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Some factors affecting the horizontal migration of *Pontoporeia affinis* (Crustacea, Amphipoda) in laboratory conditions

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Pontoporeia affinis swims actively during the night-time, thereby migrating both vertically and horizontally. Light effectively inhibits this behaviour. In the laboratory the animals were allowed to swim in 3 m long, narrow choice aquaria, equipped with recording photocells in three sections. In low-speed water currents the animals migrated in the opposite direction to the current at the moment of light-on. In a horizontal temperature gradient of about 2°C, they migrated towards the higher temperature. The swimming activity decreased with increasing temperature. In experiments with different bottom substrates, the animals preferred bottom mud to sand or a hard bottom. The substrate preference dominated over the temperature preference.

1. Introduction

The very high abundance of *Pontoporeia affinis*, i.e. 9000±2000 ind./m^2 in patches at Storfjärd, Tvärminne (Keynäs & Keynäs 1978) makes it an important part of the baltic ecosystem, that is, as a source of fish food (Aneer 1975). During the light part of the day the animals stay in the bottom substrate, and thus they also exert a major effect on local bioturbation (Segerstråle 1962, Hill & Elmgren 1987).

By night *Pontoporeia* swims actively and undertakes vertical migrations in the pelagial (Segerstråle 1937). In laboratory experiments Lindström & Lindström (1980) showed that in aquaria more than 50% of the animals swim around during the dark hours. However, most of the animals swim close to the bottom (Robertson et al. 1968, own observations). This makes the estimation of the swimming part of the population difficult, and may explain the highly aberrant results obtained by different authors. Segerstråle's opinion (1950) was that all individuals undertake pelagic excursions during the night. Marzolf (1965) never found more than 7.4% swimming animals and Hill (1984) reports 58% swimming animals late in the autumn (in laboratory conditions). During the pelagial phase the animals can be carried away by water currents unless they are able to detect these and thus to actively compensate for them by swimming.

Light checks the swimming activity of the animals and causes them to dig into the bottom substrate even at very low intensities. Just a few photons per ommatidium and per second was sufficient to maintain a diel activity rhythm in laboratory populations (Donner & Lindström 1980).

The density of *Pontoporeia* in the bottom substrate fluctuates and Sarvala (1986), by analysing bottom samples from a number of subsequent years, was able to show that these fluctuations included regular changes in growth rate, recruitment and voltinism. However, he was unable to demonstrate a clear relation between the changes in density and any measured environmental factor (temperature, phytoplankton biomass or primary production). Sarvala suggests the following explanation for the fluctuations: Overgrazing of the sedimental microflora leads to shortage of food, high mortality and low recruitment. This allows recovery of the food source and an increasing *Pontoporeia* population. Our, as yet unpublished, observation of a negative correlation between the density of the population from which animals have been caught and their fecal production (reflecting the food situation) supports the density dependent model alluded to above.

Repeated sampling in the same place shows that rapid (day to day) changes in population density also occur. This gives reason to assume that the animals are able to respond to some more rapid environmental changes than e.g. a slow decline of the food source. Lindström & Lindström (1980 a, b) showed that the diel activity rhythm of *Pontoporeia* is affected by the time of year, the bottom substrate and the presence of different foreign substances in the water.

This paper constitutes a review of the present state of our investigations, which aim at disentangling the possible abilities of *Pontoporeia affinis* to respond to different physical and chemical changes or gradients in the water milieu and to density changes in the population. More detailed descriptions of the methods used and analyses of the results are in preparation.

2. Material and methods

The method is based on the fact that the animals swim actively in the dark. The experiments are mainly carried out in 3 m long narrow aquaria equipped with electronic devices for detecting swimming animals in darkness (infrared sensitive photocells). Different conditions are inducible in the aquaria, e.g. water currents, horizontal temperature gradients, varying bottom substrates in different parts of the aquaria and different population densities, or combinations of these. The aquaria can be divided into sections by partitions. Thus any preference for a given section (with given conditions) can be detected by the relative activity in that section after the partitions have been put into place.

3. Results

The present, preliminary results of our investigations are:

1) In slow water currents the animals actively swam against the current at dawn when activity was slowing down, i.e. the activity was evenly distributed in the aquarium during the activity-phase during the night, but when the light came on and activity ceased the majority of the animals were found at the same end of the aquarium from which the current was introduced.
2) In a temperature gradient of about 2°C difference between the extremes the animals preferred the higher temperature, at least when the initial temperature was within the range 2–6°C (Fig. 1).
3) The swimming activity of the animals decreased with increasing water temperature, at least at temperatures below 10°C (Fig. 1).
4) In preference experiments with different bottom substrates, sand, hardbottom (glass) and mud (natural) the animals preferred the mud, and the substrate preference dominated over the temperature preference. In the daytime animals have been observed to be highly active in the bottom substrate.
5) A positive correlation between the activity-level and the population density was detected.

