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ROTIFERA AND TARDIGRADA FROM SOME CRYOCONITE HOLES ON A SPITSBERGEN (SVALBARD) GLACIER

by

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SUMMARY

Seven species of rotifer (2 bdelloids and 5 monogononts), and two species of tardigrade were identified in 8 cryoconite holes from a Spitsbergen glacier.

Keywords : Rotifera, Tardigrada, Arctic, cryoconite holes, glacier, Spitsbergen.

INTRODUCTION

Cryoconite holes are water-filled depressions in the surface of glaciers. They are up to 60 cm deep and from a few millimetres to a metre or more in diameter. The holes are usually found in the ablation zone, and often occupy a vast area. They have been reported from the Arctic, and to a lesser extent from the Antarctic, and also from some glaciers in temperate regions (WHARTON *et al.*, 1985). They are formed by the absorption of solar radiation by the dark, wind-borne inorganic and organic sediment (cryoconite) that accumulates on the surface (*e.g.* PHILIPP, 1912 in STEINBÖCK, 1936 ; GRIBBON, 1979). Subsequent melting of the underlying ice produces cylindrical holes. At the bottom of the holes there is a more or less gelatinous and sandy, dark brown to blue-black sediment, containing micro-organisms. Besides physical factors (absorption of direct and diffuse solar radiation, downward convection of warm water, etc.), biological activities such as photosynthesis of algae, metabolic processes due to growth and reproduction of micro-organisms, etc., may also contribute to their formation and growth (STEINBÖCK, 1936 ; GERDEL and DROUET, 1960 ; MCINTYRE, 1984).

Cryoconite holes have been found to contain bacteria and fungi (GERDEL and DROUET, 1960), algae (*e.g.* WITTROCK, 1885 ; VON DRYGALSKI, 1897 ; GERDEL and DROUET, 1960 ; WHARTON and VINYARD, 1983 ; WHARTON *et al.*, 1981), ciliates (STEINBÖCK, 1938, 1957) and rotifers and tardigrades. Information on the last two groups is rather scanty with many doubtful identifications. Reports of rotifers are restricted to *Brachionus* sp. by VON DRYGALSKI (1897), *Philodinavus paradoxus* (MURRAY, 1905) (sub *Microdina paradoxa* MURRAY, 1905) by GERDEL and DROUET (1960) (1), both from the Greenland Ice Cap, and « probably » *Philodina aculeata* EHRENBERG, 1832 and *P. roseola* EHRENBERG, 1832 by STEINBÖCK (1957) from cryoconite holes on a glacier in the Stubaier Alps.

References to tardigrades are almost as rare as for rotifers. Thus VON DRYGALSKI (1897) mentioned « probably » *Macrobiotus hufelandi* SCHULTZE, 1833 from the Greenland Ice Cap, STEINBÖCK (1957) reported *Macrobiotus* sp. from the Stubaier Alps, RAMAZZOTTI (1968) found *Hypsibius janetscheki* RAMAZZOTTI, 1968 and *H. convergens* (URBANOWICZ, 1925) from the Nare glacier (Himalaya); DASTYCH (1985) listed *Diphascon recamieri* RICHTERS, 1911, *Hypsibius dujardini* (DOYÈRE, 1840) and *H. arcticus* MURRAY, 1907 from Spitsbergen.

The present paper reports on the rotifers and tardigrades from a small number of cryoconite holes from a Spitsbergen glacier, sampled during a biological expedition of Antwerp University.

MATERIAL AND METHODS

Eight cryoconite holes in the ablation zone of the Hyrnebeen glacier (Hornsund, Spitsbergen, Svalbard) were sampled on 15.08.1991. Geographic coordinates are 77°49′33″N, 16°14′43″E. The holes were 20-30 cm deep and 8-12 cm broad. Water temperature was about 0.2° C. Physical and chemical characteristics of the water (measured at one hole only) were as follows pH 4.62, conductivity 38 μScm^{-1}, turbidity and true colour 100 % transmission, chlorides 5.5 mgl^{-1}, sulphates 7.0 mgl^{-1}, orthophosphates < 0.1 mgl^{-1}, ammonium nitrogen < 0.1 mgl^{-1}, nitrites and nitrates 0.0 mgl^{-1}, Na 4.4 mgl^{-1}, K 0.8 mgl^{-1}, Ca 1.2 mgl^{-1}, Mg 0.51 mgl^{-1}, Si 0.08 mgl^{-1}.

