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Culture and field studies of Ulvellaceae and other microfilamentous green seaweeds in subarctic and arctic waters around Iceland

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With 20 figures and 1 table

Abstract: Knowledge relating to the distribution of microfilamentous green algae in marine environments in the northern North Atlantic is extended with collections from waters around Iceland in the years 1999 and 2005 to 2007. These algae were looked for and some of them identified in the field samples, while the identification of most species depended on morphological structures observed in cultured material. Twenty-five species were identified, of which eleven were new records for Iceland. *Arthrochaete penetrans*, an arctic species was studied in culture for the first time. Other species have a wider distribution in the North Atlantic. A number of species were only found growing into calcareous substrata, i.e. *Ostreobium quekettii*, *Phaeophila dendroides*, *Eugomontia sacculata* and *Gomontia polyrhiza*. *Pseudendoclonium submarinum* and *Dilabifilum arthropyreniae* were found on wood. Some species were confined to a specific host; *Tellamia contorta* on the prosobranch *Littorina obtusata*, *Pseudendoclonium dynamenae* on the hydroid *Dynamena pumilla* and *Ulvella operculata* in *Chondrus crispus*, although most taxa were associated with a variety of host species.

Key words: Ulvophyceae, epi-endophytes, North-Atlantic, *Ulvella*, *Arthrochaete*.

Introduction

Microfilamentous green algae are widespread in the marine environment, growing in the littoral zone and to a considerable depth (more than 30 m) in the sublittoral (South 1974, Nielsen & McLachlan 1986a, Brodie et al. 2007). They are epi- or endophytes of larger algae and seagrasses, epi- and endozoic on various benthic animals, such as bryozoans, hydroids and molluscs, and grow on hard substrata and sometimes into calcified material (e.g. mollusc shells). In general these algae are poorly known, because they are difficult to find and highly problematic to identify due to similarities in their appearance and lack of information about critical characters (Nielsen et al. 2013). This has led to sporadic records and poorly known distribution for most of the species.

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These green algae are taxonomically heterogeneous. Formerly most of them were referred to the Chaetophoraceae (Huber 1892, Printz 1926, South 1974). In several recent studies based on culture studies, ultrastucture and molecular data, they are placed in seven families: Gomontiaceae, Bolbocoleaceae, Kornmanniaceae, Ulvaceae, Phaeophilaceae, Ulvellaceae and Ostreobiaceae within three orders: Ulotrichales, Ulvales and Bryopsidales of the class Ulvophyceae (O'Kelly et al. 2004a,b, Brodie et al. 2007, Nielsen et al. 2013).

In the Icelandic marine flora, host species of the microfilamentous green algae include both cold and warm water representatives. The sea around Iceland is partly influenced by the North Atlantic circulation coming from the south and partly by Polar water being transported southwards within the East-Greenland current (Hansen & Østerhus 2000, Blindheim & Østerhus 2005). The south and the southwest of Iceland are dominated by North Atlantic water with relatively warm temperatures. Travelling clockwise around Iceland, the influence of the cold Polar water gradually increases and the eastern coast generally has the lowest water temperatures (Astthorsson et al. 2007). Several temperate species have their northern distribution limit in Southwestern Iceland as e.g. *Desmarestia ligulata* (Stackhouse) L.V.Lamouroux and *Plocamium lyngbyanum* Kützing while a few arctic species with their southern distribution limit in Iceland are found only in Northern and Eastern Iceland as e.g. *Coilodesme bulligera* Stömfeldt and *Pantoneura fabriciana* (Lyngbye) M.J.Wynne. Hard substrata, suitable for seaweed growth, can be found in nearly all parts of the coast except for large stretches of the south coast where most of the shore is formed of black, volcanic sand.

Previous records of microfilamentous green algae in Iceland date back to H.Jónsson (1903), who recorded nine species. Since then seven species have been added (Caram & S.Jónsson 1972, Gunnarsson & S.Jónsson 2002). All these older records were based on observations of plants as they appeared in nature with most of the species recorded from only one or a few localities. The aim of the present study was to document the presence and diversity of the algae at the coast of Iceland based on morphological observations of specimens in nature supplemented by culture studies, which in many cases are necessary to identify species (Nielsen et al. 2013). Included as synonyms are names used in former checklists of Icelandic seaweeds (H.Jónsson 1903, Caram & S.Jónsson 1972, Gunnarsson & S.Jónsson 2002).

Materials and methods

Seaweeds were sampled in the waters around Iceland in the summer months (June, July and August) of 1999, 2005, 2006 and 2007 with one additional collection in December 2003 (Fig. 1 and Table 1). Collections were obtained by hand, both in the littoral and by scuba divers in the sublittoral. The samples were kept in a refrigerator during transport to the laboratory and examined fresh within a few days of collection. Permanent slide preparations were prepared by embedding the algae in 50% aqueous solution of KARO® corn syrup. Calcified material was decalcified by leaving it in 5% acetic acid overnight and then rinsing in seawater. Cultures were initiated when small green algae were observed by placing small pieces (<1 mm diameter) of the host organism or scrapings off pebbles, rocks, wood or calcareous substrata, into test tubes with modified Provasoli medium (MV30, Christensen 1982) with GeO_2 added to prevent diatom growth (Lewin 1966). Seawater was obtained from open water in the North Sea with a salinity above 30 psu. The raw cultures were brought to

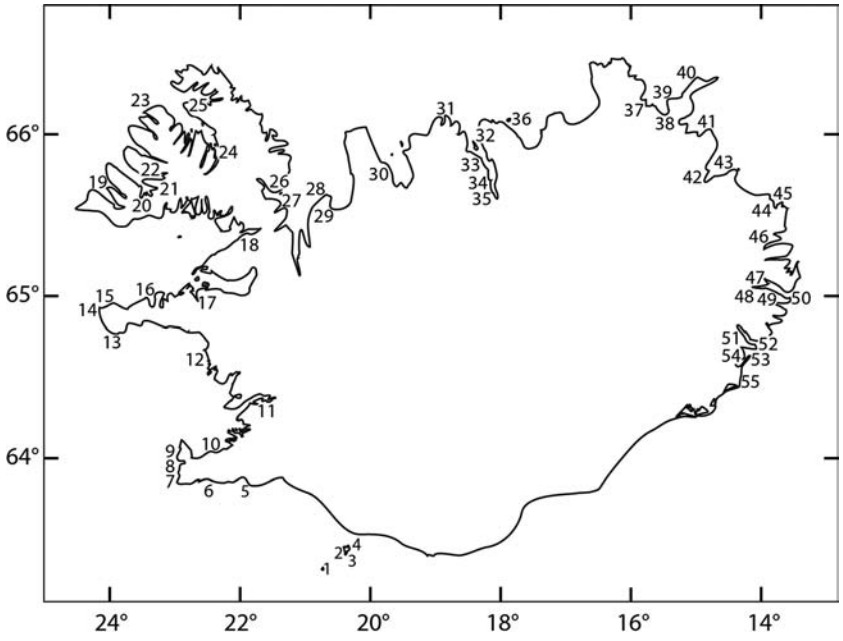

Fig. 1. Sampling stations for microfilamentous green seaweeds at the coast of Iceland. The numbers refer to stations listed in Table 1.

Copenhagen, where unialgal cultures were obtained by serial isolations into clean Petri-dishes using a sterile micropipette (Nielsen et al. 2013). The cultures were maintained in test-tubes or Petri-dishes with MV30 at 4 or 15°C and an irradiance of c. 16 µmol m^{-2} s^{-1} provided by fluorescent lamps (Phillips TL 40W) in a 16:8 h light:dark cycle. Autoclaved, transparent, mollusc shells were added to test the ability to grow into calcified material. Growth forms of plants in Petri-dishes were studied using a water-immersion objective lens (×20). Strain numbers refer to cultures, of which dried samples are maintained at the algal Herbaria, Copenhagen (C). Permanent slides of voucher specimens with host material are kept in C and in the Icelandic Institute of Natural History, Reykjavik (ISL). In the text, new records for Iceland are marked with an asterisk.

Results

Ulotrichales

Gomontiaceae

Eugomontia sacculata Kornmann

In nature it grew in calcified material (e.g. dead shells of molluscs and barnacles) as irregularly branched filaments of cylindrical cells, 3–7 µm in diameter and 3–6 times as long. The transverse walls were occasionally thickened (Fig. 2A). Rounded to sac-shaped sporangia were observed and measured 25–60 µm across.

Table 1. Samplings stations for Ulvellaceae and other microfilamentous green seaweeds at the coast of Iceland with coordinates and sampling dates.

No.	Locality		Latitude	Longitude	Sampling date
1	Surtsey	S	63°18.282'	20°35.556'	15.7.2009
2	Sölvaflá	S	63°24.234'	20°17.388'	12.8.1999
3	Erlendarkrær	S	63°24.312'	20°16.388'	12.8.1999
4	Vestmannaeyjar	S	63°26.760'	20°14.988'	12.8.1999
5	Selvogur	SW	63°49.734'	21°41.916'	10.8.1999
6	Hópnes	SW	63°49.392'	22°24.078'	2.8.1999
7	Kista	SW	63°50.082'	22°42.888'	23.8.2013
8	Ósabotnar	SW	63°56.280'	22°40.320'	12.7.2005
9	Stafnes	SW	63°58.338'	22°45.426'	4.8.1999
10	Kálfatjarnarkirkja	SW	64°01.080'	22°18.054'	17.7.2005
11	Fossá	W	64°21.258'	21°27.606'	26.8.2010
12	Akrar	W	64°37.896'	22°23.172'	15.7.2005
13	Malarrif	W	64°43.578'	23°47.946'	15.8.2007
14	Öndverðarnes	W	64°53.196'	24°02.676'	14.8.2007
15	Krossavík	W	64°54.966'	23°54.042'	9.7.2005
16	Suður-Bár	W	64°58.458'	23°13.662'	7.7.2005
17	Álftafjörður	W	64°58.794'	22°36.300'	16.7.2005
18	Tjaldanes	W	65°24.114'	21°57.384'	25.7.2012
19	Sellátrar	NW	65°40.944'	24°01.692'	8.7.2008
20	Fossfjörður	NW	65°38.160'	23°32.376'	25.4.2011
21	Borgarfjörður	NW	65°46.170'	23°11.064'	4.7.2005
22	Hjallkárseyri	NW	65°45.744'	23°17.130'	4.7.2005
23	Skálavík	NW	65°11.064'	23°28.596'	13.7.2008
24	Hveravík	NW	65°55.734'	22°25.530'	29.6.2005
25	Maríuhorn	NW	65°15.042'	22°52.530'	2.7.2005
26	Drangsnes	NW	65°41.042'	21°25.944'	29.6.2005
27	Kollafjarðarbotn	NW	65°33.576'	21°28.692'	28.6.2005
28	Kálfavík	N	65°39.894'	20°44.856'	7.6.2006
29	Hvítserkur	N	65°36.384'	20°38.100'	7.6.2006
30	Grettislaug	N	65°52.896'	19°44.106'	8.6.2006
31	Siglunes	N	66°11.814'	18°51.120'	16.6.2006
32	Laugarkambur	N	66°01.554'	18°24.330'	14.6.2006
33	Hrísey	N	66°58.764'	18°21.252'	14.6.2006
34	Víkurbakki	N	66°54.600'	18°17.202'	13.6.2006
35	Pétursborg	N	66°43.614'	18°08.592'	19.6.2006
36	Flatey	N	66°09.174'	17°50.496'	24.6.2006
37	Ytra Áland	N	66°12.798'	15°32.496'	22.6.2006
38	Tófutangi	N	66°10.308'	15°20.682'	21.6.2006
39	Þórshöfn	N	66°12.018'	15°20.556'	6.12.2003
40	Brimnes	E	66°20.952'	15°00.174'	22.6.2007
41	Steintún	E	66°03.366'	14°45.432'	7.6.2007

