The benthic algae of the Bærum basin in the inner Oslofjord

A comparison of eight sites between 1993-94 and 2018

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Abstract

This qualitative study has investigated the type and number of macroalgal species found in tidepools, supralittoral, littoral and upper sublittoral zones down to 3 m depth, of eight coastal sites located within the Bærum basin. The results of this study were compared with previous research on the area, mainly an investigation of the same eight sites, by Jon F. Larsen (1995). This was done in order to determine changes in biodiversity and presence of macroalgae. The investigated area has a long history of eutrophication. Moreover, there is still a profound influence from human activity, such as boat traffic and pollution from the nearby city of Sandvika. The results will give a snapshot of the environmental status of the Bærum basin, using macroalgae communities as environmental indicators. Furthermore, parts of the area are at times highly influenced by freshwater, due to the input of the large Sandvika river. The area stands out by having permanent anoxic conditions below 20 m in some areas, due to its topography. Samples were collected in May and August of 2018 while snorkelling. Every specimen was identified to the lowest taxonomic level possible, using morphological characters. A total of 54 different algal taxa were identified, in addition to one cyanobacterium and one higher plant. This number is slightly lower than the 64 taxa identified during Larsen's (1995) investigation. However, the decline was mainly within the red and green algae groups. There has been a clear reduction in the presence of the unwanted and eutrophication tolerant species *Fucus distichus* subsp. *evanescens* between the two studies. Yet, the presence of the wrack species that indicate good environmental health remains relatively unchanged, with a slight expansion of *Fucus spiralis* and recession of *Fucus serratus* and *Fucus vesiculosus*. The native wrack species *Ascophyllum nodosum* is still absent from the area. Moreover, the presence of the invasive red algae species *Dasya baillouviana* has expanded throughout the entirety of the Bærum basin, apart from Høvikodden. It is from this investigation unclear which drivers have had the most significant impact on macroalgal biodiversity and presence. However, the hot summer of 2018 might have influenced the result. Overall, the environmental status of the algal communities within the Bærum basin does not appear to have improved since 1993-94. Still, further investigations entailing both qualitative and quantitative data, should be compared with this study too broaden the knowledge of their environmental status.

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Table of contents

1. Introduction

1.1 Algae as an environmental indicator

The implementation of protective measures towards preservation and rehabilitation of marine environments, require both suitable and reliable indicators of environmental change. Benthic organisms in shallow coastal areas are readily used as environmental indicators (Edwards, 1972, Fredriksen and Rueness, 1990, McCormick and Cairns, 1994). Moreover, benthic macroalgae are thought to be especially suited to reflect the effects of eutrophication, which is one of the major anthropogenic threats to aquatic ecosystems (McCormick and Cairns, 1994, Diaz and Rosenberg, 2008). Eutrophication is a process in which a body of water becomes overly enriched by nutrients, in particular nitrogen and phosphorus, causing excessive growth of aquatic algae (Chislock, 2013). Benthic algae are particularly suited to indicate the state of this process, because they are directly affected by the increase in nutrients and stay attached to the substrate. Some species of macroalgae, including the wrack and kelp species, are perennial, which make them particularly suitable for long-term monitoring efforts. Mapping and monitoring of algal communities can therefore be a viable tool for quantifying the Earth's aquatic environmental status. Furthermore, algal indicators can be used to assess the effectiveness of already implemented regulations designed to rehabilitate damaged ecosystems (Fredriksen and Rueness, 1990, McCormick and Cairns, 1994).

1.1.1 Effects of eutrophication

Human intervention and activity can cause unnatural and accelerated eutrophication (Gorman and Connell, 2009). This change in nutrient composition can have a wide range of adverse effects on aquatic ecosystems, including changing the competitive relationship between different algal species (Rueness, 1973). Opportunistic algal species, usually belonging to the green algae group, grow fast and have short lifespans. This makes them better adapted to taking advantage of the increased nutrient availability, allowing them to outcompete the previously dominant species – the K-selected species (Grenager, 1957, Bokn and Lein, 1978, Klavestad, 1978, Larsen, 1995). Eutrophication can therefore change the algal community from a perennial dominant to an annual dominant community. The opportunistic group of algae can grow on both rocks (epilithically) or other algae and plants (epiphytically) forming a dense layer of filaments, plumes and branches collectively known as turf. The resulting overgrowth may completely cover the substrate needed for spore settlement and zygote germination of slow growing canopy-forming algal species (Rueness, 1973, Connell and Russell, 2010). Furthermore, the resulting turf causes sediment accumulations, which reduces germination rates and survival of the slow growing species (Gorman and Connell, 2009, Filbee-Dexter and Wernberg, 2018). Already established macrophyte individuals may also suffer from reduced photosynthetic ability and nutrient absorption due to this epiphytic growth (Kangas, 1982, Sundene, 1973, Moy and Christie, 2012).

To clarify, turf algae is a collective term that describe a diverse group of opportunistic macroalgae, with similar morphologies and ecological traits, that do not form three-dimensional canopy seascapes (Filbee-Dexter and Wernberg, 2018). Eutrophication may change healthy, canopy forming kelp and wrack communities into low-productivity, biodiversity-poor wastelands of algal turf (Connell et al., 2014). The effects appear to intensify in shallow areas of protected fjords, due to higher water temperatures and low wave action (Filbee-Dexter and Wernberg, 2018).

There is a variety of physicochemical, biotic and abiotic factors that determine the spatial occupation and boundaries of different species in the euphotic zone. The euphotic zone of the benthic realm is the layer that receives enough light to sustain the photosynthetic requirements of aquatic autotrophic organisms, such as algae (Lüning, 1990). The supralittoral and upper littoral zones are mainly determined by abiotic factors, such as extreme temperatures and desiccation. The lower levels, such as littoral and sublittoral are typically determined by competitive ability of species and light conditions (Lüning, 1990). Algae that can tolerate drought and high temperature will therefore often be found in the upper levels, since they cannot compete with the competitively superior species found in the lower littoral zone. Similarly, species that tolerate low levels of light are often found in the deeper zones. Not necessarily because they prefer these conditions.

Areas effected by eutrophication will have increased phytoplankton densities, resulting in reduced light penetration. This will decrease the depth of which macroalgae can grow and survive (Fredriksen and Rueness, 1990, Kautsky et al., 1992, Vogt and Schramm, 1991). Additionally, densities of filter-feeders such as blue mussels, may also increase due to the upsurge in phytoplankton, further affecting the macroalgae by elevating the competition for substrate (Bjerkeng and Kirkerud, 1994, Moy, 1985).

1.1.2 Ecosystem services of canopy forming macroalgae

Seaweeds such as kelp and wrack provide several ecosystem-services that are vital to many costal ecosystems. The macroalgae vegetation produced by these species form biogenic three-dimensional structures essential for several algae and animals inhabiting rocky shores (Christie et al., 2009, Hop et al., 2012, Lippert et al., 2001, Carlsen et al., 2007, Teagle et al., 2017). The canopy provide refuge for fish, gastropods and crustaceans (Duffy and Hay, 1991, Martin-Smith, 1993, Teagle et al., 2017) as well as a point of attachment for many epiphytes and filter-feeders (Hayward, 1980). Herbivores gastropods, isopods and sea urchins can graze directly upon the algal vegetation, including the green algae (Lein, 1980, Fredriksen, 2003, O' Brien and Scheibling, 2016). This grazing can in some instances help to keep the wrack species free from excessive epiphyte growth (Barker and Chapman, 1990, Norton et al., 1990).

1.2 History of eutrophication in the inner Oslofjord

From the early 1900s to 1970, there was a large increase in sewage waste entering the inner Oslofjord. The introduction of the flush toilet and a continued increase in industry and households resulted in large amounts of phosphorus and nitrogen entering the fjord system (Baalsrud and Magnusson, 2002). Sludge from treatment plants and septic tanks were dumped into the surface water of the fjord. At its worst, the pollution was so severe that several beaches and bathing areas were forced to shut down to prevent infections from sewage bacteria. The sludge was dumped within Steilene until the 1950s, and from the outer Oslofjord until 1974 (Bergstøl et al., 1981).

Trygve Braarud and Johan T. Ruud were the first to notice that large blooms of phytoplankton were forming around the cities were the sludge was dumped (Baalsrud and Magnusson, 2002). However, it was not until 1949/50, when Fredrik Beyer and Ernst Føyn provided evidence of anoxic conditions in the bottom water, that preventative measures were considered (Baalsrud and Magnusson, 2002). The poor circulation and high nutrient availability allow bacteria to deplete the oxygen, making the waters uninhabitable for animal life (Diaz and Rosenberg, 2008). Back in the 1700s, the bottom water of the Bærum basin was anoxic below about 25 m. Later, the boundary of the anoxic water moved up to about 20 m by the end of the 1800s, which coincides with the increase in sewage pollution observed at that time (Alve et al., 2009, Lundsør et al., 2018).

All the studies on benthic algae from the inner Oslofjord in 1940-1970, concluded that there had been dramatic changes to the benthic algae vegetation (Sundene, 1953, Grenager, 1957, Klavestad, 1967). There has also been large changes since Gran's (1897) investigation, in the distribution and presence of several fucoid species, including *Ascophyllum nodosum, Fucus serratus, Fucus spiralis, Fucus vesiculosus* and *Fucus distichus* subsp. *evanescens* (Gran, 1897, Grenager, 1957, Klavestad, 1967, Rueness, 1973, Bokn and Lein, 1978, Kroglund et al., 2017). The most dramatic changes were the massive recession of the native *A. nodosum* and largescale invasion of the unwanted and eutrophication-tolerant *F. distichus* subsp. *evanescens*, in the inner parts of the Oslofjord.

Several treatment plants were built during the 1900s, but chemical treatment was not introduced until 1971 (Skarpsno) and 1973 (Bekkelaget). The large Sentralrenseanlegg Vest (SRV) treatment plant, also known as VEAS, was built in 1982. This facility now handles sewage from more than 600.000 residents from Oslo and municipalities west of the Oslofjord, according to their website. The Emissions from VEAS are now released into the Vestfjorden at a depth of 50 m, to try to prevent surface water contamination. The utilization of this new treatment plant resulted in large improvements in surface water quality, visibility and lower chlorophyll levels (Bokn et al., 1992). Also, many of the previously lost fucoid species returned to the inner Oslofjord (Bokn et al., 1992). The investigations by Jon F. Larsen (1995) showed the return of *F. vesiculosus* and *F. serratus* to many of the inner Oslofjord basins. Magnusson et al. (1991) and Bokn et al. (1992) both conclude that the increased presence of the native fucoid species suggested an improvement in the water quality within the fjord.

The chemical treatment of phosphorous started between 1970 and 1990, while removal of nitrogen started in 1995/96 and was completed in 2001 (Berge et al., 2011). Norwegian Institute for Water Research (NIVA) calculated the supply of phosphorus (Figure 1) and nitrogen (Figure 2) to several Norwegian coastal areas, including the inner Oslofjord, from 1985 and every year since 1990.

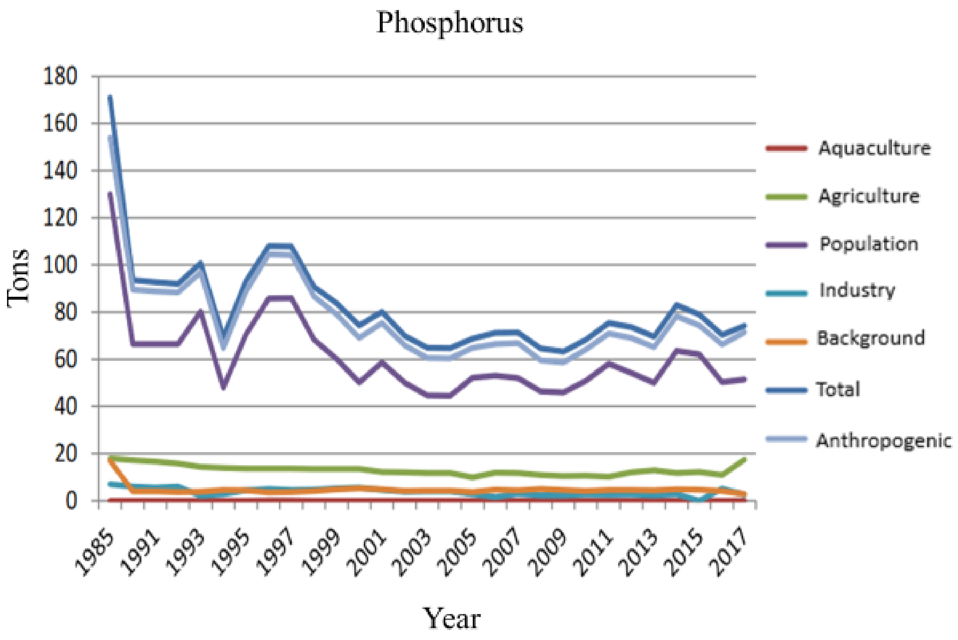


Figure 1. The supply of phosphorus (tons) to the inner Oslofjord, using the TEOTIL-model. The figure is acquired from (Selvik and Sample, 2018).

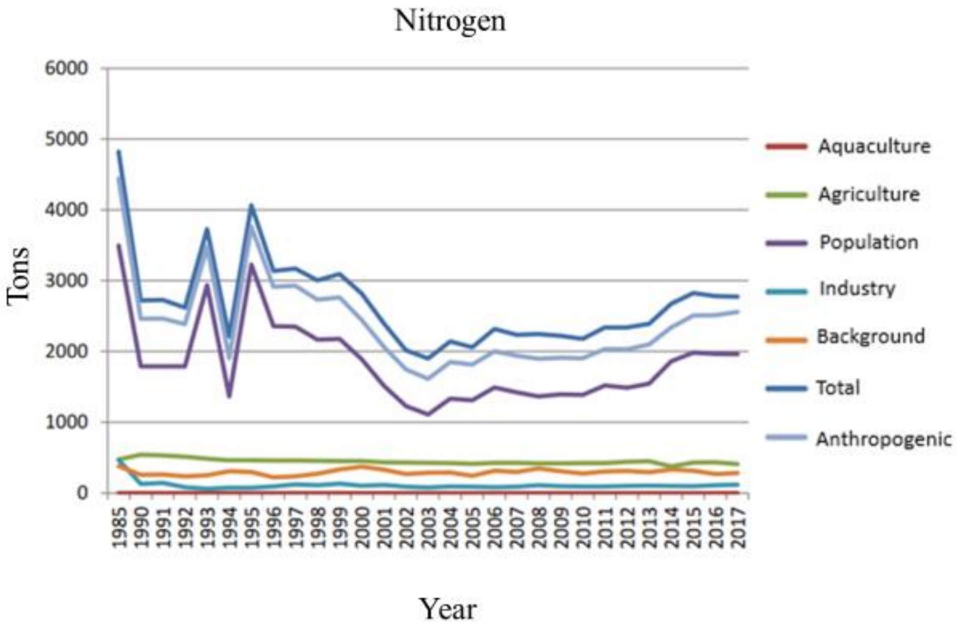


Figure 2. The supply of nitrogen (tons) to the inner Oslofjord, using the TEOTIL-model. The figure is acquired from (Selvik and Sample, 2018).

The calculations show that most of the added nutrients are of anthropogenic origin, primarily from the population (Selvik and Sample, 2018). The supply of both nutrients rapidly reduced sometime around the end of the 1990s, hitting its minimum in 2003-2004. The supply of phosphorus has later increased slightly. However, nitrogen levels have significantly increased after around 2013, until now. This is probably caused by the ever-increasing population of humans in the area.

Bekkelaget (UBRA) treatment plant is currently undergoing expansion and will likely be complete sometime in 2020, according to Oslo municipal websites. The facility currently treats sewage from 300.000 residents in the eastern part of Oslo. This will increase to 500.000 residents upon completion, which is the estimated runoff capacity for year 2040.

1.3 Topography and hydrography

1.3.1 Topography and deep-water circulation

The inner and outer Oslofjord is separated by a 19 m deep sill located in Drøbaksundet, which greatly affects the circulation of the inner Oslofjord. Furthermore, the inner Oslofjord is divided into two main basins; Vestfjorden and Bunnefjorden. These two basins are furthermore separated by 60 m deep sill that severely limit the circulation of water into Bunnefjorden. This part of the fjord usually only undergo deep water renewal every third to forth year (Baalsrud and Magnusson, 2002). However, Vestfjorden typically undergo deep water renewal annually.

The Bærum basin is the shallowest part of Vestfjorden, and has a maximum depth of 31 m and an average depth of about 10 m. There are many islands, peninsulas and smaller sills located within the Bærum basin resulting in poor water circulation. The combined effect of this restricted deep water renewal coupled with eutrophication is thought to be the cause of the anoxic conditions currently observed below around 20 m (Alve et al., 2009, Lundsør et al., 2018).