Since there was no suitable method of separately sampling the cryoconite and the supernatant, the mixture was stirred up until it was homogeneous and a sample taken of it. Seven of the samples were immediately preserved with formalin; the other one was kept cool and used for culture experiments began three days later at the laboratory in Antwerp.

All the tardigrades present were counted; differential counts of rotifers were based on 500 individuals per sample. Size classes between ecdyses of tardigrades were separated by plotting data for body length, grouped in 5 µm size classes, as cumulative percentages on probability paper (LEWIS and TAYLOR, 1967).

(1) The « diatom » mentioned on p. 264 and pictured in fig. 20 by these authors are jaws of a bdelloid rotifer.

RESULTS AND DISCUSSION

The cryoconite was dark black, slightly gritty with much plant debris and some coarser mineral particles, remains of feathers and a solitary bird vertebra. Microscopically the organic and inorganic material was loosely bound by hyphae of fungi. All samples contained small numbers of red unicellular algae and larger quantities of the desmids *Ancylonema nordenskioeldi* BERGGREN, 1871 and *Cylindrocystis* sp. Two samples showed important numbers of a filamentous member of the Cyanobacteria. Ciliates (at least four species) were present at low numbers in all samples. Rotifers and tardigrades were abundant in all samples.

Rotifera

All the cryoconite holes contained high densities of bdelloids (2 species) and small numbers of monogononts (5 species). Two (*Keratella cochlearis* (GOSSE, 1851) and *K. quadrata* (O.F. MÜLLER, 1786)) are invariably planktonic and live in the water on top of the sediment. The other species are benthic.

Macrotrachela insolita DE KONING, 1947

The species preponderated (> 99 % of total number of rotifers) in all samples. The body is carmine red and up to 300 µm long. The teeth on the trophi were variable and had a dental formula of 2/2, $2/2_{+1}$, $2_{+1}/2_{+1}$ and rarely $2_{+2}/2_{+1}$. Many eggs were seen, measuring 50-53 µm × 75-80 µm. They were oval, with one or two poles slightly indicated. This is a highly variable cosmopolitan species, usually found among terrestrial and submerged mosses, algae and litter. The closely related (synonymous ?) *M. habita* (BRYCE, 1894) was found in terrestrial and submerged mosses on Spitsbergen by BRYCE (1897 sub *Callidina habita* BRYCE, 1894 ; 1922) and SUMMERHAYES and ELTON (1923).

Philodina acuticornis odiosa MILNE, 1916

Two individuals were observed in each of two samples. This species is ubiquitous and probably cosmopolitan. The *Philodina erythrophthalma* EHRENBERG, 1832 and *P. acuticornis* MURRAY, 1902, mentioned by BRYCE (1897, 1922) from terrestrial mosses collected in Spitsbergen, probably refer to this species.

Dicranophorus permollis permollis (GOSSE, 1886)

Found in two holes, one and four individuals. This species has a holarctic distribution. At Svalbard it has been recorded from terrestrial mosses (BRYCE, 1897 sub *Diglena permollis* GOSSE, 1886) and submerged mosses in a pond (DE SMET, 1990 sub *Encentrum* sp.).

Encentrum mucronatum WULFERT, 1936

Two specimens in one sample only. A cosmopolitan and ubiquitous species that has been reported from Svalbard in submerged mosses, puddles and shallow pools (DE SMET, 1990).

Keratella cochlearis (GOSSE, 1851)

One specimen in each of two holes. These individuals belonged to the form *macracantha* (Lauterborn). This cosmopolitan and eurythermic species is rare at Svalbard, where it has been reported from ponds and lakes (THOMASSON, 1958, 1961 ; AMRÉN, 1964c).

Keratella quadrata (O.F. MÜLLER, 1786)

Observed only once. The species is cosmopolitan and eurythermic ; found in fresh waters of all types, also saline waters. It was present in 16 of the 72 ponds and puddles studied by AMRÉN (1964a, b, c) on Spitsbergen. According to the latter it is not found in lakes and extreme arctic ponds. No other Svalbard records.