4. Discussion

The results so far show that *Pontoporeia* is able to orientate itself in relation to a temperature gradient and a water current. Moreover the animals

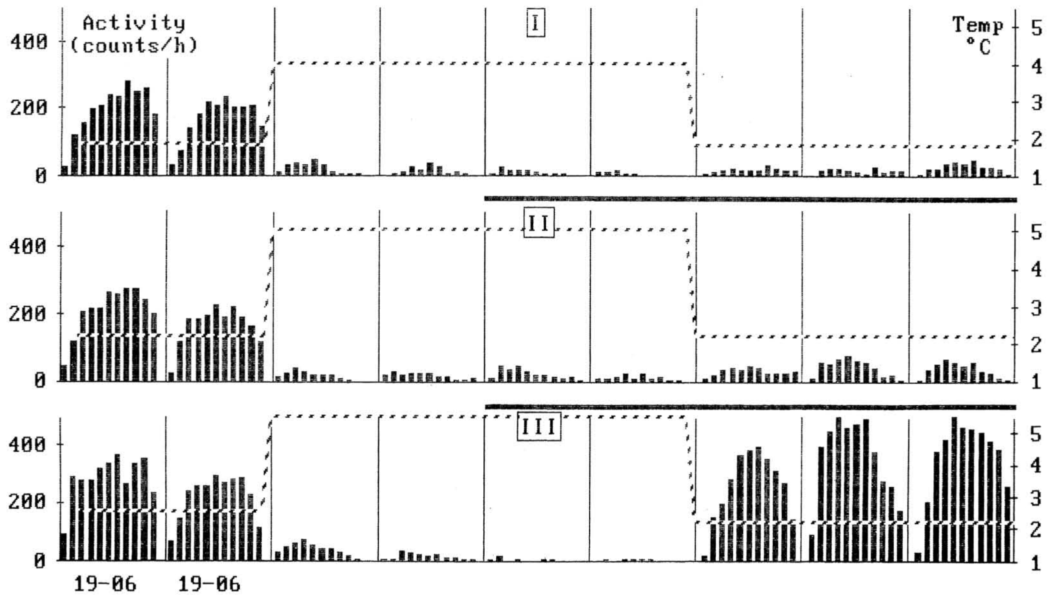

Fig. 1. Part of an experimental sequence using a temperature gradient (nine nights). The activity was recorded simultaneously in three sections of the aquarium. I = left, II = middle, and III = right section. The activity is shown as the number of passages through the photocell beam per hour. Only the night hours from 1900–0600 are shown, because the day-time activity is minimal. During day 2 (between second and third night) the warming of section III created a temperature gradient in the aquarium. Thereafter the temperatures were 4°, 5° and 5.5°C in sections I, II, and III, respectively. During nights 3–6 the activity was low in the whole aquarium because of the increased temperature (lowest in section III, which is the warmest). During day 4 the sections were separated by walls (heavy black horizontal lines). During day 6 the temperature was lowered to close to the original. The activity then increased in all sections, but especially in section III. The animals thus migrate towards higher temperature within the limits used. Black bars = activity, scale on left ordinate. Dotted line = temperature, scale on right ordinate.

are able to choose a suitable bottom substrate within at least a three metre range. We have few data on the interrelationships between different stimuli, but e.g. high population density seems to increase the sensitivity of the response to temperature changes.

Migration against the current is known among amphipods living in streams (Elliot 1971, Hultin 1971, Meijering 1972). In *Pontoporeia* this particular orientation behaviour seems to occur mainly in the relatively short period of downward swimming, when light intensity increases in the morning. Vision is probably needed for this response since it is unlikely that the animals are able to detect a slow motion in the surrounding medium (Donner & al. 1988).

A field study (Donner et al. 1988) revealed great changes in the population density and swimming behaviour of *Pontoporeia* at different times of the year, with the vertical migration activity peaking from the middle of July to the beginning of October. However, some of the rapid density declines were correlated to periods of falling water levels (= outward bound water current from the bay where the study was carried out). In these cases the current was probably far too strong for the animals to compensate for it by active swimming. No corresponding increase in density during rising water levels was observed. Rapid fluctuations in the population density have also been observed by e.g. Segerstråle (1962), Andersin & al. (1978) and Sarvala (1985).

The temperature experiments show that the animals prefer a higher temperature within a given interval. At the same time their swimming activity decreases (Fig. 1). This correlation could create a stationary population in favourable conditions because the animals would not be exposed to e.g. passive transport by strong currents. Active orientation towards optimal temperature conditions might explain why animals have been observed at highly varying depths at different times of the year (Samtner & Weltner 1904, Grimås 1979). Some of our preliminary observations indicate that very high temperatures (about 20°C) also increase the activity level.

To facilitate the making of detailed observations of specific behaviour we have developed a system for video recording in infrared light (invisible to Pontoporeia). Thus in the future we hope to be able to answer questions like: How is the substrate preference and other choices realized? Is the swimming velocity temperature dependent? What percentage and which fraction of the population is active in different conditions?

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