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# The northernmost populations of *Tetraspora gelatinosa* (Chlorophyta) from Spitsbergen

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**Abstract**: This article describes the morphological characteristics of the populations of green alga, *Tetraspora gelatinosa*, growing in the stressful Arctic conditions (77°00'22" N, 015°32'54.33" E). We present the first detailed morphological characteristics of this species from such a high latitude. Populations from both stagnant and flowing waters were studied. Depending on the type of habitat, their mucilaginous colonies (thalli) have different shapes, but the structure, size and the placement of the vegetative cells, akinetes and ameboid forms, as well as the pseudocilia morphology of both populations, were very similar. Literature data on the distribution of *T. gelatinosa* indicate that it is a cosmopolitan species. Our data are compared with some characteristic features of this species growing in different geographical and climatic zones. No significant differences were found in the morphology of the colonies compared, nor in the location and the inner structure of cells. However, there were slight differences in cell size between the populations from warm and cold zones.

Key words: Arctic, Svalbard, green algae, Volvocales, pseudocilia.

## Introduction

*Tetraspora gelatinosa* (Vaucher) Desvaux, 1818, is a species characteristic of cold and clean freshwater habitats, such as streams, lakes, rivers and ponds (Borge 1911; Downing 1970; Sheath *et al.* 1986, 1989; Vinocur and Pizarro 2000; Shubert 2003; Wehr and Sheath 2003). In the first classifications it was placed in Chlorophyta, order Tetrasporales (Desvaux 1818; Fott 1972; Bold and Wynne 1978), but Hoek *et al.* (1995), Graham and Wilcox (2000) and Shubert (2003) classified it in the order Volvocales.

The literature records to date suggest that *Tetraspora gelatinosa* occurs on almost all continents. It is most often observed in temperate climates (Korshikov

1953; Prescott 1962; Rhodes 1967; Lakshminarayana 1976; Komarenko and Vasil'eva 1978; Starmach 1986; Sheath *et al.* 1986, 1989; John *et al.* 2002; Simić *et al.* 2002; Cărăuş 2003; Caisová *et al.* 2009; Lukavský 2009,) but its habitats are also located in the equatorial and subtropical zones (Woodhead and Tweed 1957; Rhodes 1967; Cambra *et al.* 1998; Ghazala *et al.* 2004; Branco *et al.* 2005; Islam and Irfanullah 2005; Valeem and Shameel 2005; Krupek et al. 2007, 2008). There is limited information on *T. gelatinosa* from polar regions. For example, in the Arctic and subarctic the species was noted in Alaska (Roeder 1973; Sheath *et al.* 1986), the Primorsky Region of Russia (Medvedeva and Semenchenko 2003; Medvedeva 2010) and Greenland (Benninghoff and Robbins 1953). In the Antarctic the species was found on King George Island (62°23' S, 58°67' W) by Vinocur and Pizarro (2000). In the European part of the Arctic, *e.g.* in Spitsbergen (Svalbard Archipelago), there are two known localities and these both sites are situated the closest to the pole.

The first information about the presence of *T. gelatinosa* in Spitsbergen comes from Borge (1911), who recorded the alga in the southern coastal region around Isfjorden in the ponds and lakes on the edge of Kol-Bay (78°12' N, 14°93' E). The author unfortunately did not provide diagnostic features of the species. The second locality of *T. gelatinosa* on Spitsbergen near Hornsund was found in 2005 (Richter, Matuła and Pietryka unpubl.). Research carried out in that period, together with the present data, provide detailed information on the morphology and ecology of the *T. gelatinosa* populations growing in polar conditions. The results presented in this article supplement the current knowledge about the species and provide detailed morphological and metric data lacking in the literature.

The wide geographical range of *Tetraspora gelatinosa*, described in the published literature, indicates its possibly cosmopolitan character. So far, studies on this species have been based on morphological characters so it is likely that molecular techniques may reveal that *T gelatinosa* is a complex of cryptic taxa. Therefore molecular analysis of isolated strains would be very important, but it is not always possible to conduct. In the field and the laboratory this species is difficult to obtain in homogeneous populations. The distribution of this species presented in this paper should be treated as preliminary and will be supplemented in future by a more detailed study of the subject.

## Materials and methods

The studied material was collected in the Fuglebekken catchment area on the northwest side of Hornsund fjord (West Spitsbergen). Numerous colonies of this species were sampled using a hard brush or a knife and placed in 100 ml plastic containers. Algae were scratched from surfaces of the area of 20–30 $cm^2$ from stones and the bottoms of small lakes and streams. The identification was performed on

Table 1

The physico-chemical properties of the water reservoirs where material was collected.

| Habitats: | Stagnant water (lake) | | Flowing water (stream) | |
|---|---|---|---|---|
| Years: | 2005–2010 | | 2008–2010 | |
| Factors | Mean | Range | Mean | Range |
| pH | 8.98 | 8.62–9.38 | 8.88 | 8.14–9.63 |
| Conductivity (μS $cm^{-1}$) | 152.52 | 138.81–168.30 | 153.30 | 145.30–161.30 |
| Temp. (°C) | 6.36 | 4.66–8.30 | 8.60 | 8.20–9.00 |
| F (mg $l^{-1}$) | 0.043 | 0.003–0.104 | 0.013 | 0.013–0.013 |
| $Cl^-$ (mg $l^{-1}$) | 6.52 | 0.46–11.68 | 9.37 | 7.30–11.45 |
| $NO_2^-$ (mg $l^{-1}$) | 0.07 | 0.00–0.12 | 0.056 | 0.042–0.071 |
| $NO_3^-$ (mg $l^{-1}$) | 4.27 | 2.37–6.76 | 3.11 | 1.05–5.17 |
| $NH_4^+$ (mg $l^{-1}$) | – | – | 0.008 | 0.005–0.011 |
| $PO_4^{3-}$ (mg $l^{-1}$) | – | – | – | – |
| $SO_4^{2-}$ (mg $l^{-1}$) | 4.30 | 3.66–5.80 | 6.41 | 6.19–6.63 |
| Br (mg $l^{-1}$) | 0.29 | 0.03–1.11 | 0.027 | 0.025–0.030 |
| $Na^+$ (mg $l^{-1}$) | 3.91 | 1.35–6.05 | 5.46 | 4.13–6.80 |
| $K^+$ (mg $l^{-1}$) | 1.03 | 0.37–1.50 | 0.82 | 0.36–1.29 |
| $Ca^{2+}$ (mg $l^{-1}$) | 12.53 | 3.01–22.21 | 23.33 | 22.36–24.31 |
| $Mg^{2+}$ (mg $l^{-1}$) | 1.44 | 0.61–2.43 | 1.25 | 0.92–1.59 |

fresh material and later material was preserved with "etaform" (3:1 alcohol, formalin). The algae samples were then stored in the dark. Morphological observations and analyses were conducted with a digital microscope, Nikon Eclipse TE2000-S light, equipped with a Nikon DS-Fi1 camera (magnification 400×, 600×, 1000×), and on a stereoscopic microscope, Nikon SMZ745T with a Moticam 5 MP (magnification 63×) camera. Populations found in stagnant and flowing water were described in detail, taking into account the morphology of thalli, the shape and structure of the cells and the morphology of pseudocilia (Table 2, Figs 3–6).