1.3.2 Water visibility and turbidity

The average underwater visibility measured during 2016-2018 was 4,2-4,3 m from two sites around Kalvøya (bk1 and bk2), and 4,5 m from one site close to Borøya Nord (Bl4) (Lundsør et al., 2018). The visibility was measured using the secchi disc method, which involves lowering a white disc into the water until it becomes invisible. This depth is then measured. The low visibility is associated with high turbidity, which can influence the vertical distribution of macroalgae (Lundsør et al., 2018).

1.3.3 Salinity

The Bærum basin is characterized by Norconsult as “highly influenced by freshwater” (Lundsør et al., 2018). Ocean salinity is measured in the unit PSU (Practical Salinity Unit). There are large variations in surface water PSU throughout the year, mainly due to the amount of freshwater input from rain, rivers and drainage from land (Lundsør et al., 2018). The freshwater from the Sandvika river empties into the Bærum basin, reducing the PSU of the surface waters (Solheim, 1972). In 2018, there was a large amount of drainage from land in April and May, followed by a very dry summer with low amounts of drainage and precipitation (Lundsør et al., 2018, Grinde et al., 2018b) The PSU of the Bærum basin waters was at its lowest during late May through June, then increased through the autumn (Lundsør et al., 2018).

Furthermore, the wind can influence surface water PSU by pushing the brackish water either into or away from coastal areas (Sundene, 1953). Southern winds will tend to retain the brackish water, whereas northern winds will push the brackish water out and reduce the impact of lower PSU. Southern winds occur most frequently during the summer months.

1.3.4 Tides and water levels

The tide normally fluctuates with about 28 cm in the inner Oslofjord. Still, the highest and lowest water levels ever recorded, compared to chart datum (0-level), were 189 cm in 1987 and negative 111 cm in 1999 (Baalsrud and Magnusson, 2002).

1.3.5 Climate and water temperature

Temperature and precipitation influence environmental conditions and freshwater runoff. The water temperature will determine the upper and lower horizontal distribution of specific macroalgae, by limiting were they can grow, reproduce and survive (Lüning, 1990). The summer of 2018 was the sixth warmest summer recorded since 1900 (Grinde et al., 2018b). Moreover, the average temperature recorded from Blindern was 5.3 °C above normal during May, 3.2 °C above normal during the summer, and 1-1.5 °C above normal in August (Grinde et al., 2018a). The station at Blindern reported the third lowest precipitation levels since the start of the recording in 1937, during May-August (Grinde et al., 2018b). The seawater temperature of the inner Oslofjord was also significantly higher than normal in 2018 (Figure 3).

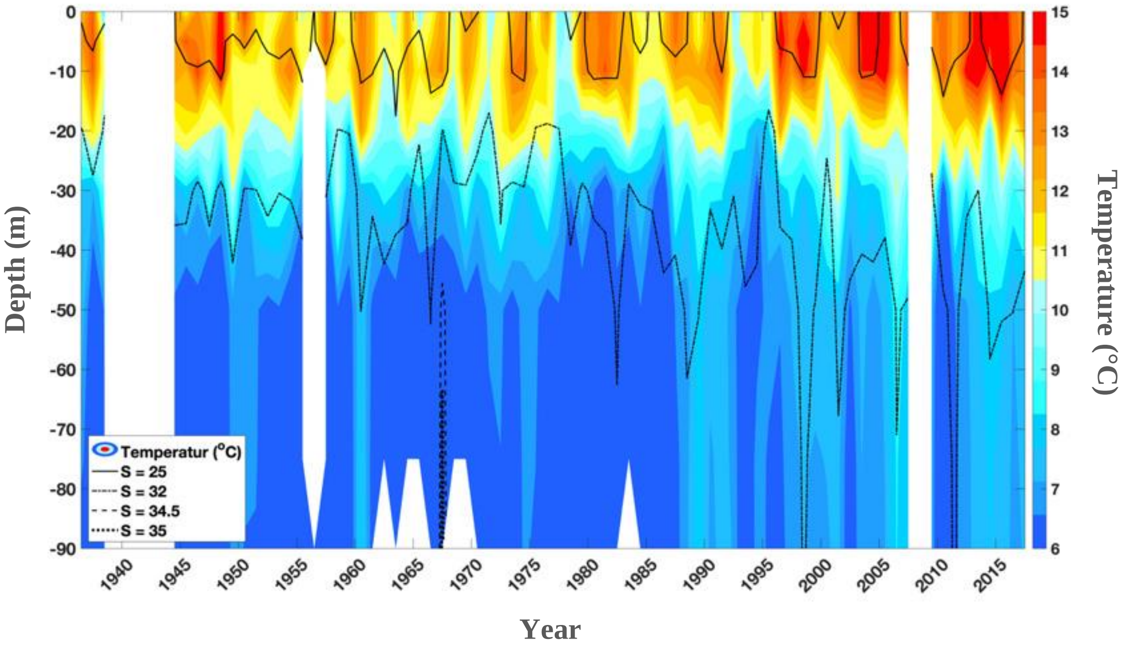


Figure 3. Water temperatures measured every autumn (September – October) during 1937 – 2018, from Steilene in the inner Oslofjord. The temperature is colour coded blue to red in relation to degrees of Celsius ranging from 6 to 15 °C, respectively, as shown on the far right. White areas indicate periods or depths were measurements were not available. The different lines indicate a variety of salinities (S) found in the box to the bottom left, used to describes the origin of the water (Brackish, costal, upper or lower Skagerrak and Atlantic water, respectively). The figure is acquired from SALT (Arvnes et al., 2019) .

The seawater temperature in the Oslofjord normally ranges from 2 to 18 °C, but there are often large fluctuations throughout the seasons. However, temperatures can vary from negative 2 °C to as high as 26 °C in shallow bay areas during calm weather, such as Kalvøya in the Bærum basin (Figure 4).

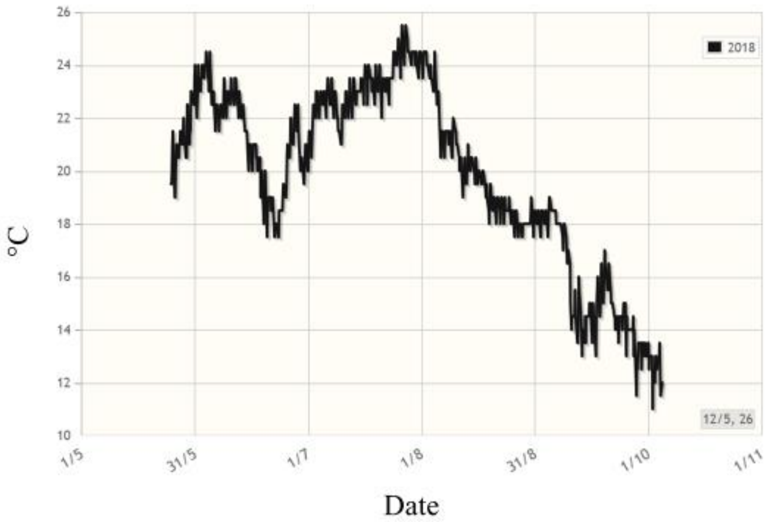


Figure 4. Surface water temperatures measured automatically from a buoy of the coast of Kalvøya at 40 cm below the surface. The figure is acquired from Badevann.no.

The fjord climate is also affected by the North-Atlantic oscillations (NAO), which is a fluctuation in the differences of atmospheric pressure between the islandic low and Azores high. These effect the weather systems in the north Atlantic. High (positive) NAO index indicates low pressure over Island, resulting in warmer temperatures and southern winds in Scandinavia. Low (negative) indexes will indicate high pressures over Island, and subsequent cold northern winds in Scandinavia.

1.3.6 Ice coverage

The Norwegian coast, including the Oslofjord, does not freeze during winter due to the warm water transported by the Golf Stream. However, some of the innermost basins do tend to freeze when temperatures stay below zero degrees for longer periods. The Bærum basin is usually covered by ice at some point during the winter months.

1.4 Previous research

The first studies on marine benthic macroalgae in the Oslofjord dates back to the 1770s. The Dane Otto Friedrich Müller described several species, including benthic algae, from areas around Drøbak. Later, The now famous Georg Ossian Sars collected marine organisms from the fjord during the late 1800s (Baalsrud and Magnusson, 2002). Additionally, the hand-written notes of Haakon Hasberg Gran from 1885 describes benthic algae around Bygdøy and other areas in the inner Oslofjord. The early investigations on macroalgae in the area gives a detailed description of the macroalgae communities of the inner Oslofjord from a time relatively untouched by pollution. Several other studies have since then followed the evolution of both pollution and macroalgae communities in the Oslofjord (Table 1). Single species studies are not included here.

Table 1. Overview of previous research in the Oslofjord, where the studies have been done and where the reference material is stored.

Study	**Description**	**Location**	**Herbaria**
Økonomiprotokol for dampkanonbåten Ellida – 1891-92	Hand-written journals from the Norwegian steam gunship Ellida, describes benthic algae in the Oslofjord	The Oslofjord	Unknown
Gran (1897)	Investigation during the summer of 1893-94, red and brown algae in the Oslofjord. F.C Schübeler, and N. Wille helped with the collection of samples. The material was processed by M. Foslie. The inner Oslofjord material was collected during the spring.	Drøbaksundet, Sandøsund, Bolærne, Hvalerøyene and inner Oslofjord.	Botanical museum of Oslo
Sundene (1953)	Investigation of macroalgae vegetation, during1940-42 and 1947-52. Sundene (1953) looked at the presence of different species in correlation to different environmental factors. The samples were collected from all seasons.	From the outer Oslofjord to Nesoddtangen	The Department of Biosciences, University of Oslo.

Grenager (1957)	Investigation of macroalgae. Samples were collected from late summer 1945 until October 1946, but he avoided typical winter and spring species.	Oslofjord; Bærumsbassenget, Lysakerfjorden, Oslohavn, Oslo-islands and the first parts of Bunnefjorden.	The Botanical museum of Oslo.
Klavestad (1967)	A collaboration called “Oslofjorden og dens forurensningsproblemer” with UiO and Norwegian institute for water science (NIVA) in 1962, focusing on benthic algae. Samples were collected from 1962-64. Klavestad also used supplementary samples from 1964 and 1966.	Areas south of Drøbak, Fildtvedt and deep into Bunnefjorden	Parts of the herbaria is in the Department of Biosciences, University of Oslo.
Lein (1976)	Investigations of areas in Drøbak and inner Oslofjord, to find a numerical expression for the structure of the littoral-zone.	Drøbak and inner Oslofjord	Unknown
Bokn et al. (1992)	NIVA has performed several investigations of macroalgae. The presence of five fucoid species were investigated from 123 sites in the inner Oslofjord during 1974-80	Inner Oslofjord	Unknown
Johnsen et al. (1992)	Investigation with NIVA on upper and lower growth limits of macroalgae were examined from seven different sites during 1981-83 and 1989/1991	Inner Oslofjord	Unknown
Fredriksen & Rueness (1990)	Investigations on presence of macroalgae in the outer Oslofjord.	Outer Oslofjord	The Department of Biosciences, University of Oslo.

Larsen (1995)	Thesis on the presence of macroalgae in the north end of the inner Oslofjord. Comparison of former investigations.	North end of the inner Oslofjord.	The Department of Biosciences, University of Oslo.
Kroglund et al. (2017)	Monitoring program on the presence of five fucoid species from 123 sites in the inner Oslofjord from 1974 to 2013, by NIVA.	Inner Oslofjord	Unknown
Lundsør et al. (2018)	Monitoring program on the presence of five fucoid species from 123 sites in the inner Oslofjord from 2015-2017, by Norconsult	Inner Oslofjord	Unknown

1.5 Aims for this investigation

The aim of this study is to investigate the type and number of macroalgal species found in tidepools, supralittoral, littoral and upper sublittoral zones down to 3 m depth, of eight coastal sites located within the Bærum basin. Due to its long history of eutrophication and ongoing human activity, the area needs environmental status evaluation. The results of this investigation compared with previous research in the area, mainly an investigation of the same eight sites by Jon F. Larsen (1995), will give insight into the environmental status of the Bærum basin. Due to the observation of large improvements in the algal communities of the inner Oslofjord between Grenager (1957), Klavestad (1978) and Larsen (1995), the main hypothesis of this study is;

"The environmental status of algal communities in the Bærum basin has improved since 1993-94."

The following additional questions will be answered in this study:

- What is the total number of algal taxa compared to Larsen's (1995) investigation?
- How does the presence of green, brown and red algae compare with Larsen's (1995) investigation, with regards to both total taxa and taxa of each site?
- Are the macroalgal communities different between now and 1993-94?
- How has the presence of five wrack species (*Ascophyllum nodosum*, *Fucus distichus* subsp. *evanescens*, *Fucus vesiculosus*, *Fucus serratus* and *Fucus spiralis*) changed in the Bærum basin, compared to previous studies?

2. Materials and methods

Samples were collected both during the spring and autumn of 2018, to detect seasonal variations. The spring samples were collected on the 25th of May and the autumn samples on the 21th of August.

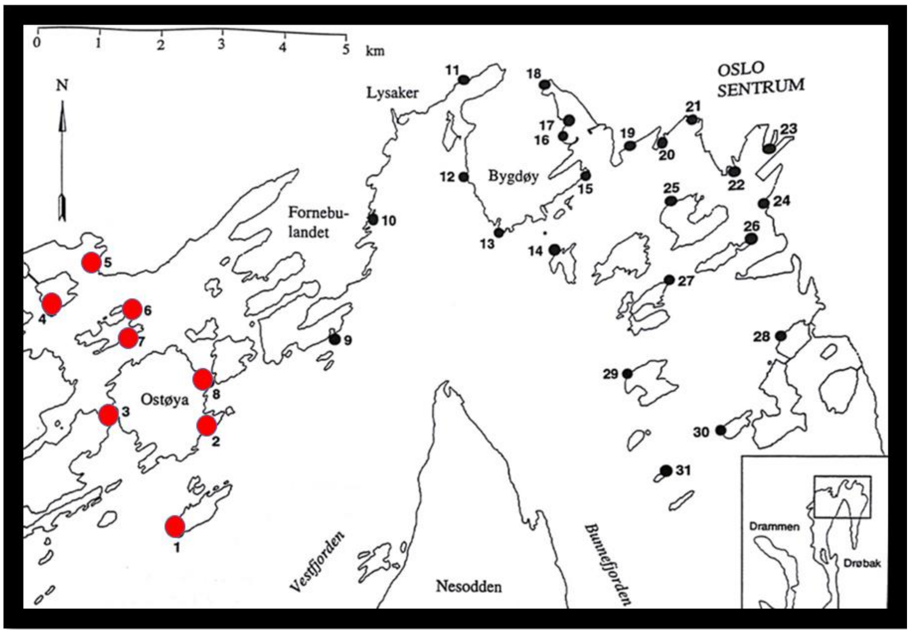
Larsen (1995) collected samples during the spring and summer of 1993 and the autumn of 1994. Larsen (1995) writes that typical spring algae and species within the family fucaceae was collected during the spring.

Grenager (1957) collected material from the summer to autumn over a two-year period. Whereas, Klavestad (1978) additionally collected material during the winter and spring months for some of the locations, and his investigations lasted over several year.

2.1 Sampling area

The samples were obtained from eight sites located within the Bærum basin in the inner Oslofjord (Figure 5). The exact coordinates are listed in appendix 3. The sites were selected among the original thirty sites investigated by Larsen (1995). Larsen (1995) selected these thirty sites based on locations previously investigated by Grenager (1957), Klavestad (1978) and NIVA (1992) as part of a monitoring program of the inner Oslofjord (Magnusson et al., 1992). The sampling area is close to the city of Sandvika, which together with inputs from the Sandvika river, high boat activity and E18 highway, considerably influences much of the basin. The Bærum basin is highly regarded by the leisure boating community, swimmers and beachgoers. As of this year, dumping of snow into the Sandvika river is illegal, which has been an environmental concern due to pollutants within the snow.

The investigated sites are located on a group of small islands that have bedrock formed by sedimentary rocks from Ordovician and Silurian period. Most sites have a slight inclination, but there are large differences in exposure and orientation among some of the sites. The length of the studied coastline also varied among sites ranging from about 10 to 25 m. The effect of variable transect width among the different studies should be minimal, as this study, Grenager (1957), Klavestad (1978) and Larsen (1995) all seemingly collected from the most biodiverse areas within each site.



	Name of site
1	Gåsøya
2	Flisbukta
3	Store Ostsund
4	Kalvøya
5	Høvikodden
6	Borøya Nord
7	Borøya Sør
8	Lille Ostsund

Figure 5. Map of the inner Oslofjord showing sites visited by Grenager (1957), Klavestad (1978) and Larsen (1995). The sites that were revisited in this study (Sites 1-8) are listed on the right and highlighted in red on the map. The map is acquired from (Larsen, 1995).

