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On the ecology of Acoela living in the Arctic Sea ice

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ABSTRACT. A common meiofauna representative found in the pore system of the arctic sea ice from the Laptev, Barents and Greenland Seas was found to be a species of the Acoela characterized, among other features, by its bright red colour. It was studied by video recording of specimens moving in slices of ice and in 0°C sea water cultures after thawing of the ice. It is evidently well adapted to live and move in the partly very narrow brine channels. It has a great vertical distribution in the ice, but has its highest concentration in the lowermost 15 cm. In ice core samples from the Greenland Sea densities of up to 16,200 specimens per square meter were found. Diatoms were seen being eaten and were also found in the digestive parenchyma of sectioned specimens. Once a young nematode was observed being eaten. A description of the acoel species is given elsewhere.

KEY WORDS: Platyhelminthes, Acoela, arctic, meiofauna, sea ice.

INTRODUCTION

About 150 years ago arctic and antarctic sea ice of brown colour was discovered, the colour of which was found to be due to pennate diatoms and other microscopic algae (EHRENBERG 1841, 1853; HOOKER, 1847). Ciliates in the arctic ice were reported by NANSEN (1906) and USACHEV (1949). In addition to these organisms multicellular animals occur in the brine channels of arctic and antarctic sea ice. These channels form a branched network inside the ice matrix and they are most often very narrow, typically about 200 µm in diameter, but sometimes up to 5 cm in diameter (WEISSENBERGER et al., 1992; EICKEN et al., 1995; own observations). This limits the size of the metazoan inhabitants, which represent meiofaunal species of a number of groups.

In the Greenland Sea pack ice ciliates, nematodes, acoels and crustaceans were found to be dominant among the meiofauna (FRIEDRICH, 1997; GRADINGER et al., 1999). Acoels were found to be a prominent component of the antarctic ice as well; two species (not determined) were found by JANSSEN and GRADINGER (1999). Earlier reports of the occurrence of turbellarians in the sea ice were given by e.g. KERN and CAREY (1983), GRAINGER & HSIAO (1990), GRADINGER et al. (1991) and MELNIKOV (1997).

The most common acoel found in the pore system of the arctic sea ice is a species characterized by its bright red colour (FRIEDRICH, 1997). Its vertical distribution in the sea ice of the Laptev, Barents and Greenland Seas, its movements in the ice and its uptake of food are reported here. In this context some of the earlier results of studies of its ecology, reported in German (FRIEDRICH, 1997), are summarized.

MATERIAL AND METHODS

The material for this study was collected during cruises ARK IX/4 (6/8-5/10 1993) and ARK X/1 (6/7-15/8 1994) with RV "Polarstern" to the Arctic Sea. The material used for the studies of the behaviour of the Acoela in the ice was collected in the Greenland Sea during the 1994 cruise. Sampling stations were erected on relatively flat parts of the ice floes, reachable from the ship or by using a helicopter. Ice cores of 7.5 or 10 cm in diameter were drilled from the surface to the bottom of the ice and immediately cut into 1-10 cm long sections. While in the lowermost parts 1, 2 and 10 cm thick sections were investigated, in the upper segments that usually contain lower organism densities, sections of 20 cm (2x10 cm) were investigated for abundance of the meiofauna. These sec-

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tions were thawed in darkness in 0.2 μm prefiltered sea water at 4°C to avoid osmotic stress (GARRISON & BUCK, 1986). After complete melting of the segments, after about 24h, the animals were filtered from the sea water using a 20 μm sieve. In this paper the designation meiofauna is used for all the multicellular animals retained by this method, whereas the ciliates are not included.

Most of the material was sorted alive in the laboratory of the ship. Bouin´s fluid or formalin solution was used for fixation; samples for taxonomic studies were fixed exclusively with Bouin´s fluid. Some of the largest acoels were embedded in paraffin, serially sectioned, stained with eosin and hematoxylin and mounted on slides for light microscope studies.

