Ann. Zool. Fennici 18: 229-232. 1981

Eudiaptomus gracilis (Copepoda, Calanoida): diel vertical migration in the field and diel oxygen consumption rhythm in the laboratory

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Gyllenberg, G. 1981: Eudiaptomus gracilis (Copepoda, Calanoida): diel vertical migration in the field and diel oxygen consumption rhythm in the laboratory. — Ann. Zool. Fennici 18: 229—232.

The diel migratory rhythm of *Eudiaptomus gracilis* was investigated both in the field and as the diel rhythm of oxygen consumption in the laboratory. The animals maintain an increase in oxygen consumption between 24.00 and 03.00 hours. This is in accordance with the field results, which show an ascent of the individuals to the surface layer after midnight.

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1. Introduction

Diel vertical migration among zooplankton is investigated. Previous studies on the Baltic and the Gulf of Finland have been published by e.g. Halme 1937a, Halme 1937b, Lassig & Niemi 1978 and Burris 1980. The zooplankton most extensively studied under natural conditions in lakes is Cladocera (Schwoerbel 1977). Some work has also been done on the endogenous periodic activity rhythms of zooplankton in the lakes of British Columbia (Duval & Geen 1976). They concluded that zooplankton maintain their rhythm in spite of the absence of external periodic stimuli, such as temperature and light. The diel rhythm of some *Chaoborus* species (Diptera) (Sigmon et al. 1978) and of *Pontoporeia* (Amphipoda) (Cederwall 1979) has been investigated. The present investigation demonstrates the diel vertical migration of *Eudiaptomus gracilis* in the field as changes in frequency, and as the corresponding changes in respiratory activity in the laboratory. Light was used as an external stimulus acting on the respiratory rhythm. The studies were carried out at Lammi Biological Station.

2. Methods

Individuals of *Eudiaptomus gracilis* were sampled at lake Pääjärvi (southern Finland) (Gyllenberg et al. 1977, Gyllenberg & Salonen 1980). The samples were taken with a Sormunen sampler (length 1 m, volume 6.4 l) as vertical series from the bottom to the surface, filtered through a 25-μm net and preserved with formalin. One sample was taken at each depth. The samples were left to settle in 50 ml cuvettes for some hours. An inverted microscope was used for counting. The central point of the frequency distribution column was calculated as

$$(D_s \times N_s) \; / \; N,$$

where D_s = mean depth of sample s, N_s = number of specimens in sample s and N = total number of specimens.

Living *Eudiaptomus* individuals were introduced into a respiration chamber and the oxygen consumption was measured with polarographic equipment according to Gyllenberg & Lundqvist (1976). Some 20 animals were maintained in the chamber during each experiment (experimental period 12 hours) at 20°C and with 3 hours light, 6 hours dark and 3 hours light conditions (normal daylight).

3. Results

Fig. 1 shows that *Eudiaptomus gracilis* migrates to the surface during the dark part of the day, and sinks back to deep layers during daytime. Since the dark period started earlier in 1977 (Fig. 1 A) the light conditions evidently act as a trigger initiating migration to the surface, which occurred earlier in 1977 than in 1980. The weather conditions on both sampling dates were clear cloudless sky. The migration picture looks very much the same as that referred to by Redfield & Goldman (1978) for zooplankton in general.