There are large variations in fetch among the different sites (Table 2). The amount of fetch will determine the distance in which wind is able to build up waves, resulting in either a sheltered or exposed area (Kaiser et al., 2011). This factor can influence the algal community, as some species only are found in specific levels of exposure. The high boat activity in the Bærum basin acts as a modifying factor to fetch, adding to the creation of waves.

Table 2. List of the wind exposure (fetch) for each site. The fetch was calculated by placing of a circle, divided into 36 lines, directly over each site, then measuring and adding the distances where each line hits shore. The radius of the circle was 5 cm, which was the maximum fetch score of each line. 5 cm equals 12.000 m on the nautical map that was used.

Site number	**Name**	**Fetch**
1	Gåsøya	109,6
2	Flisbukta	74,3
3	Store Ostsund	54,7
4	Kalvøya	58,4
5	Høvikodden	53,7
6	Borøya Nord	65,7
7	Borøya Sør	42
8	Lille Ostsund	40,7

2.1.2 Description of the sites

Site 1. Gåsøya stands out as the most heavily vegetated location. The site had an area to the west with muddy substrate inhabited by fields of eelgrass, and to the east a steep wall of solid rock with thick belts wrack (Figure 6). The site is facing southward, directly into the open fjord. Moreover, Gåsøya gave the impression of having the highest amount and diversity of fish while snorkelling.

Figure 6. Gåsøya (Site 1) in August.

Site 2. Flisbukta was highly vegetated, and gave the impression of a diverse algal community while snorkelling (Figure 7). The site is facing southward and is partially blocked by Gåsøya. The substrate was mostly solid rock, with a slight inclination, and some areas of sand within a small bay.

Figure 7. Flisbukta (Site 2) in August.

Site 3. Store Ostsund gave the impression of having intermediate vegetation with large amounts of blue mussels (*Mytilus edulis*), while snorkeling (Figure 8). The substrate is a mix of solid rock and gravel with scattered cobbles. The site has varied inclination from intermediate to steep and is facing southwest. Moreover, the site is located directly in the middle of a passage with high boat traffic.

Figure 8. Store Ostsund (Site 3) in August.

Site 4. Kalvøya gave the impression of having the least amount of vegetation of all the sites. Small patches of wrack were scattered around the shoreline, while most of the seabed remained barren (Figure 9). In August, there were large colonies of the cyanophyte *Rivularia atra* on the rocky shoreline. The substrate was mostly solid rock and cobbles, with an intermediate inclination. Moreover, the site is facing southward.

Figure 9. Kalvøya (Site 4) in May

Site 5. Høvikodden was almost completely barren in the shallows, with only a few scattered patches of wrack. However, I followed a large pipe (Figure 10) a few meters down into a massive field of *Z. marina* covered with epiphytes (Figure 11). The substrate in the shallows was mainly cobbles, then transitioning into mud further down. The site faces westward, and the inclination is intermediate. This site is close to a large berth (with a floating fuel dock) with high boat activity.

Figure 10. Høvikodden (Site 5) in August

Figure 11. Høvikodden (Site 5) in August

Site 6. Borøya Nord had multiple areas with good vegetation of wrack, but some areas were severely overgrown by epiphytes (Figure 12). The seafloor of the area was noticeably polluted with garbage from leisure boat activity. The substrate was mainly solid rock close to shore, with areas of mud and cobbles further out. The site has a slight inclination and faces eastward.

Figure 12. Borøya Nord (Site 6) in August

Site 7. Borøya Sør had a seabed dominated by mud, with very little algae growth (Figure 13). Small patches of wrack grew close to the shoreline. Also, the area is very sheltered (Table 2). The site has a slight inclination and faces southeast.

Figure 13. Borøya Sør (Site 7) in August

Site 8. Lille Ostsund had small patches of wrack close to the shoreline. The seabed was seemingly void of vegetation below one meter, were the substrate was mainly dominated by mud. In the shallows above one meter, the substrate was a mix of cobbles and gravel (Figure 14). The site has a slight inclination and faces southeast. Moreover, the site is located at the opening of a narrow passage with heavy boat traffic (Figure 15).

Figure 14. Lille Ostsund (Site 8) in May

Figure 15. Lille Ostsund (Site 8) in May

2.2 Sampling methods

The sampling was executed by hand and by snorkelling, as in Larsen's (1995) investigation. Grenager (1957) and Klavestad (1978) used the throwable rake method, which may overlook small, rare epilithic algae species found in the sublittoral zone.

Macroalgae were collected from tidepools, the supralittoral, littoral and sublittoral zones down to three meters depth. This was copied from Larsen's (1995) investigation, to compare algae with similar vertical distribution. The snorkelling time of each site ranged from about 10 to 30 minutes.

The organisms were stored and preserved in labeled plastic bottles containing a mixture of formalin and seawater (2% formalin). Specimens collected from tide pools were kept in separate smaller bottles. The species *Desmarestia viridis* was also stored in separate containers due to its acidic properties, which could damage the rest of the samples (Eppley and Bovell, 1958). All containers were stored at room temperature.

Photographs of locations and vegetation were taken above and below the surface in field, using a Sony handheld camera with an underwater housing.

2.3 Laboratory work

The samples were prepared for identification by removing the formalin solution. This was done by draining the bottles of liquid, then rinsing the samples in fresh water. Afterwards, the samples were stored in seawater for a minimum of 24 hours before handling, to remove the remaining formalin. The bottles were prepared one at a time to prevent samples from decaying during the identification process. Firstly, the samples were put in a deep plastic tray with seawater to get a better overview. Then, individual species were examined using a (Nikon SMZ1290) stereo microscope. Smaller species were examined using a (Nikon eclipse E200) compound microscope. Special solutions were used on certain species to make identification easier. A weak acid was used to separate the periaxial cells of the *Polysiphonia* genus, making them easier to count. The number of periaxial cells is a key character used in the identification of this genus. Iodine was used to stain the starch surrounding pyrenoids of certain green algae. The number of pyrenoids is an important character used to separate species within the genus *Ulva*. Some species required transverse sections to identify whether the thallus was single, double or multilayered in thickens.

Both the stereo- and compound microscopes were fitted with a camera (Nikon digital sight DS-L1) providing photographic evidence when needed. Most of the identified taxa were made into a collection of permanent slides. However, some of the larger algal species were photographed. A small piece of algae was placed on a glass slide and given a drop of fixative solution containing 20 ml of distilled water, 10 ml of corn syrup, 10 ml of 38% formalin and 1 ml of 1% aniline. The slides were numbered and kept in a reference collection.

2.3.1 Morphological identification

The specimens were identified to the lowest taxonomic level possible using morphological characters. There are some small differences between studies, in depth of taxonomic level of some of the species. However, by compiling the problematic species into genus, such as *Cladophora* and *Acrochetium*, the issue should be neglectable.

Almost all the species were identified in the laboratory at the University of Oslo. *Saccharina latissima* was identified in the field.

There are a few groups of algae that are deliberately left out of this study and some of the previous research. Gran (1897) identified endophytes (algae living within other plants and algae) and several epiphytic calcareous algae. Klavestad (1978) also identified endophytes and calcareous algae. Grenager (1957), Larsen (1995) and I did not include endophytes or calcareous algae, apart from the endophyte *Ulvella viridis* and encrusting *Phymatolithon lenormandii*.

Grenager (1957), Klavestad (1978), Larsen (1995) and I all struggled with confidently identifying some of the species within the family fucaceae. Many individuals within this family have been incorrectly identified in Grenager (1957) and Klavestad's (1978) herbaria, according to Larsen (1995). It is probable that both Larsen (1995) and I also made some mistakes regarding this family. Some species within fucaceae have large morphological variations and can often be very hard to distinguish from each other, during certain life stages or conditions (Grenager, 1957, Rueness, 1977). This especially concerns *Fucus vesiculosus* and *F. spiralis*, see the taxonomic overview (3.2) for further details. Moreover, hybridization between *F. distichus* subsp. *evanescens* and *F. serratus* has been shown to cause morphological variations, though this usually happens in areas with high densities of both species together (Coyer et al., 2002). These hybrids have been recorded from the inner Oslofjord (Lein, 1984)

2.3.1 Literature

A variety of literature was used in the identification process. Identification keys for brown, green and red algae made by Rueness (2006) was used in conjunction with; Rueness (1977), Maggs and Hommersand (1993), Burrows (1991), Fletcher (1987), Dixon and Irvine (1977), Kornmann & Sahling (1977), McLachlan & Bird (1992), Brodie, Maggs & John (2007) and Coppejans (1995)

All the species names agree with Algaebase.org (December 2019) for the current accepted nomenclature.

2.4 Analysis method

The dataset from both 1993-94 and 2018 was statistically analysed using a non-metric MDS (nMDS-analysis), to better visualize the differences in macroalgae communities between the two periods. A matrix was made, including all the species from both studies in alphabetic order, showing presence or absence (1/0) at each site from both periods (see appendix 2). The nMDS-analysis method used is referred to as Plymouth Routines In Multivariate Ecological Research (PRIMER), and is based on the Bray-Curtis similarity index using untransformed (present/absent) data. nMDS-analysis is used to compare different samples in a multidimensional space, represented as a two-dimensional diagram to illustrate similarities between them (Clarke, 1993). The method produces an orientation based on distance or a dissimilarity-matrix, in this case the similarity of the species composition between different sites during 1993-94 and 2018. The program will make several orientations to try and find the optimal grouping of samples, which will be given a stress score based on how accurate these groupings are. The nMDS-analysis preformed in this study received a 2D stress score of 0.11. This is acceptable, meaning the groupings can be trusted. The proximity of the different samples in the two-dimensional diagram indicates how similar they are. In this case, sites grouped together will have more similar macroalgae communities than those apart (Clarke, 1993).

3 Results

3.1 Overview of algal communities

3.1.1 Comparison of total algal taxa between 1993-94 and 2018

A total of 54 different algal taxa were identified in this study, in addition to one cyanobacterium and one higher plant. This number is slightly smaller than the 64 taxa identified during Larsen's (1995) investigation.

There is a somewhat even distribution in the number of taxa between the three main groups of algae for both investigations (Figure 16). However, there has been a notable decline in the number of green and red algae taxa compared to Larsen's (1995) investigation. This resulted in the change from a green algal dominance, of 34% of total taxa, observed in Larsen (1995) investigation, to a brown algae dominance of 37% observed in 2018.

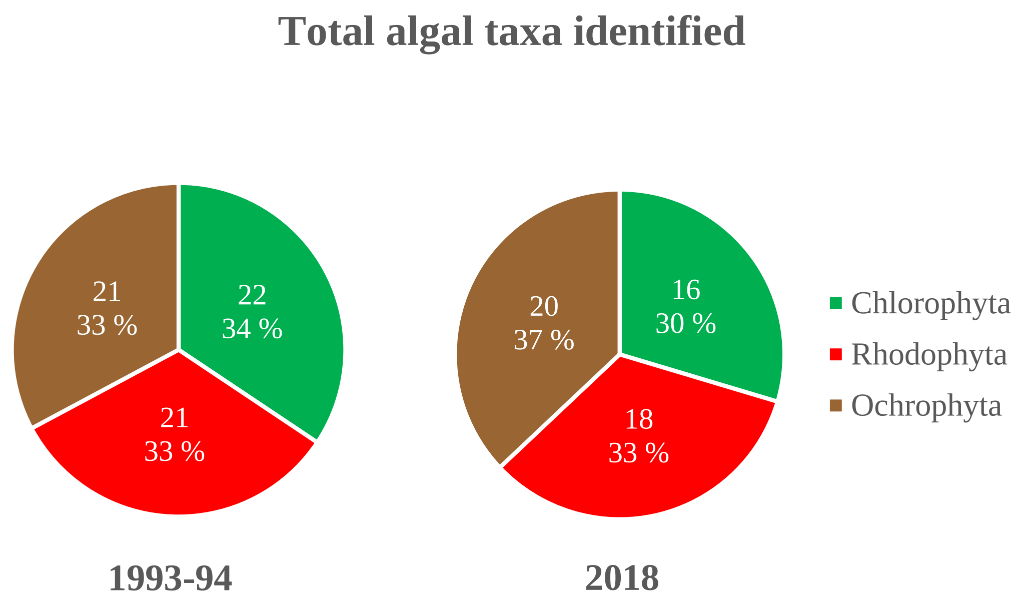


Figure 16. The total taxa and percentages of each algal group identified from all eight sites located in the Bærum basin. The diagrams do not represent abundance or biomass of each species. The algal taxa identified by Larsen (1995) during 1993-94 is displayed in the pie chart to the left. The pie chart to the right display taxa identified during 2018. Each algae group is colour coded and listed to the far right.

There was a total of 29 algal taxa identified in 1993-94, that I did not find in 2018 (Table 3). However, I identified 21 taxa that were not identified in 1993-94, including one cyanobacterium and one higher plant.

Table 3. The list to the left contains all the algal taxa identified in 1993-94 by Larsen (1995) that were not found in 2018. Oppositely, the list to the right contains the taxa that I identified in 2018, but Larsen (1995) did not find in 1993-94.

1993-94	**2018**
Acrosiphonia arcta	*Carradoriella elongata*
Blidingia marginata	*Ceramium tenuicorne*
Ceramium cimbricum	Cf. *Furcellaria lumbricalis*
Ceramium strictum	*Chorda filum*
Chaetomorpha ligustica	*Cladophora rupestris*
Chordaria flagelliformis	*Cladophora* sp.
Cladophora cf. *sericea*	*Gracilaria gracilis*
Cladophora cf. *vagabunda*	*Phymatolithon lenormandii*
Codium fragile	*Pogotrichum filiforme*
Gayralia oxysperma	*Porphyra umbilicalis*
Melanothamnus harveyi	*Rivularia atra***
Nemalion helminthoides	*Saccharina latissima*
Petalonia fascia	*Sargassum muticum*
Polysiphonia hemisphaerica	*Spermatochnus paradoxus*
Porphyra cf. *purpurea*	*Ulva* cf. *linza*
Punctaria tenuissima	*Ulva* cf. *torta.*
Pyropia cf. *leucosticta*	*Ulva compressa*
Ralfsia verrucosa	*Ulvella viridis*
Rhodomela confervoides	*Urospora wormskioldii*
Spongomorpha aeruginosa	*Zostera marina***
Stragularia clavata	
Striaria attenuata	
Stylonema alsidii	
Ulothrix cf. *flacca*	
Ulothrix cf. *implexa*	
Ulva lactuca	
Ulva spp.	
Urospora penicilliformis	

*Cyanobacteria, **Higher plant

3.1.1 The number of algal taxa at each site

The largest number of taxa, for both studies, was identified from Gåsøya and Flisbukta (Figure 17). Moreover, these two sites had the largest number of brown and red algae compared to the other sites. Larsen (1995) identified a striking number of taxa from Gåsøya compared to any of the other sites, of both studies. The largest decline in number of taxa was observed from Gåsøya (Site 1), Høvikodden (Site 5), Borøya Sør (Site 7) and Lille Ostsund (Site 8). Furthermore, Kalvøya (Site 4), Høvikodden (Site 5), and Borøya Sør (Site 7) exhibited the absolute lowest number of algal taxa in 2018 and gave the impression of being the most barren during snorkeling. The absolute lowest total number of taxa, including zero green algae, was identified from Store Ostsund (Site 3) during 1993-94. In 2018, the same site exhibited intermediate numbers of total taxa, with a large share belonging to the brown algae group.

In contrast to the total taxa, it was the red algae that dominated most of the individual sites in 2018, apart from Store Ostsund and Lille Ostsund (Figure 17). Larsen's (1995) investigation displayed a more varied hierarchy, in terms of numbers of taxa, between algal groups throughout the different sites. Red algae dominated the number of taxa from Gåsøya, Borøya Nord and Borøya Sør, while brown algae dominated from Flisbukta, Store Ostsund and Kalvøya. The green algae dominated from Høvikodden and Lille Ostsund. Furthermore, Larsen (1995) identified significantly more green algae taxa from Høvikodden, Borøya Sør and Lille Ostsund compared to 2018.