42	Sandvík	E	65°44.124'	14°51.336'	5.6.2007
43	Hamralending	E	65°45.426'	14°36.252'	7.6.2007
44	Borgarfjörður	E	65°31.698'	13°48.888'	8.6.2007
45	Hafnarhólmi	E	65°32.568'	13°45.462'	10.6.2007
46	Skógar	E	65°31.698'	13°48.888'	1.6.2007
47	Hólmanes	E	65°02.424'	13°59.706'	13.6.2007
48	Holtastaðir	E	65°00.858'	14°08.856'	2.6.2007
49	Eyri	E	65°00.666	13°59.700'	2.6.2007
50	Vattarnes	E	64°56.088'	13°40.884'	19.6.2007
51	Eyvindarnes	E	64°44.754'	14°25.692'	12.6.2007
52	Fálka-Jónshólmi	E	64°39.978'	14°15.414'	15.6.2007
53	Hlífólfssker	E	64°39.420'	14°12.708'	15.6.2007
54	Melrakkanes	E	64°35.514'	14°27.150'	13.6.2007
55	Krossanes	E	64°26.514'	14°29.874'	17.6.2007

In culture, plants formed similar irregularly branched filaments. The cylindrical cells were 10–17 µm in width and 4–25 µm long. Each cell contained a parietal chloroplast with 1 (–2) pyrenoids (Fig. 2B). Thickenings of transverse walls were occasionally observed. Balloon-like swollen cells, considered to be sporangia occurred in the middle part of plants and measured up to 70 µm across (Fig. 2C). The cultured plants also grew into transparent mollusc shells (Fig. 2D). The studied plants were similar to plants from Helgoland cultured by Kornmann (1960).

Found in the littoral zone at the following sites (cf. Fig. 1 and Table 1): 6, 10, 15, 17, 21, 29, 41, 47, 49, 51, 52.

Gomontia polyrhiza (Lagerheim) Bornet & Flahault

Unicells with multiple rhizoids were commonly found in calcareous substrata (Fig. 2E). In a few localities these *Gomontia*-phases were found in association with plants resembling the gametophyte of *Gomontia polyrhiza* as illustrated by Kornmann (1959). We therefore refer our finds to this species although similar *Gomontia*-phases are known from other species, such as *Collinsiella cava* (Yendo) Printz and *Monostroma* spp. (Chihara 1962) and depend on cultural studies for correct determination.

H.Jónsson (1903) also recorded this species as common in mollusc shells, *Balanus* spp. and *Lithothamnion* sp. At that time the filamentous *Eugomontia sacculata* was included in the species concept of *G. polyrhiza* (Bornet & Flahault 1888) but later separated by Kornmann (1960). As H.Jónsson (1903) made no comments about the morphology, his records may include *E. sacculata.* We have not been able to trace any of H.Jónsson's *G. polyrhiza* samples and are therefore unable to comment further on the identity of his plants.

Found in various calcareous organisms in the littoral zone and in the sublittoral to 30 m depth.

Recorded at the following sites (cf Fig. 1 and Table 1): 5, 9, 10, 16, 19, 47, 48, 55.

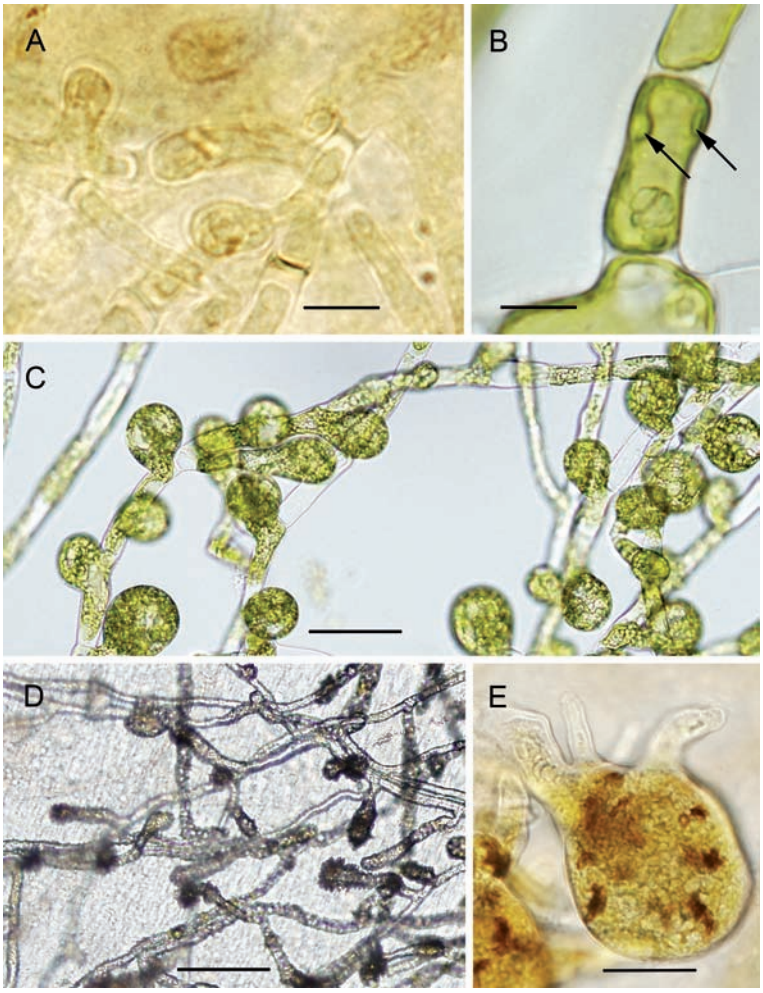

Fig. 2. *Eugomontia sacculata*. A. Branched filaments with thick crosswalls within shell of *Mya arenaria* Linnaeus, 1758. Slide preparation of decalcified material in KARO®, strain IS06004-1. B. Vegetative cell with 2 pyrenoids (arrows), strain IS07004. C. Sporophyte with balloon-like middle cells, strain IS07004. D. Branched filaments within a transparent mollusc shell, strain IS06004-1. *Gomontia polyrhiza* cf. E. Single cell. Note the layered walls of rhizoidal branches. Slide preparation of decalcified mollusc shell. Scale bars = 10 µm (A, B), 25 µm (C, E), 50 µm (D).

Ulvales

Bolbocoleaceae

Bolbocoleon piliferum Pringsheim

Plants in culture formed almost globular tufts of alternately branched, radiating filaments (Fig. 3A). The cylindrical cells of the distal filaments measured 10–15(–22) µm

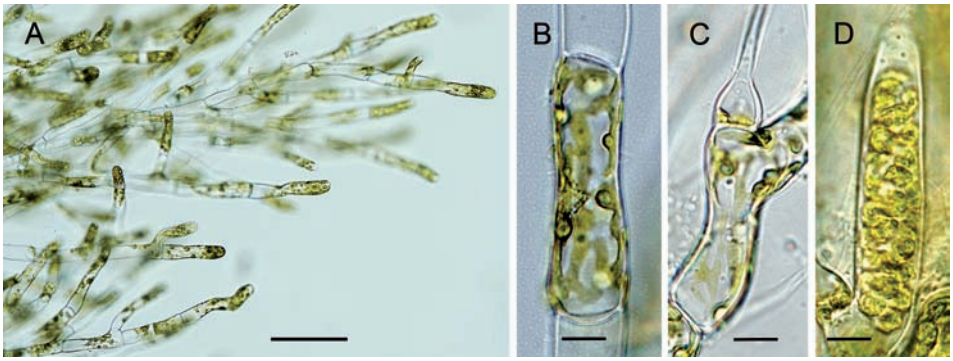

Fig. 3. *Bolbocoleon piliferum*. A. Distal part of a vegetative plant, strain IS99019-08-1. B. Reticulate chloroplast with several pyrenoids, strain IS99019-08-1. C. *Bolbocoleon*-type hair, strain IS07019-2. D. Sporangium, strain IS07019-2. Scale bars = 50 μm (A), 10 μm (B–D).

in width and were 4–7(–10) times as long. Shorter and broader cells occurred in the middle part of the plants. Each vegetative cell had a parietal reticulate chloroplast with 4–6(–9) pyrenoids (Fig. 3B). The *Bolbocoleon*-type hairs had a long extension from an onion-shaped base with a small chloroplast and usually 1–2 pyrenoids (Fig. 3C). Sporangia were elongated, almost cylindrical, with 16–32 swarmers when mature (Fig. 3D). Biflagellate, drop-shaped swarmers were observed, with a basal chloroplast, a pyrenoid, and a stigma and measured about 9 × 6 μm. Plants studied agreed with those from Denmark (Nielsen 1979).

Found in the littoral zone and the sublittoral to 15 m depth where it was observed among surface cells and as an epiphyte on the brown algae *Coilodesme bulligera* Strömfelt, *Petalonia fascia* (O.F.Müller) Kuntze, *Punctaria plantaginea* (Roth) Greville and *Scytosiphon lomentaria* (Lyngbye) Link and the red alga *Lomentaria orcadensis* (Harvey) F.S.Collins ex W.R.Taylor.

Recorded at the following sites (cf. Fig. 1 and Table 1): 3, 6, 8, 9, 12, 17, 31, 33, 35, 42, 43, 44, 51, 54.

Kornmanniaceae

Dilabifilum arthropyreniae (Vischer) Tschermak-Woess

Young plants in culture formed bushes of radiating filaments with cylindrical cells 3.5–5 μm wide and 2–8 times as long. Distal cells in older plants were similar, while cells in the middle part grew upward to form a dense mass of rounded to elongated cells (Figs 4A, 4B). These cells developed into almost cylindrical sporangia with rounded apices. At maturity they were 22–31 μm long and 10–13 μm in width and contained many zoospores (Fig. 4C). After germination the spores remained part of the young plants (Fig. 4D).