Due to their bright red colour acoels occasionally could be observed in the underside of the cores immediately after drilling. To obtain an impression of their mobility in the ice 1–2 cm thick slices of the undersides of those ice cores with visible high densities of acoels were transferred in tight sealed sample containers to the ship laboratory within a few minutes. The slices were cooled down on a tissue cool plate (Reichert-Jung) every time the melting of the ice was visible. By this method the samples could be observed for up to about 15 minutes. The acoels moving in the ice pore system were recorded by using a video camera (JVC) mounted on a dissecting microscope. To record the animals in melted ice cultures an inverted microscope was used (Zeiss Axiovert 135) equipped with a video camera (Sony). Some of the vital studies were performed under the dissecting microscope on material brought to the laboratory in Kiel and kept in culture at 0-1°C in dark/light periods of 12h/12h, using a mixed algal culture as food.

RESULTS

A dominating acoel species

All worms of turbellarian shape in the samples were found to belong to the Acoela. This was evident from features of their general morphology, including a typical statocyst somewhat behind the front end, and from studies of the sectioned material under a light microscope. In life, most of them were of a bright red colour and were so similar to each other in appearance that we came to the conclusion that they belong to one and the same species. In one station in the Greenland Sea five white specimens were found. They were not studied further and may represent another species of the Acoela. This means that all the information given below refers to the bright red acoels.

As far as we know this species found in the arctic sea ice is not described in the literature, but videoprints of it have been published by FRIEDRICH (1997). Since this species occurred frequently in all investigated regions and makes up a significant part of the meiofaunal biomass of the arctic sea ice (GRADINGER et al., 1999) it will be described in spite of the fact that we did not find any fully mature specimens – in fact, most of the specimens were small, less than 0.5 mm, while the largest ones were about 1.2 mm. The description will be published separately.

Occurrence and distribution in the ice

The red acoel was found in ice cores in the Laptev, Barents and the Greenland Seas; median ice thickness 133 cm, 197 cm, and 270 cm, respectively (FRIEDRICH, 1997). It has a great vertical distribution, as is shown in Fig. 1. The acoels were found at a maximum distance of

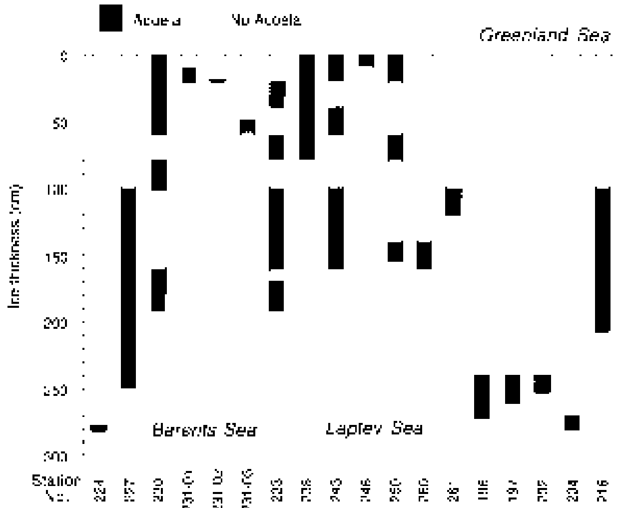

Fig. 1. – Vertical distribution of the red acoel in the sea ice of Barents Sea, Laptev Sea and Greenland Sea. Only cores from which all segments were investigated are shown. An exception is the core from station 227, where only the segments 1-20, 50-70, 100-120, 150-170, 200-220 and 240-252 cm were investigated. In one station (231) three cores were taken and fully investigated.

180 cm from the bottom of the ice. However, their highest concentration was found in the lowermost 15 cm with up to 293 specimens/l ice (Station 240, Laptev Sea), 258 specimens/l (Station 230, Barents Sea) and 222 specimens/l (Station 204, Greenland Sea). In the lowermost 15-30 cm up to 37 specimens/l were found (Station 196, Greenland Sea), but in the levels above 30 cm from the bottom the densities found did not exceed 22 specimens/l.