Additionally, the water from the studied basins was analyzed for physico-chemical properties (Table 1). For that purpose water samples were collected in three places between 2005 and 2009: from stagnant water (Figs 1a, 2a), from the beginning and from the end of flowing water (Figs 1b–c, 2b–c). Chemical analyses were performed in the Polish Polar Station chemical laboratories. Water samples were filtered using Millipore 0.45 μm White Gridded cellulose nitrate membrane filters. Specific conductivity (Elmetron CC-401) and pH (Elmetron CP-401) were measured once more in unfiltered and filtered samples. Anion and cation concentrations were determined by high-performance liquid chromatography (HPLC) with two separate Methrom Compact IC 761 Systems. Only for anions the analyses were done with a suppressor.

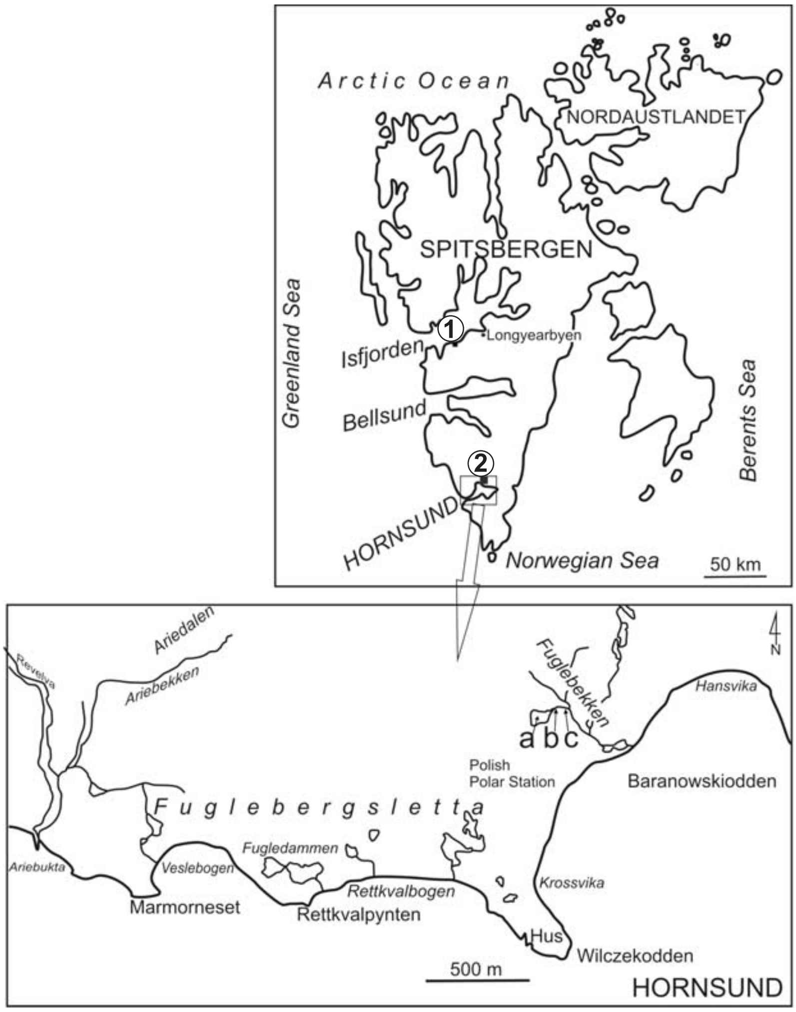


Fig. 1. Study area: **1**. *Tetraspora gelatinosa* locality (Borge 1911); 78°12' N, 14°93' E. **2**. *Tetraspora gelatinosa* locality (this study; 77°00'22" N, 15°33' E); small lake with stagnant water (a), water course characterized by a slow current at the beginning (b) and at the end (c).

The taxonomy and nomenclature were after Desvaux (1818), Fott (1972), Bold and Wynne (1978), Ettl and Gärtner (1988), Hoek *et al.* (1995), Graham and Wilcox (2000) and Shubert (2003).

## Study area

The studies were carried out during the Arctic summer in July and August from 2005 to 2011. Some 30 samples of *T. gelatinosa* were collected in Fuglebergsletta, Fuglebekken (77°00'22.3" N, 15°32'54.3" E), a basin situated in the northern coast

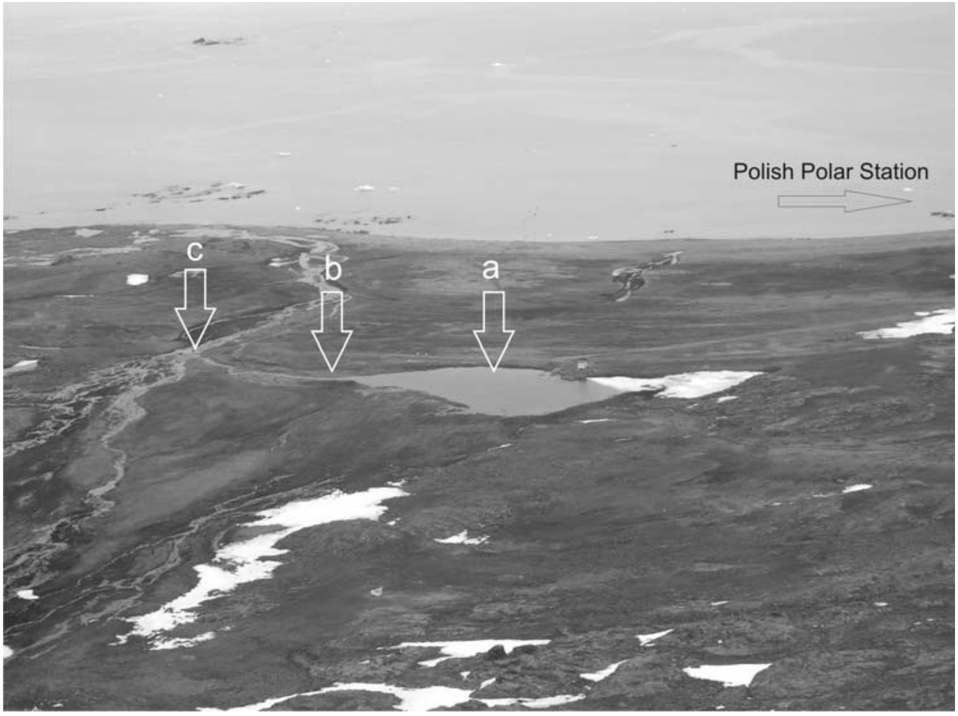


Fig. 2. The location of the site from which the samples were taken; small lake with stagnant water (a), water course characterized by a light current and shallow water (b, c).

of Hornsund, West Spitsbergen (Figs 1–2). The analyzed species was growing in stagnant water on stones and the muddy bottom of small lakes (50×30 m) not deeper than 0.5 m (Fig. 1a) and on stones in streams characterized by a slow current and a depth of 0.1 m (Figs 1b, c).