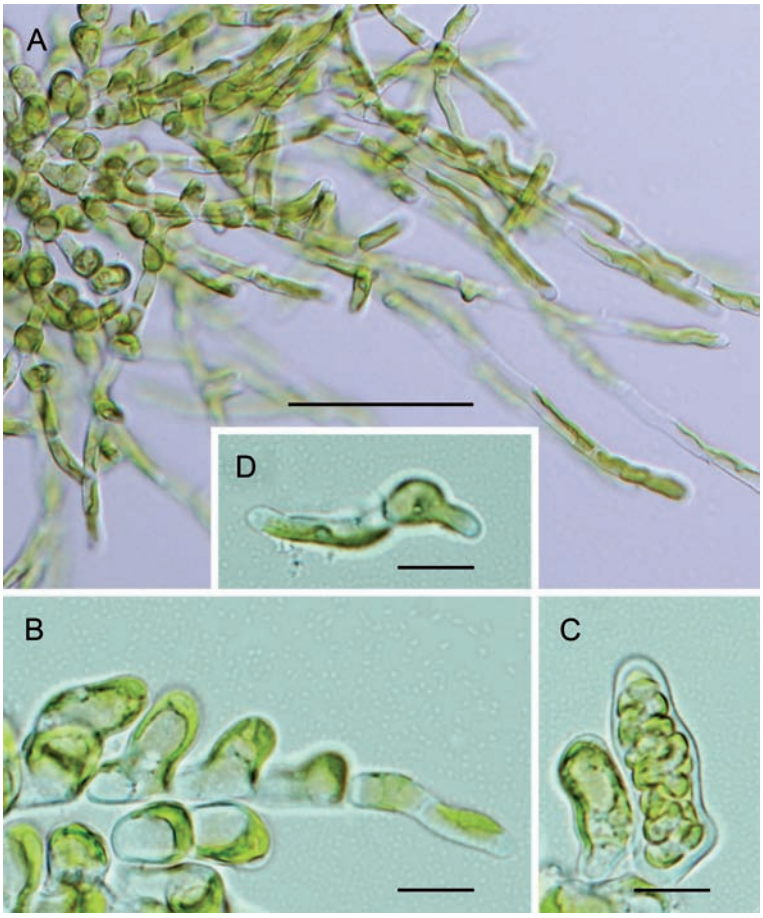

Fig. 4. *Dilabifilum arthropyreniae*, strain IS07005-1-2. A. Part of a large plant. B. Distal branch. Note the shape of growth. 1 pyrenoid per cell. C. Sporangium. D. Two celled plant. Scale bars = 50 µm (A), 10 µm (B–D).

The plants resembled those described by Visher (1953) and Tschermak-Woess (1970) and plants of the original isolate (467-2) obtained from the Culture Collection of Algae (SAG), the University of Göttingen.

Occurred on a wooden pole in the upper littoral zone at station 48 (cf. Fig. 1 and Table 1).

****Pseudendoclonium dynamenae*** R.Nielsen

Recorded in nature within the theca of the hydrozoan *Dynamena pumila* (Linnaeus, 1758), where plants had openly branched peripheral filaments of cylindrical cells 2.5–4 µm in width and a dense central part of rounded cells 5–7.5 µm in diameter (Fig. 5A).

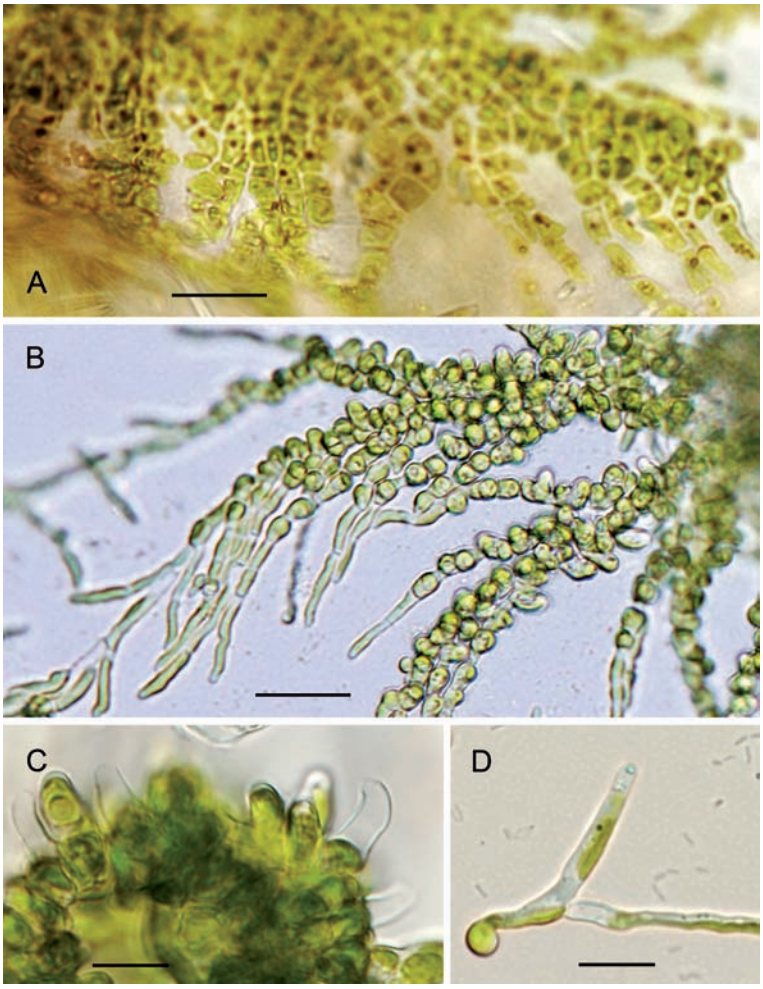

Fig. 5. *Pseudendoclonium dynamenae.* A. Vegetative plant in theca of *Dynamena pumila*, slide preparation in KARO, strain IS05047. B. Morphology in culture, strain IS06003-1. C. Part of plant with mature and empty sporangia, strain IS06003-1. D. Young plant, strain IS06003-1. Scale bars = 50 µm (A, B), 10 µm (C, D).

In culture, a pseudoparenchymatous basal layer formed in contact with a solid substratum (Fig. 5B). Elongate sporangia with a conical top develop from the middle rounded cells. They contained only few spores at maturity (Fig. 5C). Zoospores with 4 flagella were observed. After germination, the spores remained part of the young plants (Fig. 5D) but we did not find an empty sporewall as reported by Nielsen (1984).

In the littoral zone and at 2 m depth at the following sites (cf. Fig. 1 and Table 1): 6, 7, 10, 12, 13, 14, 28, 46, 48, 49, 50, 51, 54.

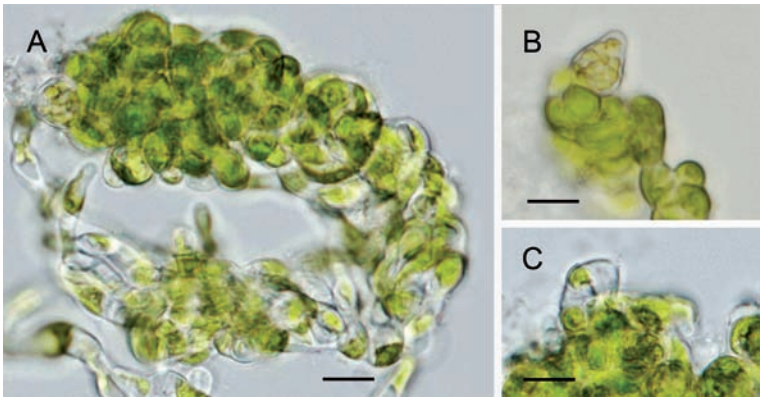

Fig. 6. *Pseudendoclonium fucicola,* strain IS99012-85-1. A. A lumpy plant with mutually free curved filaments. B. Sporangium. C. Empty sporangium. Scale bars = 10 µm.

Pseudendoclonium fucicola (Rosenvinge) R.Nielsen (= *Pseudopringsheimia fucicola* (Rosenvinge) Wille, *Ulvella fucicola* Rosenvinge)

Recorded in nature as a green powder-like cover on *Fucus vesiculosus* Linnaeus.

Plants in culture were pseudoparenchymatous with a lumpy growth (Fig. 6A). At the distal part, short filaments had cylindrical cells 5–6 µm in width and 1–2 times as long. Rounded cells in the middle part measured 5–7 µm across. The plants had a dark green colour, with a parietal chloroplast and a single pyrenoid per cell. Sporangia developed from intercalary cells in the middle part. They had a conical top (Figs 6B, 6C).

Our plants resembled those from the northern Kattegat, Denmark studied in culture by Nielsen (1980).

Found on *Fucus vesiculosus* in the littoral zone at the following sites (cf. Fig. 1 and Table 1): 4, 5.

Pseudendoclonium submarinum Wille

Middle part of plants in culture formed masses of rounded cells, 9–12 µm in width. Distal branches and young plants had cylindrical cells 2–4 µm in width and 3–7 times as long (Fig. 7A). Vegetative cells contained a parietal chloroplast with 1–2 pyrenoids. Sporangia formed from the rounded cells, that became slightly elongate at maturity and 7.5–11 µm in width (Figs 7B, 7C). Settled zoospores germinated unilaterally and remained part of the developing plants (Fig. 7D).

The plants from Iceland were similar to cultures initiated from plants collected at the type locality in Drøbak, Norway (Nielsen pers. obs).

Found on a wooden pier in the littoral zone at station nr 27 (cf. Fig. 1 and Table 1).

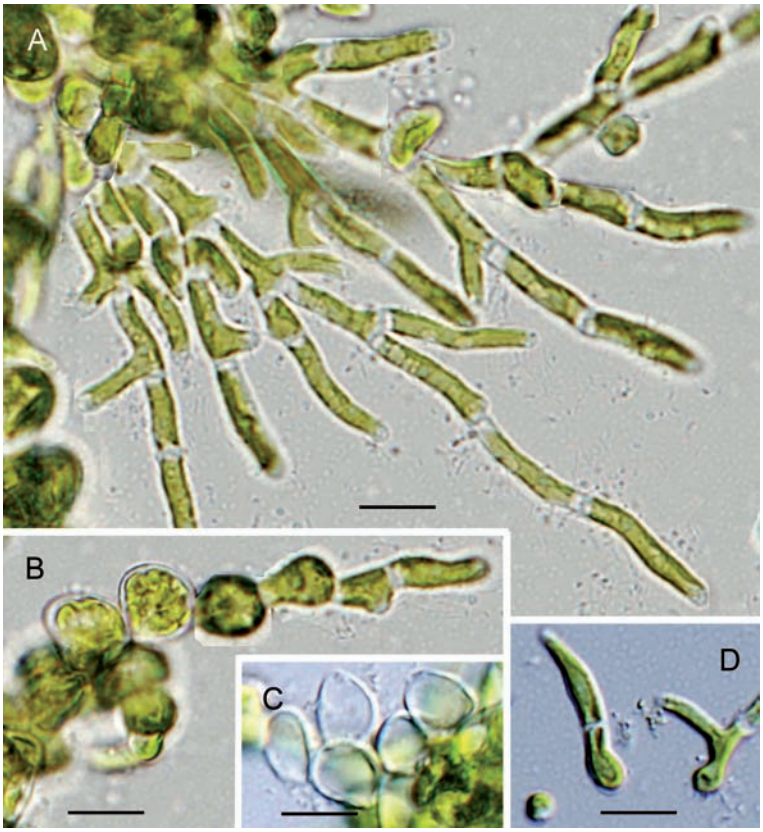

Fig. 7. *Pseudendoclonium submarinum*, strain IS05023-1. A. Distal part of a large plant. Vegetative cells with a single pyrenoid. B. Branch with sporangia. C. Empty sporangia. D. Germlings. Scale bars = 10 μm.

