

RESEARCH/REVIEW ARTICLE

The algal vegetation in the outer part of Isfjorden, Spitsbergen: revisiting Per Svendsen's sites 50 years later

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Abstract

The benthic algal vegetation was investigated at two different sites in the outer part of Isfjorden, Svalbard, during 27–29 July 2007. One exposed site at Kapp Linné and one sheltered site in Ymerbukta were sampled both in the littoral and sublittoral zones. A total of 83 different taxa were recorded, 81 from the sublittoral and 40 from the littoral zone. The sublittoral zones at the two sites did not differ much in terms of the taxa recorded, but the number of species in the littoral differed between the two sites: Kapp Linné had 39 while only five species were found in Ymerbukta. The results are compared to a survey made by Per Svendsen in 1954 and 1955 in order to seek any changes in the diversity. Even though the number of species is difficult to compare directly, we registered a higher species number than Svendsen did 50 years ago. The difference seemed more pronounced in the littoral zone than in the sublittoral. Possible explanations for the differences between the two investigations are discussed. Two species not previously recorded in Svalbard, *Antithamnionella floccosa* and *Litosiphon laminariae*, were registered.

The marine benthic algal vegetation on Spitsbergen is relatively poorly studied. Lindblom (1839) drew up the very first list: 19 species. During the second half of the 1800s, Agardh (1862; 1868) studied samples from several Swedish expeditions and increased the total number of species from Spitsbergen to 51. When Kjellman participated in the Swedish polar expedition from July 1872 through August 1873, he studied the algal vegetation on the western and northern side of the island of Spitsbergen. An unplanned overwintering in Mosselbay, northern Spitsbergen, allowed Kjellman to sample benthic algae under the ice during the winter and to observe that algae grew and reproduced there (Kjellman 1875a, b, 1877). During several expeditions, Kjellman increased his study sites to include most of the Arctic Ocean, and his work must be regarded as one of the most comprehensive in the Arctic to date (Kjellman 1883).

Checklists aiming to cover all documented species have been published from the area (Vinogradova 1995; Hansen & Jenneborg 1996). The most complete list

comprises 146 species, of which 24 were reported as new for the region (Hansen & Jenneborg 1996). A few other papers dealing with Spitsbergen's benthic algae have been published: Florczyk & Latala (1989) studied the phytobenthos of Hornsund in southern Spitsbergen; Hansen & Haugen (1989) published some observations on the intertidal communities of western Spitsbergen; Weslawski et al. (1993) studied the intertidal zone at 242 sites in Svalbard; Wiktor et al. (1995) published an atlas of marine flora from the southern part of Spitsbergen; and Wiencke et al. (2004) studied species composition and the zonation pattern in Kongsfjorden. Wiencke and co-workers have published several papers on different aspects of Svalbard's marine algae (see Wiencke 2011).

The study reported in this paper builds on investigations done in 1954 and 1955 by Per Svendsen. He undertook fieldwork for his thesis in the littoral and sublittoral zones of two sites in the outer part of Isfjorden: one on the southern side of the fjord, around Kapp Linné, and the other on the northern side of the fjord, in the bay of Ymerbukta. He submitted his *Candidatus*

realium thesis in 1957 (Svendsen 1957); parts of this were later published (Svendsen 1959). At that time Svendsen was already aware that the temperature seemed to have increased since the earliest algal studies on Spitsbergen.

The main goal of our study was to revisit Svendsen's sites approximately 50 years later to seek differences in algal composition, new species from the area or changes in the zonation pattern in the littoral zone that may be caused by the steadily increasing temperature and reduced ice cover in the region (Vinje 2001).

Study area

Sampling took place in the outer part of Isfjorden, which is situated on the western side of the island of Spitsbergen, the main island of the archipelago of Svalbard (Fig. 1). Sites as close as possible to those visited by Svendsen were chosen. Svendsen sampled three sites—two sites at Kapp Linné and one site in Ymerbukta—during two consecutive years (1954 and 1955), from the beginning of July to mid-August each year. Due to time limitations we spend two days sampling at the exposed site Kapp Linné during 27 and 28 July 2007. Ymerbukta, on the northern side of Isfjorden, was included as a more sheltered site 29 July 2007.