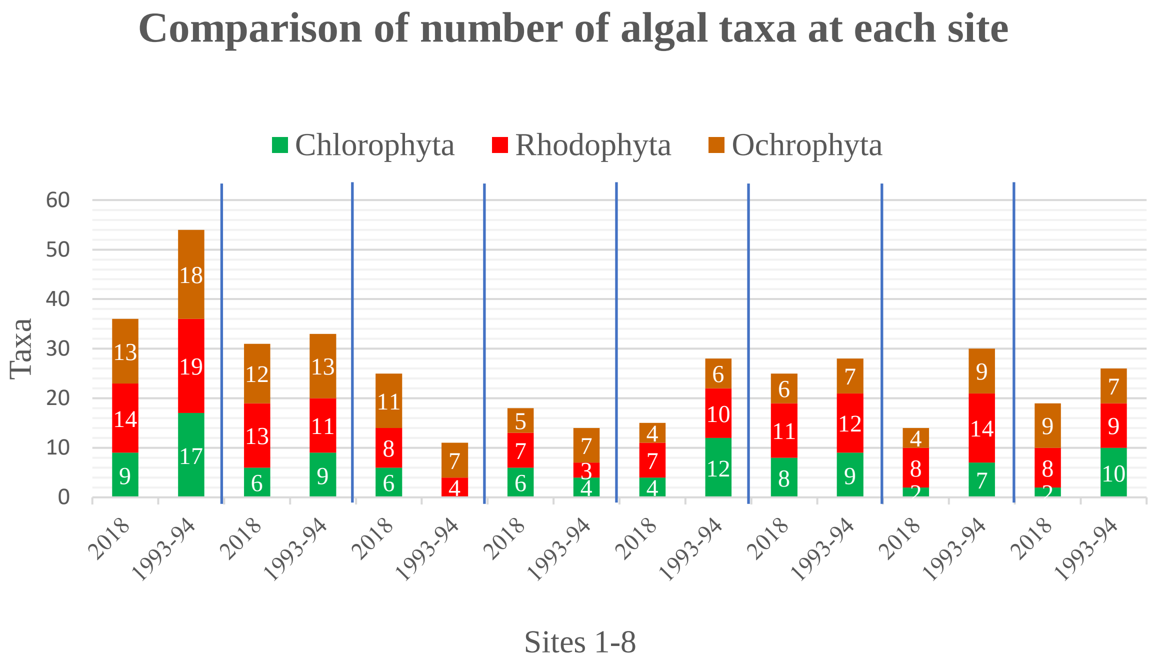


Figure 17. Comparison of number of algal taxa at each site between 2018 and Larsen’s (1995) investigation during 1993-94. The diagram does not represent abundance or biomass of each species. The different sites are separated by the blue lines, starting with site 1 on the far left, and ending up with site 8 on the far right. The cyanobacterium and higher plant were not included. Each algae group is colour coded (green, brown and red, from the bottom to the top of each bar).

3.1.2 Non-metric MDS analysis

A non-metric multi-dimensional scaling (nMDS) analysis was used to investigate the differences in algal communities between 1993-94 and 2018 (Figure 18). The two-dimensional diagram of the nMDS-analysis shows a clear horizontal separation of the two investigations, due to the difference in time. The distribution on the vertical plane is determined by the type and number of macroalgal taxa. The sites that are grouped together have similar macroalgal communities. Store Ostsund (site 3) and Kalvøya (site 4) of the 1993-94 investigation are clear outliers, gathering at the bottom of the 2D representation. Additionally, both Høvikodden (site 5) and Borøya Sør (site 7) differ significantly on the vertical plane across the two investigations, indicating large changes between the two periods.

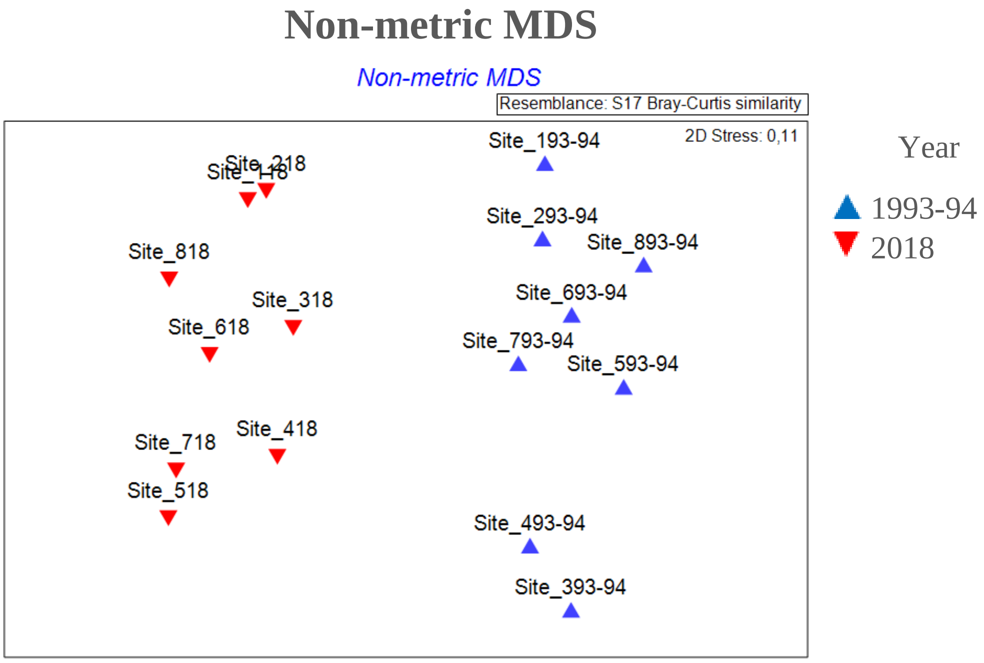


Figure 18. Non-metric multi-dimensional scaling (nMDS-analysis) with Bray-Curtis similarity, using untransformed “presence/absence” data, comparing algal taxa identified from the Bærum basin, during 1993-94 (blue triangle) and 2018 (red triangle). Each site is given a code were the first digit reveals the number of the site followed by the year. The analysis was run using PRIMER software.

3.2 Taxonomic overview

All the species are accompanied by a small map displaying the different sites of the Bærum basin. Filled circles show where the species were found. Black arrows indicate the locations that Larsen (1995) identified the same species. The overview is arranged in alphabetical order. A complete list of the taxonomic overview for 2018 can be found in appendix 1.

3.2.1 Chlorophyta

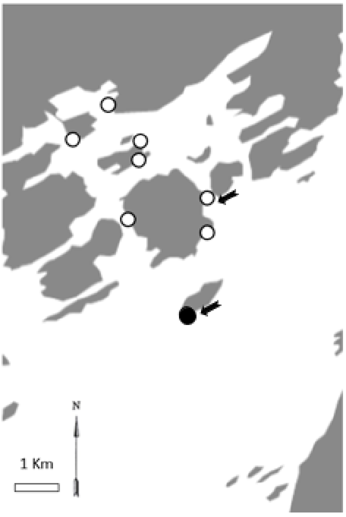
Phylum: Chlorophyta

The number of pyrenoids per cell, cell size and shape are the main characteristics used to separate and identify species within Chlorophyta.

Class: Ulvophyceae

Order: Bryopsidales

Family: Bryopsidaceae



Bryopsis hypnoides J.V. Lamouroux

Description: Thalli has prostrated rhizoidal branches that give rise to erect fronds, olive green in colour, with one to several orders of branches arranged spirally or irregularly, which separates the species from *B. plumose* that has branching arranged in two rows (Brodie et al., 2007).

The species was only identified in May.

Site: Identified from Gåsøya.

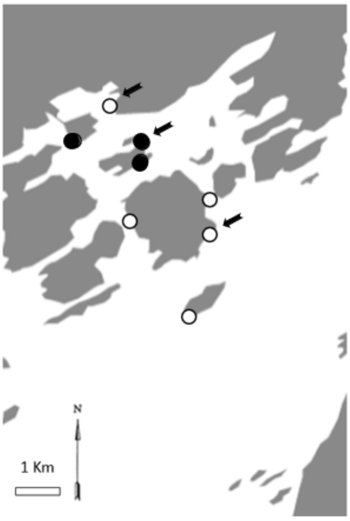
Previous findings: Larsen (1995) identified individuals from Gåsøya and Lille Ostsund. Grenager (1957) and Klavestad (1978) report no findings in any of the eight sites.

Permanent collection: Slide nr. 2.

Order: Cladophorales

Family: Cladophoraceae

Chaetomorpha cf. *linum* (O.F. Müller) Kützing



Description: Thalli are thin, dark to light green in colour, uniseriate and unbranched filaments containing barrel-shaped cells that are 0,5 – 2 times as long as they are wide, with a diameter of 120-700 µm. Furthermore, the thalli are unattached or basally attached by a discoid holdfast. (Burrows, 1991, Brodie et al., 2007).

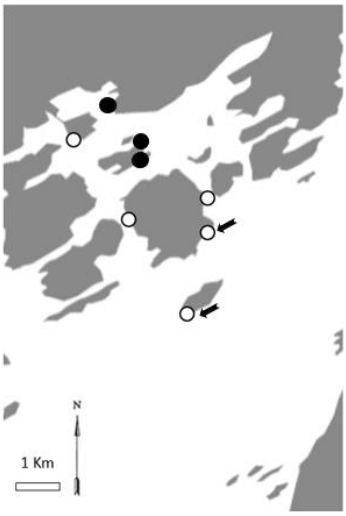
The species was identified in May and August.

Site: Identified from Kalvøya, Borøya Nord and Borøya Sør.

Previous findings: Larsen (1995) identified individuals from Høvikodden, Borøya Nord and Flisbukta. Grenager (1957) identified no individuals from the eight sites. Klavestad (1978) identified individuals from Høvikodden.

Permanent collection: Slide nr. 3.

Cladophora cf. *albida* (Nees) Kützing



Description: Thalli are uniseriate, highly branched filaments that decrease in size from base to apex. The cells are cylindrical or barrel-shaped and characteristically pale green in colour. The chloroplast is parietal with many bilenticular pyrenoids (Burrows, 1991, Brodie et al., 2007).

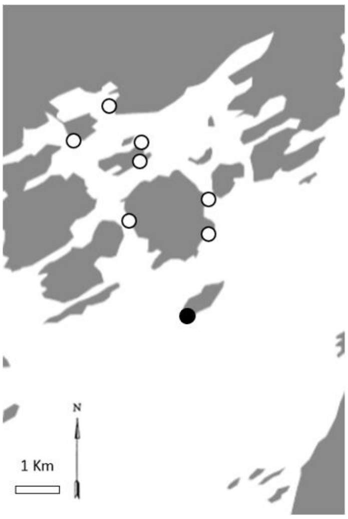
The species was only identified in May, and many individuals were epiphytes.

Site: Identified from Høvikodden, Borøya Nord and Borøya Sør.

Previous findings: Larsen (1995) identified the species from Gåsøya and Flisbukta.

Permanent collection: Slide nr. 4.

Cladophora rupestris (Linnaeus) Kützing



Description: Thalli are characteristically dark green in colour, stiff and broom-like, with densely branched and appressed filaments (Brodie et al., 2007). It was found in the subtidal zone.

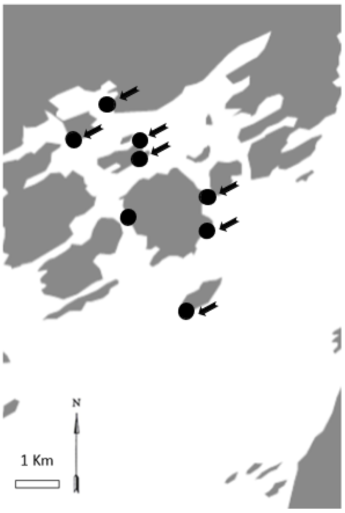
The species was only identified in the spring. Some individuals were identified from tidepools.

Site: Identified from Gåsøya.

Previous findings: There is no previous identification by Larsen (1995) or Grenager (1957) from any of the eight sites. Klavestad (1978) reported *C. rupestris* as common into Hovedøya.

Permanent collection: Slide nr. 5.

Cladophora spp.



Description: Thalli are uniseriate, profusely to sparsely branched and can be unattached or attached to the substratum by rhizoids or a discoid holdfast. The genus exhibit both apical and intercalary divisions with typical pseudodichotomous branching. The genus is one of the largest and most common green algal genera with worldwide distribution (Brodie et al., 2007).

The *Cladophora* genus is notoriously difficult to identify to species, but a few characteristics may help to suggest species. Commonly used characters to distinguish different species include; colour, mode of attachment, thallus organization, number of branches per node, insertion of branches, shape of apical cells, cell dimensions (Brodie et al., 2007).

The individuals within this genus was identified in May and August, in tidepools, and exhibited both epilithic and epiphytic growth.

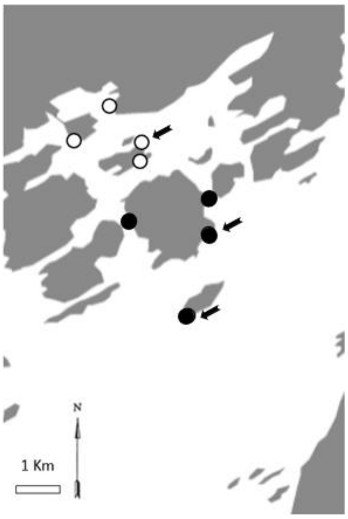
Site: Identified from all eight sites.

Previous findings: Larsen (1995) identified species within the genus *Cladophora* from all eight sites, except Store Ostsund. The species listed included *C.* cf. *albida, C.* cf. *sericea, C.*

vagabunda and *Cladophora* sp. Grenager (1957) identified *C. hirta (= C. sericea) and C. marina* (= unknown, possibly *C. hauckii*) from Høvikodden. Klavestad (1978) reported *C.* spp. as common in all subareas of the inner Oslofjord.

Permanent collection: Slide nr. 6.

Rhizoclonium tortuosum (Dillwyn) Kützing



Description: Thalli are thin, unbranched, uniseriate filaments entangled in other algae, including *Sphacelaria cirrosa*. The algae are usually unattached, and form entangled light green fleece over substrate. Cell width range of about 6-27 µm (Rueness, 1977, Burrows, 1991, Brodie et al., 2007).

The species was only identified in August, with some individuals found in tidepools. Epiphytic growth was also observed.

Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Lille Ostsund.

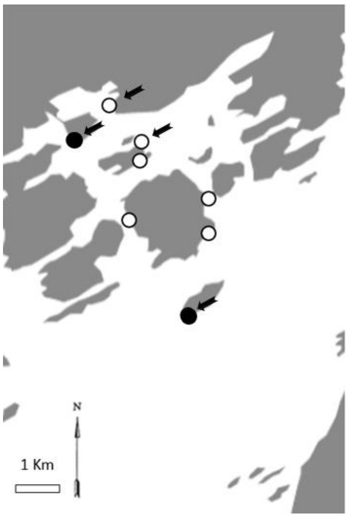
Previous findings: Larsen (1995) identified individuals from Gåsøya, Borøya Nord and Flisbukta. Grenager (1957) identified no individuals from the eight sites. Klavestad (1978) described the species as regular in most of the outer part of the Oslofjord.

Permanent collection: Slide nr. 8.

Order: Ulotrichales

Family: Monostromataceae

Monostroma grevillei (Thuret) Wittrock



Description: Gametophytic thalli is described as foliose, up to 10 cm long, monostromatic, laminate, attached by a basal disc of pseudoparenchymatic filaments and lacking a stipe (Brodie et al., 2007) Cells show a gradation in size and shape from apex to base, sometimes separated into groups of four. Distal cells are rounded, about 5-20 µm in diameter, with one pyrenoid per cell. Occurs mainly in rock pools, but has also been recorded in the sublittoral (Brodie et al., 2007).

The species was only identified in May, and one specimen grew epiphytically.

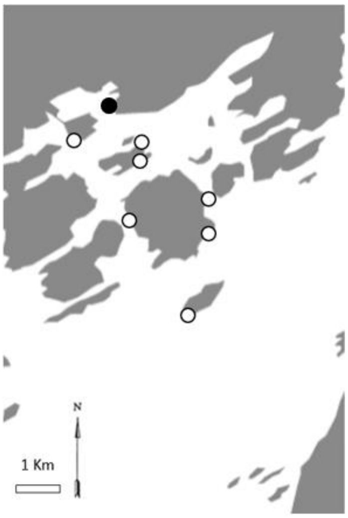
Site: Identified from Gåsøya and Kalvøya.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Kalvøya, Høvikodden and Borøya Nord. Grenager (1957) and Klavestad (1978) identified no individuals from any of the eight sites.

Permanent collection: Slide nr. 7.

Family: Ulotrichaceae

Urospora wormskioldii (Mertens) Rosenvinge



Description: Gametophytic thalli occurs as both large and small filaments with Rhizoidal attachment. Cells are cylindrical basally, becoming barrel-shaped distally, one to one and a half times as long as broad, with parietal chloroplast and numerous pyrenoids covering the full length of the cell (Brodie et al., 2007). The species may be confused with *Chaetomorpha linum*. However, *U. linum* does not form continuous glossy mats on rocks, which is caracteristic of *U. wormskioldii* (Brodie et al., 2007)

The species was only identified in May.

Site: Identified from Høvikodden.