Tellamia contorta Batters

Plants referred to this species occurred in the periostracum of *Littorina obtusata* Linnaeus, 1758 as freely-branched filaments or as dense growth (Figs 8A, 8B, 8C). Opposite branches were commonly observed. Vegetative cells measured 2.5–4 μm in width and were 2–4 times as long, each with a parietal chloroplast and a single pyrenoid. The plants were in agreement with those from Canada, Denmark, France and Great Britain studied by Nielsen & McLachlan (1986b).

Found in the littoral zone at the following sites (cf. Fig. 1 and Table 1): 4, 5, 6, 9, 10, 23.

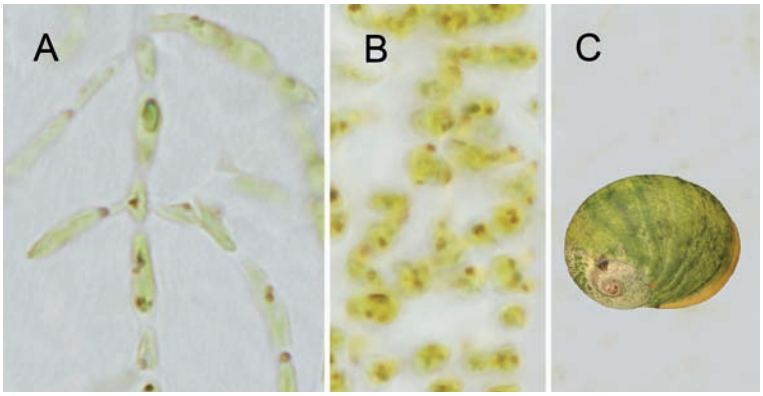

Fig. 8. *Tellamia contorta* in periostracum of *Littorina obtusata*. A. Openly branched filaments with opposite branches, strain IS99001-86. B. Dense plants of a heavy infection, strain IS99003-33. Scale bars = 10 µm. C. *L. obtusata* infested with *T. contorta*. The maximum diameter of *L. obtusata* is 11 mm.

Phaeophilaceae

****Phaeophila dendroides*** (P.Crouan & H.Crouan) Batters

Plants referred to this species were found in calcified tubes of *Spirorbis* sp. and mollusc shells. Branched filaments of cylindrical cells measured 11–13 µm in width, each cell had several pyrenoids. The wavy, twisted *Phaeophila*-type hairs were observed on vegetative cells.

Plants in culture had a similar morphology, vegetative cylindrical cells, 11–13 µm in width, each of them with many pyrenoids in a parietal, reticulate, chloroplast (Fig. 9A). Twisted *Phaeophila*-type hairs developed from vegetative cells (Fig. 9B). Sporangia formed from intercalary cells which became rounded, and had a relatively long exit-tube at maturity (Figs 9C, 9D). In young plants an evacuated zoospore-wall and germination tube were present. Plants studied agreed with those from Denmark studied by Nielsen (1972).

Found in the littoral zone at the following sites (cf. Fig. 1 and Table 1): 8, 9, 10, 12, 15, 22, 44, 52.

Ulvellaceae

Epicladia flustrae Reinke

Pseudoparenchymatous plants with mutually free alternately branched filaments at the margin observed in the zooecium of *Flustra foliacea* (Linnaeus, 1758) (Figs 10A, 10B). Cylindrical cells of the filaments measured 2.5–4 µm in width and were 3–6 times as long. The vegetative cells contained a parietal chloroplast with one pyrenoid. Cells of the central part were polygonal and measured 7–17 µm in width. Sporangia were of similar shape and size (Fig. 10B). Plants agreed with those from Denmark studied by Nielsen (1984).

Found at 5 to 30 m depth at the following sites (cf. Fig. 1 and Table 1): 1, 4.

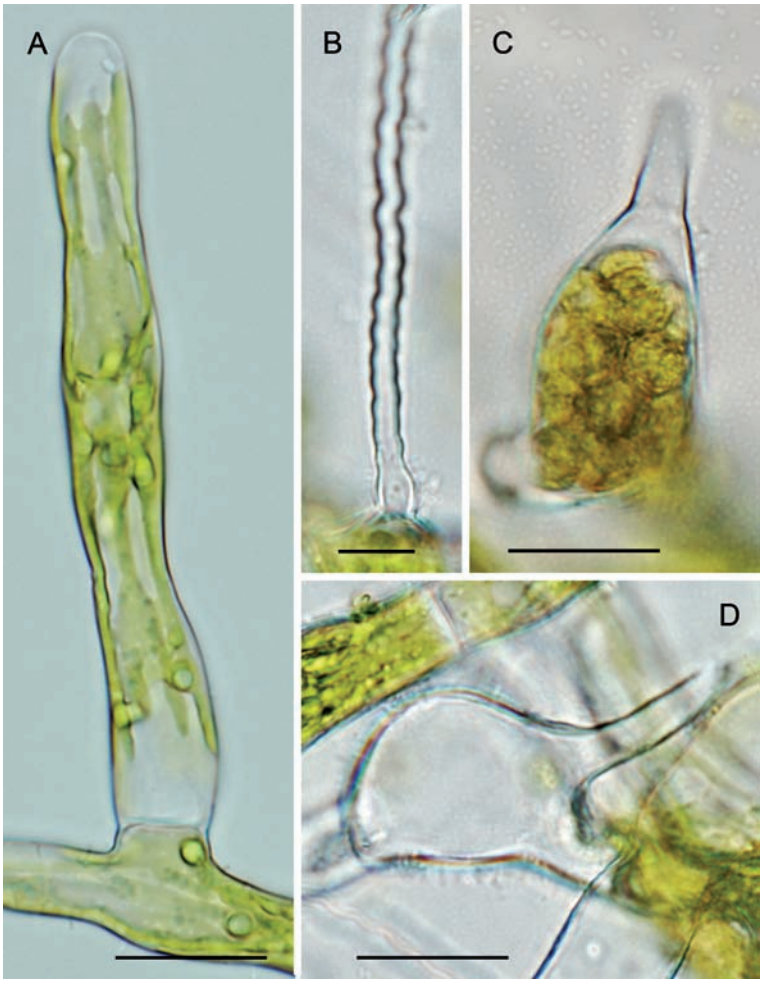

Fig. 9. *Phaeophila dendroides*, strain IS05024-2. A. Vegetative cells with a parietal lobed and perforated chloroplast with many pyrenoids. B. Twisted *Phaeophila*-type hair. C. Mature sporangium. D. Empty sporangium. Scale bars = 20 µm (A, C, D), 10 µm (B).

Epicladia heterotricha (Yarris) R.Nielsen

Plants in culture formed an attached pseudoparenchymatous layer of radiating branched filaments in contact with a solid substratum (Fig. 10C, 10G). Upright filaments formed bushes of alternate or sometimes opposite branches. Distal filaments consisted of cylindrical cells 2–4 µm in width and 3–12 times as long. Middle cells were relatively short and broad, 5–7 µm in width. Vegetative cells contained a parietal chloroplast with 1(–2) pyrenoids (Fig. 10D). Sporangia developed from intercalary cells, measured 7.5 × 10 µm and formed conical exit tubes (Fig. 10E). Zoospores remained part of the

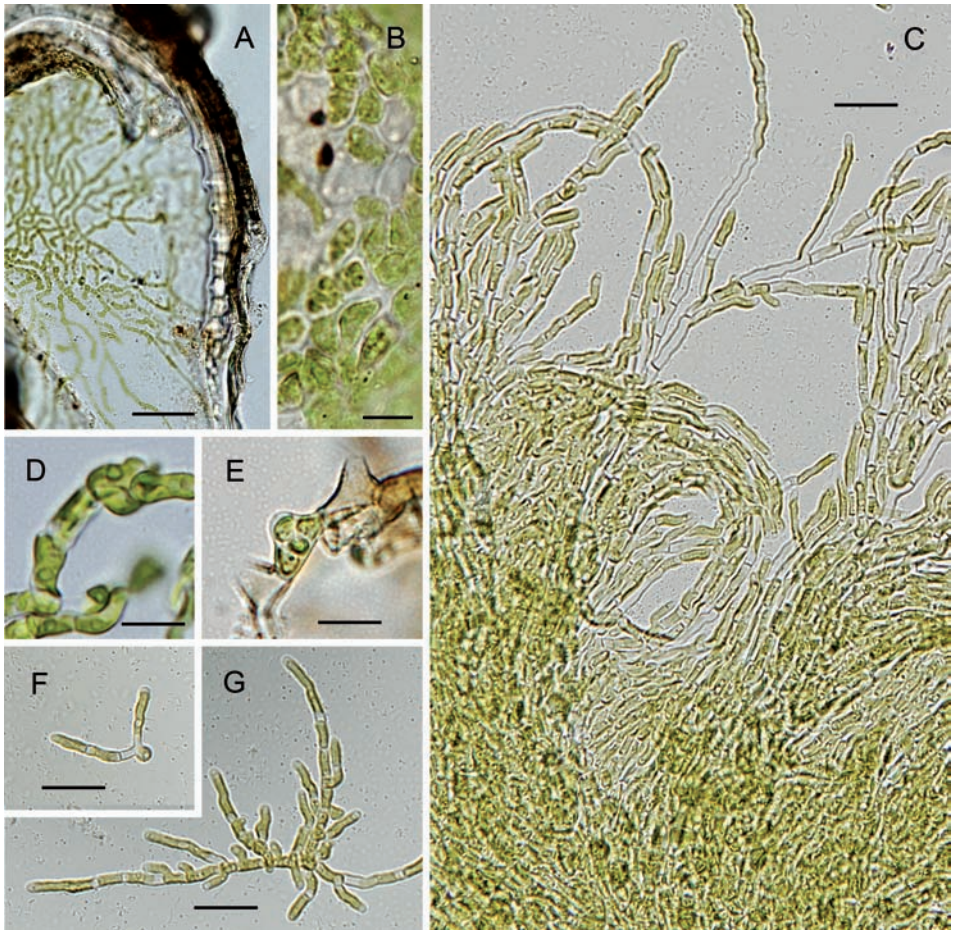

Fig. 10. *Epicladia flustrae* in hydrotheca of *Flustra foliaceae*. Slide preparation in KARO, strain IS99018-03. A. Vegetative filaments. B. Mature and empty sporangia. *Epicladia heterotricha*. C. Part of vegetative plant attached to solid substratum, strain IS06013-2-1. D. Vegetative cells with a parietal chloroplast and a single pyrenoid, strain IS99001-98-1. E. Mature and emptied sporangia, strain IS06007-2-1. F, G. Young plants, strain IS06007-2-1. Scale bars = 50 µm (A), 20 µm (C, F, G) 10 µm (B, D, E).

developing plants after germination (Fig. 10F). Plants agreed with those from Finland studied by Nielsen (1988).

Found in the littoral zone and in the sublittoral zone to 33 m depth, growing on *Laminaria* stipes, the red algae *Phycodrys rubens* (Linnaeus) Batters, *Fimbrifolium dichotomum* (Lepechin) G.I.Hansen and *Ceramium virgatum* Roth and on polychaete tubes.

Recorded at the following sites (cf. Fig. 1 and Table 1): 6, 28, 30, 33, 40.