Sampling

The littoral zone at Kapp Linné was sampled by hand picking in transects from the supralittoral down to the sublittoral. The extent of the vertical zones was estimated by placing the 0 line at the upper furoid vegetation belt and thereafter measuring the vertical distance down to the next zone. The furoid zone was used instead of the barnacle zone since the barnacles were very scattered, although quite abundant in some places. In Ymerbukta the littoral vegetation was so scarce that a vertical transect seemed meaningless. The few species found were simply picked up while we walked along the shore.

In the sublittoral zone, we attempted to use the same methods as Svendsen did 50 years earlier. However, Svendsen used a grab to sample kelp, which required a larger boat for operation. In order to collect kelp and understory vegetation we used SCUBA at two sites in the Kapp Linné area. The diver entered the water from land, going as far out as the communication cable allowed—100 m from the shore. Most other samples were collected by dredging. Constructed for hand-held use from a small boat, our triangular dredge had 25 cm sides and was weighted to help it reach the bottom in kelp vegetation. However, this was difficult in shallow areas where kelp vegetation was very dense. Dredging

was done at Kapp Linné, down to the greatest possible depth (ca. 50 m). Dredging was also carried out in Ymerbukta. This bay is very shallow, in some areas less than 1 m deep, so a throwable rake was used down to depths of about 5 m, in addition to the dredge.

All samples were put on marked plastic bottles and fixed in 2% formalin in seawater. Back in the laboratory, the formalin was thoroughly washed out in several rinses and the samples were left to soak in water for at least 24 h to get rid of the last traces of formalin. Thereafter the samples were identified to the lowest taxonomical level possible. Permanent slides of all species recorded were deposited with the programme for Marine Biology at the University of Oslo.

Results

The littoral zone

A conspicuous belt of the black lichen *Verrucaria maura* characterized the supralittoral zone at the exposed sites at Kapp Linné. Below this followed a belt, ranging between 50 and 100 cm in vertical distribution, of *Fucus distichus* (Fig. 2). Below the furoid belt we found a 60 cm vertical association composed of mainly two species, the brown alga *Chordaria flagelliformis* and the red alga *Devaleraea ramentacea*. In this association we recorded several species of green algae, the most common and prominent of which was *Acrosiphonia arcta*. This association grew all the way down to the sublittoral. A total of 39 different taxa were identified in the littoral zone at exposed sites at Kapp Linné: 11 green, 22 brown and six red algae. In comparison, Svendsen (1959) recorded 25 species during his investigation in the littoral zone in the Kapp Linné area: 8 green, 13 brown and 4 red algae. The littoral zone in the more sheltered Ymerbukta was very species poor. We found only four species of green and one brown algae there. Svendsen recorded three species—none of which was the same as what we found—in the littoral in Ymerbukta. A comparison of the number of taxa found during our investigation and Svendsen's is shown in Fig. 3.

The sublittoral zone

The sublittoral zone at shallow waters down to at least 10 m, investigated during SCUBA dives, was completely dominated by various species of kelp. The dominant kelp species at Kapp Linné were *Alaria esculenta* (Fig. 4a), *Laminaria digitata* and *Saccharina latissima*.

In the more protected Ymerbukta, *Saccorhiza dermatodea* was found to be common, in addition to the three species