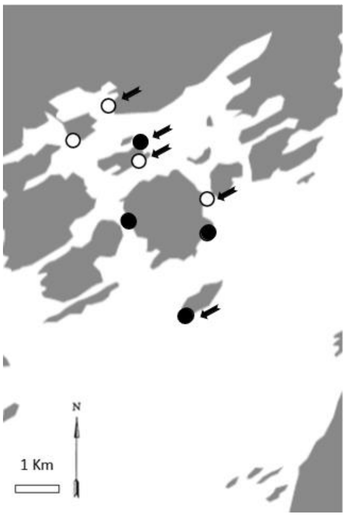
Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

Permanent collection: Slide nr. 16.

Order: Ulvales

Family: Kornmanniaceae

Blidingia minima (Nägeli ex Kützing) Kylin



Description: Thalli are tubular to flattened, irregular in width, straight, wavy, wrinkled or twisted, and typically unbranched. The species can be branched and is attached in groups to a common basal disc. The cells are rounded or polygonal, often arranged in longitudinal rows in the narrow parts, otherwise irregularly arranged, with a single pyrenoid and a diameter of around 5-10 µm (Brodie et al., 2007).

The species was identified during in May and August, with some individuals found in tidepools. Epiphytic growth was also observed.

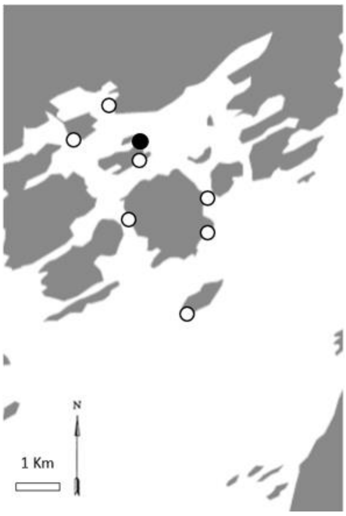
Site: Identified from Gåsøya, Flisbukta, Store Ostsund and Borøya Nord.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Høvikodden, Borøya Nord, Borøya Sør and Lille Ostsund. Grenager (1957) only identified individuals from Kalvøya. Klavestad (1978) registered the species as very common in the entire Oslofjord.

Permanent collection: Slide nr. 1.

Family: Ulvaceae

Ulva cf. *linza* Linnaeus



Description: Thalli are variable in shape, with some individuals displaying unbranched distromatic ribbons 1-8 cm wide and to 30 cm long, to compressed branched tubes 0,5-10 mm wide. The thalli can be ruffled or corkscrew-like, with hollow margins, pale green in colour and soft to the touch. Cells are quadrangular, 15 x 15 µm or rectangular, usually ordered in longitudinal and transverse rows, with single parietal chloroplast and a single pyrenoid (Brodie et al., 2007).

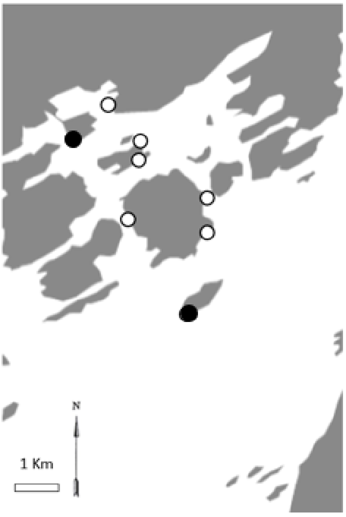
The species was only found in August.

Site: Identified from Borøya Nord.

Previous findings: Larsen (1995) and Grenager (1957) identified no individuals from any of the eight sites. Klavestad (1978) identified individuals from Kadetttangen, which is close to Kalvøya and Høvikodden but is not one of the eight sites included in this investigation. The species was much more common in the inner parts of the Oslofjord according to Klavestad (1978).

Permanent collection: Slide nr. 9.

Ulva cf. *torta* (Mertens) Trevisan



Description: Thalli are unbranched, tangled masses of filiform cylindrical tubes, and they are normally unattached. Cells are rectangular to irregularly quadrate, 12-28 x 6-14 µm, with one pyrenoid (rarely 2-3), arranged in longitudinal or spiral rows (Brodie et al., 2007)

U. torta is usually found in harbours, estuaries and tidepools, and can be confused with *U. prolifera* (Brodie et al., 2007).

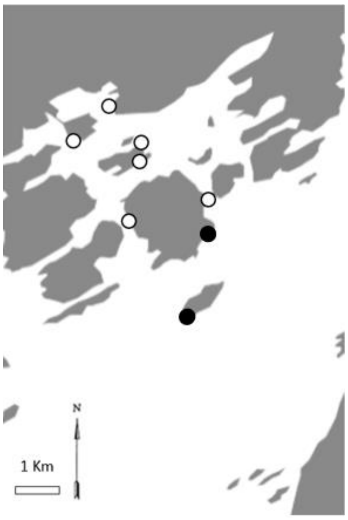
The species was identified in May and August, with some individuals found in tide pools.

Site: Identified from Gåsøya and Kalvøya.

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

Permanent collection: Slide nr. 10.

Ulva compressa Linnaeus



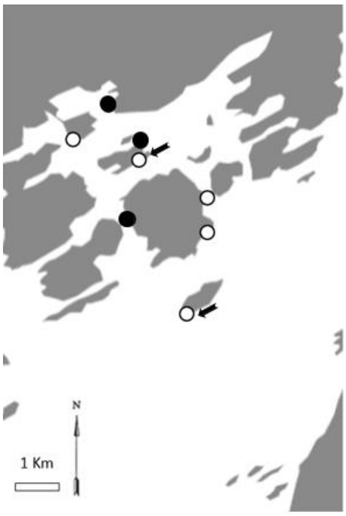
Description: Thalli are highly variable in form, tubular, but not inflated axes, compressed, highly branched, and up to 60 cm in length, forming extensive tubular branches from the main blade (Brodie et al., 2007). Cells are light to dark green in colour, polygonal, 15-40 µm in diameter, with a single hood-shaped chloroplast at the apex of the cell, and one pyrenoid (Brodie et al., 2007)

The species was only identified in August, and individuals were both found as epiphytes and in tidepools.

Site: Identified from Gåsøya and Flisbukta.

Previous findings: See *Ulva intestinalis*, as *U. compressa* is a synonym for *Enteromorpha intestinalis,* which is the name used by Larsen (1995), Grenager (1957) and Klavestad (1978).

Permanent collection: Slide nr. 11.



Ulva flexuosa Wulfen

Description: Thalli are highly variable in overall morphology, ranging from little-branched ribbons up to two centimeters broad, to narrow tubes less than one millimeter in diameter. Cells are typically rectangular, 15-30 x 9-25 µm, arranged into distinct longitudinal and transverse rows (Brodie et al., 2007).

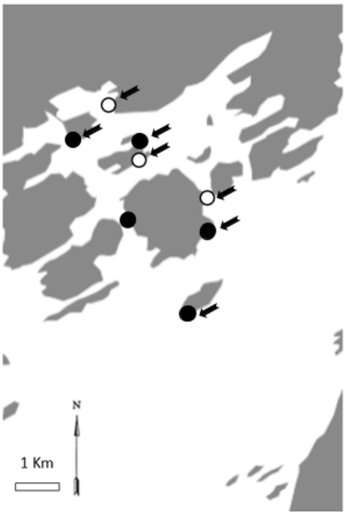
The species is most similar morphologically to *U. clathrate,* but can be distinguish by having a smaller number of pyrenoids (2-3 per cell) (Brodie et al., 2007).

The species was only identified in August, with individuals exhibiting epiphytic growth from one of the sites.

Site: Identified from Store Ostsund, Høvikodden and Borøya Nord.

Previous findings: Larsen (1995) identified individuals from Gåsøya and Borøya Sør. Grenager (1957) reported no findings on any of the eight sites. Klavestad (1978) identified individuals from Høvikodden and Borøya Nord.

Permanent collection Slide nr. 12.



Ulva intestinalis Linnaeus

Description: The species was identified from both small unattached tubular threads and other larger groups of attached thalli that increased in width from base to mid-thallus. The color ranges from dark to light green. The thalli are unbranched or with few branches towards the base, always hollow, and the tube consists of one cell layer. Cells are rounded, 8-20 µm, unordered or arranged in short longitudinal rows, and with one pyrenoid per cell (Brodie et al., 2007).

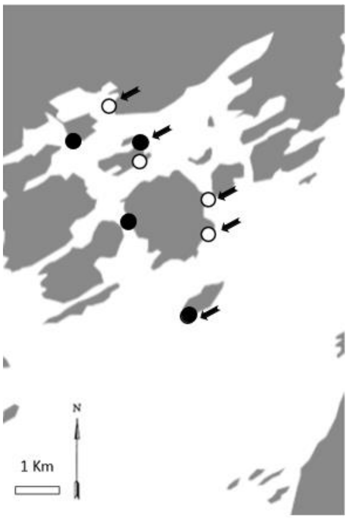
The species was identified in May and August, with some individuals found in tidepools. Epiphytic growth was also observed.

Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Kalvøya and Borøya Nord.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta, Kalvøya, Høvikodden, Borøya Nord, Borøya Sør and Lille Ostsund. Grenager (1957) and Klavestad (1978) report the species as dominating on most of the sites in the Oslofjord.

Permanent collection: Slide nr. 13.

Ulva prolifera O.F. Müller



Description: Thalli are highly variable in morphology, ranging from little-branched ribbons up to 50 cm in length, to highly branched slender tubes that are less than one millimeters in diameter. Cells are rectangular to polygonal, 10-22 x 7-12 µm, arranged in distinct longitudinal and transverse rows, and with one large central pyrenoid (Brodie et al., 2007).

The species is commonly found in eutrophicated areas, has epilithic and epiphytic growth and is often mixed with other *Ulva* species (Brodie et al., 2007).

The species was identified in May and August, with some individuals found in tidepools. Epiphytic growth was also observed.

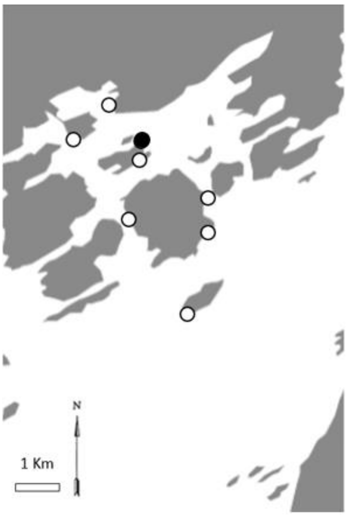
Site: Identified from Gåsøya, Store Ostsund, Kalvøya, and Borøya Nord.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta, Høvikodden, Borøya Nord and Lille Ostsund. Grenager (1957) identified individuals from one site in the inner part of the Bærum basin. Klavestad (1978) reported the species as sparse to regular in most parts of the fjord.

Permanent collection: Slide nr. 14.

Family: Ulvellaceae

Ulvella viridis (Reinke) R. Nielsen



Description: Thalli are uniseriate, mutually free, alternately branched filaments of cylindrical cells, 3-5 µm in diameter and two to three times longer (Brodie et al., 2007). Filaments with rounded cells form pseudoparenchyma in central parts. Chloroplast are parietal, with one pyrenoid. Thin hairs extend from the intercalary cells. Reported as endophyte from wide variety of host (Brodie et al., 2007), identified growing on *Vertebrata fucoides* in this study.

The endophyte was only identified in May.

Site: Identified from Borøya Nord.

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

Permanent collection: Slide nr. 30.

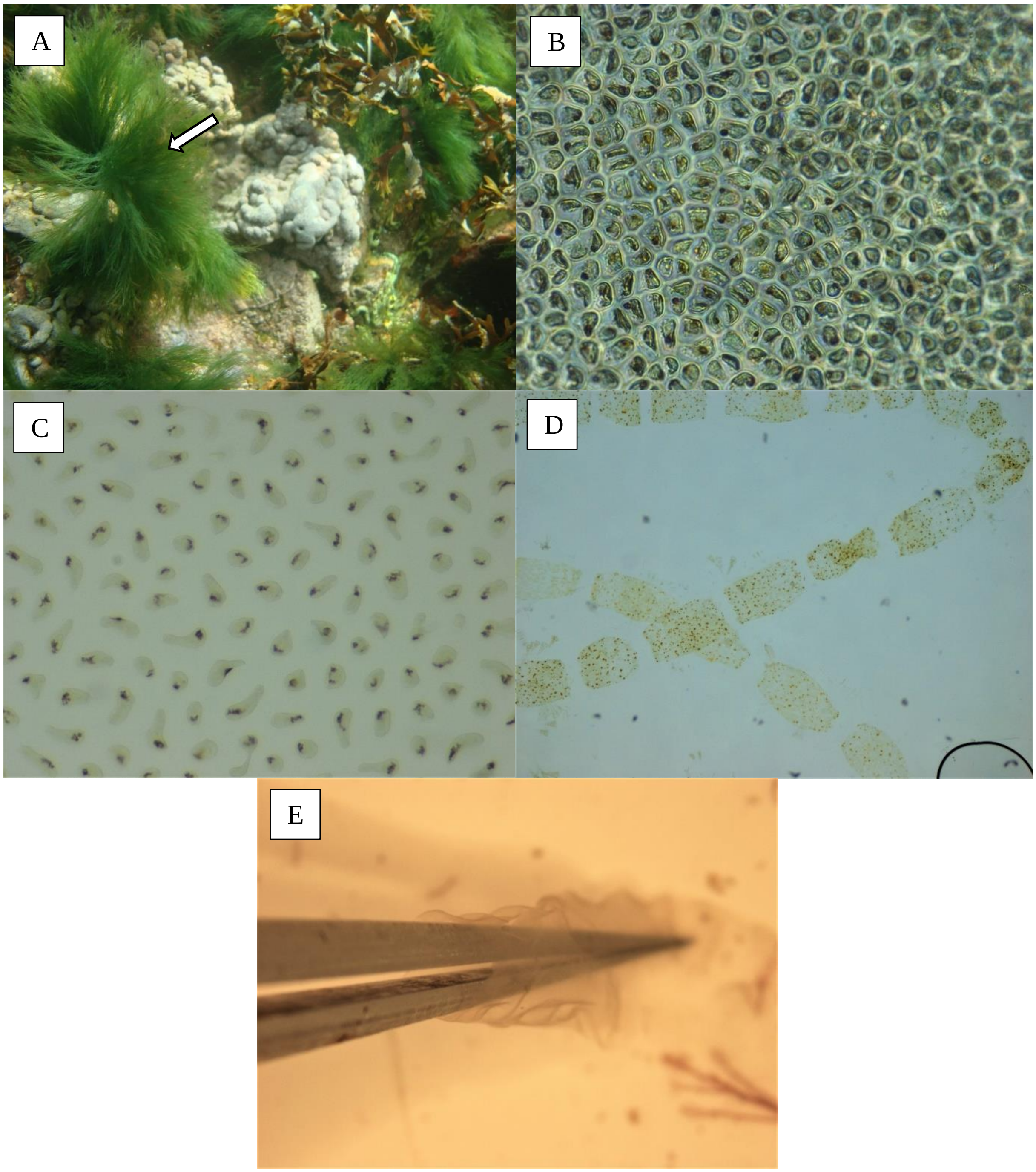


Plate 1. A: *Cladophora rupestris*, with arrow pointing at the thallus. B: *Ulva intestinalis*. C: *Monostroma grevillei*. D: *Urospora wormskioldii*. E: *Ulva intestinalis*, being propped open with tweezers to display the hollow thallus.

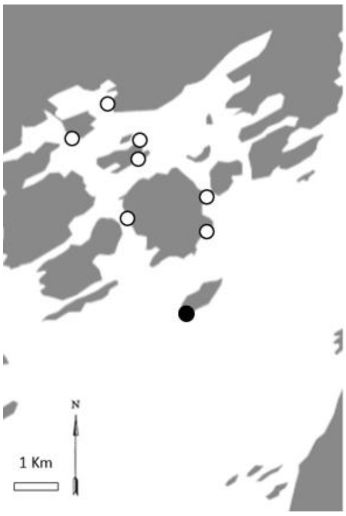
3.2.2 Ochrophyta

Phylum: Ochrophyta

Class: Phaeophyceae

Order: Chordales

Family: Chordaceae



Chorda filum (Linnaeus) Stackhouse

Description: Thalli are long, unbranched, hollow, rope-like, yellowish brown fronds, that have short colourless hairs during summer, and attached with a discoid holdfast (Rueness, 1977).

The species can be confused with *Halosiphon tomentosus*, which is covered with brown assimilation hairs (Rueness, 1977).

The species was identified in May and August.

Site: Identified from Gåsøya.