Lecane closterocerca (SCHMARDA, 1859)

Only a single specimen was found. This ubiquitous and cosmopolitan species has been reported from Svalbard by DE SMET (1988) ; OLOFSSON (1918), BRYCE (1922) and SUMMERHAYES and ELTON (1923) identified their species as *Monostyla cornuta* (O.F. MÜLLER, 1786). Never very common, it is found amongst vegetation and in the littoral zone of ponds.

Tardigrada

Eutardigrada (two species) were abundant in each of the cryoconite holes examined.

Diphascon recamieri RICHTERS, 1911

The species was found in seven of the eight samples and the 735 specimens collected amounted to 10 % of the total tardigrade population. The percentage in individual holes ranged from 1 to 18 %. This is an arctic-alpine species with a holarctic distribution ; hydrophilous and cold-stenotherm. It has been reported from Svalbard by RICHTERS (1911), WEGLARSKA (1965, sub *Hypsibius recamieri* RICHTERS, 1911)), DASTYCH (1985) and VAN ROMPU and DE SMET (1994) ; among terrestrial and submerged mosses. It was the dominant species in 7 cryoconite holes studied by DASTYCH (1985).

The total body length of the 264 specimens measured, varied from 154 to 394 µm ; the buccal tube length ranged from 40 to 97 µm. Total body length plotted against frequency is shown in Fig. 1. The multimodal distribution provides evidence

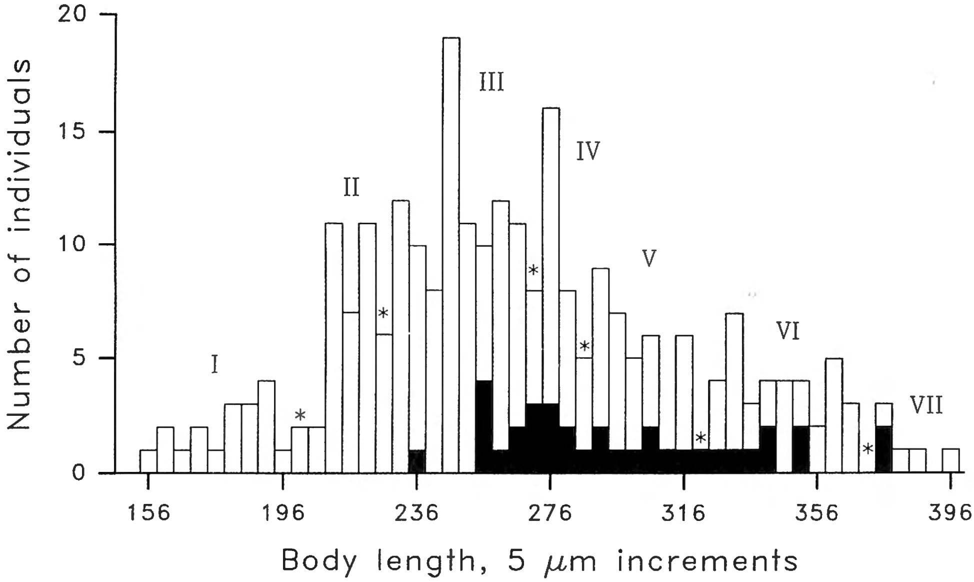

Fig. 1. — *Diphascon recamieri.* — Frequency distribution of body length (5 µm size increments). Points of probable ecdyses indicated by asterisks ; black = animals with eggs ; instars indicated by Roman numerals.