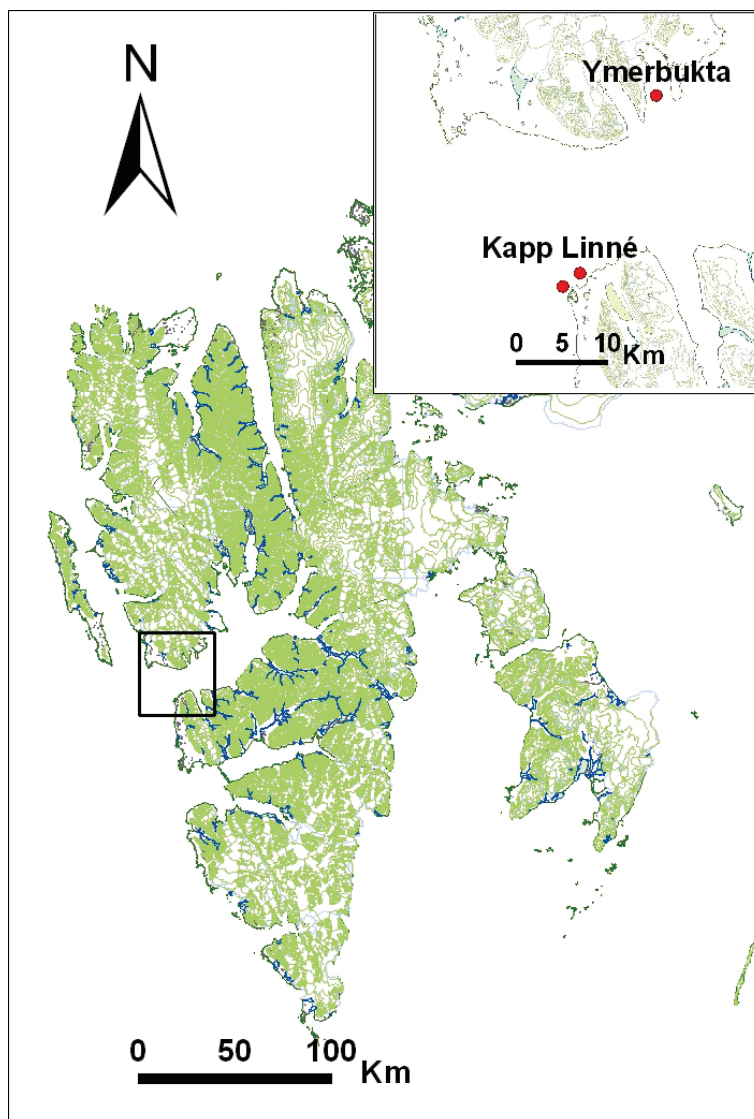


Fig. 1 Map of Svalbard. The area of investigation is marked with a square in the outer part of Isfjorden. Red dots represent the sampling sites.

mentioned above. At Kapp Linné the kelp vegetation became so dense that our triangular dredge was unable to penetrate down to the understorey vegetation. By diving we were able to determine that some of the most prominent species were *Chaetomorpha melagonium*, *Palmaria palmata*, *Acrosiphonia arcta* and *Devaleraea ramentacea* (Fig. 4b). In addition, the bottom was heavily covered by crustose corallines. In Ymerbukta, which was much shallower and where the vegetation penetrated no deeper than -7 m, brown algae like *Desmarestia aculeata*, *Fucus evanescens*, *Sphacelaria arctica* and *S. plumosa* dominated. A total of 15 green, 42 brown and 23 red algae was registered from the sublittoral zone. A comparison with the number found by Svendsen is shown in Fig. 5.

Totals

In total we identified 83 algal taxa in the outer Isfjorden area. These included 15 green algae (18% of the total number of species we recorded), 43 brown algae (52%), 24 red algae (29%) and 1 xanthophycean (*Vaucheria* sp.; 1%). In comparison, Svendsen (1959) registered a total of 59 species; 9 green, 29 brown and 21 red algae. The species in the different algal groups are shown in Tables 1–3.

Species new to Svalbard

Two species new to Svalbard were registered. One specimen of the red alga *Antithamnionella floccosa* (O.F. Müller)



Fig. 2 *Fucus distichus* from the lower intertidal zone at Kapp Linné 28 July 2007.

Whittick was found with tetrasporangia between 6 and 9 m depth at Kapp Linné (Fig. 6). The brown alga *Litosiphon laminariae* (Lyngbye) Harvey (Fig. 7) was also registered from the area for the first time. One specimen was found between 5 and 10 m depth in Ymerbukta.