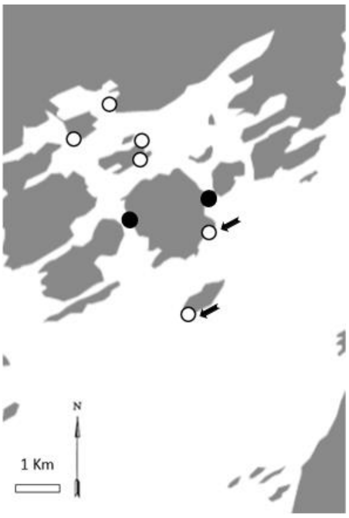
Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

Permanent collection: no.

Order: Desmarestiales

Family: Desmarestiaceae

Desmarestia viridis (O.F. Müller) J.V. Lamouroux



Description: Thalli are erect, terete, solitary, highly branched, arising from a small bulbous or flattened holdfast, and light golden brown in colour. Thalli are oppositely branched and the main axis is cartilaginous (Fletcher, 1987)

The species was only identified in May.

Site: Identified from Store Ostsund and Lille Ostsund.

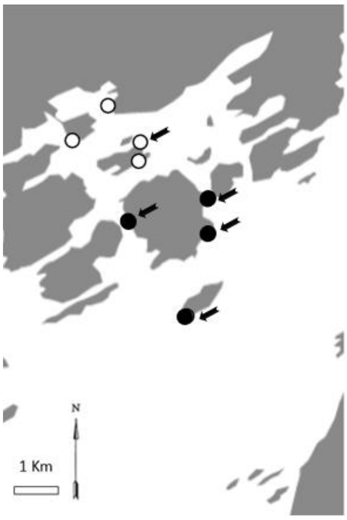
Previous findings: Larsen (1995) identified individuals from Gåsøya and Flisbukta. Grenager (1957) reported no findings of the species. Klavestad (1978) reported no findings from any of the eight sites.

Permanent collection: Slide nr. 31.

Order: Ectocarpales

Family: Chordariaceae

Dictyosiphon foeniculaceus (Hudson) Greville



Description: Thalli are abundantly and irregularly branched, commonly covered with colourless hairs, corticated by small rounded cells, unilocular sporangia spread across the surface, imbedded in the cortex (Rueness, 1977).

The species was identified in May and August. Some individuals displayed epiphytic growth and others were identified for tidepools.

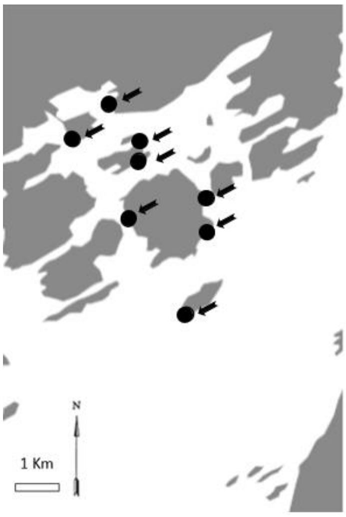
Site: Identified from Gåsøya, Flisbukta, Store Ostsund and Lille Ostsund.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta, Store Ostsund, Borøya Nord and Lille Ostsund. Grenager (1957) identified no individuals from the

Bærum basin. Klavestad (1978) reported the species as regular in the south eastern part of the Bærum basin.

Permanent collection: Slide nr. 32.

Elachista fucicola (Velley) Areschoug



Description: Thalli are brush shaped, with densely packed assimilation hairs growing from a well-developed basal part, epiphytic on *Fucus* species (Rueness, 1977)

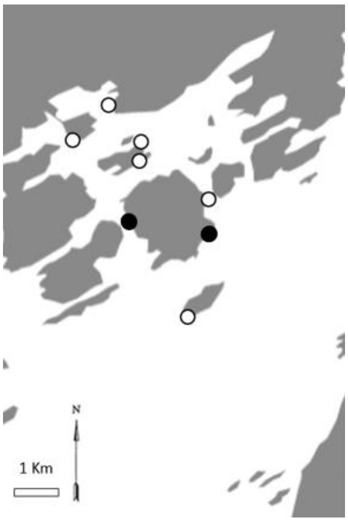
The species was identified growing epiphytically in May and August. A few individuals were found growing in tidepools.

Site: Identified from all eight sites.

Previous findings: Larsen (1995) identified individuals from all eight sites. Grenager (1957) reported the species as scattered in the area. Klavestad (1978) reported the species as regular within Gåsøya, Flisbukta and Lille Ostsund.

Permanent collection: Slide nr. 35.

Spermatochnus paradoxus (Roth) Kützing



Description: Thalli are highly dichotomously branched, composed of a central axis with apical growth, corticated by small cells surrounding larger inner cells, and with shoots that are hollow near the base (Rueness, 1977)

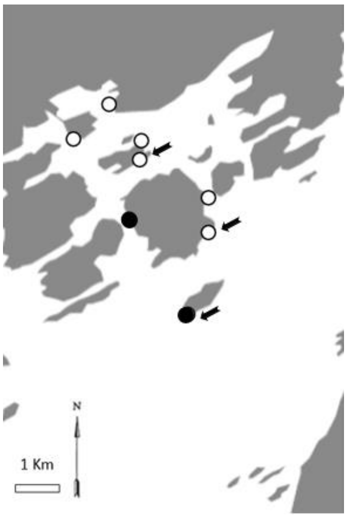
The species was identified in May and August. One of the sites had the species growing in tidepools.

Site: Identified from Flisbukta and Store Ostsund.

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

Permanent collection: Slide nr. 38.

Family: Ectocarpaceae



Ectocarpus fasciculatus Harvey

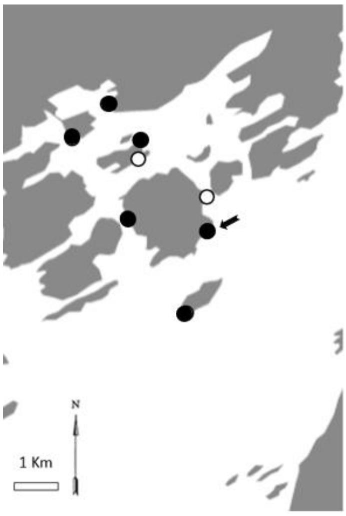
Description: Thalli are irregularly branched, with densely packed laterals in the upper part. Plurilocular sporangia are commonly form rows on the topside of branches and does not form pseudo-hairs (Rueness, 1977).

The species was identified in May, with some individuals growing epiphytically.

Site: Identified from Gåsøya and Store Ostsund.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta and Borøya Sør. Grenager (1957) and Klavestad (1978) reported the species as rare in the area.

Permanent collection: Slide nr. 33.



Ectocarpus siliculosus (Dillwyn) Lyngbye

Description: Thalli are abundantly alternately branched, with branches evenly distributed, and have long and pointy plurilocular sporangia that often ends in a pseudo-hair. Common epiphyte (Rueness, 1977).

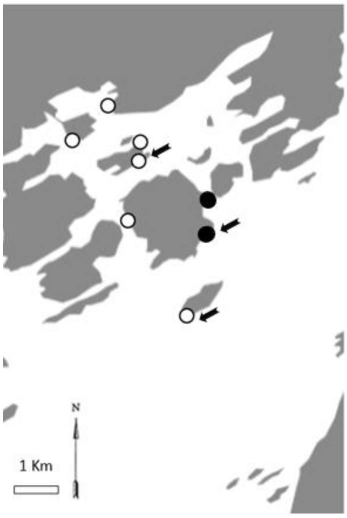
The species was identified growing epiphytically in May and August. A few individuals were found growing in tidepools

Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Kalvøya, Høvikodden and Borøya Nord.

Previous findings: Larsen (1995) only identified individuals from Flisbukta. Grenager (1957) and Klavestad (1978) reported the species as regular in the area.

Permanent collection: Slide nr. 34.

Ectocarpus sp.



Description: The genus has macroscopic thalli with abundantly branched monosiphonous threads, which may contain pseudo-hairs. Cells with one to two ribbon shaped chromatophores with multiple pyrenoids (Rueness, 1977).

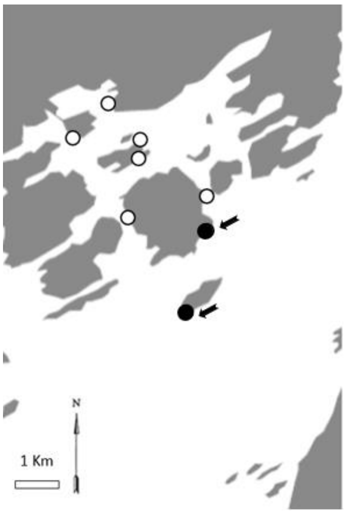
The species was identified in May and August, with some individuals growing epiphytically.

Site: Identified from Flisbukta and Lille Ostsund.

Previous findings: See *Ectocarpus siliculosus* (Dillwyn) Lyngbye and *Ectocarpus fasciculatus* Harvey

Permanent collection: Not present.

Spongonema tomentosum (Hudson) Kützing



Description: Thalli consists of intertwined, monosiphonous threads, irregularly and alternately branched, with short often recurved laterals. Plurilocular sporangia are commonly hook-shaped (Rueness, 1977).

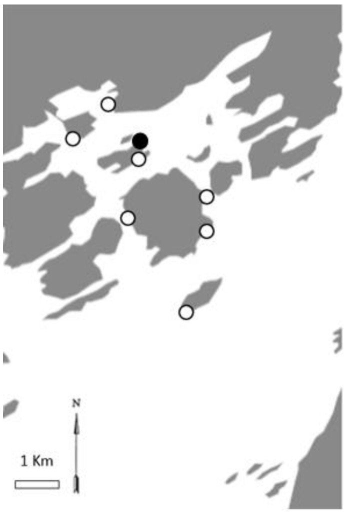
The species was identified in May and August, mostly growing epiphytically. Some individuals were identified from tidepools.

Site: Identified from Gåsøya and Flisbukta.

Previous findings: Larsen (1995) identified individuals from Gåsøya and Flisbukta. Grenager (1957) reported findings from Kalvøya. Klavestad (1978) reported the species as regular in the south eastern part of the Bærum basin.

Permanent collection: Slide nr. 40.

Family: Acinetosporaceae



Pogotrichum filiforme Reinke

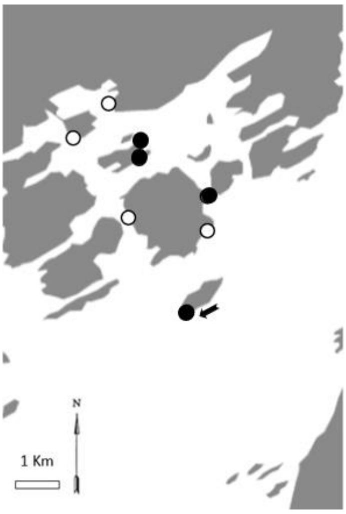
Description: Thalli are thin, hairless, unbranched threads, that grows epiphytically on *Saccharina latissima* (Rueness, 1977).

The species was identified growing epiphytically in August.

Site: Identified from Borøya Nord.

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

Permanent collection: Slide nr. 37.



Pylaiella littoralis (Linnaeus) Kjellman

Description: Thalli are irregularly branched, commonly showing opposite branches. Unilocular sporangia form intercalary series like “pearls on a string”, and plurilocular sporangia are also commonly intercalary (Rueness, 1977).

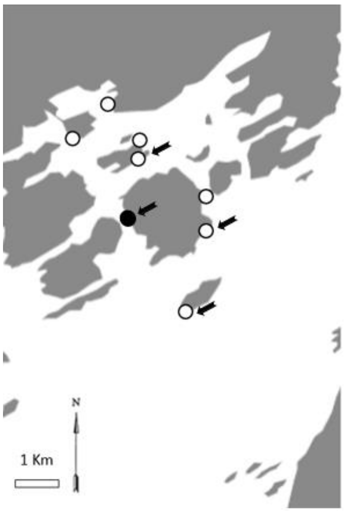
The species was mainly identified in May, but also identified form one site in August. Epiphytic growth was observed.

Site: Identified from Gåsøya, Borøya Nord, Borøya Sør and Lille Ostsund.

Previous findings: Larsen (1995) identified individuals from Gåsøya. Grenager (1957) mainly reported the species as an epiphyte from outside of the Bærum basin. Klavestad (1978) reported the species as a regular epiphyte in the inner Oslofjord.

Permanent collection: Slide nr. 36.

Family: Scytosiphonaceae



Scytosiphon lomentaria (Lyngbye) Link

Description: Thalli form erect, commonly gregarious, yellow to dark brown, tubular thalli attached by a slightly swollen discoid holdfast. The thalli are simple, hollow, flaccid circular, either collapsed or inflated (Fletcher, 1987).

The species was only identified once, in May.

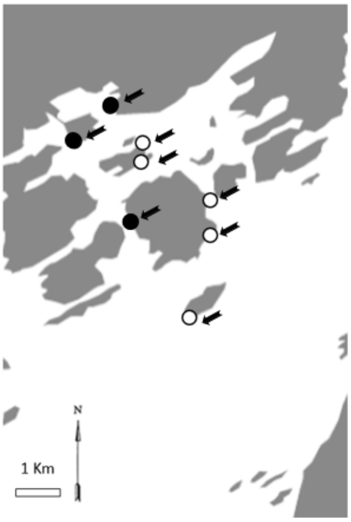
Site: Identified from Store Ostsund.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta, Store Ostsund and Borøya Sør. Grenager (1957) reported no findings from any of the eight sites. Klavestad (1978) reported the species as regular within the south eastern part of the Bærum basin.

Permanent collection: no.

Order: Fucales

Family: Fucaceae



Fucus distichus subsp. *evanescens* (C. Agardh) H.T. Powell

Description: Thalli are olive green, irregularly dichotomously branched, smooth edged, outfitted with long receptacles during the spring, caecostomata in the cortex, and have a midrib that becomes indistinct in the apex (Rueness, 1977).

Unfertile individuals of *F. distichus* subsp. *evanescens* can be confused with bladderless *F. vesiculosus.*

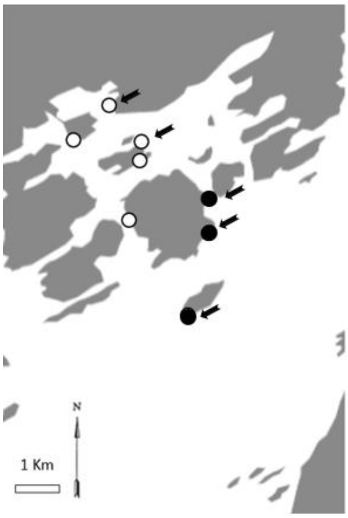
The species was identified in May and August from the three sites.

Site: Identified from Store Ostsund, Kalvøya and Høvikodden.

Previous findings: Larsen (1995) identified individuals from all eight sites. Grenager (1957) reported no findings from the eight sites. Klavestad (1978) only reported findings from Gåsøya.

Permanent collection: no.

Fucus serratus Linnaeus



Description: The species is easily recognizable due to its sawtooth-serrated thallus edge. Furthermore, the thalli are dichotomously branched with a prominent midrib, olive green in colour. The species is dioecious (Rueness, 1977)

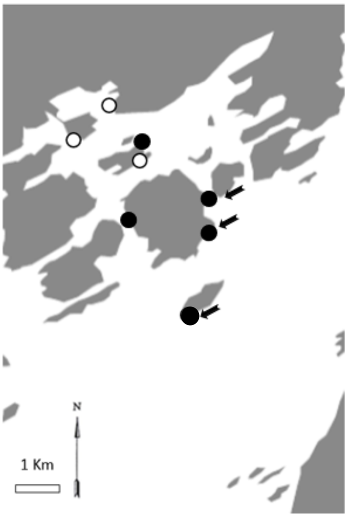
F. serratus was identified in May and August.

Site: Identified from Gåsøya, Flisbukta and Lille Ostsund.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta, Høvikodden, Borøya Nord and Lille Ostsund. Grenager (1957) reported the species as "not irregular" in the area and overgrown by epiphytes. Klavestad (1978) reported the species as rare and overgrown by epiphytes. Magnusson et al. inner limit included Gåsøya, Flisbukta and Lille Ostsund.

Permanent collection: no.

Fucus spiralis Linnaeus



Description: Thalli are olive brown in colour, somewhat irregularly dichotomously branched, smooth along the edges, lacking air bladders, sometimes spiralled and with a prominent midrib. The species is monoecious and fertile during summer (Rueness, 1977).

The species can easily be confused with bladder-less form of *F. vesiculosus*

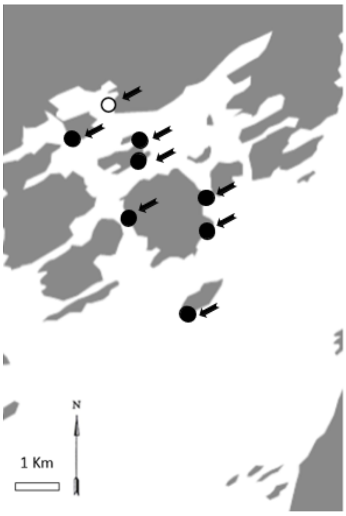
F. spiralis was identified in May and August.

Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Borøya Nord and Lille Ostsund.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta and Lille Ostsund. Grenager (1957) reported the species as regular in areas least affected by pollution, meaning no findings in any of the eight sites in the Bærum basin. Klavestad (1978) reported findings from Gåsøya. Magnusson et al. reported a slight broader presence of the species, including Gåsøya, Borøya Nord, Lille Ostsund and Flisbukta. (Magnusson et al., 1991).

Permanent collection: no.

Fucus vesiculosus Linnaeus



Description: Thalli are highly variable in morphology, typically recognized by having spherical air bladders in pair on either side of a prominent midrib, smooth margin and dichotomously branched. The species is dioecious and fertile during the spring (Rueness, 1977).

Individuals of *F. vesiculosus* lacking air bladders can be confused with *F. spiralis,* which are monoecious in contrast to *F. vesiculosus.*

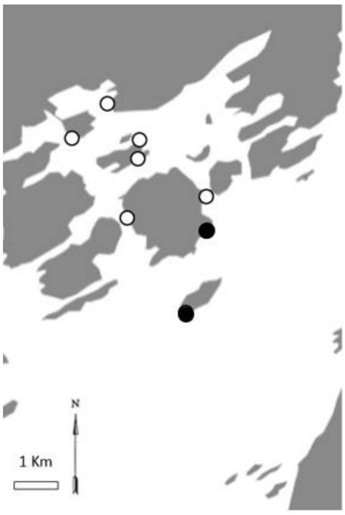
The species was identified in May and August.

Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Kalvøya, Borøya Nord, Borøya Sør and Lille Ostsund.

Previous findings: Larsen (1995) identified individuals from all eight sites, but he reported the species as rare from Borøya Sør. Grenager (1957) and Klavestad (1978) reported the species as very regular in the area. Magnusson et al. reported the species as rare from Gåsøya, Flisbukta, Borøya Nord and Lille Ostsund (Magnusson et al., 1991).

Permanent collection: no.

Family: Sargassaceae



Sargassum muticum (Yendo) Fensholt

Description: Thalli are large, brown to yellow and separated into two parts. The perennial part contains a holdfast with one of more main axes. The annual part develops from the main axis and has unlimited growth. The thalli can develop into fronds, fronds with air vesicles called aerocysts, and fronds with aerocysts and reproductive receptacles (Coppejans, 1995).

It can sometimes be problematic to assign *S. muticum* to a specific site, since the drifting parts of the species could have recently drifted in with the wind. I only found drifting specimens. However, I decided to include the species and noted were the drifting parts was found as it is an invasive species.

The species was only identified in May.

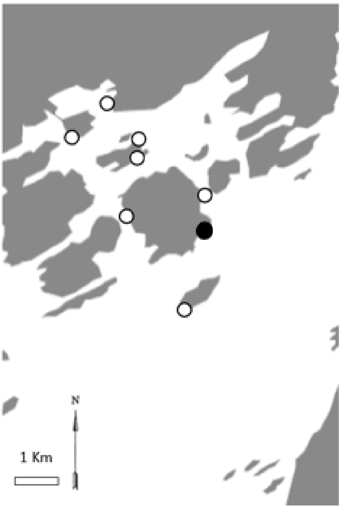
Site: Identified from Gåsøya and Flisbukta.

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites. The species was first recorded in Norway sometime after Grenager (1957) and Klavestad's (1978) investigations.

Permanent collection: no

Order: Laminariales

Family: Laminariaceae



Saccharina latissima (Linnaeus) C.E. Lane, C. Mayes, Druehl & G.W. Saunders

Description: Round and smooth stipe with a long and wide lamina, undivided, wavy and sometimes frayed at the edges. The consistency is slightly crisp, but slimy (Rueness, 1977).

The species was only identified in May.

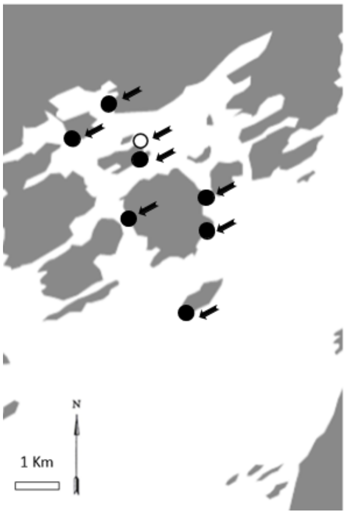
Site: Identified from Flisbukta.

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

Permanent collection: no.

Order: Sphacelariales

Family: Sphacelariaceae



Sphacelaria cirrosa (Roth) C. Agardh

Description: Thalli are stiff, protruding tufts growing epiphytically on many species of algae, or epilithic, without transverse walls in the secondary segments. Propagules are very common and consist of a short stem with three equally long branches (Rueness, 1977).

The species was identified in May and August. Most specimens grew epiphytically, but there were also a few examples of epilithic growth.

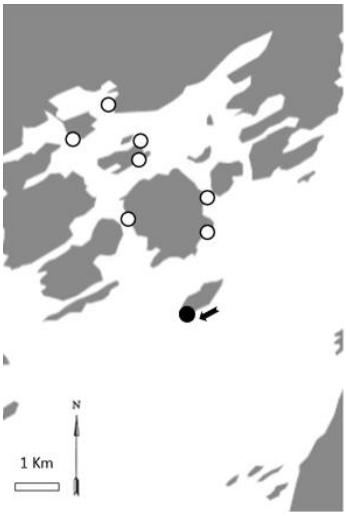
Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Kalvøya, Høvikodden, Borøya Sør and Lille Ostsund.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Kalvøya, Høvikodden Borøya Nord and Borøya Sør. Grenager (1957) reported findings from Kalvøya. Klavestad (1978) reported findings from Borøya Nord.

Permanent collection: Slide nr. 39.

Order: Stschapoviales

Family: Halosiphonaceae



Halosiphon tomentosus (Lyngbye) Jaasund

Description: Thalli are long, unbranched, and chord-like, with densely packed yellow-brown assimilation hairs (Rueness, 1977).

The species was identified in May.

Site: Identified from Gåsøya.

Previous findings: Larsen (1995) identified individuals from Gåsøya under det synonym *Chorda tomentosa* Lyngbye. Grenager (1957) reported no findings of the species. Klavestad (1978) reported findings outside of the Bærum basin.

Permanent collection: no.

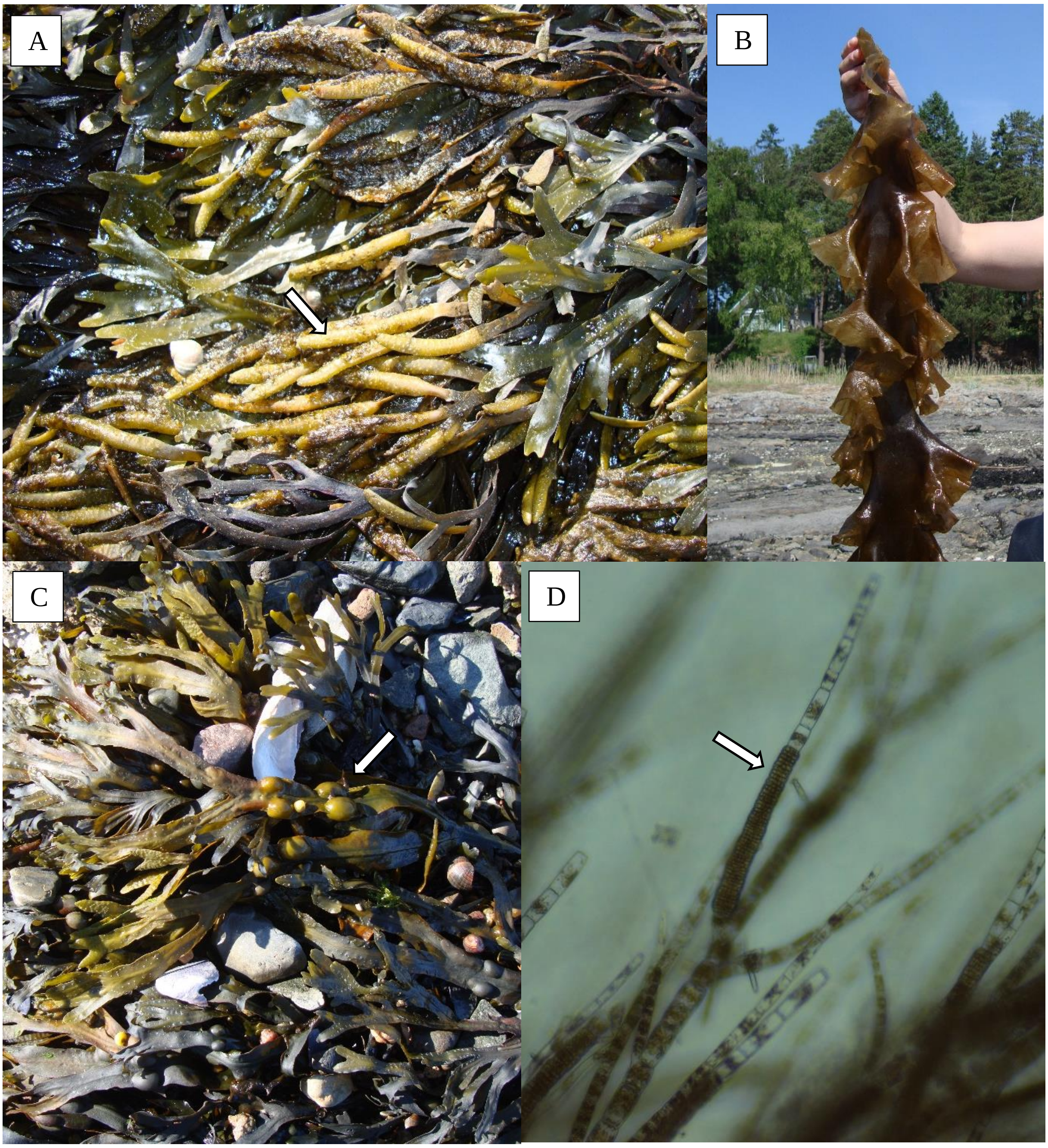


Plate 3. A: *Fucus distichus* subsp. *evanescens*, with arrow pointing at long and narrow receptacles. B: *Saccharina latissima*. C: *Fucus vesiculosus*, with arrow pointing at paired spherical air bladders. D: *Pylaiella littoralis*, with arrow pointing on intercalary plurilocular sporangia.

3.2.3 Rhodophyta

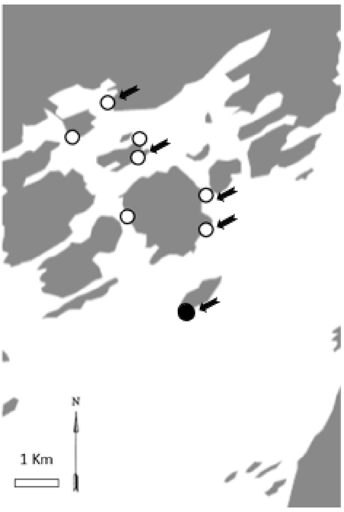
Phylum: Rhodophyta

Class: Bangiophyceae

Order: Bangiales

Family: Bangiaceae

Porphyra umbilicalis Kützing



Description: Thalli are leafy, round to lanceolate, brownish purple to red-brown, can be greenish near the base, with central holdfast, and rubbery texture (Bird and McLachlan, 1992). Can be confused with *P. purpurea*. However, this species has a more oblong shape and delicate texture (Bird and McLachlan, 1992).

The species was only identified in August.

Site: Identified from Gåsøya.

Previous findings: Larsen (1995) identified *Porphyra* spp. from Gåsøya, Flisbukta, Høvikodden, Borøya Sør and Lille Ostsund. Grenager (1957) and Klavestad (1978) found *Porphyra* individuals from the outer parts of the Bærum basin, but the exact species is questionable.

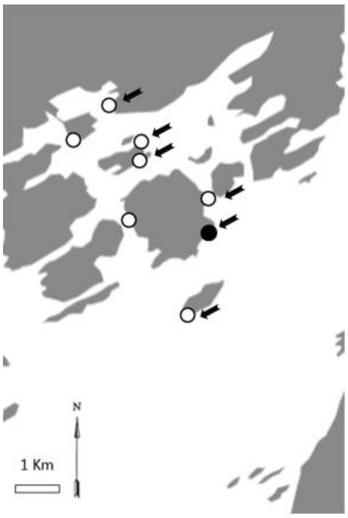
Permanent collection: Slide nr. 29.

Class: Compsopogonophyceae

Order: Erythropeltales

Family: Erythrotrichiaceae

Erythrotrichia carnea (Dillwyn) J. Agardh



Description: Thalli are mostly uniseriate, unbranched filaments, attached by a tapered basal cell with lobed rhizoids extending over and sometimes into the substratum, with stellate central plastid bearing one pyrenoid giving a rose-red colour. Epiphytic on larger algae and eelgrass and primarily observed during the summer and autumn (Bird and McLachlan, 1992).

The species can be confused with *Porphyrostromium ciliare*, which differ in its greater tendency to become multiseriate and in having a discoid phase (Bird and McLachlan, 1992).

E. carnea was identified growing epiphytically, in August.

Site: Identified from Flisbukta.

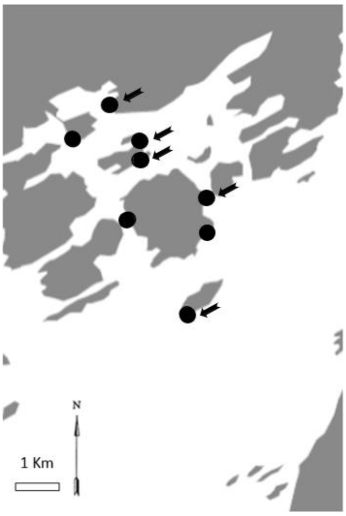
Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta, Høvikodden, Borøya Nord, Borøya Sør and Lille Ostsund. Grenager (1957) and Klavestad (1978) reported the species as a regular epiphyte in the area.

Permanent collection: Slide nr. 8.

Class: Florideophyceae

Order: Acrochaetiales

Family: Acrochaetiacea



Acrochaetium spp.

Description: The genus is composed of a heterogeneous assemblage of small red algae with branched, uniseriate, uncorticated filaments, apical growth, attachment by single cell, multicellular disc or basal filaments (Bird and McLachlan, 1992)

The family Acrochaetiacea has undergone several taxonomic changes over the years, and the species within it are highly variable (Dixon and Irvine, 1977).

Larsen (1995) and Grenager (1957) identified species within the genus *Audouinella,* which is now only used for freshwater species, according to algaebase.org.

Furthermore, individuals could easily be confused with species within the genus *Rhodochorton* Nägeli. However, individuals did not displayed many parietal chloroplasts, without pyrenoids, which is typical for the genus (Harper et al., 2002).

The specimens were identified as epiphytes in May and August.

Site: Identified from all eight sites.

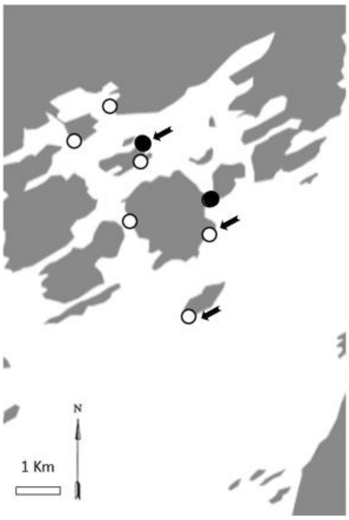
Previous findings: Larsen (1995) identified *Audouinella* cf. *virgatula* and *Audouinella* spp. *(= Acrochaetium secundatum* and likely *Acrochatium* spp., respectively*)* from Gåsøya, Høvikodden, Borøya Nord, Borøya Sør and Lille Ostsund. Grenager (1957) found *Audouinella* spp. outside of the Bærum basin. Klavestad (1978) reported several *Acrochaetium* species as rare to common within Larsen's (1995) investigation area.

Permanent collection: Slide nr. 18.

Order: Ahnfeltiales

Family: Ahnfeltiaceae

Ahnfeltia plicata (Hudson) Fries



Description: The species is heteromorphic. The gametophytes are reddish-black to dark reddish-brown, bushy, wiry, with several axes arising from a thin, spreading crustose holdfast, terete throughout, dichotomously to irregularly branched, and with texture of plastic netting (Bird and McLachlan, 1992).

A. plicata was identified in May and August.

Site: Identified from Borøya Nord and Lille Ostsund.

