Charophytes from the warm springs of Svalbard

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Two of Svalbard's Trollkjeldane (Troll Springs) have a luxuriant vegetation of charophytes. This article is based on material collected in the Trollkjeldane by Sissel Aarvik, of the Office of the Sysselmann (Governor) of Svalbard, on 28 August 1992 and 16 August 1993. *Chara canescens* is described, based on living material. The Svalbard specimens have been named *Chara canescens* f. *spitsbergensis* comb. nov., which is synonymous with *Chara aspera* f. *spitsbergensis* Nordstedt. An imperfect charophyte is described here as a new subspecies of *C. canescens*: *Chara canescens* subsp. *hoelii*, named after Adolf Hoel, who first collected specimens of this subspecies. It is believed that this subspecies originates from *Chara canescens*, presumably by a genetic reorganization or a mutation of the species. A new subspecies is justified because of the ecorticate internodes, the incomplete or lacking cortex of the branchlets, the occurrence of accessory branchlets and the special bulbils found in this taxon. These are interpreted as characteristics with positive selective value in the special environment of the spring, where asexual reproduction by bulbils presumably has the same selective value as the parthenogenic reproduction by oospores in *Chara canescens* f. *spitsbergensis*.

In a growth experiment, the best growth of *C. canescens* f. *spitsbergensis* from the springs was obtained in water with relatively low salt content.

Growing tourism in Svalbard threatens to the springs; more active protection must be evaluated. There is also an urgent need to survey the springs in more detail.

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The warm springs in Svalbard were discovered by the Norwegian scientist Adolf Hoel in August 1910 (Hoel & Holtedahl 1911). During a second visit in August 1912, he surveyed and mapped the spring area in detail (Hoel 1914). The volcanic area on Spitsbergen where the springs are found is situated in Bockfjorden (79°25′ N, 13°17′ E). There are two areas with springs: Jotunkjeldane and Trollkjeldane (the Jotun and Troll springs, respectively). This work concentrates on the Trollkjeldane, where Hoel collected algae, including specimens of a charophyte in both 1910 and 1912.

The material from 1910 was determined and described by Professor Wille in Kristiania (now Oslo), Norway and listed in Hoel & Holtedahl (1911). The charophyte was sent to Professor Otto Nordstedt in Sweden. He determined it to be *Chara aspera* and described it as a new form: f. *spitsbergensis*. Other algal material from 1912 was determined by the Norwegian phycologist Kaare Münster Strøm and published in 1921 (Strøm 1921).

On 13 August 1958 the springs were visited by Niels Foged who collected diatoms as well as specimens of *C. canescens* (Foged 1964). Foged submitted the charophyte to the eminent Swedish charologist Henning Horn af Rantzien, who "considered it a rather peculiar form of *C. canescens* Lois., but at the same time he said he felt uncertain about this definition" (Foged 1964).

Specimens of *Chara* collected by Foged and by Håvard Østhagen in 1971 were examined by me and determined to be *C. canescens* Lois. (Langangen 1979). This work includes a description of the specimens examined.

Materials and methods

This work is based on material collected in the Trollkjeldane by Sissel Aarvik, Environmental Officer of the Office of the Sysselmann (Governor) of Svalbard on 28 August 1992 and 16 August 1993. The 1993 collections were partly damaged during transportation from Longyearbyen to Oslo.

The charophytes were determined and drawn or photographed on arrival, and grown in beakers of different sizes, using water from the original localities. Specimens of *Chara canescens* f. *spitsbergensis* were living until end of 1997, when the cultures were unrolled.

Sediment and water from a *Chara*-lake (Forsberg 1965), mixed with brackish water, were used for a growth experiment. The water was mixed in different quantities and the salt content measured with a Hack Conductivitimeter (Model 44600/CND/TDS). The plants used (*C. canescens* f. *spitsbergensis*) were cut in small pieces and put in the cultivating glasses, one glass for each salt concentration (Table 1). The beakers, sediment and water were sterilized prior to the experiment.

Some chemical parameters were analysed by the laboratory of the Norwegian Water Research Institute (NIVA), in Oslo (see Table 2). The other water analyses were done in accordance with Langangen (1994).

Study sites

According to Hoel (1914), the Trollkjeldane have 14 individual ground-water sources and consist of large sinter terraces. The collections were made in a warm source (presumed to be Hoel's No. VI) and in a "cold" source (No. IV; Hoel 1914). This is based on the assumption that Hoel (1914) used the wrong photograph on Plate XI (Fig. 1a), which must be source No. IV and not No. VI. The description in the text agrees with this assumption.