Syncoryne reinkei R.Nielsen & P.M.Pedersen

Epiphytic, monostromatic rosettes measuring up to 125 µm in diameter, with mutually free marginal filaments, 5–7 µm in width (Fig. 11A). Cells in the central region of mature plants were club-shaped 6–13 µm in width and up to 20 µm high, developing into sporangia of the same size and shape. Vegetative cells had a parietal chloroplast with one pyrenoid. In the central club-shaped cells the chloroplasts were in the upper end of the cells and appeared cup-shaped with one pyrenoid. Mature plants with emptied sporangia had a bleached central area (Fig. 11B).

Plants in culture developed a similar size and morphology when growing attached to a solid substratum (Figs 11C, 11D). When growing unattached they appeared as short alternately branched filaments or became a little lumpy. Mature club-shaped sporangia were up to 20 × 37 µm tall. Quadriflagellate zoospores with red eyespots were observed. After settlement they germinated by enlargement into young plants, consisting initially of two semi-circular cells. Plants both in nature and culture agreed with those from Denmark studied by Nielsen & Pedersen (1977).

Found in the littoral zone epiphytic on *Phycodrys rubens*, *Polysiphonia stricta* (Dillwyn) Greville, *Antithamnionella floccosa* (O.F.Müller) Whittick, *Rhodochorton purpureum* (Lightfoot) Rosenvinge, *Odonthalia dentata* (Linnaeus) Lyngbye, *Erythrodermis traillii* (Holmes ex Batters) Guiry & Garbary and *Sphacelaria* sp.

Recorded at the following sites (cf. Fig. 1 and Table 1): 4, 5, 6, 9, 12, 28, 33, 34, 45, 49, 52, 55.

H.Jónsson (1903) recorded *Ulvella scutata* (Reinke) R.Nielsen, C.J.O'Kelly & B.Wysor (as *Pringsheimia scutata* Reinke) in SW and NW-Iceland. Re-examination of the specimens referred to by H.Jónsson kept in (C) revealed it to be *S. reinkei* (cf. Gunnarsson & S.Jónsson 2002) separated from *U. scutata* by Nielsen & Pedersen (1977).

****Ulvella elegans*** R.Nielsen & Gunnarsson

Plants in culture formed monostromatic rosettes with a dense central area of rounded cells surrounded by mutually free filaments at the border (Figs 12A, 12B) or the plants grew unattached as uniseriate branched filaments. Branches were alternate or opposite with almost cylindrical cells 3.5–6.5 µm wide and 2–4 times as long, the rounded middle cells 10.5–12.5 µm across. The vegetative cells contained a parietal chloroplast with one pyrenoid. Hairs have not been observed. Sporangia developed from the rounded cells and became almost barrel shaped, 11–13.8 µm tall, with a conical apex (Fig. 12C). Settled spores germinated unilaterally, an evacuated, often brown pigmented, spore-wall and a germtube were visible in young plants (cf. Nielsen et al. 2014).

Found at 30 m depth growing on a polychaete tube at station nr 32 (cf. Fig. 1 and Table 1).

****Ulvella heteroclada*** (J.A.Correa & R.Nielsen) R.Nielsen, C.J.O'Kelly & B.Wysor

Plants in culture formed a pseudoparenchymatous layer with mutually free filaments at the margin in contact with a solid substratum (Fig. 12D). The distal cylindrical cells were 3–5 µm in width and c. 4 times as long. The middle part of larger plants

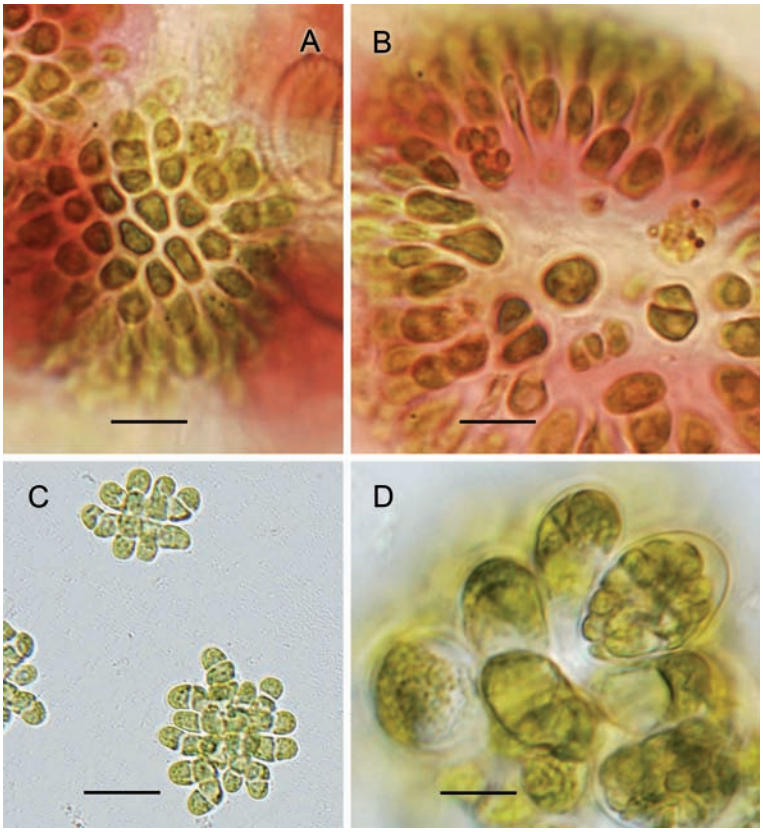

Fig. 11. *Syncoryne reinkei*. A, B. Vegetative and mature plants, epiphytic on *Polysiphonia stricta*, strain IS99017-64. C. Vegetative plants, strain IS99017-64-1. D. Mature plant with a club shaped sporangium, strain IS07026-2-1. Scales = 10 µm (A, B, D), 20 µm (C).

consisted of upright relatively broad filaments; the cells were 7–10 µm in width and up to 2 times as long (Fig. 12E). A parietal chloroplast with one pyrenoid occurred in cells of the narrow filaments while the chloroplast of cells of the broad filaments contained 1–3 pyrenoids. Free floating plants had similar filaments. *Acrochaete*-type hairs formed on apical cells of upright filaments (Fig. 12F). Sporangia were elongate, tapering upwards and formed apically on upright branches (Fig. 12G). Plants were in agreement to those described from *Chondrus crispus* Stackhouse in Canada by Correa et al. (1988).

Found in the littoral zone on *Chondrus crispus, Rhodochorton purpureum, Cystoclonium purpureum* (Hudson) Batters, *Scytosiphon lomentaria, Fucus serratus* Linnaeus and mollusc shell.

Recorded at the following sites (cf. Fig. 1 and Table 1): 5, 8, 9, 10.

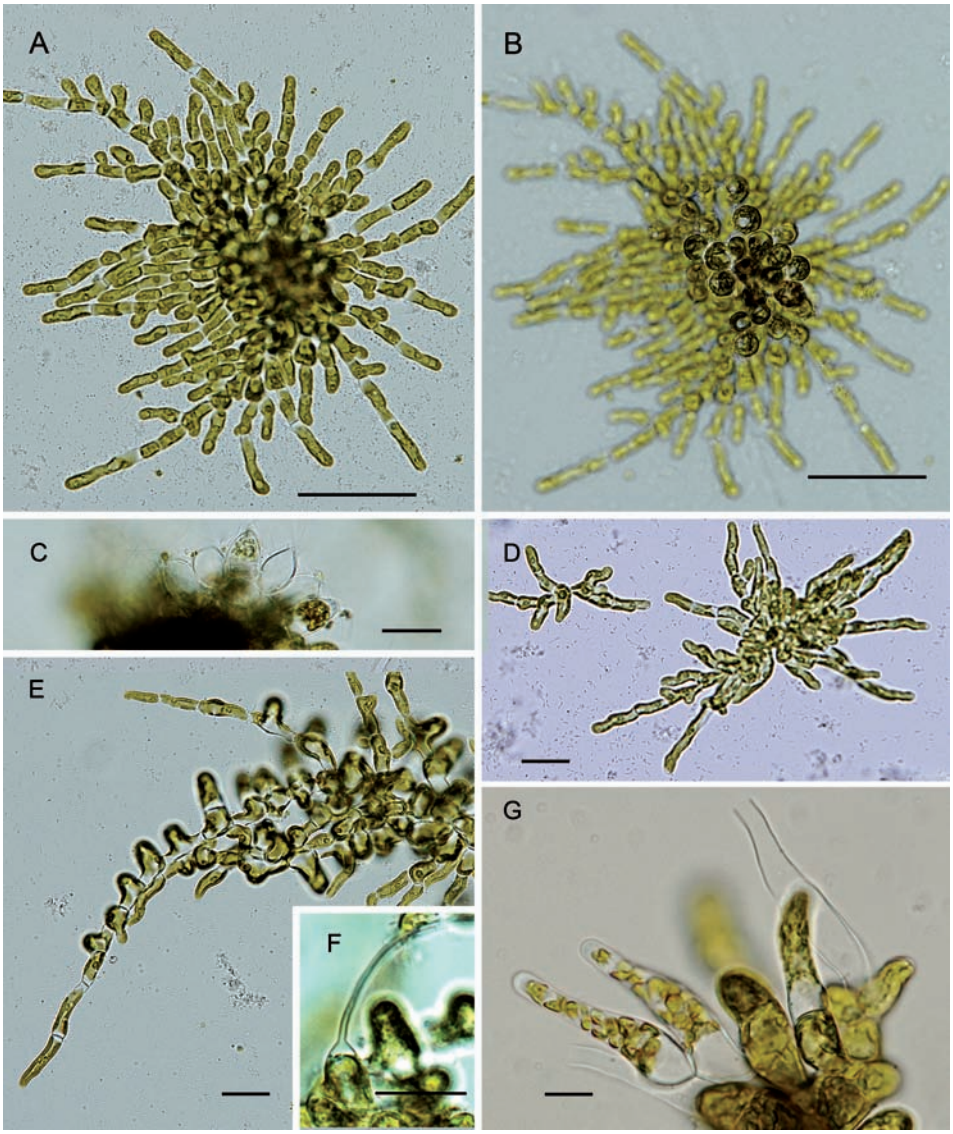

Fig. 12. *Ulvella elegans*. A, B. Mature plant, shown in different focus, with mutually free distal filaments and pseudoparenchymatous central area with rounded sporangia. C. Barrel shaped mature and empty sporangia. *Ulvella heteroclada*. D. Young vegetative plants attached to a solid substratum, strain IS99003-64-1. E. Heterotrichous growth, strain IS05046-4. F. Apical *Acrochaete*-type hair, strain IS05046-4. G. Mature and emptied sporangia, strain IS05046-4. Scale bars = 50 µm (A, B), 20 µm (C–F), 10 µm (G).

Ulvella islandica R.Nielsen & Gunnarsson

Plants in culture were heterotrichous consisting of dense tufts of broad erect filaments and rhizoidal narrow branched filaments given off from broad basal cells (Fig. 13A, 13B, 13C). The cylindrical cells of erect filamens were 10–15 µm wide, with rounded cells at base, 20–32 µm across. The rhizoidal filaments were irregularly branched, they consisted of cylindrical cells of 4.5–6 µm wide (Fig. 13B). Vegetative cells contained a parietal, slightly lobed chloroplast with 1(–3) pyrenoid(s). Sporangia developed from similar cells and became elongate, linear-cylindrical, with an apical pore at maturity (Fig. 13C). *Acrochaete*-type hairs occurred apically on cells of broad filaments (Fig. 13D). Brown-pigmented evacuated spore walls were attached to germlings (Fig. 13E) (cf. Nielsen et al. 2014).