## Results and discussion

**Physico-chemical characteristics of habitats with *Tetraspora gelatinosa*.** — The pH values in water habitats studied were alkaline and ranged from 8.6 to 9.63 in lakes and streams. Conductivity was low (139–168 μS). Elevated concentrations of nitrogen compounds indicate the mesotrophic character of habitats. The range and average values are presented in Table 1.

Physico-chemical properties of *T. gelatinosa* habitats as well as the morphology of the species are insufficiently documented in previously published literature. Most publications present data concerning only pH and conductivity. The species occurs in a wide pH spectrum, from acid to alkaline (pH 4.5–9.63), and conductivity (10–2335.4 μS). Most often, however, it was found in the pH range 6.0–7.0 and the conductivity range 56–470 μS (Rhodes 1967; Lakshminarayana

Table 2

The size analysis and morphological features of *Tetraspora gelatinosa* morphotypes found in Spitsbergen, Hornsund.

| *Tetraspora gelatinosa* in flowing water | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n = 50 | | | | | | n = 100 | | | | | | | |
| | young colony | | | old colony | | | vegeta-tive cells diameter | amoeboid cells | | pseudocilia | | akinetes dia-meter | wall of akinetes thick-ness | pire-noids dia-meter |
| | length [µm] | width [µm] at the | | length [cm] | width [cm] at the | | | length | width | length | width | | | |
| | | top | base | | top | base | [µm] | | | | | | | |
| min. | 700 | 75 | 50 | 30 | 0.40 | 0.30 | 7.60 | 7.20 | 5.90 | 50.90 | 0.70 | 11.15 | 0.50 | 1.00 |
| max. | 1800 | 160 | 100 | 50 | 0.50 | 0.40 | 13.00 | 9.50 | 7.90 | 155.00 | 2.30 | 17.55 | 1.30 | 2.20 |
| mean | 1399 | 118.7 | 81.80 | 42.65 | 0.70 | 0.37 | 9.90 | 8.67 | 6.75 | 94.04 | 1.49 | 13.79 | 0.88 | 1.59 |
| mean deviation | 402.2 | 22.33 | 12.84 | 5.82 | 0.38 | 0.02 | 0.97 | 0.43 | 0.39 | 16.76 | 0.28 | 1.14 | 0.14 | 0.22 |

| *Tetraspora gelatinosa* in stagnant water | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n = 50 | | | | | | n = 100 | | | | | | | |
| | young colony | | | old colony | | | vegeta-tive cells diameter | amoeboid cells | | pseudocilia | | akinetes dia-meter | wall of akinetes thick-ness | pire-noids dia-meter |
| | length [µm] | width [µm] at the | | length [cm] | width [cm] at the | | | length | width | length | width | | | |
| | | top | base | | top | base | [µm] | | | | | | | |
| min. | 620 | 25 | 65 | 5 | 0.60 | 0.30 | 8.00 | 7.70 | 5.40 | 62.10 | 0.90 | 11.50 | 0.50 | 0.90 |
| max. | 1500 | 75 | 300 | 10 | 0.70 | 0.50 | 11.80 | 11.60 | 8.85 | 136.60 | 2.20 | 17.20 | 1.30 | 3.70 |
| mean | 1065 | 54 | 184.40 | 7.80 | 0.66 | 0.43 | 9.70 | 9.60 | 6.90 | 92.70 | 1.30 | 13.90 | 0.80 | 1.70 |
| mean deviation | 297 | 15.98 | 63.86 | 1.51 | 0.27 | 0.05 | 0.60 | 0.69 | 0.55 | 16.30 | 0.29 | 0.95 | 0.15 | 0.30 |

1976; Komarenko and Vasil'eva 1978; Sheath *et al.* 1986, 1989; Vinocur and Pizarro 2000; Gutowski *et al.* 2004; Islam and Irfanullah 2005; Krupek *et al.* 2007). Only the data from Europe (Gutowski *et al* 2004), Canada (Sheath *et al.* 1989) and the Antarctic (Vinocur and Pizarro 2000) provide information on the content of basic nutrients. The content of nitrogen compounds $N\text{-}NO_3^-$ and $N\text{-}NH_4^+$ was 0.1–11.8 and 0.01–8.0 mg $l^{-1}$, respectively, whereas $Ca^{2+}$, $K^+$, $Na^+$ and $Cl^-$ content was 1.1–28.8, 0.01–0.0, 1.1–16.9 and 1.3–27.1 mg $l^{-1}$, respectively (Sheath *et al.* 1989). As Table 1 suggests, the content of the above nutrients in our stations was within the ranges presented in the literature (Antarctic, Vinocur and Pizarro 2000) and $NO_3^-$ and $N\text{-}NH_4^+$ were in slightly higher ranges (Gutowski *et al.* 2004). In Antarctic and Spitsbergen conditions *T. gelatinosa* occurs in oligo- and low mesotrophic waters, whereas in the temperate zone it occurs in low eutrophic waters (Gutowski *et al.* 2004).

**Morphological characteristics of *Tetraspora gelatinosa* from the Fuglebekken catchment area**. — Detailed data on the morphology of the alga studied are presented in Table 2. The examined *T. gelatinosa* forms firm, light-green, ge-