The warm spring is small: approximately 3 m long, 2 m wide and 1 m deep (Hoel 1914). There is a large shallow pool around the spring. The surface temperature was found to be 26°C in 1912 (Hoel 1914) and 25°C in 1993 (S. Aarvik, pers. comm.). There is a considerable flow of water from the spring, estimated by Hoel (1914) to be at least 100 litres per minute. The outlet of this spring was dominated by filamentous algae, and the spring itself was dominated by reproductive *Chara canescens*.

The "cold" spring (Fig. 1) was the biggest ground-water source in the area. Its shape was irregular; it was approximately 11 m long, 7 m wide and 2 m deep (Hoel 1914) and appears to have changed very little since Hoel photographed the locality in August 1912 (Hoel 1914). The surface temperature was 21°C in 1912 (Hoel 1914) and 19°C in 1993 (S. Aarvik, pers. comm.). Bubbles of gas were observed in 1992 in the eastern part of the source. The shallow area of the spring was dominated by filamentous algae and charophytes covered most of the bottom. Some of the charophytes were covered by a thin layer of

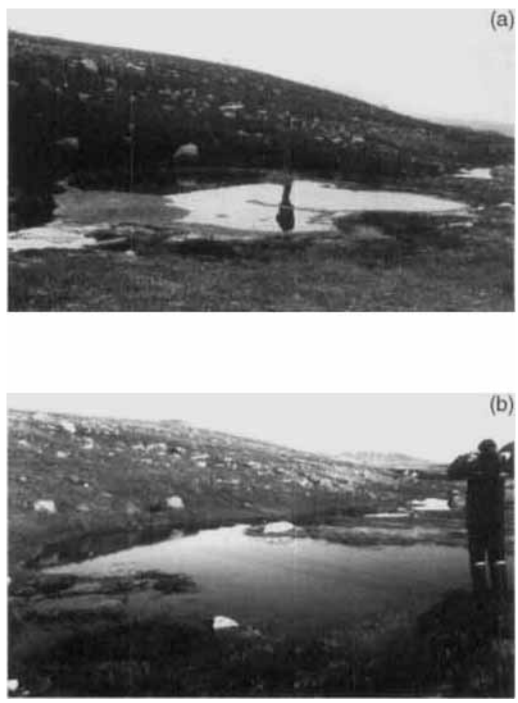

Fig. 1. The "cold" spring, Trollkjeldane, on (a) 3 August 1912 and (b) 28 August 1992 (photo: S. Aarvik). Note the reduced algae cover on the surface in the more recent photograph.

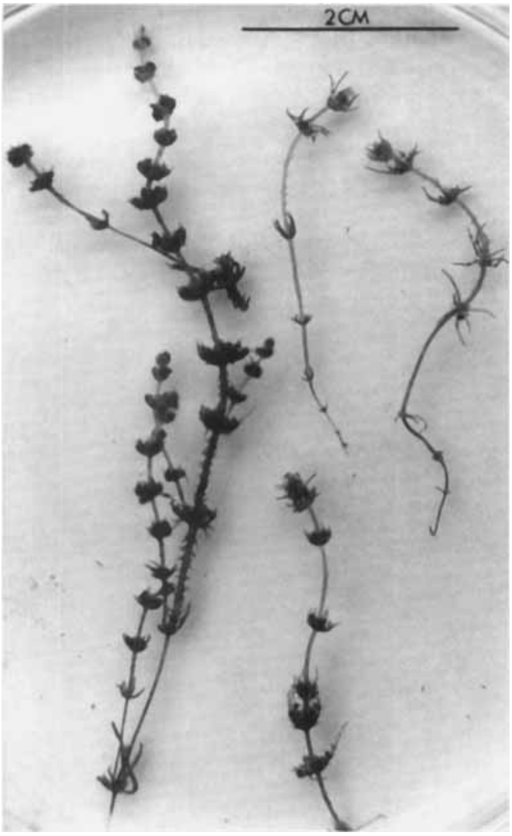

Fig. 2. Chara canescens specimens of different lengths from the warm spring. The specimens to the left are covered by a brown clayish coating.

mud, possibly due to disturbance caused by human activities.

Results

Description of the charophytes

1) *Chara canescens* Lois. (Figs. 2, 3)

Chara canescens was found in both springs, but dominated the vegetation in the warm spring and was the only charophyte collected there (S. Aarvik, pers. comm.). Specimens from Svalbard have previously been described in Langangen (1979); the description here is based mainly on material from 1992 and 1993. Material collected in 1912 by Hoel was also examined for comparison.