Discussion

During this study we registered a total of 83 different taxa of benthic macroalgae, 81 from the sublittoral and 39 from the littoral zone. Svendsen (1959) registered altogether 59 different taxa during his survey in the mid-1950s. Of the species he recorded, 14 species were not observed during this study. This discrepancy could be explained by year-to-year variation or local extinction. It is also possible that we simply overlooked the species

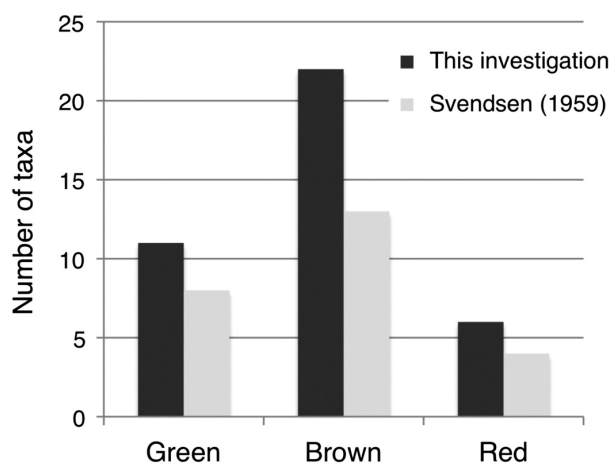


Fig. 3 Number of taxa in the three algal groups recorded in the littoral zone during this investigation and from Svendsen (1959).

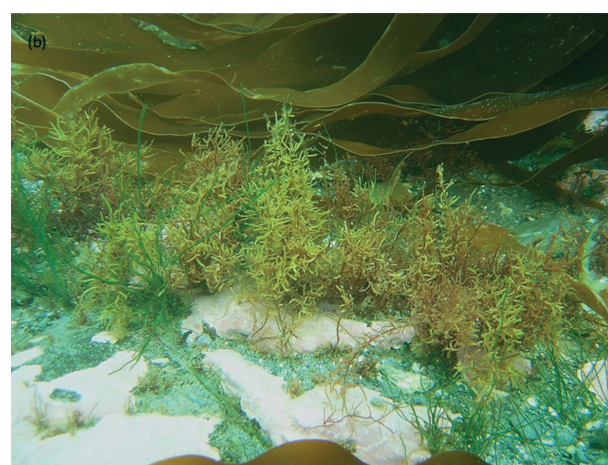


Fig. 4 (a) Dense vegetation of the kelp *Alaria esculenta* in the shallow subtidal. (b) The understory vegetation at 5 m depth, showing *Devaleraea ramentacea*, *Chaetomorpha melagonium* and crustose corallines. Both photographs were taken at Kapp Linné on 28 July 2007.

during our study, although species like *Dilsea carnosa*, *Dilsea integra*, *Fimbrifolium dichotomum* and *Coccotylus truncatus* are large and easy to recognize. Svendsen (1959) noted that the first three of these species were all very scarce, while *C. truncatus* was found occasionally to form luxurious stands. In a survey in 2010 *Dilsea integra* and *Coccotylus truncatus* were both recorded from Isfjorden (our own unpubl. data).

We registered 24 more species than Svendsen did in his study. While this suggests that diversity has increased significantly during the last 50 years, a comparison of the number of species should be treated with caution. Svendsen (1959) concentrated on the larger species, and did not pay as much attention to the smaller ones. An apparent increase in the number of taxa could, in fact, reflect a difference in the precision of the species

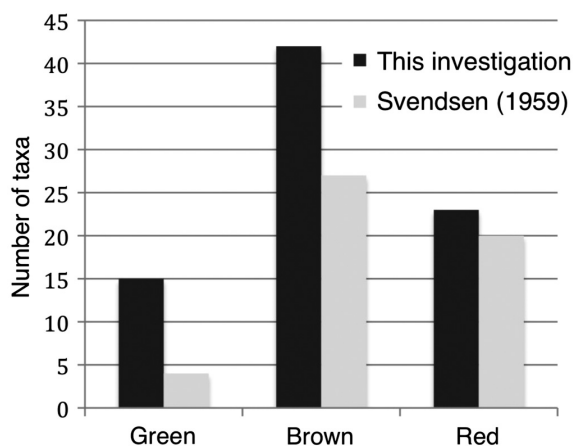


Fig. 5 Number of taxa in the three algal groups recorded in the sublittoral zone during this investigation and from Svendsen (1959).

identification. Figures 3 and 5 seem to indicate a higher number of species recorded during this survey, especially brown algae from the littoral and green algae from the sublittoral zone. The importance of precision in species identification is illustrated by comparing our results with the paper by Weslawski et al. (1993), who sampled 242 localities in the Svalbard Archipelago. Their total of only 22 macrophytes registered from the littoral zone would probably have increased with a greater precision in the identification process.