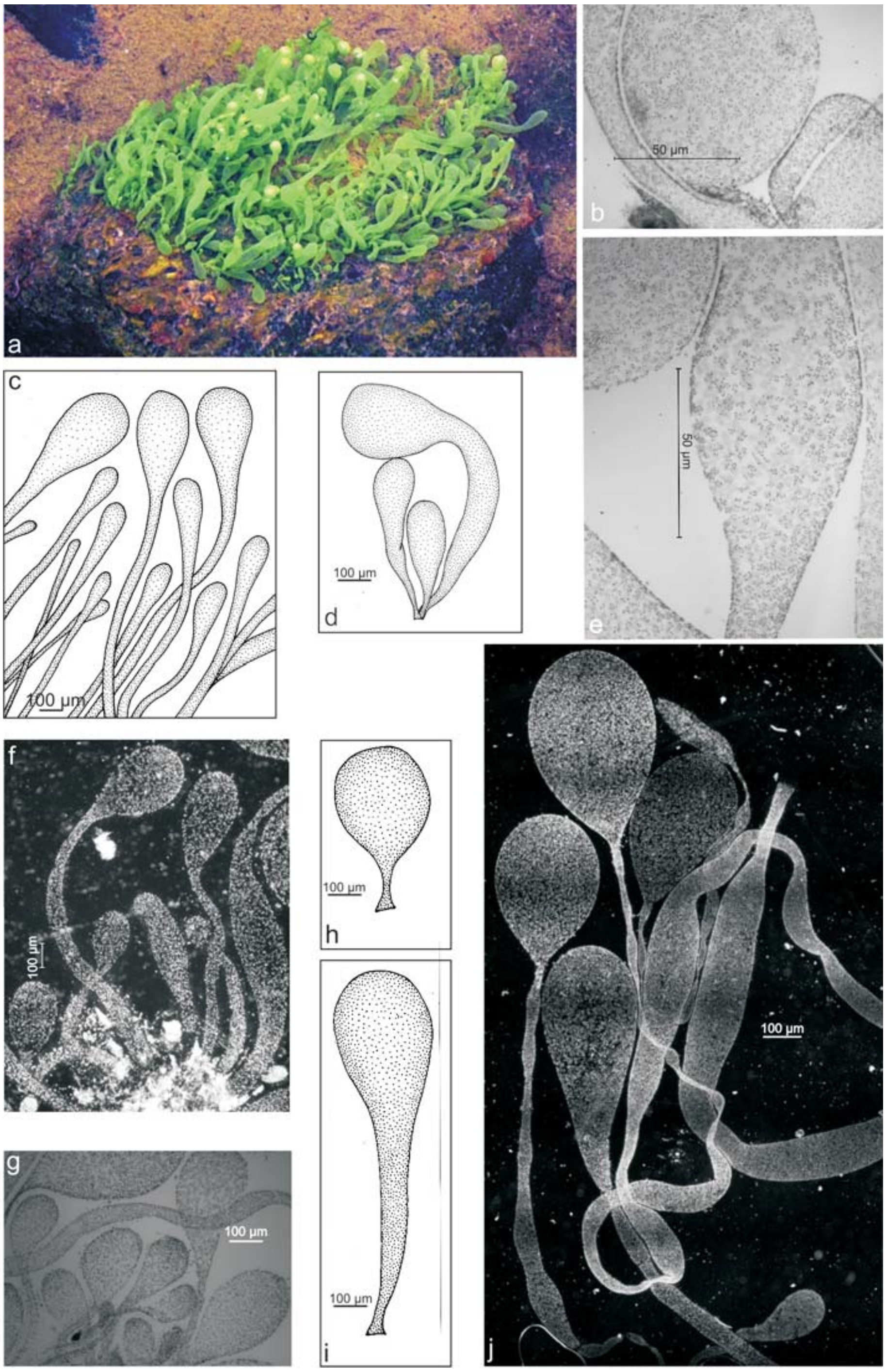


Fig. 3. *Tetraspora gelatinosa*; macroscopic colonies shapes (a), thallus appearance in stagnant water (b–j).

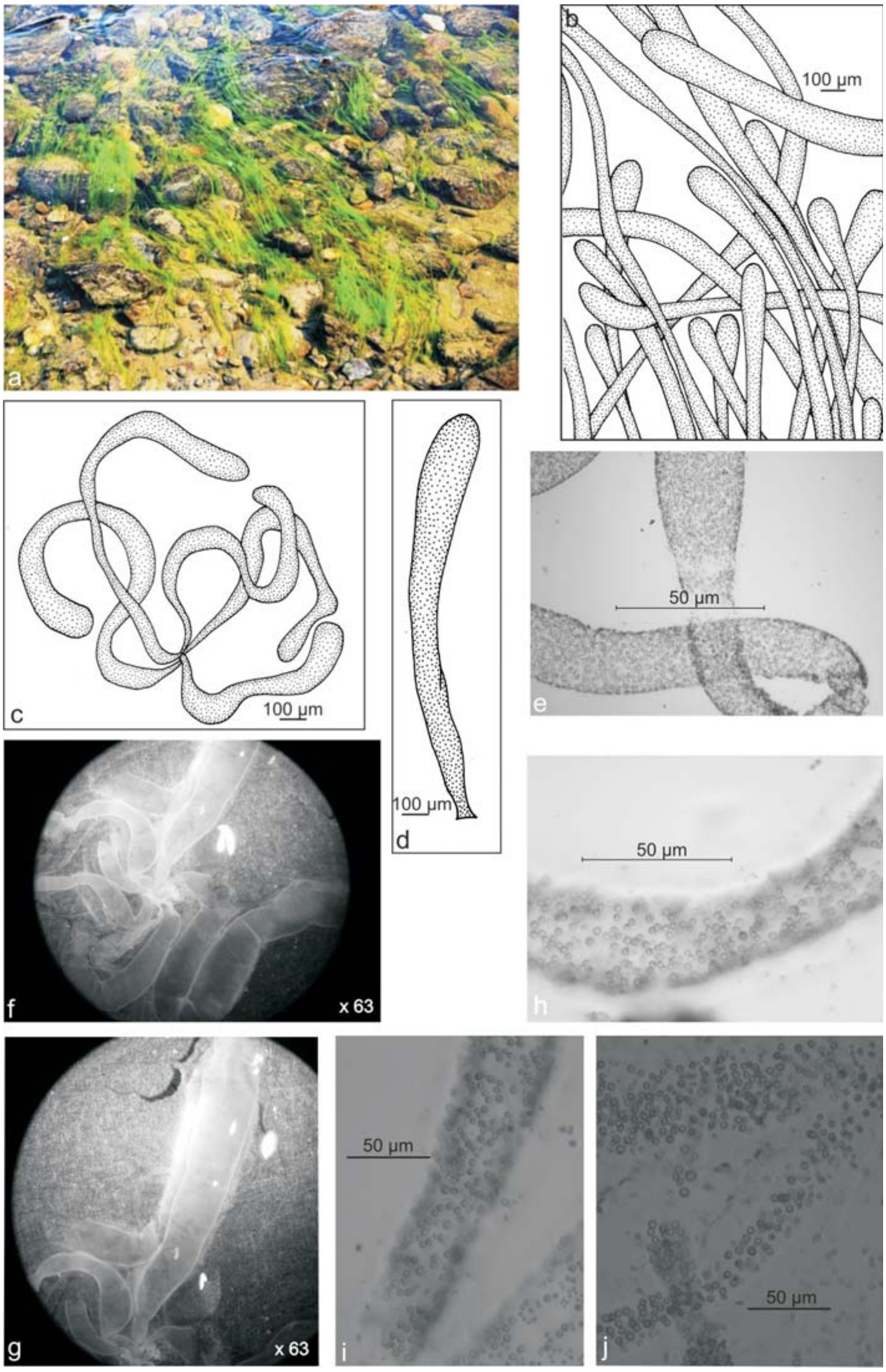


Fig. 4. *Tetraspora gelatinosa*; macroscopic colonies shapes (a), thallus appearance in flowing water (b–j), visible in a stereoscopic microscope (f–g).