The plants were divided into short specimens, 3–8 cm high, and long specimens, 15–24 cm high (Fig. 2). These are not thought to represent different populations as variation in length of the plants in the field is probably continuous. Plants were unbranched to strongly branched, not encrusted with calcium carbonate or only slightly encrusted in part of the whorls. The axes were 400 to 750 μm in diameter, and the internodes 2 to 15 mm in length, 1 to 4 times as long as the branchlets. Old plants were commonly brown (Fig. 2) while new plants were green. The brown colour of old plants seems to have been caused by a red/brown clayish coating, possibly as a result of disturbance in the water due to upwelling of bottom sediments. The stem cortex was regularly haplostichous in younger internodes, and irregular or absent from older internodes. Spine cells were acute, often short but in some cases up to 1.5 times the diameter of the axes (Fig. 3). In the material from 1912 the spine cells were more consistently long. Spine cells were often solitary, but pairs and groups of three or four were found (Fig. 3a). Stipulodes were in 1–2 tiers, 2 per branchlet, reduced to 500 μm long. In some cases the cells in the upper row are long and in the lower reduced, which probably caused confusion in determining the number of rows of stipulodes. In the material from 1912 the stipulodes were more regular and normal. Branchlets were 7–9 in a whorl, up to 4 mm long, slightly connivent, with 3–4 segments, and with end segments of up to 3 ecorticate cells. The end segments were up to 2 mm long, and longer than the corticate segments. The branchlet cortex was more or less regular, but appeared in many cases rudimentary or absent (gymnophyllous forms) (Fig. 3c). Bract cells were verticillate and well developed, approximately 500 μm long. Bracteoles were up to 1 mm long. The whorls were often "nestlike" (Fig. 2), consisting of relatively short branchlets filled with oogonia and black ripe oospores. These whorls were 3.2–5.0 mm wide. The plants were dioecious, and only oogonia were found. The reproductive organs were extremely abundant. Oogonia (675–825 μm long, 275–450 μm wide, with 9–10 convolutions, coronula 50 μm long and 125 μm wide) were found adjacent to both corticate and ecorticate internodes, but were most common on the two lowest branchlet nodes. Oospores were black, ovoid to elliptical, 475–600 μm long to 325–400 μm wide, and with 9 ridges.

These specimens from Svalbard differed from typical *C. canescens*. Nordstedt, in Strøm (1921), named these specimens *Chara aspera* f. *spitsber-*

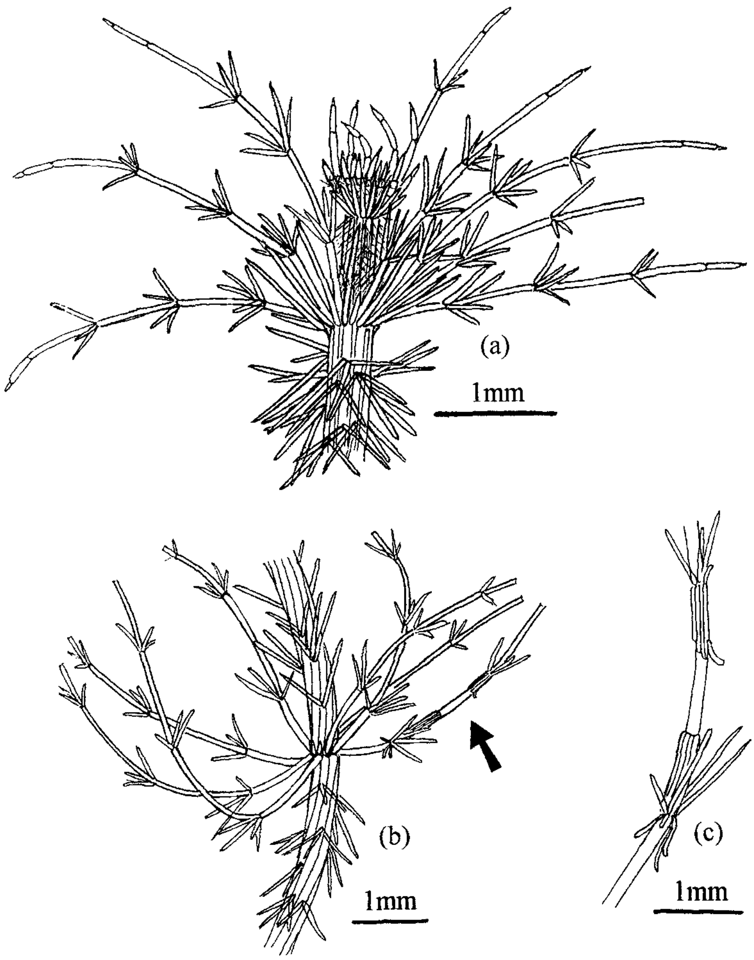

Fig. 3. Chara canescens from the warm spring: (a) uppermost whorls of specimen; (b) branchlet with rudimentary cortex; (c) third whorl from the top, one branchlet internode (see b) with rudimentary cortex (arrow). Stem with spine cells in pairs or three together. Drawing by Werner Krause.

gensis. The epithet *spitsbergensis* is now used for the new combination, and the correct name of the taxon is now *Chara canescens* f. *spitsbergensis* comb. nov.