The Arctic littoral has often been regarded as supporting meagre life (Thorson 1933; Gurjanova 1968), mainly because of ice scouring. This affects large parts of the Arctic, though localities rich in life are occasionally found

(Ellis & Wilce 1961). According to Ellis & Wilce (1961), the main reason for the difference in abundance of intertidal populations in the Arctic seems to lie in the relationship between the tidal amplitude and the thickness of the sea ice. High tidal amplitude results in a much more intensive ice scouring than small tidal amplitude. The average spring tidal range in the Isfjorden area is 130 cm according to Svendsen (1959).

The littoral zone at Ymerbukta was very poor: we found only five species. In his study in the same area Svendsen (1959) recorded just three species, none of the same that were found during the present investigation. The scarcity of life in the littoral zone in this sheltered bay is probably due to Esmarkbreen, the glacier in the inner part of the bay. During spring and summer the glacier continually releases pieces of ice of various sizes, which scour the littoral and decrease the salinity there. According to Lüning (1980), salinity in such “fjord water” may drop down to 3–4 ‰.

The sublittoral in the sheltered site Ymerbukta also seems very similar to what was found 50 years ago, with the same dominant species. The kelp and understory vegetation consisted of more or less the same species. Exceptions include the brown alga *Desmarestia viridis*, the red algae *Coccolytus truncatus* and *Rhodomela lycopodioides*, three species found by Svendsen (1959) that we did not find in 2007. Year-to-year variation, rather than any major diversity shifts, may account for this.

In a comparison of Svendsen’s findings with our own, the littoral at the exposed site differed more than the one at the sheltered site. At Kapp Linné we recorded a total of 39 taxa, whereas Svendsen found 25 species. The major

Table 1 Chlorophyceae (green algae) registered during this investigation compared to registrations in Svendsen (1959), Vinogradova (1995) and Hansen & Jenneborg (1996).

Taxon (own registrations)	Svendsen (1959)	Vinogradova (1995)	Hansen & Jenneborg (1996)
<i>Acrochaete flustrae</i>			
<i>Acrochaete</i> sp.		X	X
<i>Acrosiphonia arcta</i>	X ^a	X	X
<i>Blidingia minima</i>	X ^b	X	X
<i>Capsosiphon groenlandicus</i>			X
<i>Chaetomorpha linum</i>			
<i>Chaetomorpha melagonium</i>	X	X	X
<i>Cladophora</i> spp.	X	X	X
<i>Kornmannia leptoderma</i>			X
<i>Rhizoclonium riparium</i>	X	X	X
<i>Spongomorpha aeruginosa</i>			X
<i>Ulothrix</i> cf. <i>implexa</i>		X	X
<i>Ulothrix flacca</i>	X	X	X
<i>Ulothrix subflaccida</i>			X
<i>Ulva prolifera</i>	X	X	X

^aSvendsen found *Spongomorpha* sp. and stated that this should probably be referred to *S. arcta*, today regarded as a synonym for *Acrosiphonia arcta*.

^bSvendsen found *Enteromorpha* sp. and stated that it agrees with *E. minima*, today regarded as a synonym for *Blidingia minima*.

Table 2 Phaeophyceae (brown algae) registered during this investigation compared to registrations in Svendsen (1959), Vinogradova (1995) and Hansen & Jenneborg (1996). The species name in boldface is regarded as new to Svalbard.