for the presence of different age classes. Determination of the size classes suggested that there were 7 size classes and 6 lengths, as indicated by asterisks in Fig. 1, where ecdyses probably occurred. The average egg dimensions were 61 × 65 µm. According to HALLAS (1972) the length of the larvae should not deviate considerably from 3 × the egg diameter. Expected length of the largest larvae of *D. recamieri* would therefore be about 195 µm, which agrees with the upper size limit of 204 µm noted for the first size class. Thirteen percent of the population carried eggs. The number of eggs per individual ranged from 1-3 (average 2). Developing eggs were present in animals from 255-376 µm long ; exuvia with eggs were found in animals from 236-333 µm. Animals longer than 204 µm and less than 236 µm may therefore be classed as juveniles. From the evidence of Fig. 1 it is suggested that there is only one juvenile instar. Reproduction occurs in periods between several ecdyses (instars 3-7) ; the last ecdysis occurs at about 371 µm. From the size-frequency histogram it further follows that adults preponderate, making up 88 % of the total population, with the third instar showing the highest numbers of individuals (38 %). The dominance of middle-sized animals, including individuals capable of egg production, has been explained by HIGGINS (1959), POLLACK (1970) and MORGAN (1977) as a rapid development of juveniles, leading to early recruitment into these middle-size classes, which are slower growing and persist longer. Lower numbers of animals in the larger size classes may reflect a higher mortality, possibly stemming from the effects of egg production (MORGAN, 1977).

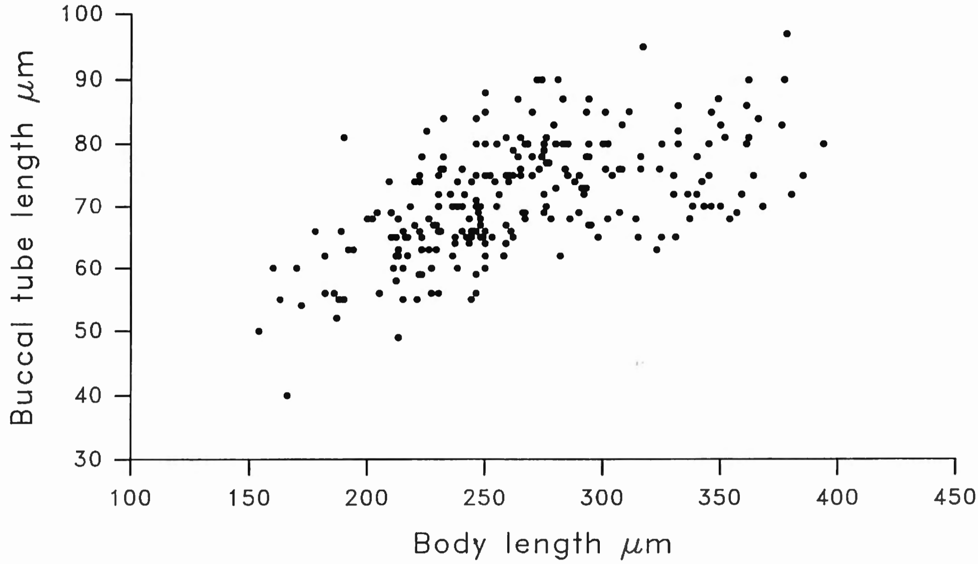

Fig. 2. — *Diphascon recamieri.* — Relation of buccal tube length to body length.

The relationship between buccal tube length and body length is shown in Fig. 2. Both dimensions are positively correlated and increase fast up to about 250 µm. When body length exceeds 250 µm, buccal tube length increases only slightly with increasing body length. A similar relationship, whereby the buccal tube reaches its maximum length early in life and retains it without appreciable change thereafter has been reported for *Echiniscoides sigismundi groenlandicus* Kristensen and Hallas, 1980 by Kristensen and Hallas (1980) and *Pseudobiotus augusti* (Murray, 1907) by Kathman and Nelson (1987). The latter authors suggest that the appropriate size for the food supply is reached early, and is independent of the final size of the mature animal.

Isohypsibius granulifer Thulin, 1928

This species was present in all samples. A total of 6.369 individuals, or 90 % of the total tardigrade number, was collected. The share of *I. granulifer* varied from 82-100 % in the different samples. It is a hydrophilous species with a cosmopolitan distribution, and is usually the most dominant taxon in submerged mosses from arctic freshwater habitats (Van Rompu and De Smet, 1991). It has been reported from Svalbard by De Smet *et al.* (1988), Van Rompu and De Smet (1988, 1991, 1994) and Dastych (1985) who mentions *Isohypsibius ? granulifer* from mosses on stones near stream.