2) *Chara canescens* subsp. *hoelii* subsp. nova (Figs. 4, 5)

Chara canescens subsp. *hoelii* is only found in the "cold" spring, where it grows in pure stands or in mixed populations with *C. canescens* f. *spitsbergensis*. There are few records of how the two taxa are distributed in the spring. In a future survey of this spring it will be of interest to map the relative distribution of the species.

When collected, the plants were up to 14 cm high (Fig. 4a), but in culture grew to up to 40 cm high and were mildly to strongly encrusted with calcium carbonate. Axes were 350 µm in diameter, internodes up to 2 cm long, in cultivated specimens up to 4 cm long. Stems were ecorticate. Short primary cortical cells were present ascending and descending from the nodes, without being attached to the internodal cells. Stipulodes were not observed, but many stem nodes had hypertrophied embryonic cells (Fig. 4e). There were 7–9 branchlets, which were up to 15 mm long, 0.5 to 3 times the length of the internodes, with 5–10 segments (Fig. 4). Branchlets were tipped with 2–3 ecorticate cells. Cortex on branchlets was variable but mostly rudimentary or missing, often with cortical cells standing out from the branchlet internodes (Fig. 4a, b). In some whorls an equal number of shorter, accessory branchlets are found in rows above and/or below the primary branchlets. The accessory branchlets had 4–5 segments, few cortical cells, and were often held at an angle to the stem. Bracteoles on primary branchlets were