Found at 1–5 m depth growing on *Euthora cristata* (C.Agardh) J.Agardh at station nr 32 (cf. Fig. 1 and Table 1).

Ulvella operculata (J.A.Correa & R.Nielsen) R.Nielsen, C.J.O'Kelly & B.Wysor (= *Acrochaete operculata* J.A.Correa & R.Nielsen)

Observed as an endophyte of *Chondrus crispus* with narrow filaments 2.5–3 µm in width growing through the medulla of the host and few-celled broader filaments 4–6 µm in width among cortical cells.

Plants in culture consisted of openly branched filaments of narrow long cells with rounded swellings at irregular intervals (Fig. 14A). The branches were usually alternate but opposite branches also occurred. The narrow parts of cells measured 2.5–5 µm in width and were up to 40 µm long. Cells with swellings were most frequent in the middle part of the plants and measured 12–20 µm in width. Vegetative cells contained a parietal chloroplast with 1–3 pyrenoids. Sporangia formed from the swollen cells. Each empty sporangium had a brown coloured apex and a lid-like structure (Figs 14B, 14C). In young plants, an evacuated spore wall and a germination tube were present (Fig. 14D). Plants were in agreement with those described from *Chondrus crispus* in Canada by Correa et al. (1988).

The species was found growing in the littoral zone at the following sites (cf. Fig. 1 and Table 1): 2, 6, 9, 10.

Ulvella parasitica (Oltmanns) R.Nielsen, C.J.O'Kelly & B.Wysor (= *Acrochaete parasitica* Oltmanns)

Middle part of plants in culture consisted of short branches of rounded cells 20–25 µm in width. Short radiating filaments of cylindrical cells 8–11 µm in diameter grew at the margin. *Acrochaete*-type hairs occurred apically on cells of the middle part (Fig. 15A). One to three pyrenoids were present in each cell (Fig. 15B). Sporangia formed from the rounded cells and became club shaped or oblong 12.5 µm in width and 27 µm long (Fig. 15C). Plants were in agreement with those from Denmark studied by Nielsen et al. (2013).

Found in the littoral zone endophytic in *Fucus* sp., *Petalonia fascia* and *Scytosiphon lomentaria*.

Found at the following sites (cf. Fig. 1 and Table 1): 5, 10, 35, 45.

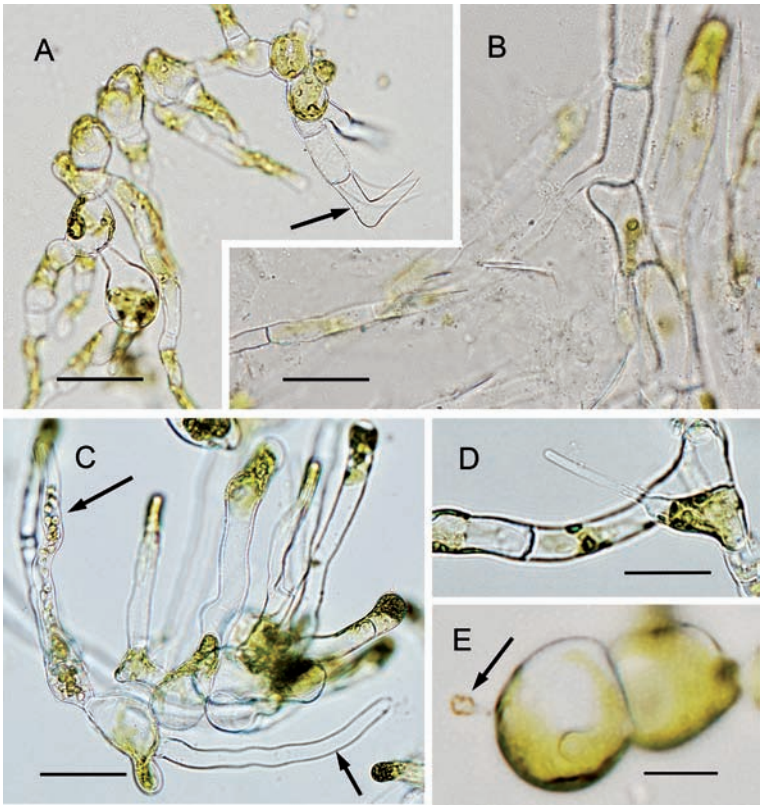

Fig. 13. *Ulvella islandica*, A. Broad rounded cells and narrow distal filaments. Empty sporangia (arrow). B. Cylindrical vegetative cells with rhizoid-like filaments. C. Tuft of cylindrical cells with rounded cells at the base. Mature and empty sporangia (arrows). D. *Acrochaete*-type hair. E. Germling with evacuated spore-wall attached (arrow). Scale bars = 50 µm (A, C), 25 µm (B), 20 µm (D), 10 µm (E).

****Ulvella pseudorepens*** R.Nielsen

Plants in culture formed tufts of upright filaments 7.5–10 µm in diameter (Fig. 16A) sometimes with apical *Acrochaete*-type hairs (Fig. 16B). Radiating filaments of cylindrical cells occurred at the base of the upright branches. Vegetative cells contained 3–8 pyrenoids in a reticulate, parietal chloroplast (Fig. 16C). Sporangia formed from apical cells of broad filaments, and were elongate and slightly tapering towards the apex (Fig. 16D). Empty spores were separated from living cells of germlings by a cell wall (Fig. 16E). Plants were in agreement to those described from Denmark by Nielsen et al. (2013).

Found in the littoral zone growing on the theca-walls of *Dynamena pumilla*, and on *Scytosiphon lomentaria* and *Stictyosiphon tortilis* (Gobi) Reinke.

Recorded at the following sites (cf. Fig. 1 and Table 1): 5, 9, 10.

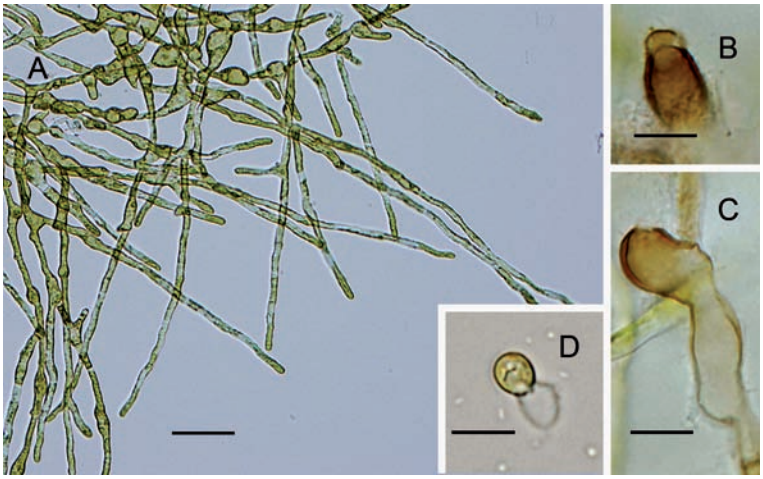

Fig. 14. *Ulvella operculata*, strain IS99017-62-1. A. Vegetative plant. B. Apical part of an empty sporangium, note the lid-like structure. C. Irregularly shaped, intercalary, empty sporangium. D. Germling with an evacuated spore-wall. Scale bars = 20 µm (A), 10 µm (B–D).

Ulvella ramulosa (L.Moewus) R.Nielsen, C.J.O'Kelly & B.Wysor

Plants in culture formed small tufts of radiating filaments with cylindrical cells, 2–5 µm in diameter and 2 times as long. Middle parts of plants had rounded cells 8–10 µm in width. Vegetative cells contained a parietal chloroplast with one pyrenoid (Fig. 17A). *Acrochaete*-type hairs occurred on intercalary rounded cells, with two merocytic extensions sometimes observed from the same bulbous base (Fig. 17B). Sporangia formed from intercalary rounded cells and became bottle-shaped with a conical exit tube (Fig. 17C). They measured 8–10 µm in width.

The specimens agreed with the delimitation of this species by Nielsen et al. (2013) and with the original description by Moewus (1949).

Found in the littoral zone, growing in *Erythrodermis traillii* at the sampling site nr 15 (cf. Fig. 1 and Table 1).

****Ulvella reticulata*** (Printz) R.Nielsen, C.J.O'Kelly & B.Wysor

Plants in culture formed tufts of radiating filaments (Fig. 17D). The distal cells measured 13–20 µm in width and were 1.5–4 times as long. Cells in the middle parts were rounded, almost globular, 22–28 µm in width. Each vegetative cell contained a parietal, reticulate, chloroplast with 3–6 pyrenoids (Figs 17D, 17E). Coarse *Acrochaete*-type hairs developed apically on short filaments or on short extensions of intercalary cells (Fig. 17E). Sporangia developed from the rounded cells and became oblongate or subglobose, c. 25 µm in width, with short conical exit tubes (Fig. 17F). Spores remained part of developing young plants (Fig. 17G). The Icelandic specimens resemble those studied in culture by Nielsen et al. (2013), which were isolated from endophytes of *Laminaria* sp. obtained from Western Norway close to the type locality (Printz 1926).

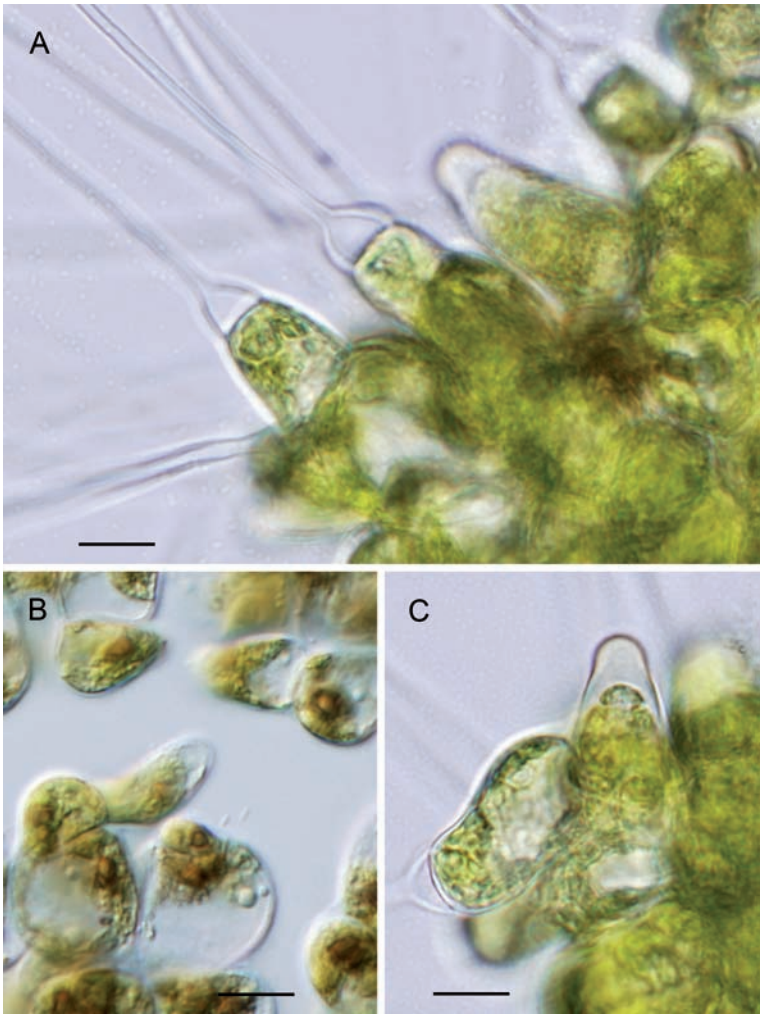

Fig. 15. *Ulvella parasitica*, strain IS06023-1. A. Part of large plant with *Acrochaete*-type hairs. B. Vegetative cells with 1–3 pyrenoids, stained with iodine. C. Mature sporangium. Scale bars = 10 µm.