In the relatively old and thick ice of the Greenland Sea integrated densities of up to 16,200 specimens/m^2 ice (Fig. 2) were found with a median value of 2,260 specimens/m^2. In the younger and thinner ice of the Laptev Sea the abundance of the acoels was lowest, with up to 5,350 specimens/m^2, while in the Barents Sea ice up to 9,870 specimens/m^2 with a median density of 660 specimens/m^2 were found. In Fig. 2 the percentage of the total meiofauna abundance that is made up by the specimens of the red acoel is indicated, showing its high variability from 0 to 100%. In the core where the red acoel was found to have its highest density it made up 35% of the total meiofauna.

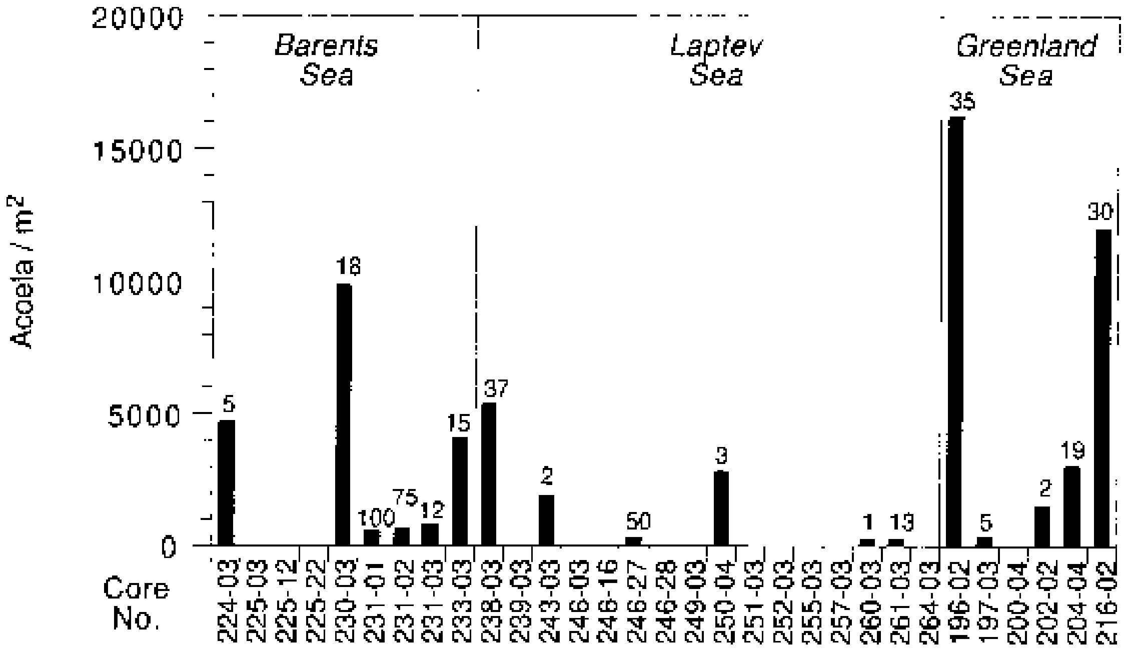

Fig. 2. – Abundance of Acoela in the sea ice cores from Barents Sea, Laptev Sea and Greenland Sea. All cores in which the abundance of meiofauna was studied are included, also those in which no acoels were found. The red acoel made up the total number of acoels in all cores except for 204:4, in which 5% of the specimens were white and thus may be of another species. The percentage of the total meiofauna made up by the acoels (in each station where acoels were found) is indicated by the figures above the columns.

Movements in the ice pore system

The specimens of the red acoel (Fig. 3) were observed to move through the brine channels in different directions, vertically as well as horizontally. As was demonstrated in our video recordings, they often seemed to be hindered by narrow passages, but after a while they succeeded in getting into a broader channel by pressing themselves through openings with a diameter smaller than the one they have when swimming in a relaxed way. When no hindrance had to be passed, they were observed to cover distances of a few cm within few minutes.