Taxon (own registrations)	Svendsen (1959)	Vinogradova (1995)	Hansen & Jenneborg (1996)
<i>Alaria esculenta</i>	X	X	X
<i>Cf. Pogotrichum filiforme</i>			
<i>Chorda filum</i>	X	X	X
<i>Cf. Chordaria chordaeformis</i>			
<i>Chordaria flagelliformis</i>	X	X	X
<i>Climacosorus mediterraneus</i>	X ^a		X
<i>Delamarea attenuata</i>	X	X	X
<i>Desmaresita aculeata</i>	X	X	X
<i>Desmarestia viridis</i>	X	X	X
<i>Dictyosiphon chordaria</i>	X	X	X
<i>Dictyosiphon foeniculaceus</i>	X	X	X
<i>Ectocarpus fasciculatus</i>	X ^b		
<i>Ectocarpus siliculosus</i>	X	X	X
<i>Elachista fucicola</i>	X	X	X
<i>Eudesme virescens</i>	X ^c		X
<i>Fucus distichus</i>	X	X	X
<i>Fucus evanescens</i>	X		X
<i>Halosiphon tomentosus</i>	X	X	X
<i>Haplospora globosa</i>	X	X	X
<i>Isthmoplea sphaerophora</i>	X	X	X
<i>Laminaria digitata</i>	X	X	X
<i>Laminaria solidungula</i>	X	X	X
<i>Leptonematella fasciculata</i>			X
<i>Litosiphon laminariae</i>			
<i>Myrionema corunnae</i>		X	X
<i>Omphalophyllum ulvaceum</i>		X	
<i>Petalonia fascia</i>			X
<i>Petalonia zosterifolia</i>		X	X
<i>Petroderma maculiforme</i>			X
<i>Phaeostroma pustulosum</i>		X	X
<i>Punctaria cf. plantaginea</i>		X	
<i>Punctaria tenuissima</i>			X
<i>Pylaiella littoralis</i>	X	X	X
<i>Pylaiella varia</i>	X	X	X
<i>Saccharina latissima</i>	X	X	X
<i>Saccorhiza dermatodea</i>	X	X	X
<i>Saundersella simplex</i>	X ^d	X	X
<i>Scytosiphon lomentaria</i>	X	X	X
<i>Sphacelaria arctica</i>	X ^e	X	X
<i>Sphacelaria plumosa</i>	X	X	X
<i>Sphacelaria radicans</i>	X ^e	X	X
<i>Stictyosiphon tortilis</i>		X	X
<i>Stragularia clavata</i>			X

^aAccording to Hansen & Jenneborg (1996), this species was misidentified by Svendsen (1959) as *Isthmoplea sphaerophora*.

^bSvendsen registered *Ectocarpus* spp. *E. fasciculatus* may be included here.

^cSvendsen found *Mesogloia cf. vermiculata*, according to Hansen & Jenneborg (1996) this is a misidentification of *Eudesme virescens*.

^dAccording to Vinogradova (1995), Svendsen (1959) could have registered this species as *Asperococcus* sp.

^e*Sphacelaria* sp. was recorded by Svendsen (1959). *S. arctica* and/or *S. radicans* may be included here.

zones in the littoral seem to be similar in both studies: a zone dominated by *Fucus distichus* with some *Pylaiella littoralis*, followed by a zone dominated by *Chordaria flagelliformis* with elements of different red and green algae. This latter zone stretched down to the sublittoral. In this last zone Svendsen (1959) reported the red alga

Devaleraea ramentacea to be rare, but in 2007 it was one of the dominant species. The vertical extent of these zones within the same area differed, probably due to local effects of exposure. Hansen & Haugen (1989), who investigated a large part of the littoral in western Spitsbergen, concluded that the intertidal zone in the

Table 3 Rhodophyceae (red algae) registered during this investigation compared to registrations in Svendsen (1959), Vinogradova (1995) and Hansen & Jenneborg (1996). The species name in boldface is regarded as new to Svalbard.