Found in the littoral and in shallow sublittoral down to 3 m on mollusc shells and *Polysiphonia fucoides* (Hudson) Greville.

Recorded at the following sites (cf. Fig. 1 and Table 1): 17, 24.

Ulvella scutata (Reinke) R.Nielsen, C.J.O'Kelly & B.Wysor (= *Pringsheimiella scutata* (Reinke) Marchewianka, *Pringsheimia scutata* Reinke)

Observed in nature as pseudoparenchymatous monostromatic discs up to 200 µm in diameter, with marginal growth and some bifurcate peripheral cells (Fig. 18A). Cells in

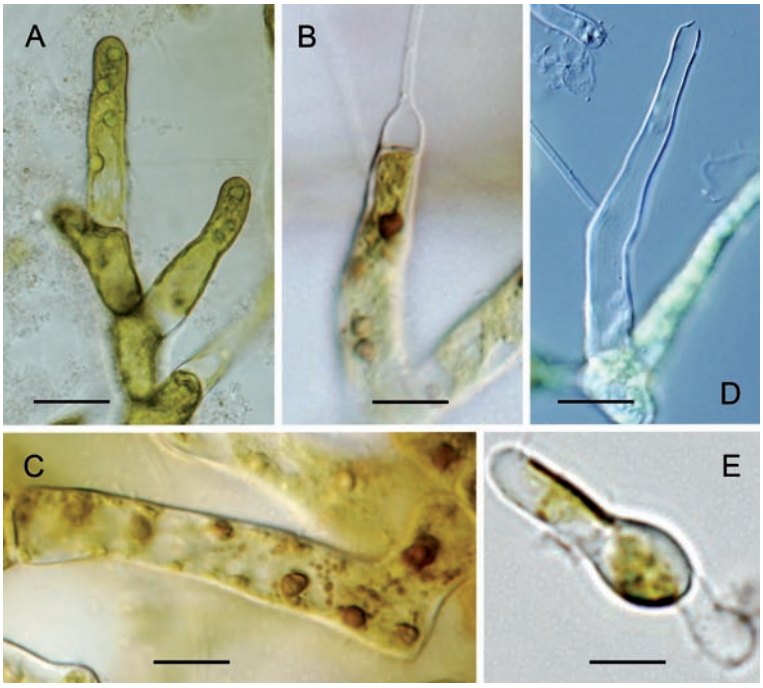

Fig. 16. *Ulvella pseudorepens*. A. Apical vegetative branch, strain IS05050-3. B. Apical *Acrochaete*-type hair, strain IS05050-3. C. Vegetative cell with 8 pyrenoids stained with iodine, strain IS05050-3. D. Empty sporangium, strain IS05050-3. E. Germling, strain IS99003-61-2. Scale bars = 10 µm.

the peripheral region of the discs were 4–5 µm in width and 2–4 times as long. In the middle of the discs, the cells were 4–6.5 µm in width and 1.5–2.5 times as long. Vegetative cells had a parietal chloroplast with one pyrenoid. Centrally placed cells developed into sporangia, thus old plants with evacuated sporangia had an empty central area. Plants were in agreement with those from Denmark studied by Nielsen & Pedersen (1977).

In culture, plants were similar in size and morphology. Hairs were observed on plants kept under strong light conditions.

During the present study *U. scutata* was found epiphytic on the red algae *Ceramium virgatum, Polysiphonia fucoides, Rhodochorton purpureum, Devaleraea ramentacea* (Linnaeus) Guiry from the littoral.

Found at the following sites (cf. Fig. 1 and Table 1): 6, 8, 17, 39.

Ulvella viridis (Reinke) R.Nielsen, C.J.O'Kelly & B.Wysor (= *Acrochaete viridis* (Reinke) R.Nielsen)

Referred to *U. viridis* were plants in culture that formed bushes of radiating filaments of cylindrical cells, 3–5 µm in width and 2–4 times as long (Fig. 18B). In the middle region the cells were rounded 3–7 µm in width and slightly longer than wide.

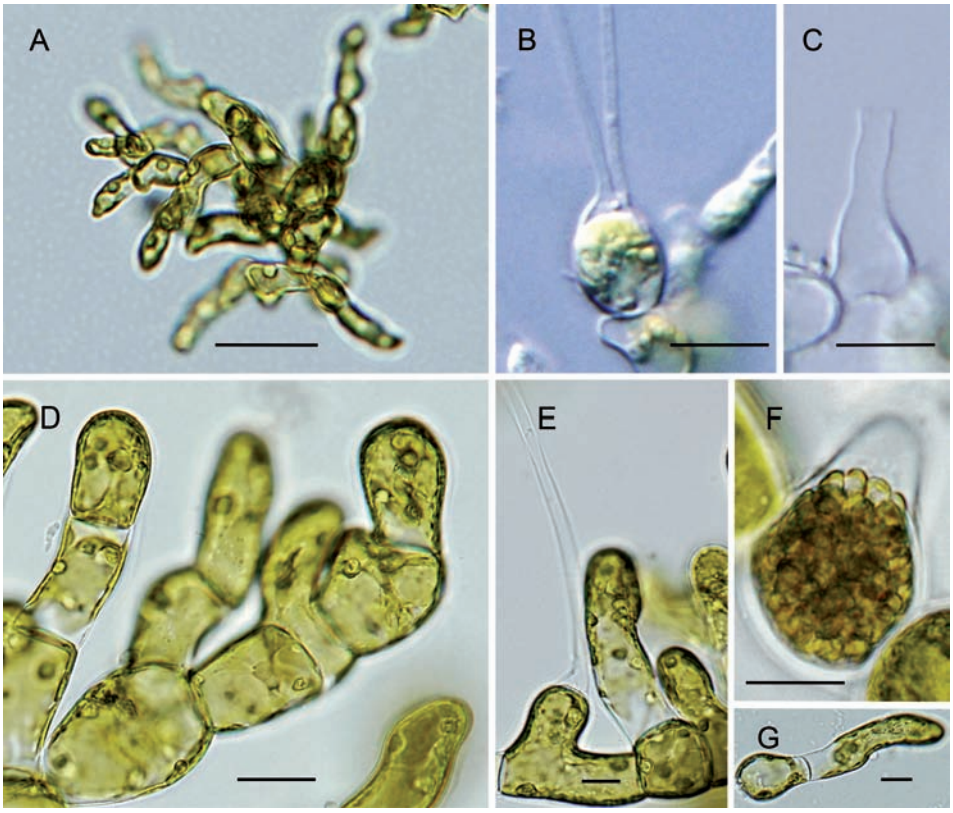

Fig. 17. *Ulvella ramulosa*, strain IS05042-9-1. A. Vegetative plant with a single pyrenoid per cell. B. *Acrochaete*-type hair with two merocytic extensions. C. Empty sporangium. *Ulvella reticulata*, strain IS05012-2-3. D. Vegetative cells with several pyrenoids. E. *Acrochaete*-type hair. F. Mature sporangium. G. Two-celled plant. Original spore remains part of the plant. Scale bars = 20 µm (A, D), 10 µm (B, C, E–G).

Pseudoparenchymatous parts developed in contact with a solid substratum. *Acrochaete*-type hairs developed on intercalary cells (Fig. 18C). Vegetative cells contained a parietal chloroplast, with a single pyrenoid (Fig. 18B). Sporangia developed from intercalary cells. They became bottle-shaped or similar to vegetative cells with an exit tube (Fig. 18D).

Found in the littoral zone and in the sublittoral zone to 30 m depth, growing in various species of red algae and in *Laminaria hyperborea* (Gunnerus) Foslie.

Found at the following sites (cf. Fig. 1 and Table 1): 10, 15, 28, 33, 36, 37, 43, 45.

Ulvella wittrockii (Wille) R.Nielsen, C.J.O'Kelly & B.Wysor (= *Acrochaete wittrockii* (Wille) R.Nielsen, *Ectochaete wittrockii* (Wille) Kylin, *Entoderma wittrockii* (Wille) Lagerheim)

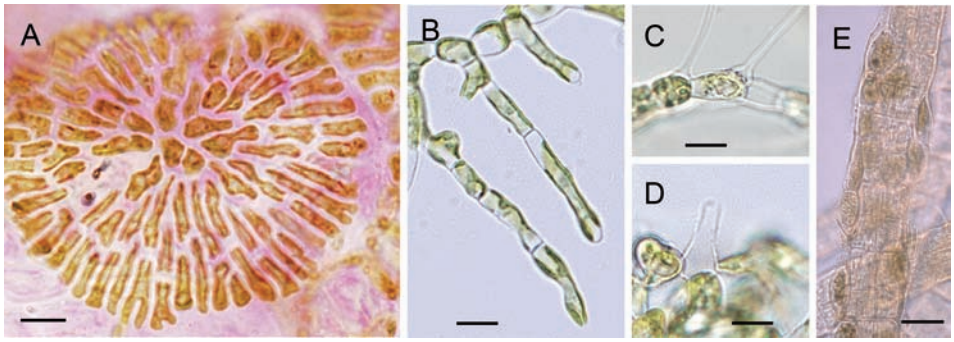

Fig. 18. *Ulvella scutata.* A. Plant epiphytic on *Devalerea ramentacea*, slide preparation in KARO®, strain IS99001-98-2. *Ulvella viridis.* B. Vegetative cells with a single pyrenoid, strain IS07012-2. C. *Acrochaete*-type hairs on intercalary cells, strain IS07012-2. D. Empty sporangium, strain IS06001-1-2. *Ulvella wittrockii.* E. Vegetative cells and a mature sporangium in cell wall of *Protohalopteris radicans*. Scale bars = 10 µm (A–D), 5 µm (E).

Little branched, uniseriate filaments were observed in the cell walls of various filamentous brown algae (Fig. 18E). Vegetative cells were 5–8 µm in width and 1.5–2.5 times as long. *Acrochaete*–type hairs occurred on intercalary cells. Sporangia were intercalary, formed by transformation of vegetative cells, conical, 8 µm high and 16.5 µm in length (Fig. 18E). The Icelandic specimens resemble those from Denmark studied in culture by Nielsen (1983).

Found in the littoral zone and in the sublittoral to 9 m in the walls of brown filamentous species, such as *Ectocarpus* spp., *Pylaiella littoralis* (Linnaeus) Kjellman, *P. varia* Kjellman, *Stictyosiphon tortilis, Fosliea curta* (Foslie) Reinke and *Protohalopteris radicans* (Dillwyn) Draisma, Prud'homme van Reine & H.Kawai.