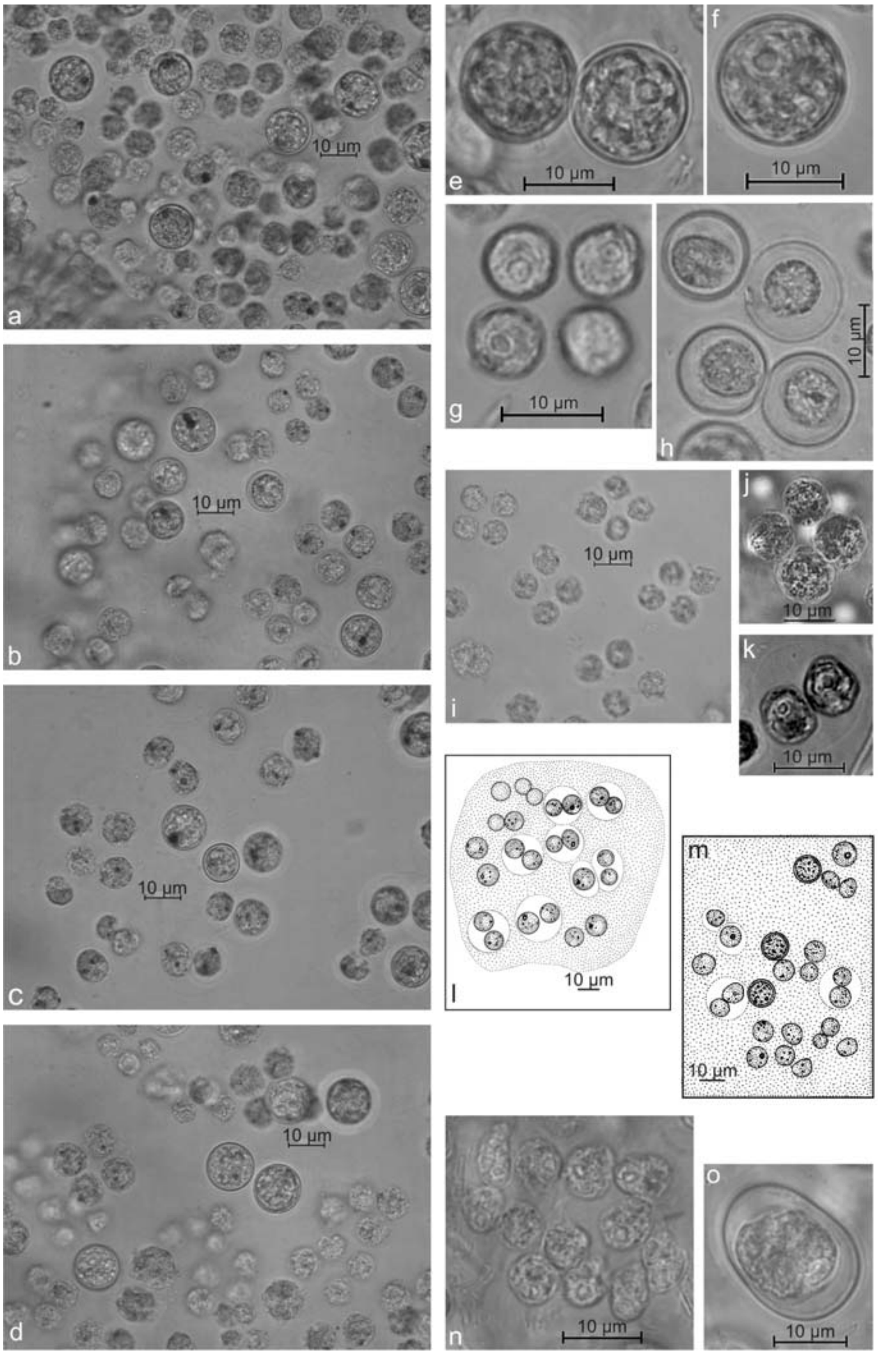

Fig. 5. *Tetraspora gelatinosa*; vegetative cells and akinetes (a–d), cells showing pyrenoids (e–g), young akinetes (h), cells in groups of two to four (i–k), individual gelatinous sheaths surrounding each group of recently formed cells (k–m), amoeboid cells (n), mature akinetes (hypnospores) during the division into ameboid cells (o).

latinous colonies attached to the submerged substrate with a short and narrow base. It was observed that the characteristic shape and size of the colonies were determined by the type of the habitat and in each locality two types of colonies were observed:

(a) in stagnant water (Figs 1a, 2a) the colonies were up to 10 cm long, with the shape varying from short sack-like to club-like colonies, or even cylindrical with a balloon-like end (0.3–0.7 cm broad, 5–10 cm long).

(b) in flowing water (Figs 1b–c, 2b–c) the alga formed narrow cylindrical structures of 0.3–0.5 cm in diameter, sometimes swollen at the ends and with length up to 50 cm.

Young thalli also demonstrated differences in shape depending on the locality. In flowing water the thalli were more or less cylindrical and only slightly rounded at the sheath, whereas the thalli from stagnant water were club-like or balloon-like at one end (Figs 3–4). The described differences in the shapes of colonies were not related to their internal characters (the cell layout, the presence of gelatinous concentric layers, the morphology of vegetative cells and akinetes).

In both populations numerous thin-walled spherical or oval vegetative cells were gathered into gelatinous colonies. The colonial matrix is structureless, except for a single gelatinous sheath surrounding each group of recently formed cells (Fig. 5k, m). The vegetative cells were arranged in groups of two or four, but in many cases they were irregularly scattered at the periphery. The diameter of the cells ranges from (7.60) 09.60 to 10.20 (13.00) µm (Fig. 5a–g, i–m). Each cell has a cup-shaped chloroplast and a central single pyrenoid with a diameter from (0.90) 1 to 2.10 (3.70) µm (Fig. 6e–g). At the edge of the colony each cell has two pseudocilia (Fig. 6) of up to 155 µm (average 70–120 µm long and 0.70–1.60 (2.30) µm broad). The pseudocilia have a regularly striped structure of light and dark sections visible in the light of the microscope (Fig. 6a–j). The light and transparent parts between the stripes are of equal length (Fig. 6f, g).

Vegetative cells may also develop into thick-walled akinetes (hypnospores) (Fig. 5a–d, h) with thick brown and smooth cell walls. The inside of the akinetes is irregular, grainy and has a single dark leucosis corpuscle. Akinetes are round, with a diameter of (11.15) 12.90–15.80 (17.55) µm; the cell wall thickness is (0.50) 0.60–1.10 (1.30) µm. Inside the gelatinous colonies there are ameboid protoplasts which are evolved in the process of division of mature akinetes (Fig. 5n). The ameboid cells dimensions were 7.20–11.60 × 5.40–8.85 µm.