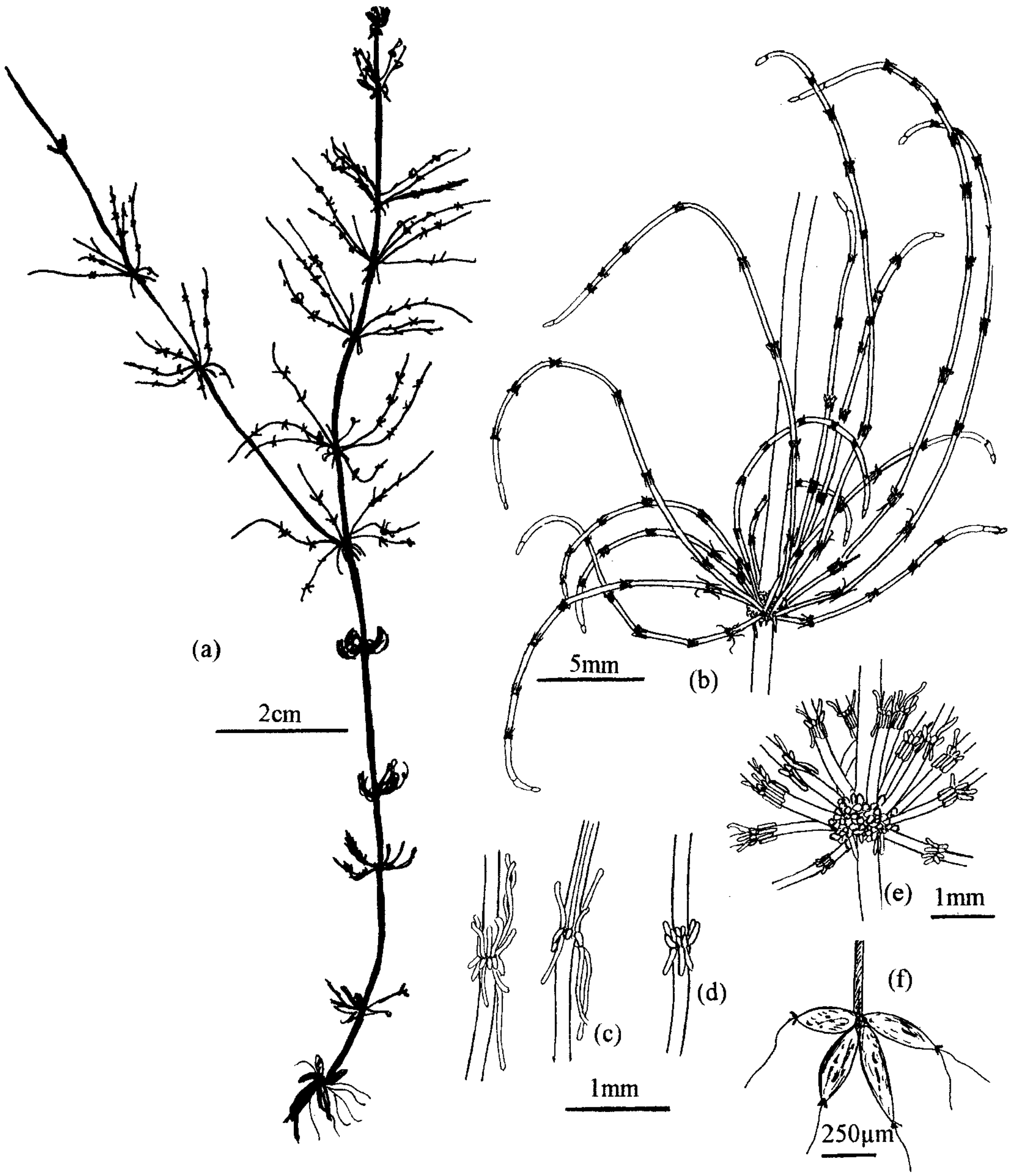

Fig. 4. Chara canescens subsp. *hoelii* subsp. nov.: (a) habit of plant; (b) habit of one whorl; (c) rudimentary cortication at undermost nodes of branchlets; (d) rudimentary cortication at higher nodes of branchlet; (e) stem node with hypertrophied embryonal cells and accessory branchlets; (f) bulbils. Drawings (b)–(e) by Werner Krause.

numerous, irregular, developed on both sides, and up to 300 µm long (Fig. 4). Gametangia were not found in natural population, but in culture one irregular, red cell bunch was found in place of a gametangium (Fig. 5). The type of bulbils found in this species is new to charophytes (Bharathan 1987). They are one-celled, acute, ovoid, 750–1500 µm long, and up to 600 µm wide (Fig. 4f).

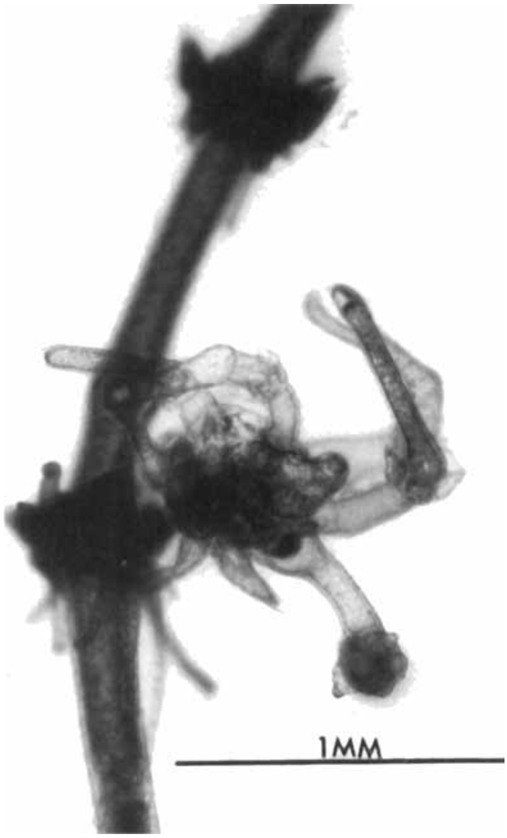

Fig. 5. Chara canescens subsp. *hoelii* subsp. nov. Branchlet with "abnormal" oogonia.

They occurred as solitary bulbils, in pairs or in groups of three or four. Specimens of this taxon were also collected by A. Hoel in August 1912, and the taxon appears to have remained constant since that time.

Latin diagnosis: Plantae ad 14 cm altae, modice/maxime incrustatae. Caulis ecorticatus, 350 μm diametro. Internodia ad 2 cm longa, ecorticata. Cellula stipulares nullae. Verticilli ad 7–9 in nodio, numerus aequalis verticillarum accidentium. Verticilli ad 15 mm longi, cum 5–10 internodiis. Cortex deformis, cellulis abbreviatis, internodis non adpressis, distantiens. 2–3 cellulae terminalis ecorticatis. Folia irregularia, prolongata ad 300 μm. Gametangia non presentia, in cultura fascicularis cellularum irregularis solus. Bulbilli uno-cellulari, stipulares, oviformii, 750–1500 μm longis ad 600 μm lati, singulares, duplices aut ad quattuor.

Holotype: Svalbard, Norway; the Trollkjeldane (Troll Springs) in Bockfjorden, the "cold" spring, 28 August 1992, Sissel Aarvik. Deposited in Bot. Museum, Oslo (Herb. O). Additional specimens from the same collection and from 16 August 1993 have also been examined.

Distribution: Only known from the type locality.

Cultivated plants: Cultivated plants: plants collected in 1992 were grown in culture until 3 January 1993. One plant reached a length of 40 cm.

Etymology: Named after Adolf Hoel, director of the Norwegian Polar Institute, 1928–1945.

