jul 1967	3.0–8.6	8.8–9.4	7.1–9.6
30–31 Aug 1967	4.8–8.4	6.0–8.8	*
7–8 Feb 1968	1.8–4.8	*	*
6–7 Mar 1968	1.8–3.7	*	4.3–7.3
3–4 Apr 1968	3.0–4.1	3.0–7.0	3.8–4.0

* Population negligible.

Since no previous detailed information on the diurnal migration pattern of rotifers is available, comparison with our work is not possible. The amplitude of migration is far less in rotifers than with any of the crustaceans studied by Worthington (1931). But the maximum velocity of ascent in *F. terminalis* of 0.018 cm/sec is almost equal to the velocity of ascent before dusk for the adult *Mesocyclops leuckarti*, the slowest among the crustaceans.

The rotifers as a group seem to show diurnal migration far less strikingly than the crustaceans (Hutchinson 1967). More extensive study may show that the rotifers also exhibit this phenomenon, but of a magnitude commensurate with their size.

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