Of the 590 individuals measured, the shortest was 118 µm and the longest 425 µm ; buccal tube length ranged from 19 to 49 µm. Size-frequency and cohort analysis suggest 5 possible ecdysis points and 6 size classes (Fig. 3). Animals in the

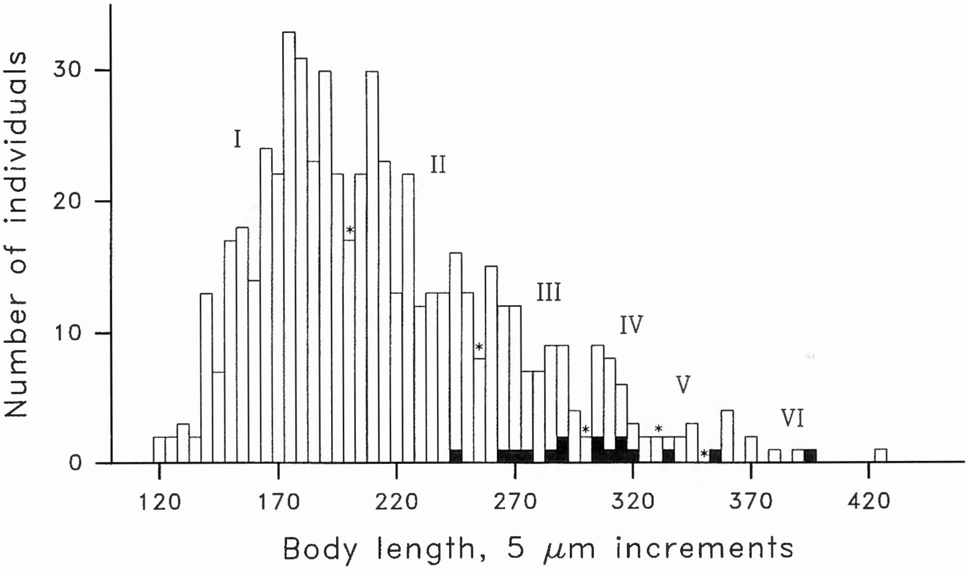

Fig. 3. — *Isohypsibius granulifer.* — Frequency distribution of body length (5 µm size increments). Points of probable ecdyses indicated by asterisks; black = animals with eggs; instars indicated by Roman numerals.

first size class were 118-202 µm long. Average egg-size was 58 × 70 µm. According to the three times rule of HALLAS (1972), the larval stage should therefore include animals to about 210 µm long, which agrees fairly well with the observed upper limit (202 µm) of the first size class. Only 2.7 % of the population was carrying eggs. Egg number per individual varied from 2 to 6 (average 4). Developing eggs were found in animals from 247 to 393 µm long; exuvia with eggs were not seen. Animals longer than 202 µm and less than 247 µm are assumed to be juveniles. The ecdysis points suggest that there is only one juvenile instar. Egg production occurs during instars 3 to 6. The last ecdysis point is indicated at 350 µm length. In contrast with *Diphascon recamieri*, where 88 % of the population were adults, the majority (75 %) of the individuals of *Isohypsibius granulifer* were larvae (48 %) and juveniles (37 %). This preponderance of smaller-sized classes, together with the smaller number of instars (6 versus 7 in *D. recamieri*), suggests a slower development for *I. granulifer*.

Buccal tube length and body length are positively correlated. The relationship is slightly curvilinear (Fig. 4), there being an indication of a proportionately faster increase of body length for animals from 225-425 µm. A similar relationship has been found in *Macrobiotus islandicus* RICHTERS, 1904 by HIGGINS (1959), *M. grandipes* SCHUSTER, TOFTNER and GRIGARICK, 1977 by SCHUSTER *et al.* (1977), *Isohypsibius saltursus* SCHUSTER, TOFTNER and GRIGARICK, 1977 by WAINBERG and HUMMON (1981), and *Milnesium tardigradum* DOYÈRE, 1840 by SCHUETZ (1987).