**Geographical distribution and populations features of *Tetraspora gelatinosa*.** — *Tetraspora gelatinosa* is found at all latitudes and in all climatic zones including both polar regions and the equatorial zones (Table 3, Fig. 7).

Most of the corresponding references provide only information on the occurrence and the type of a habitat. They lack, however, a more detailed morphological and ecological analysis of the species. The majority of data concern only the size of vegetative cells, sometimes also the size and shape of the thalli. Actually, using the

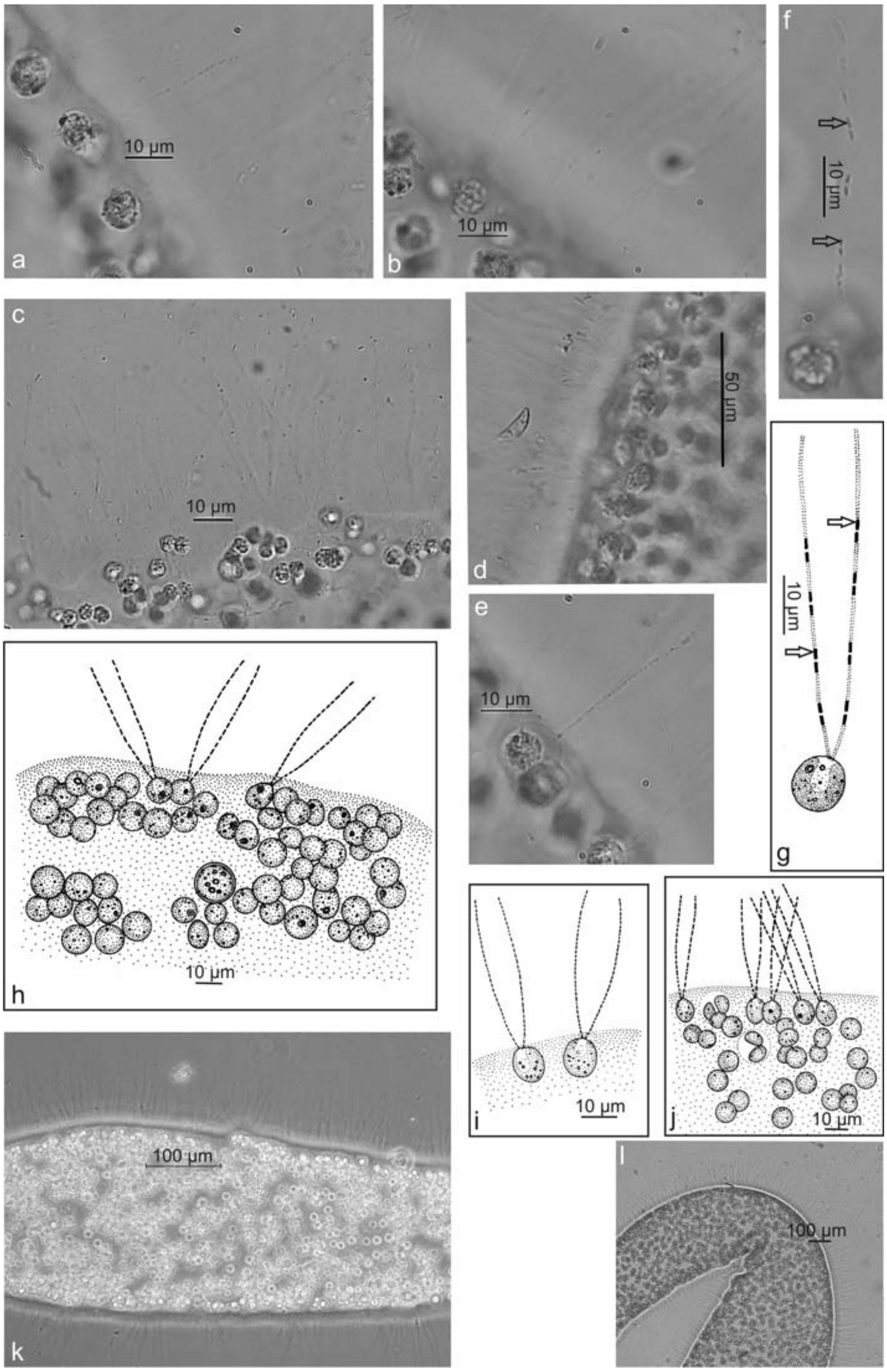


Fig. 6. *Tetraspora gelatinosa*; enlarged parts of colonies with pseudocilia (a–e, h–j), cell with pseudocilia (arrows showing stripes) (f–g), parts of colonies with pseudocilia (k–l).

Table 3

The geographical distribution of the *Tetraspora gelatinosa*. Morphotypes found in Spitsbergen (Hornsund) and other regions obtained from literature along with the data about climatic regions, latitudes, countries, locations, collector names or authors. * Global Biodiversity Information Facility, National Museum of Natural History (NMNH) Botany Collections, http://www.discoverlife.org/mp/20q?search=Tetraspora+gelatinosaandb=EOL/pages/921039