Fig. 2 shows how respiratory activity is adjusted

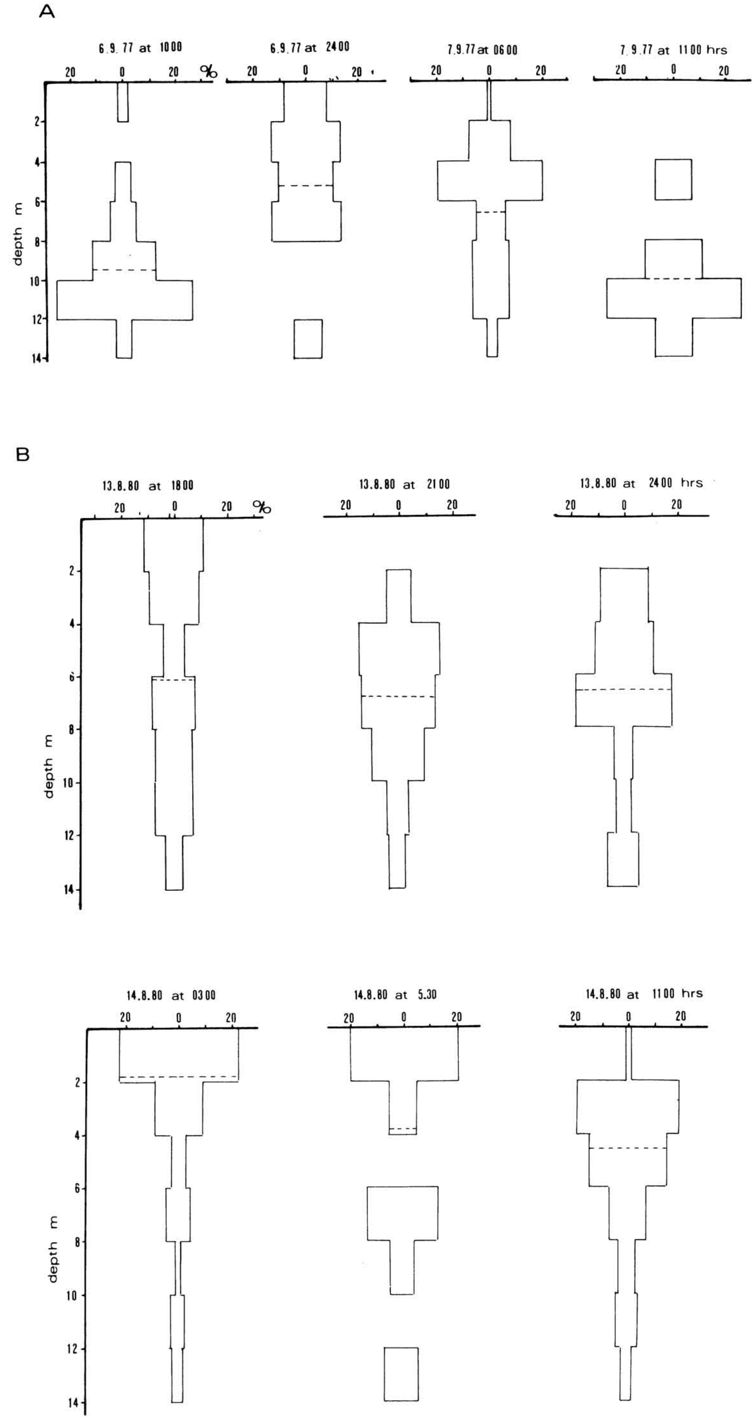

Fig. 1. Distribution of *Eudiaptomus gracilis* numbers in the different layers of lake Pääjärvi, given as percentages of the total numbers, — — — central point of distribution. A. Distribution pattern in 1977. B. Distribution pattern in 1980. 100—500 individuals were sampled on each sampling date.

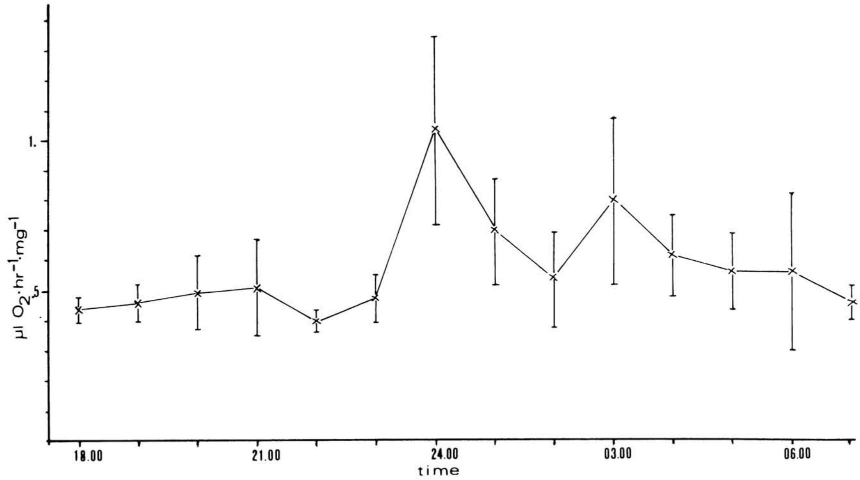

Fig. 2. Diel oxygen consumption rhythm in *Eudiaptomus gracilis* as affected by daylight in the laboratory. The value at 24.00 hours is significantly different from the preceding level ($P < 0.01^{**}$). The experiment was carried out simultaneously with the field experiment on August 14, 1980.

to the diel periodicity rhythm on 14.8.1980. It appears that ascent is accomplished in two peak stages: at first there is a larger peak at about 24.00 and then a smaller peak at 03.00 hours. The activity then gradually decreases until the resting metabolic rate is achieved at about 07.00 hours. The peak at 24.00 hours is significantly different from the preceding level ($P < 0.01^{**}$), whereas the 03.00 hours peak is not statistically different ($P \approx 0.1$). The activity period evidently starts at 24.00 hours and it takes three hours for the animals to reach the surface (Fig. 1 B).

4. Discussion

These results are not consistent with those found by Duval & Geen (1976). They investigated diel rhythms in zooplankton at a constant temperature and in the absence of periodic light stimuli. Their results showed a bimodal activity rhythm with peaks at 06.00 and 18.00 hours with low activity in between. The present peaks are at 24.00 and 03.00 hours during the ascent period. The results presented are also in accordance with the peak in numbers observed at 03.00 hours in the field. It appears that the typical midnight sinking period and respiratory activity again in the early morning hours is more or less absent in *Eudiaptomus*.

A typical bimodal vertical migration rhythm with a midnight sinking period is also demonstrated for *Daphnia magna* (Cladocera) (Schwoerbel 1977). This species concentrates around the compensation level of the sea during daytime. When the spectral composition and light exceed the tolerance level, the *Daphnia* migrate, actively searching for the deep layers (Schröder 1962a, 1962b).

Halme (1937b) has shown that zooplankton in brackish water move away from red light and are attracted by blue light. This could explain the movements of *E. gracilis* at twilight when blue light is prevailing.

Acknowledgement. My thanks are due to Mr. Nigel Billany, who revised the manuscript.

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Received 6. I. 1981
Printed 31. XII. 1981