Taxon (own registrations)	Svendsen (1959)	Vinogradova (1995)	Hansen & Jenneborg (1996)
<i>Antithamnionella floccosa</i>			
<i>Audouinella</i> spp.		X	X
Calcareous crusts	X	X	X
<i>Ceramium</i> sp.	X	X	X
Cf. <i>Rhodophysemia</i> sp.			X
<i>Colaconema membranaceum</i>	X	X	X
<i>Devaleraea ramentacea</i>	X	X	X
<i>Euthora cristata</i>	X	X	X
<i>Halosaccicolax kjellmanii</i>			X
<i>Hildenbrandia rubra</i>	X	X	X
<i>Meiodiscus spetsbergensis</i>		X	X
<i>Odonthalia dentata</i>	X	X	X
<i>Palmaria palmata</i>	X	X	X
<i>Phycodrys rubens</i>	X	X	X
<i>Polysiphonia arctica</i>	X	X	X
<i>Polysiphonia fucooides</i>		X	X
<i>Polysiphonia stricta</i>		X	X
<i>Porphyra amplissima</i>	X	X	X
<i>Ptilota gunneri</i>	X	X	X
<i>Ptilota serrata</i>	X	X	X
Red fleshy crusts			
<i>Rhodochorton purpureum</i>	X	X	X
<i>Rhodomela confervoides</i>	X ^a	X	X
<i>Scagelothamnion pusillum</i>	X ^b	X	X

^a*Rhodomela lycopodioides* f. *tenuissima* was recorded by Svendsen (1959). This is currently accepted as a synonym for *R. confervoides*.

^b*Antithamnion boreale* recorded by Svendsen (1959) is currently accepted as a synonym for *Scagelothamnion pusillum*.

outer Isfjorden area (Kapp Linné) was very poorly developed and decided not to investigate this area any closer. Instead they did some quantitative analyses at Danskeøyene further north and found a total of 14 different algal taxa. The vertical distribution of dominant algae found by Hansen & Haugen (1989) concurs with what we recorded at Kapp Linné in 2007.

In addition to mechanical stress caused by drifting ice, the upper littoral may be covered by an ice foot. This ice foot can be a protection against mechanical stress for resistant species that can tolerate freezing (Wiencke et al. 2004). On the other hand, an ice foot makes colonization of the upper littoral by perennial species impossible (Svendsen 1959; Keats et al. 1989). Svendsen's paper (1959) includes a photograph of the ice foot at Kapp Linné in late June 1952. No such ice foot was observed during the investigation in 2007. Higher temperatures will reduce the likelihood of ice formation. According to meteorological observations (Norwegian Meteorological Institute 2007), the two years before our investigation were ice-free in this area, conditions favouring more luxurious algal vegetation in the littoral zone. The higher temperatures in the area are attested to by the observation of blue mussels (*Mytilus edulis*) at Sagaskjæret in

Isfjorden in 2005 (Berge et al. 2005) after an absence of about 1000 years.

Of the new species recorded, *Antithamnionella floccosa* is limited to cold-water environments. According to Jacobsen et al. (1991) the southern limit of this species is set by the lethal summer temperature of 17°C. *A. floccosa* has been previously found along most of the Norwegian coast, on Iceland and on the east coast of Canada (South & Tittley 1986). It is also registered from Greenland (Rosenvinge 1898) and from Bjørnøya (Athanasiadis 1990). The brown alga *Litosiphon laminariae* is found along the entire Norwegian coast (Rueness 1977) and is also widely distributed around the British Isles (Fletcher 1987). According to South & Tittley (1986) *L. laminariae* is also registered from Iceland.

The green alga *Chaetomorpha linum* identified during this study has previously not been recorded from Svalbard. According to Brodie et al. (2007), this species is not found further north than Scandinavia, and not on Iceland, though Cross et al. (1987) found it in Baffin Island, Canada. The morphological characteristics of this species vary extensively with environmental conditions (Brodie et al. 2007), and there may be some taxonomic confusion that needs to be resolved. Hansen & Jenneborg