Growth experiment and ecological factors

The growth of *Chara canescens* f. *spitsbergensis* was best in water with relatively low salt content, in the range 0.30–2.50 g L^{-1} (Table 1).

The climate of Svalbard is high Arctic; the

Table 1. Results of the growth experiment, started 12 August 1993 and ended 22 September 1993. The plants (*C. canescens* f. *spitsbergensis*) used were cut in small pieces and put in the cultivating glasses, one glass for each salt concentration.

Salt content g L^{-1}	Description of the plants
0.30	Excellent growth. Shoots up to 8 cm long. Total 20 normal plants.
0.70	Plants normal, 10 shoots up to 2.5 cm high. Some growth of *Oedogonium.*
1.00	Good growth. Plants up to 3 cm high, but healthy and normal.
1.62	Good growth. 20 plants, a few normal and up to 6 cm long. Many still embryonic.
2.50	Good growth, but of 22 plants only 2 are normal.
4.00	One normal plant, 3 cm high. 12 embryonic plants.
6.00	12 embryonic plants, 2 to 3 cm long.
8.23	Two small more or less normal plants, 2 and 4 cm. 10 embryonic plants.
10.06	Mostly dead plants. Two small (embryonic) plants found, 2–3 mm long. These were without cortex.
13.06	No living plants.

Table 2. Ionic composition of the water from the Trollkjeldane (Troll Springs), Svalbard, with comparative data from "the average" *Chara*-lake (Forsberg 1965; Langangen 1974) and the Kuhgrabensee (Winter et al. 1987).

Parameter	28.08.92 (NIVA) "cold"	16.08.93 "cold"	28.08.92 warm	*Chara*-lake (mean)	Kuhgrabensee
Conductivity $\mu S\ cm^{-1}$	1630	1470	1600		
Tot. dissolv. solids $g\ L^{-1}$	(0.522)[A]	0.740	0.805		1.500
pH[B]	7.6	8.0	7.0	8.0	8.0
Cations					
Ca $mg\ L^{-1}$	107.0	130.0	125.0	62.0	171.7
Mg $mg\ L^{-1}$	34.0			7.0	22.8
Na $mg\ L^{-1}$	216.0			6.0	357.5
K $mg\ L^{-1}$	13.4			2.0	5.1
Fe $\mu g\ L^{-1}$	27.0			Tot-Fe 100	
Al $\mu g\ L^{-1}$	26.0				
Anions					
Chloride $mg\ L^{-1}$	50.5			11.0	716.3
Sulphate $mg\ L^{-1}$	50.0			55.0	212.8
Silicate $mg\ L^{-1}$	50.0				
Other parameters					
Tot. N $\mu g\ L^{-1}$	86.0			550.0	
Tot. P $\mu g\ L^{-1}$	3.0			15.0	
Tot. org. C $mg\ L^{-1}$	0.4				

[A]Sum of ions.
[B]pH was measured upon arrival in Oslo.

average maximum temperature of the warmest month is lower than 5°C. Precipitation occurs mainly as snow (Foged 1964). Another important ecological factor is light. In Longyearbyen (78°02′ N) there is midnight sun from 20 April to 22 August and polar night from 27 October to 15 February. The temperature of the spring water is believed to be more or less constant throughout the year. Though no written documentation for this has been found, local inhabitants say that the springs are free of ice during winter. This means that the growth period is relatively long in the springs compared to other parts of the islands.

The bottom sediment of the springs is a grey, lime-rich fine sand (travertine). I have not found any references to this kind of sediment in the literature. This sediment had an organic matter content of 13.4%, and gave off carbon dioxide when treated with hydrochloric acid, indicating the presence of calcium carbonate.

The water was slightly brackish with an ionic composition different from both "the average" *Chara*-lake (Forsberg 1965; Langangen 1974) and brackish water (Kuhgrabensee; Winter et al. 1987). The spring water has high concentrations of Na, Ca, Mg, K, and SiO_2 and low concentrations of chloride, total nitrogen and total phosphorus (Table 2).

Discussion

The occurrence of charophytes so far north is remarkable, but can be explained by the presence of a few suitable localities in warm springs in this polar area, which is normally unsuitable for charophytes. This only partly accounts for it, however; in warm springs in Greenland, at 70° N, no charophytes have been found yet (Halliday et al. 1974).

It would be interesting to discuss how charophytes might have arrived at this remote locale, but at present the explanations rely too much on conjecture. In the future, it is hoped that genetic analysis will give us more reliable data. Two possible explanations are briefly mentioned here.

1) Langangen (1979) suggested that the first oospores arrived in the springs during a warmer period, and that the population has survived in ice-free refugia, which may have existed in western Spitsbergen for as long as the last 33 000 years. This hypothesis is difficult to prove, and seems rather speculative today.