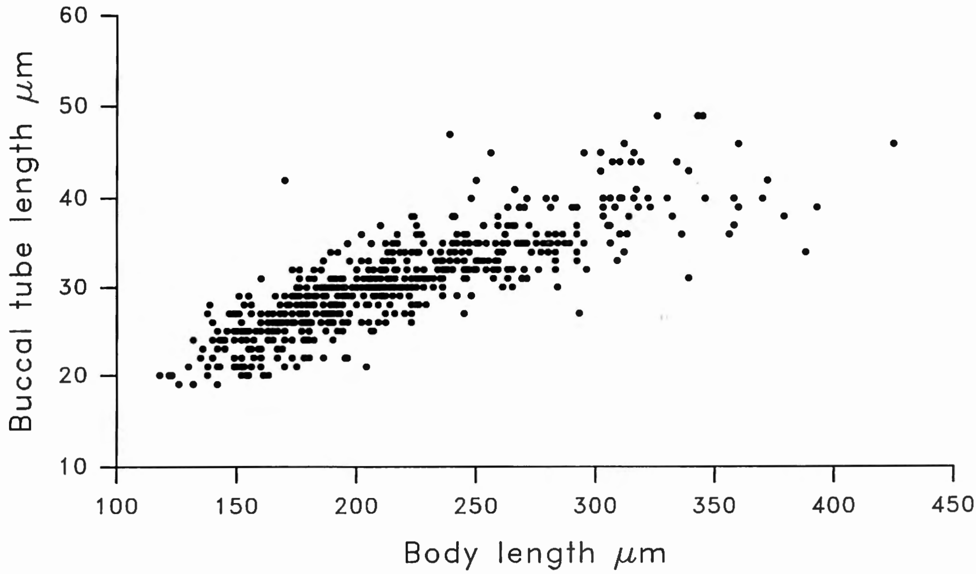

Fig. 4. — *Isohypsibius granulifer*. — Relation of buccal tube length to body length.

Life spans of active tardigrades have been estimated to range from 3 to 30 months, with 3 to 11 ecdyses occurring during this period (*e.g.* HIGGINS, 1959; FRANCESCHI CRIPPA and LATTES, 1967; POLLOCK, 1970; SCHUSTER *et al.*, 1977; WAINBERG and HUMMON, 1981; RAMAZZOTTI and MAUCCI, 1983; KATHMAN and NELSON, 1987). Our results for *Diphascon recamieri* and *Isohypsibius granulifer* from cryonite holes suggest 7 and 6 instars respectively. Since cryoconite holes are only ice-free during 2-3 months, the animals will be in a latent state of cryobiosis during the rest of the year. Because of these cryptobiotic periods, the total life span of these tardigrades may therefore extend to several years.

CONCLUDING REMARKS

It is clear that cryoconite holes can be regarded as individual ecosystems with distinct boundaries, energy flow and nutrient cycling (WHARTON *et al.*, 1985). They are inhabited by a species-poor microflora and microfauna, with specific representatives living in or on the cryoconite sediment, and in the water on top of it. Only few species show mass development. Rotifers (mainly the bdelloid *Macrotrachela insolita*) appeared to be the largest component by number of individuals, in the cryoconite holes studied. Tardigrades, represented by *Diphascon recamieri* and *Isohypsibius granulifer*, also occurred in substantial numbers. Ciliate populations were insignificant. Most of the species found feed on algae, bacteria and/or detritus. As such, tardigrades and most of the rotifers probably utilise the same niche and may be in competition for food. The rotifer *Dicranophorus permollis* is a voracious carnivore, feeding *inter alia* on small rotifers. This means that the ecological pyramid is formed by three trophic levels.

Species other than those found by us have previously been reported (for references see Introduction), and still more will presumably be found in future research. The species composition in the holes probably depends on latitude and length of ice-free period, hole dimensions (cryoconite holes can be regarded as islands), age of hole, nutrients available, etc.

Most of the rotifers and tardigrades found are widespread or cosmopolitan species. Their reproductive strategies are strongly orientated towards achieving maximum dispersal : they reproduce parthenogenetically and form resting eggs and/or resting stages, which can be passively transported by wind and birds. Passive dissemination on the glacier, and to some extent active dispersal, will often take place when continuous melting during summer causes the water in cryoconite holes to overflow.

Cryoconite holes probably persisted during the Pleistocene, and played an important role in the biological colonization of the newly exposed aquatic and terrestrial habitats following deglaciation (STEINBÖCK, 1936 ; WHARTON *et al.*, 1985 ; DE SMET, 1993).

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