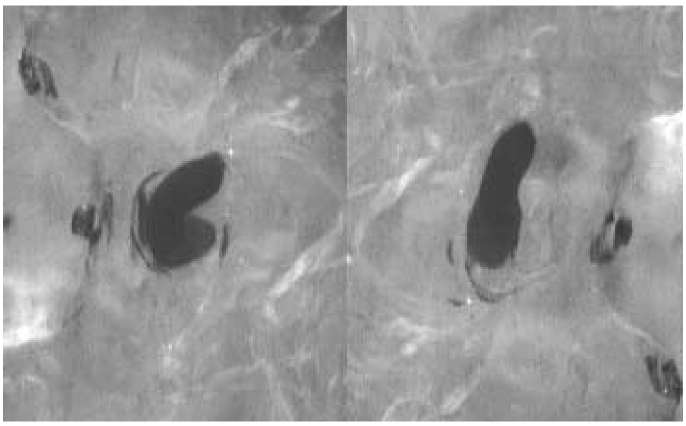

Fig. 3. Videoprints of living specimens of the red acoel in the ice, made from freshly cut ice cores on board of RV "Polarstern" by stereomicroscopy. As the magnifications were frequently changed, no exact scale bars can be given, but the length of each worm is approximately 1 mm.

Uptake of food

When the specimens of the red acoel were observed in culture dishes they were often seen to engulf diatoms. When a specimen, while gliding by ciliary motion, is passing over a diatom resting on the bottom of the dish it forms a furrow from the mouth opening (which is situated on the ventral side near the middle of the body) to near the front end. The engulfing can be described as a sucking movement, which evidently engages much of the ventral muscle layers of the animal. At the same time the acoel often contracts its sides so it becomes broader both in front of and behind the mouth. When it has passed over the place, the diatom is no longer seen in the dish, so evidently the engulfing is successful. Often several diatoms were observed being engulfed during a time period of one to two minutes. That diatoms are really eaten is evident also from studies of the sectioned material in which diatoms were found in the digestive parenchyma. The red acoel may also feed on other members of the meiofauna. Once a specimen was observed to engulf a young nematode. Though the latter was bending its body in different directions, the acoel succeeded in swallowing it.

DISCUSSION

A lot of observations speak in favour of the red acoel being very well adapted for a life in the brine channel system of the arctic sea ice. (1) Its occurrence in sea ice over a large area of the Transpolar Drift System of the Arctic Sea, the Laptev Sea, northern Barents Sea and Greenland Sea, (2) its great vertical distribution in the sea ice, (3) that the specimens move so easily in the brine channel system, (4) that they evidently to a great extent feed on diatoms, a rich food resource in the brine channels, (5) that they can live for long periods (at least 1.5 years) in cultures kept at a temperature of about 0°C (FRIEDRICH, 1997), and (6) that they tolerate salinities from 5 to 65‰ and temperatures down to -6°C (FRIEDRICH, 1997). The typical vertical distribution of the Acoela is very similar to the chlorophyll distribution, which is also highest in the bottom of the ice (GRADINGER et al, 1999) providing a rich food supply for the acoels. In addition the brine channels become smaller in diameter in the upper parts of the ice (MELNIKOV, 1997), thus limiting the space for the organisms. However, the flexible body and cilia coverage on their surface seems to enable at least some specimens to reach the higher levels of the floes.

Whether the acoels reproduce sexually in the brine system is not yet shown, but the occurrence of all size dimensions from a lot of very small specimens to some very big ones indicate that they live at least a very great part of their lives in the ice.

The extreme conditions under which the meiofaunal organisms live in the brine channel system of the arctic and antarctic sea ice may explain the low number of turbellarian-shaped species. Also in the antarctic sea ice only one red and one white species (neither of them determined) of the Acoela were found (JANSSEN and GRADINGER, 1999). In addition to the acoels a species (not determined) of the Macrostomida has been reported from arctic ice by MELNIKOV (1997).

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