Recorded at the following sites (cf. Fig. 1 and Table 1): 9, 11, 13, 14, 18, 25, 26, 28, 30, 46, 48, 51, 54.

Bryopsidales

Ostreobiaceae

Ostreobium queketti Bornet & Flahault

Siphonous filaments, with reticulate branching pattern (Fig. 19A). Filaments were 1–4 µm in width. Irregularly formed sporangia up to 82 µm in width were observed (Fig. 19B).

Found in mollusc shells or other calcified organisms, especially common in calcified polychaete tubes. Found from the littoral and sublittoral zone to 30 m depth. Plants both in nature and culture agreed with those from Helgoland studied by Kornmann & Sahling (1980).

Recorded at the following sites (cf. Fig. 1 and Table 1): 2, 5, 6, 8, 9, 15, 16, 22, 26, 36, 38, 43, 47, 53.

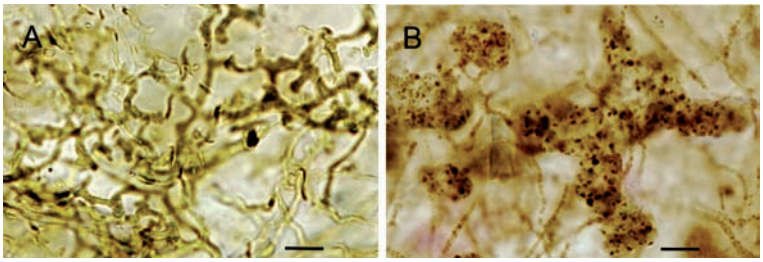

Fig. 19. *Ostreobium quekettii*. A. Reticulate branching pattern of filaments. Slide preparation of decalcified material in KARO®, strain IS06037-32. B. Irregularly shaped sporangia. Decalcified material of *Pomatoceros* sp. in KARO®, strain IS99004-20. Scale bars = 10 µm.

Incertae sedis

Arthrochaete penetrans Rosenvinge

Plants in culture formed tufts of isodiametric filaments with cylindrical cells, 7–10 µm in width and 1–3 times as long (Fig. 20A). Alternate branches were often at 70 to 90° angle to the main axes. When attached to a solid substratum, a pseudoparenchymatous basal layer was formed with cells 1–1.5 times as long as wide (Fig. 20D). Multicellular hairs occurred both on upright branches and from the basal layer (Figs 20B, 20C). The hairs tapered gradually from the slightly swollen base to the apex measuring 4–5 µm in diameter just above the base and 2.5 µm at the apex with cells 10–15 times as long as wide. Each vegetative cell contained a parietal chloroplast with a single pyrenoid (Fig. 20D). Ovoid sporangia, developed from the vegetative cells, they were intercalary or lateral (Figs 20E, 20F).

Plants were in agreement with the original description of *A. penetrans* and from the same host as those described by Rosenvinge (1898) in the Scoresbysund area, East-Greenland.

Found at 12 to 29 m depth as endophytic filaments in *Turnerella pennyi* (Harvey) Schmitz at sampling stations 20 and 36 (cf. Fig. 1 and Table 1)

Discussion

In the present study *Eugomontia sacculata*, *Gomontia polyrhiza*, *Pseudendoclonium dynamenae*, *P. fucicola*, *Tellamia contorta*, *Epicladia flustrae*, *Syncoryne reinkei*, *Ulvella operculata*, *U. scutata*, *U. wittrockii* and *Ostreobium quekettii* were identified in the field collections. *Bolbocoleon piliferum*, *Phaeophila dendroides* and *Arthrochaete penetrans* were also recorded in field collections, but only a few times the characteristic hairs were observed. The culture studies confirmed the identity of these species and additional records were obtained when a species occurred in crude culture, not noticed in the field collections. Records of *Dilabifilum arthropyreniae*, *Pseudendoclonium submarinum*, *Epicladia heterotricha*, *Ulvella elegans*, *U. heteroclada*, *U. islandica*,

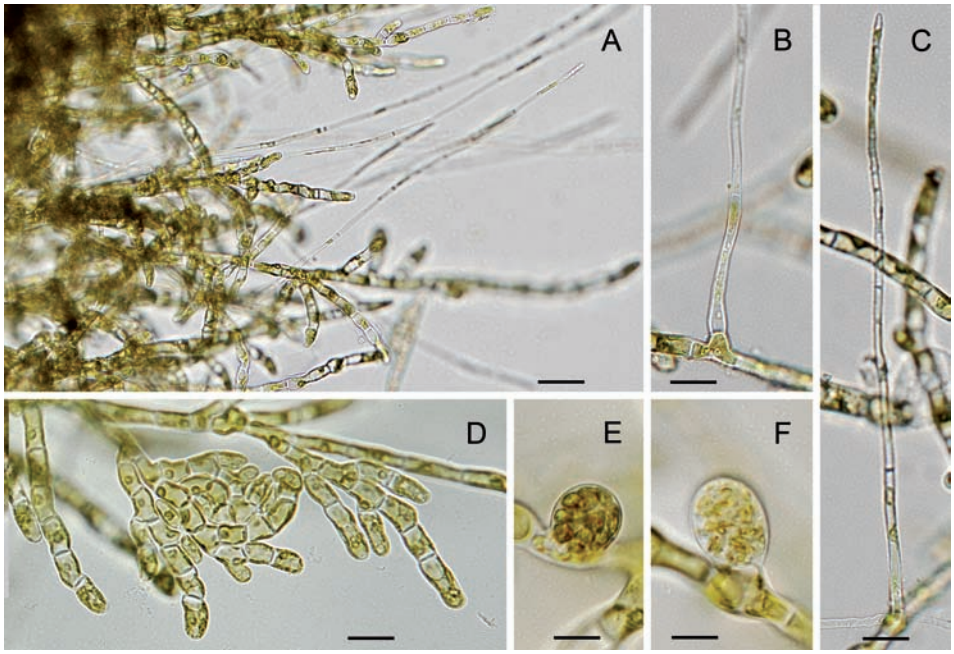

Fig. 20. *Arthrochaete penetrans*, strain IS06037-3-1. A. Vegetative plant with several hairs. B. Basal part of a hair. C. Four-celled young hair. D. Basal layer, 1 pyrenoid per cell. E. Intercalary sporangium. F. Lateral sporangium. Scale bars = 20 µm (A), 10 µm (B–F).

U. parasitica, *U. pseudorepens*, *U. ramulosa* and *U. reticulata* were obtained after the observations of these species in culture.

This is the first time the microfilamentous green seaweeds from Iceland have been studied in culture. A total of twenty-five species were identified, eleven of which were new records for the Icelandic seaweed flora. Additionally H.Jónsson (1903) recorded *Ulvella repens* (Pringsheim) R.Nielsen, C.J.O'Kelly & B.Wysor (as *Acrochaete repens* Pringsheim) and *Ochlochaete hystrix* Thwaites ex Harvey (as *Ochlochaete ferox* Huber), neither of which were found in the present study.

Some of the microfilamentous green algae are host specific as found here in the Icelandic collections as well as according to published records. This concerns *Tellamia contorta* only found in the periostracum of *Littorina obtusata* (6 localities ; Nielsen & Gunnarsson 2001, Nielsen & McLachlan1986), *Pseudendoclonium dynamenae* exclusively found in the theca wall of *Dynamena pumilla* (13 localities; Lein et al. 1999, Nielsen 1984, Nielsen & Gunnarsson 2001) and *Ulvella operculata* always in *Chondrus crispus* (4 localities; Correa et al. 1988, Nielsen & Gunnarsson 2001). *Gomontia polyrhiza*, *Eugomontia sacculata*, *Phaeophila dendroides* and *Ostreobium queketti* are only found in calcareous substrata (8, 11, 8 and 14 localities respectively). Most species are generalists, found on or in various substrata.

Arthrochaete penetrans, is a new record for Iceland. It was described by Rosenvinge (1898) from plants growing on *Turnerella pennyi* in eastern Greenland. Later Lee (1980) also found *A. penetrans* in arctic Canada growing in various red and brown algae. *Arthrochaete penetrans* was described as a member of Chaetophoraceae (Rosenvinge 1898). The multicellular hairs and the sporangia developing into special structures are unique characters for *A. penetrans*. As information on ultrastructure and molecular data are lacking, the proper taxonomic placement of *A. penetrans* awaits future studies.

Dilabifilum was originally considered a member of Chaetophoraceae (Tschermak-Woess 1970). The systematic position of *Dilabifilum*, is uncertain and referred to "*Ulvales incertae sedis*" by Guiry in Guiry & Guiry (2015). Here it is referred to the family Kornmanniaceae, based on morphological similarity with *Pseudendoclonium*. This act is supported by the molecular data obtained by Thüs et al. (2011). They found that several species of *Dilabifilum* form a well suported clade with *Blidingia* and *Kornmannia* as a sister clade. Both of these genera belong in Kornmanniaceae which is here extended to include *Dilabifilum*.

The diversity of the microfilamentous green seaweeds is high, with 25 species being reported in Iceland compared to 18 species in the Faroes (Nielsen & Gunnarsson 2001), 28 in Norway (Printz 1926, Lein et al. 1999, Norwegian Seaweeds website), 22 in Eastern Canada (South 1974, Nielsen & McLachlan 1986a), 14 in Arctic Canada (Lee 1980) and 14 in Greenland (Pedersen 1976). Six species (*Dilabifilum arthropyrenia, Epicladia heterotricha, Ulvella elegans,U. islandica, U. pseudorepens* and *U. ramulosa*) have their northern North-Atlantic records in Iceland. Eight species (*Bolbocoleon piliferum, Gomontia polyrhiza, Ostreobium quekettii, Pseudendoclonium fucicola, P. submarinum, U. scutata, U. viridis* and *U. wittrockii*) have been recorded for all the areas compared. *Ulvella inflata, U. lens* and *Blastophysa rhizopus* which were found in the area but not recorded in Iceland, probably represent warm-water species (Nielsen, pers. observation) with their northern distribution limit south of Iceland; the first two have been recorded in Norway and the third also in Eastern Canada. The only species restricted to Arctic waters is *Arthrochaete penetrans*, recorded in Iceland, Greenland (Lund 1959) and in Arctic Canada (Lee 1980).

Many of the species were impossible to identify from field collections alone and could be identified only after they had been studied in culture in the laboratory, emphasizing the importance of such studies for this group of algae. As species of this group are tiny and for the most part impossible to identify in field collections, the species sampling is somewhat arbitrary. For initiating cultures only small parts from larger substrata or hosts that looked homogenous, were used. Species could therefore easily be overlooked and knowledge of their distribution is still incomplete. This could also explain why two species previously recorded in Iceland (H.Jónsson 1903) were not found during the present study. Numerous unialgal cultures were established during the present study, some of which could not be referred to known species and indicate the presence of additional species.

This paper describes diversity based on morphological observations of plants in nature and culture. Recent molecular studies have revealed considerably higher diversity amongst the microfilamentous green algae than had been known before using only morphological methods (Rinkel et al. 2012, Nielsen et al. 2013, 2014). To correlate the

results of molecular studies with actual plants, observation of morphological characters is needed. For a complete understanding of the biology, taxonomy and biogeography of filamentous green algae, combining the two methods is therefore necessary.

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