2) It has been demonstrated both by experiments and observations that long distance dispersal by birds is possible (Proctor 1959; de Vlaming & Proctor 1968; Carlquist 1974). Furthermore, it is well documented that different species of shore

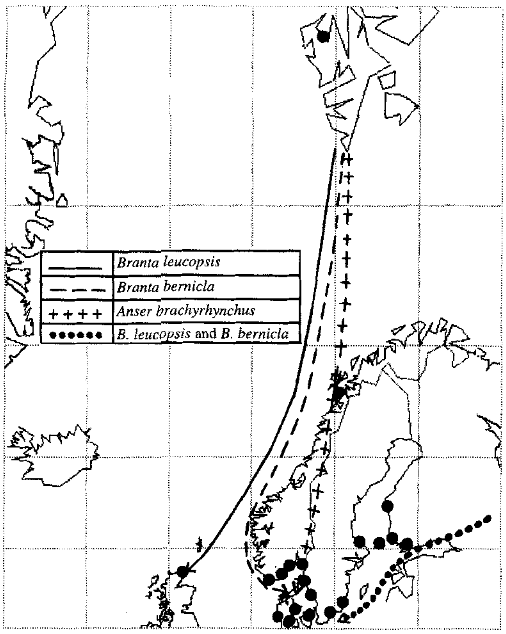

Fig. 6. Known distribution of *Chara canescens* in Scandinavia, Finland and Scotland (•), including old and new finds, and present migrating routes for three relevant species of geese. (Distribution of *C. canescens* not completely shown for Sweden and Finland; only finds near the migration routes are indicated.)

birds and waterfowl can ingest and disperse charophyte oospores over long distances (Imahori 1954; Proctor 1962, 1967, 1968). The time aspect for such dispersal is 5–6000 years as the Svalbard springs are presumed to be of this age (Elvebakk & Spjelkavik 1981).

In north-western Europe *C. canescens* is known from Scotland, southern parts of Finland and Scandinavia, Germany and The Netherlands (Migula 1897; Hasslow 1931; Olsen 1944; Langangen 1974; Moore & Green 1983; Nat et al. 1994). An unusual find of *C. canescens* was made in 1994, in Nordland county in northern Norway (Langangen et al. 1994) (Fig. 6). This find provides a link between the records of *C. canescens* in Svalbard and the occurrence of the species in southern Norway.

The locality in Nordland is also a spring and autumn resting place for migrating pink-footed geese (*Anser brachyrhynchus*), on their way between Svalbard and Denmark, Belgium and The Netherlands (Bollingmo 1991; Madsen 1991). Other possible dispersal agents of *C. canescens* are brent geese (*Branta bernicla*) which migrate from Denmark to Svalbard, and barnacle geese (*Branta leucopsis*) which migrate from Scotland to Svalbard. All these species of geese have resting places along the coast of Nordland while migrating and are regularly seen in the spring area every spring and summer.

The Svalbard *C. canescens* differs in many respects from the typical specimens of the species. It has been described as f. *spitsbergensis*, with the same description as given by Nordstedt (1921) for *Chara aspera* f. *spitsbergensis*. *C. canescens* is an exceptionally variable species, and many forms have been described. Of these, f. *thermalis* A.Br., a form with small, sparse spine cells and short bract cells, has been described from springs in France. An ecorticated form of *C. canescens* has been described by Langangen (1993). Charophytes found in warm springs are often different from the nominal species, e.g. *Chara vulgaris* L. f. *decipiens* Mig., found in Hungary, which is sterile and irregular in many characters, except the cortex, and *C. pistianensis* Vilhelm, found in Slovakia, which has irregular branchlet cortication (Vilhelm 1923).

The other taxon, *Chara canescens* subsp. *hoelii*, is believed to originate from *C. canescens*, presumably by a genetic reorganization or a mutation in the species. There is another reason to link it to *C. canescens*, as it is imperfectly developed and without sexual organs, and therefore at present difficult to place in the taxonomic system. *Chara canescens* subsp. *hoelii* was first collected by Hoel in 1912. As Nordstedt described specimens *C. canescens* from the 1910 material, he could not have overlooked this taxon, which must mean that *C. canescens* subsp. *hoelii* was not in the samples.

Chara canescens subsp. *hoelii* is most probably an imperfect form of *C. canescens*, without functional sexual organs. The one "abnormal" oogonium observed in culture, was an irregular, red bunch of cells. The outer cells are apparently aborted or shortened branches, possessing nodes and bracteoles. This supports the theory that the gametangia are reduced branches (Goebel 1918). Similar development of an oogonium has been found in *Nitella syncarpa* (Thuill.) Chev. (Ernst 1901).