| No. in Fig. 3 | Climatic zone | Lat.-long. | Locality and habitat | Reference |
|---|---|---|---|---|
| 1 | polar | 76°69' N, 67°75' W | Greenland, Nunatarssuaq, Thule District, near north twin lakes | GBIF, NMNH, Botany Collections, Benninghoff and Robbins (1953)* |
| 2 | | 78°12' N, 14°93'E | Spitsbergen: Isfjorden between Longyearbyen and Barentsburg, Kol-Bay | Borge (1911) |
| 3 | | 77°00'22.3" N, 015°32'54.33" E | Spitsbergen (Hornsund fjord, south-western part of the Island), small lake and streams | Richter, Matuła and Pietryka (unpubl.) |
| 4 | | 62°23' S, 58°67' W | South Shetlands, King George Island, Potter Peninsula, lake | Vinocur and Pizarro (2000) |
| 5 | subpolar | 63.1° N, 149.1° W | Alaska; Imuruk Lake, Granite Bay Camp, Seward Peninsula | GBIF, NMNH, Botany Collections, Roeder (1973)* |
| 6 | | 63° N, 145° W | Alaska, stream | Sheath *et al.* (1986) |
| 7 | | 47°13'38.69" N, 138°47'27.06" E | NE Russia, Primorsky Region: Samarga River basin | Medvedeva and Semenchenko (2003) |
| | | 50° N 137°00'E | Zea River | Medvedeva (2010) |
| 8 | cool temperate | 47°34'3" N, 52°42'26" W | Newfoundland, near St. John's; small freshwater pools | Lakshminarayana (1976) |
| 9 | | 62° N, 15° E | Sweden, near Uppsala | GBIF, NMNH, Botany Collection* |
| 10 | | 62°02' N, 129°44' E | NE Russia, rivers | Komarenko and Vasil'eva (1978) |
| 11 | warm temperate | 48°57'–49°24' N, 57°49'–57°37' W | Newfoundland, slow streams | Sheath *et al.* (1989) |
| 12 | | 46.4° N, 93.4° W | USA, Minnesota, Itasca State Park, headwaters of the Mississippi River | GBIF, NMNH Botany Collections, Drouet (1954)* |
| 13 | | 42.2° N, 81.2° W | border of USA and Canada, western Lake Erie | Downing (1970) |
| 14 | | 50° N, 86° W | Canada, Ontario, St. Lawrence River | GBIF, NMNH, Botany Collections, Patrick* |
| 15 | | 48°46'–52°36' N, 78°42'–77°22' W | Canada, west-central Quebec, stream | Sheath *et al.* (1989) |
| 16 | | 46.5° N, 66.8° W | New Brunswick, Grand Fallus | GBIF, NMNH, Botany Collections, Hebeeb (1950)* |
| 17 | | 44° N, 87° W | USA, Wisconsin, western Great Lakes Area | Prescott (1962) |
| 18 | | 55° N, 4.5° W | British Isles | John *et al.* (2002) |
| 19 | | 52.5° N, 2.5° W | British Isles, freshwater | Pentecost (2002) |
| 20 | | 42°27' N, 0°36' E | France, freshwater | Desvaux (1818) |
| 21 | | 53.07° N, 4.75° E | Netherlands | GBIF, NMNH, Botany Collections* |
| 22 | | 52° N, 13° E | Germany, central highlands, stream | Ettl and Gärtner (1988), Gutowski *et al.* (2004) |

Table 3 – *continued*.

| No. in Fig. 3 | Climatic zone | Lat.-long. | Locality and habitat | Reference |
|---|---|---|---|---|
| 23 | warm temperate | 49°11' N, 13°11' E | Czech Republic, Czarne Lake | Lukavský (2009) |
| 24 | | 47.3° N, 13.3° E | Austria, Pielach near Schwarzenbach | GBIF, NMNH, Botany Collections, Stockmayer (2008)* |
| 25 | | 49° N, 20° E | Poland, Mszana Dolna, Białka and Piekielnik streams | Starmach (1986) |
| 26 | | 48° N, 45° E | Ukraine, river | Korshikov (1953) |
| 27 | | 45° N, 28° E | Romania | Cărăuş (2003) |
| 28 | | 44° N, 22° E | Serbia, Timok River | Simić *et al.* (2002) |
| 29 | | 49°11'02" N, 86°38'11" E | Kazachstan, Bukhtarma and Berel Rivers | Caisová *et al.* (2009) |
| | subtropical | – | North America-United States | Smith and Sinnott (1950), Wehr and Sheath (2003) |
| 30 | | 38.5° N, 117° W | USA, Nevada, Stewart Creek, Toiyabe range, Reese River valley | GBIF, NMNH, Botany Collections, Frantz (1954)* |
| 31 | | 34.2° N, 111.9° W | USA, Arizona, Baboquiviri Mountains, Brown's Canyon, between Brown's well and Ranchhouse | GBIF, NMNH, Botany Collections, Drouet and Hevly (1960)* |
| 32 | | 35.3° N, 98.7° W | USA, Oklahoma, Gramma Lake | GBIF, NMNH, Botany Collections, Bragg (1946)* |
| 33 | | 31.2° N, 100.1° W | USA, Texas, Spring Creek springs | GBIF, NMNH, Botany Collections, Whitehouse (1948)* |
| 34 | | 38.3° N, 92.4° W | USA, Missouri, Redby | GBIF, NMNH, Botany Collections, Drouet (1928)* |
| 35 | | 35° N, 83° W | USA, Tennessee, one mile east of Maryville, creek | Rhodes (1967) |
| 36 | | 28.1° N, 81.7° W | USA, Florida, Spillway Pond, St. Marks wildlife refuge | GBIF, NMNH, Botany Collections, Nielsen* |
| 37 | | 40.1° N, 74.4° W | USA, New Jersey, Cranberry Lake | GBIF, NMNH, Botany Collections, Hebeeb (1952)* |
| 38 | | 39.5° N, 8° W | Portugal, Serra da Estrela | GBIF, NMNH, Botany Collections, Santos (1994)* |
| 39 | | 40° N, 5° W | Spain | Cambra *et al.* (1998) |
| 40 | | 25° N, 68° E | Pakistan, Hyderabad, waste water | Ghazala *et. al.* (2004) |
| 41 | | 37° N, 82° E | Pakistan | Valeem and Shameel (2005) |
| 42 | | 28° N, 138° E | China, freshwater | Hu and Wei (2006) |
| 43 | | 36°15' N, 140°7' E | Japan, Mt. Tsukuba, stream | Yasuno *et al.* (1982) |
| 44 | | 36° N, 138° E | Japan, Hanslu | GBIF, NMNH, Botany Collections, Kamyia* |
| 45 | | 33° S, 146° E | Australia-New South Wales | GBIF, NMNH, Botany Collection* |
| 46 | | 37° S, 144° E | East Australia-New South Wales, Victoria, stream in the mountains | Entwisle and Skinner (2001) |
| 47 | | 38° S, 176° E | New Zealand, North Island, Whakarewarewa | GBIF, NMNH, Botany Collections* |
| 48 | | 41° S, 174° E | New Zealand-North Island, Hutt Valley | Chapman (1951) after Mather (1928) |

Table 3 – *continued*.

| No. in Fig. 3 | Climatic zone | Lat.-long. | Locality and habitat | Reference |
|---|---|---|---|---|
| 49 | tropical | 24° N, 88° E | India, West Bengal, Calcutta, Auckland square | NMNH Botany Collections* |
| 50 | | 22° N, 89° E | Bangladesh, Burburia River | Islam and Irfanullah (2005) |
| 51 | | 25°13'–25°26' S, 51°13'–51°28' W | Brazil, stream | Krupek *et al.* (2007, 2008) |
| 52 | | 33° S, 56° W | Uruguay, Montevideo | GBIF, NMNH, Botany Collections* |
| 53 | | 32° S, 147° E | East Australia and New Zealand | Day *et al.* (1995), Chapman *et al.* (1957), Phillips (2002) |
| | | 37° S, 144° E | New South Wales, Victoria | |
| | | 23° S, 143° E | Queensland | |
| 54 | equatorial | 18.2° N, 66.6° W | Puerto Rico, west of Humacao | GBIF, NMNH, Botany Collections, Wille (1915)* |
| 55 | | 10° S, 55° W | Brazil, São Paulo State, Riacho, Rio Grande, São Bernardo | GBIF, NMNH, Botany Collections, Joly (1953)* |
| 56 | | 20°58' S, 49°25' W | Brazil, São Paulo State, stream | Branco *et al.* (2005) |
| 57 | | 8° N, 13° W | Sierra Leone | Woodhead and Tweed (1957) |
| 58 | | 13° N, 122° E | Philippines, Dilian | GBIF, NMNH, Botany Collections, Valero (1955)* |