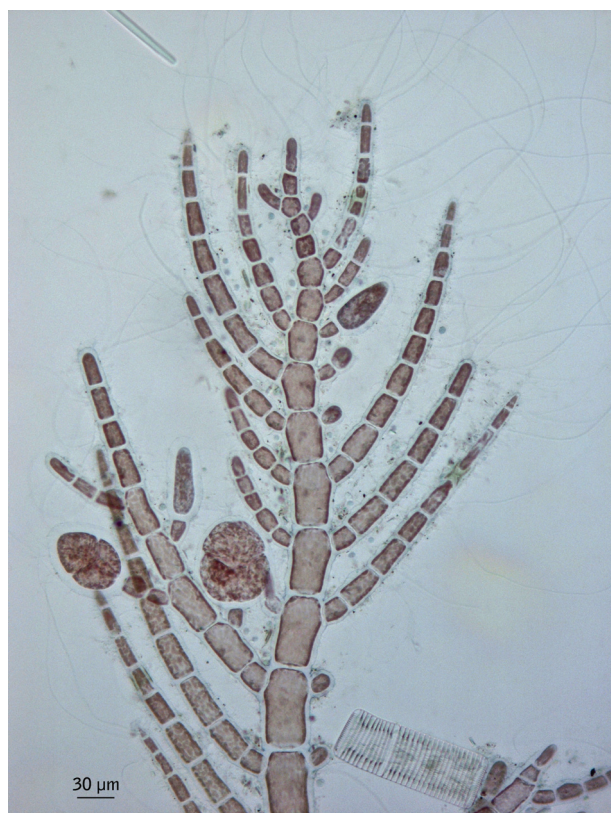


Fig. 6 The red alga *Antithamnionella floccosa*, with tetrasporangia, from Kapp Linné.

(1996) listed two different species in the genus: *C. melagonium* and *C. mediterranea*. Because of the potential confusion surrounding this species, we will not state that our finding is a new record for the area.

In areas that are explored comparatively infrequently, like Svalbard, investigations will often turn up species not previously documented. Such “new” species may have been overlooked during the few earlier investigations or name changes may have created taxonomic confusion, as indicated above. Alternatively, the new records could, in fact, represent recently introduced species. This possibility is highly relevant in today’s discussions about climate change and the warming of Arctic waters since higher temperatures allow species to establish themselves further north. As traffic increases in the Arctic, the number of vectors for species dispersal is also on the rise. Benthic algae are suitable indicators of changes in the environment since they remain in one place once they have established themselves. For all of these reasons, monitoring programmes that include benthic algae would be useful tools to identify environmental changes.

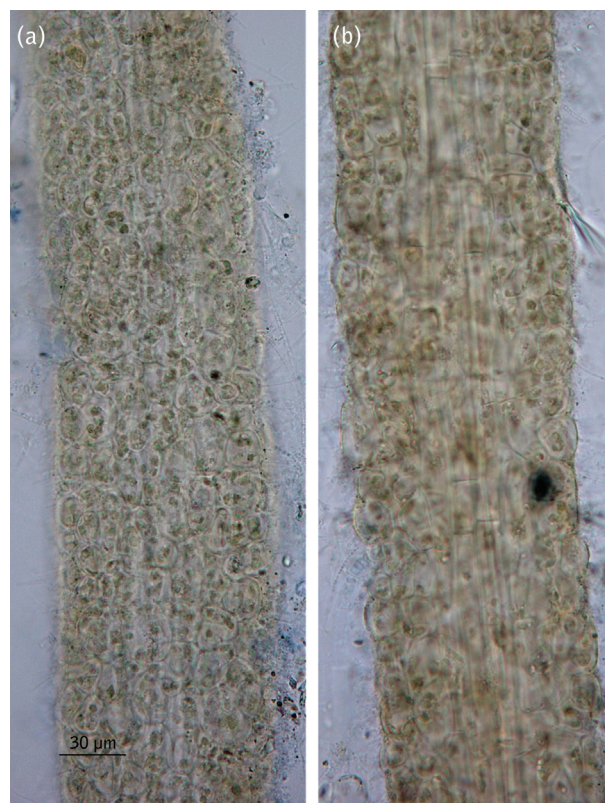


Fig. 7 *Lithosiphon laminariae*: (a) surface view; (b) view of larger internal cells.

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