Other special characters found in the new subspecies are the ecorticate internodes, the incomplete or lacking cortex of the branchlets and the occurrence of accessory branchlets. From the nodes one can see descending primary cortical cells, rudimentary and similar to the cortication in the "Nacktfüssige Zweige" described by Pringsheim (1863, pl. 13). Absent or rudimentary cortication of the branchlets is well known among charophytes, e.g. in *Chara imperfecta* A.Br. Judged from morphological characters other than the sexual organs, this taxon (subsp. *hoelii*) could have been described as a new species, which would have been in accordance with the species concept described in Blazencic (1995). The position of this taxon is uncertain and it is therefore described as a subspecies of *C. canescens*.

C. canescens reproduces by parthenogenesis (Braun 1857) in northern Europe, including Svalbard. For species of this kind, one original oospore would be enough to found a new population. If that is so, all specimens in Svalbard would descend from the same genotype. The different phenotypes found would then be ecotypes. Genetic analyses would give an answer to this hypothesis.

At some point in time, a genetic reorganization or mutation took place somewhere in the population. The new genotype survived, although it had ecorticate internodes, incomplete or lacking cortex on the branchlets and accessory branchlets. The special bulbils found in this taxon, unknown from *Chara canescens*, are suggested to have a positive selective value, securing survival of the genome through the dark period of the year, as the taxon do not have any oospores. This dark period must be a bottleneck for the charophytes as there is no photosynthesis and only respiration. The parthenogenic oospores are believed to give a similar survival advantage in the springs. It is difficult to know how these two genotypes will compete in the future. More information about how the taxa are distributed in the springs would be useful in this context. One cannot reject the possibility of an ongoing speciation in the springs which can result in a taxon which is better adapted to the environment there. This is believed to be the case with the new species of diatoms which have been described from the springs (Foged 1964).

A list of freshwater algae from Svalbard was published by Borge (1911). Ström (1921) added 12 species. The mats of filamentous algae in the springs are of special interest. They fill the shallow areas around the springs, and smaller areas in the springs themselves. The species found here belong to three different genera of green algae: *Oedogonium*, *Spirogyra* and *Zygnema*. These algae are abundant, presumably because of the high water temperature and the continuous light in summer. The growth is presumed to be limited by the water flow and by the low content of total phosphorus in the spring water (3.0 $\mu g\,L^{-1}$). In the average Scandinavian *Chara*-lakes, total phosphorus is lower than 15 $\mu g\,L^{-1}$ (Forsberg 1965). The low concentration of phosphorus and the type of bottom sediment is presumed to explain the lack of flowering plants in the springs. In a Greenland spring the plant *Subularia aquatica* L. has been found (Halliday et al. 1974).

The spring water has a relatively high ion content, and must therefore be characterized as slightly brackish. The salinity has been measured to 0.52 to 0.80‰. *Chara canescens* is reported as a brackish water species by most authors (e.g. Olsen 1944), with tolerance limits for salinity 4.0 to 20.0‰. The first find of the species in the oligohaline area was documented by Winter et al. (1987), from Kuhgrabensee near Bremen, Germany. They measured the salinity in this lake as 1.5‰.

In culture, Langangen (1993) obtained optimal growth of *C. canescens* in the oligohaline range, which was confirmed in the growth experiment with specimens from Svalbard. This is in accordance with the salinity in the Svalbard springs, where the growth is luxuriant in the oligohaline area. Experiments, e.g. Winter & Kirst (1990), showed that the salinity tolerance of *C. canescens* is 0.5 to 34.0‰. Again, this explains why *C. canescens* can survive in the spring water in Svalbard. The reason why *C. canescens* is not found in low salinities in other European localities is presumably due to competition from other plants in these areas.

The Trollkjeldane are found in an area with large sinter terraces. These are fragile formations, sensitive to human activities. Such activities have increased during the last few decades. Elvebakk & Spjelkavik (1981) say, for instance (translated from Norwegian): "These unique springs have turned out to be a botanical eldorado. . . . But they are small and are easy influenced even by small changes. Brattbakk mentioned that the populations of charophytes were noticeably smaller than 7 years ago. In the era of helicopters (and snowmobiles) the distances are short; we found a folding chair at a stone nearby."

There is increasing human activity in the area, which includes driving with snowmobiles, walking around and bathing in the springs. Increased use of the area could threaten the springs, and consequently the charophytes. Human activities like bathing will stir up the bottom sediment and cover the charophytes with mud. The brown colour of some specimens could have been caused by this. Increasing tourism on Svalbard could also be a threat to the springs in Bockfjorden. Although these springs are located inside a national park, they should be under even stricter protection. The future development of the springs and the spring area should be monitored closely, and a full scientific survey of the area, including geology, hydrology and biology, should be undertaken.

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