available literature sources and our data, we are able to compare the features of the populations from the four following climatic zones: polar, tropics, warm and cool temperate zones. The comparison took into account the following features: the size of the vegetative cells and the size of akinetes. Available data suggest that in the tropics the vegetative cells are smaller: 6–9 μm (Entwisle and Skinner 2001; Ghazala *et al.* 2004; Islam and Irfanullah 2005; Krupek *et al.* 2008). In the temperate zones they are between 6–12–(14) μm (Desvaux 1818; Korshikow 1953; Prescott 1962; Downing 1970; Lakshminarayana 1976; Komarenko and Vasileva 1978; Starmach 1986; Ettl and Gärtner 1988; John *et al.* 2002). In the polar zone there are three known localities: on King George Island in the Antarctic (Vinocur and Pizarro 2000), in Greenland (Benninghoff and Robbins 1953) and Svalbard (Borge 1911) and the locality described in this paper. In this climatic zone the size of the cells ranged from 7.50 to 13.00, mean value 9.70–9.90 μm (Table 1). These sizes are comparable to the sizes observed in temperate zone populations. The size of akinetes in all climatic zones was between 9 and 20, rarely up to 24 μm (Korshikov 1953). The examined populations showed no differences in comparison to the populations from various geographical and climate regions, either cold or warm.

For *Tetraspora gelatinosa* the optimal growth conditions are in clean or low mesotrophic and cold waters in cool temperate, sub-polar and polar zones. In tropical zones, by comparison, the temperature conditions (too high temperatures) might be more difficult, which would explain the smaller sizes of vegetative cells.

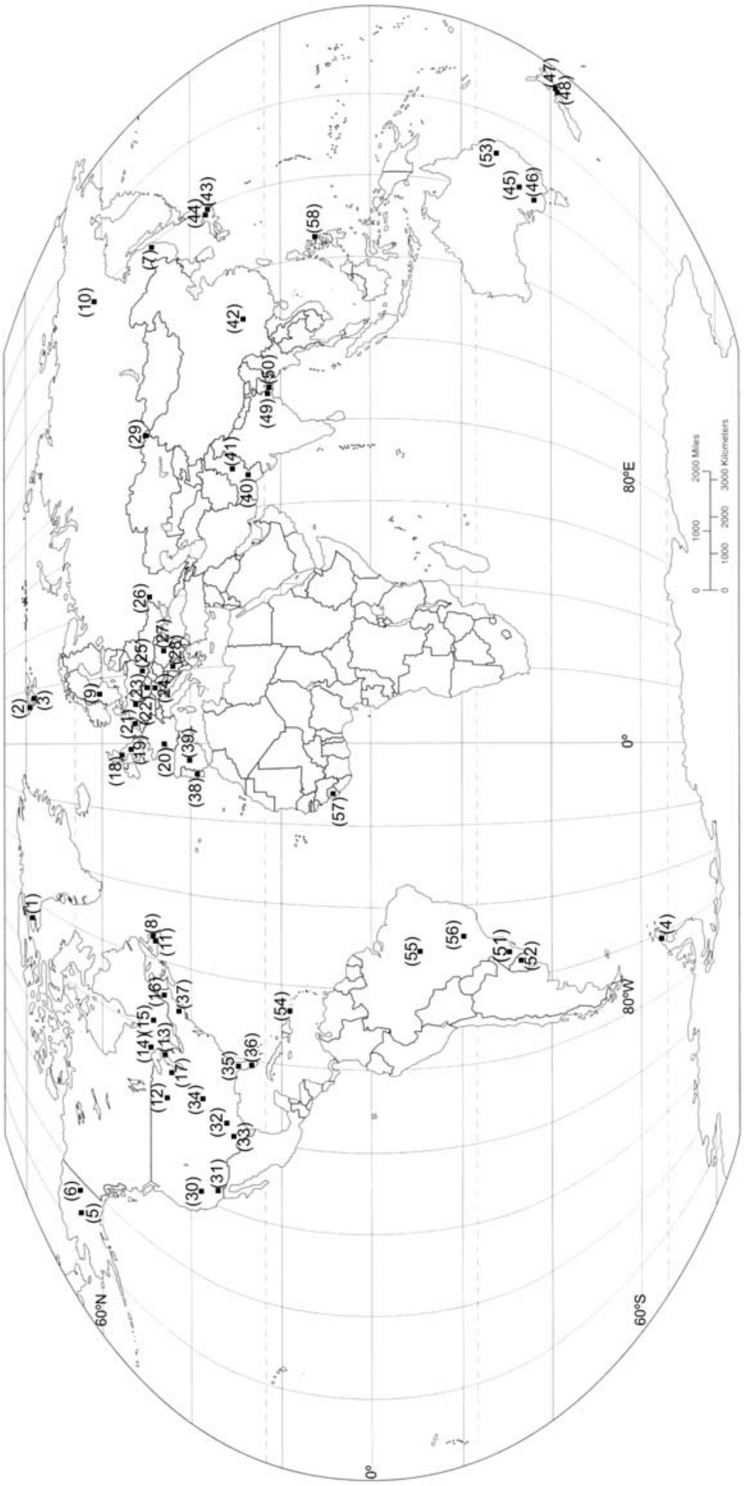


Fig. 7. The geographical distribution of *Tetraspora gelatinosa*.

## Conclusions

This article presents the detailed morphological characteristics of the *Tetraspora gelatinosa* populations from two stations of the Fuglebergsletta marine terrace at Fuglebekken (Spitsbergen, Svalbard). The two populations living in ecologically different habitats did not show clear differences in their cell structure, the manner of cell division and reproduction or in the structure of the akinetes. The only differences were visible in the macroscopic morphology of the colony. The differences in the shape of colonies indicated two morphological forms. The water current was a factor which significantly influenced the morphological forms. Additionally, the comparison of the thalli from the Spitsbergen colony with those recorded in other climatic zones showed no relation between the shape of the colony and the climate.

The analysis of the physico-chemical parameters of water in the habitats of the studied *Tetraspora gelatinosa* populations did not reveal any significant differences. However, the data give a full image of the ecological conditions where the species occurred. Scarce literature data on physico-chemical properties of *T. gelatinosa* habitats from other climatic zones show that this species is tolerant to such parameters as pH, conductivity and nutrients.

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