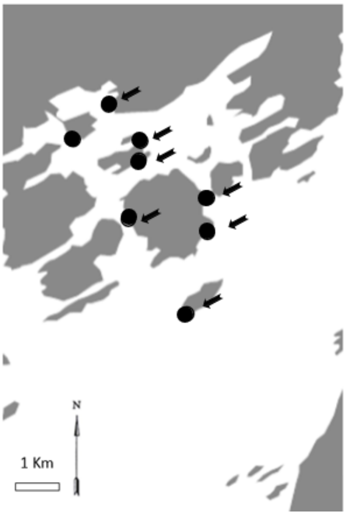
Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta and Borøya Nord. Grenager (1957) reported no findings of this species. Klavestad (1978) reported the species as regular from Gåsøya and Flisbukta.

Permanent collection: no.

Order: Ceramiales

Family: Ceramiaceae

Ceramium tenuicorne (Kützing) Waern



Description: Thalli consisting of entangled axes giving rise to dense hemispherical to cylindrical tufts, repeatedly pseudodichotomously branched, dull purple in colour that bleaches to yellowish. Incomplete cortication leaves distinct cortical bands visible to the naked eye, levelled with the internodal axial cells (Maggs, 1993). The species has 6-7 periaxial cells.

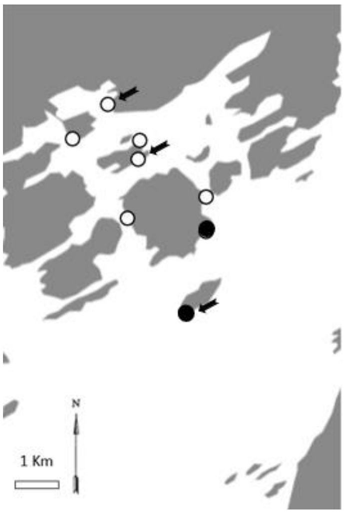
C. tenuicorne was mainly identified in August, apart from one individual found in May. The species exhibited both epiphytic and epilithic growth and was sometimes growing in tidepools.

Site: Identified from all eight sites.

Previous findings: Larsen (1995) identified individuals under the synonym *C. strictum (= C. tenuicorne*) from Gåsøya, Flisbukta, Store Ostsund, Høvikodden, Borøya Nord, Borøya Sør and Lille Ostsund. Grenager (1957) identified similar individuals from Gåsøya. Klavestad (1978) reports the same species as rare to regular in the Oslofjord.

Permanent collection: Slide nr. 21.

Ceramium virgatum Roth



Description: Thalli consist of irregularly branched and irregularly shaped tufts of one to several erect axes attached by a dense mass of multicellular rhizoidal filaments, dull brownish-red in colour, with 6-7 periaxial cells (Maggs, 1993). The thalli are typically fully corticated, sometimes with internodular constrictions (Maggs, 1993).

The species was identified in May and August, with some individuals found in tidepools. Epiphytic growth was common.

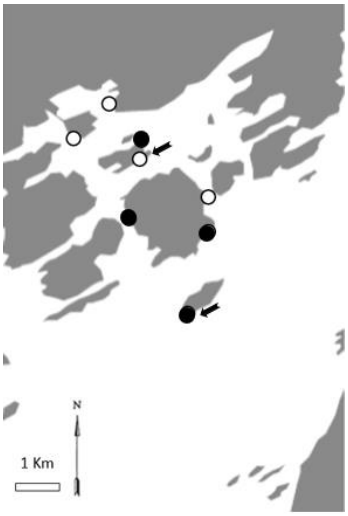
Site: Identified from Gåsøya and Lille Ostsund.

Previous findings: Larsen (1995) identified individuals named *C. nodulosum* (= *C. virgatum* Roth) from Gåsøya, Høvikodden and Borøya Sør. Gran found the species *C. rubrum* (= *C. virgatum* Roth) regularly distributed. Grenager (1957) reports the algae as very regular in all location except for Høvikodden. Klavestad (1978) reports the same as Grenager (1957) but includes Høvikodden.

Permanent collection: Slide nr. 22.

Family: Callithamniaceae

Callithamnion corymbosum (Smith) Lyngbye



Description: Thalli consisting of single erect, naked axis attached by discoid holdfast, with aggregations of corticated rhizoidal filaments, orange-pink to deep red in colour, flaccid and delicate (Maggs, 1993).

Can be confused with species from the *Aglaothamnion* genus, but is distinguished by having multinucleate vegetative cells

C. corymbosum was identified in May and August. Epiphytic growth was observed, and some individuals grew in tidepools.

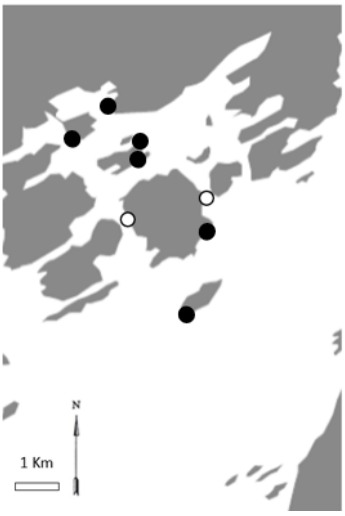
Site: Identified from Gåsøya, Flisbukta and Store Ostsund.

Previous findings: Larsen (1995) identified individuals from Gåsøya and Borøya Sør. Grenager (1957) report no findings from any of the eight sites. Klavestad (1978) reports the species as regular from Borøya.

Permanent collection: Slide nr. 19.

Family: Rhodomelaceae

Carradoriella elongata (Hudson) A.M. Savoie & G.W. Saunders



Description: Thalli consisting of a single branched erect axis attached by a holdfast, with four periaxial cell, branches replacing trichoblasts, with young branches spindle-shaped and markedly constricted basally (Maggs, 1993).

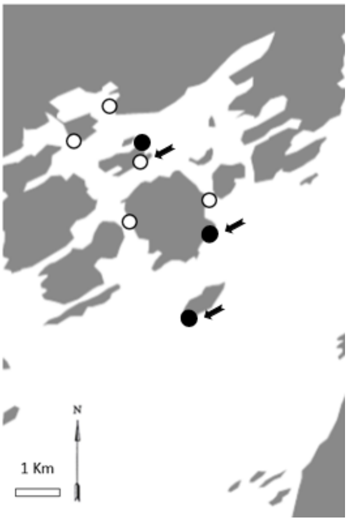
C. elongate can be confused with *Melanothamnus harveyi* However, *M. harveyi* has transparent periaxial cells with the chloroplasts close to the central cell, and branches that are not constricted basally (Maggs, 1993).

The species was mostly identified in August, apart from one individual in May. One of the sites had individuals growing in tidepools.

Site: Identified from Gåsøya, Flisbukta, Kalvøya, Høvikodden, Borøya Nord and Borøya Sør.

Previous findings: There is no previous identification of *C. elongata* by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites. However, Larsen (1995) identified *Polysiphonia harveyi* (= *M. harveyi*) from Gåsøya, Flisbukta and Lille Ostsund. Neither Gran (1897), Grenager (1957) or Klavestad (1978) identified *P. harveyi*.

Permanent collection: Slide nr. 20.



Leptosiphonia fibrillosa (Agardh) A.M. Savoie & G.W. Saunders

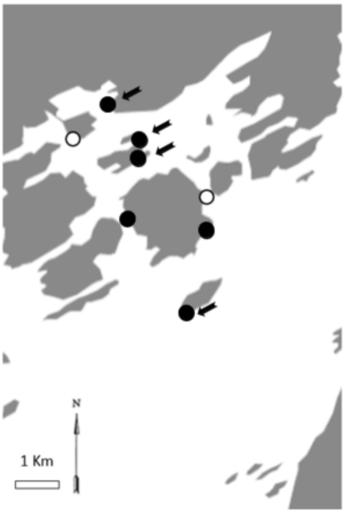
Description: Thalli has initially a single much branched erect axis, with discoid holdfast, four periaxial cells, cortication near the base at least, and ovoid or globular cystocarp with narrow ostiole (Maggs, 1993) The species show great morphological variability and can be confused with other species within the family Rhodomelaceae, including *Carradoriella elongate* and *Melanothamnus harveyi* (Maggs, 1993).

The species was identified in May and August. Epiphytic growth was observed, and one individual grew in tidepools.

Site: Identified from Gåsøya, Flisbukta and Borøya Nord.

Previous findings: Larsen (1995) identified individuals under the synonym *Polysiphonia fibrillosa* from Gåsøya, Flisbukta and Borøya Sør. Grenager (1957) reported findings from Kalvøya, but some of this material was identified as *P. hemisphaerica* (Rueness, 1971). Klavestad (1978) reports the species as regularly distributed in the Oslofjord.

Permanent collection: Slide nr. 28.



Vertebrata fucoides (Hudson) Kuntze

Description: Thalli consists of dense cylindrical to irregularly rounded tufts, dark brownish-red in colour, attached by tangled prostrate axes compacted by densely matted rhizoids, with highly variable branching. The main axes usually remains distinct, with 11-21 straight or slightly spiralled periaxial cells, with cortication present on lower main axes (Maggs, 1993).

The branching pattern of *V. fucoides* may sometimes resemble that of *Boergeseniella thuyoides*, which is distinguished from *V. fucoides* by having cortication along the entirety of the thallus.

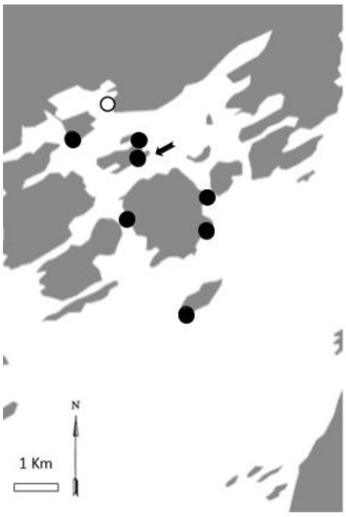
The species was identified in May and August. One of the sites had individuals growing in tidepools.

Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Høvikodden, Borøya Nord and Borøya Sør.

Previous findings: Larsen (1995) identified individuals under the synonym *Polysiphonia fucoides* from Gåsøya, Høvikodden, Borøya Nord and Borøya Sør. Grenager (1957) reports the species as scattered in the area. Klavestad (1978) reports the species regularly distributed.

Permanent collection: Slide nr. 30.

Family: Delesseriaceae



Dasya baillouviana (S.G. Gmelin) Montagne

Description: Thalli is bright to dark brownish-red in colour, up to 50 cm tall from a discoid base, freely alternately branched, with a single axial filament surrounded by five periaxial cells, and well-developed cortex. The lateral branchlets are pseudodichotomously branched. The species is unlikely to be confused with any other species in the Norwegian flora (Bird and McLachlan, 1992) Furthermore, *D. baillouviana* is an invasive species (Rinde et al., 2017)

The species was only identified in August.

Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Kalvøya, Borøya Nord, Borøya Sør and Lille Ostsund.

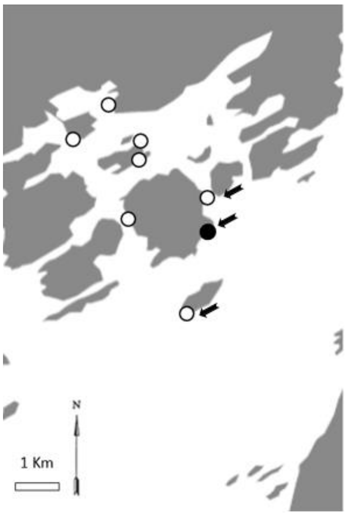
Previous findings: Larsen (1995) identified individuals from Borøya Sør exclusively. The species was not identified by Grenager (1957) or Klavestad (1978) on any of the eight locations.

Permanent collection: Slide nr. 24.

Order: Corallinales

Family: Lithothamniaceae

Phymatolithon lenormandii (Areschoug) W.H. Adey



Description: Thalli are encrusting, brownish, reddish, greyish or pinkish in colour, thin and flat, with smooth surface, margin with strong orbital ridges, without branches or protuberance, conceptacles present throughout the year, and medulla to 50% thallus thickness (Irvine et al., 1994).

The species was identified in May.

Site: Identified from Flisbukta.

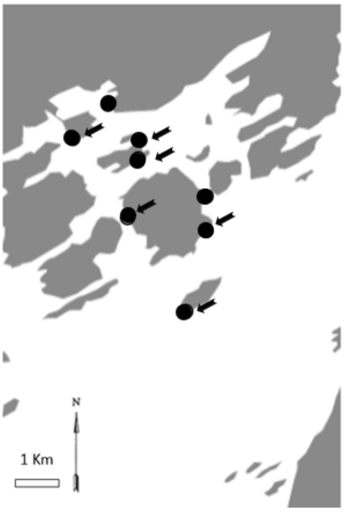
Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta and Lille Ostsund. Grenager (1957) reported no findings of the species. Klavestad (1978) reported the species as regular from Gåsøya.

Permanent collection: no.

Order: Gigartinales

Family: Gigartinaceae

Chondrus crispus Stackhouse



Description: Thalli are variable in form, usually less than 12 cm, bushy, with loose to dense clumps of fronds arising from an extensive crustose holdfast, repeated widely divergent dichotomous branching in one line above a tapered stipe-like lower portion, compressed to flattened throughout except for the terete base (Bird and McLachlan, 1992).

C. crispus can be mistaken with many other species, including *Mastocarpus stellatus*, and species from the genera *Gymnogongrus* and *Phyllophora*. However, the stipe edges of *M. stellatus* curve slightly inward and the fronds are roughened by reproductive papillae. Species of *Gymnogongrus* has medulla of large cells instead of filaments, and cystocarps protrude bilaterally. The species of

Phyllophora that resemble *C. crispus* generally have a thinner and more membranous leafy portion and a medulla of consistently rounded cells (Bird and McLachlan, 1992).

The species was identified in May and August, and sometimes found in tidepools of the two most exposed sites.

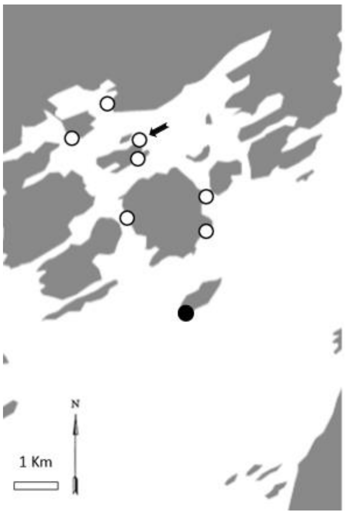
Site: Identified from all eight sites.

Previous findings: Larsen (1995) identified individuals from Gåsøya, Flisbukta, Store Ostsund, Kalvøya, Borøya Nord and Borøya Sør. Grenager (1957) reported scattered individuals in the Bærum basin. Klavestad (1978) reported scattered individuals from the Vestfjord, including some of the Bærum basin.

Permanent collection: Slide nr. 23.

Family: Polyidaceae

Polyides rotunda (Hudson) Gaillon



Description: Thalli are bushy, dark red-brown to blackish-red, with several repeatedly dichotomously branched fronds from a discoid holdfast, axes terete and uniformly slender, firm and cartilaginous in texture, the intervals between branches diminish towards the apex (Bird and McLachlan, 1992).

Vegetative *P. rotunda* closely resembles *Furcellaria lumbricalis*. However, *F. lumbricalis* has a fibrous holdfast and greenish colour (Bird and McLachlan, 1992).

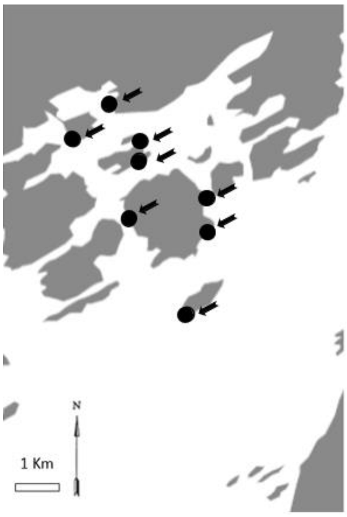
P. rotunda was only identified from one site, in May.

Site: Identified from Gåsøya.

Previous findings: Larsen (1995) only identified individuals from Borøya Nord. Grenager (1957) did not identify the species. Klavestad (1978) reports the species as common from Gåsøya.

Permanent collection: no.

Family: Dumontiaceae



Dumontia contorta (S.G. Gmelin) Ruprecht

Description: Thalli are bright red-brown to bleached pallid brownish, with one to several erect fronds attached by a discoid holdfast, axes irregularly alternately branched to one degree, initially terete and filiform with tapered apices, becoming hollow and irregularly compressed with age. The texture is flaccid and somewhat slippery (Bird and McLachlan, 1992)

Young individuals of *D. contorta* can resemble small *Cystoclonium purpureum* (Bird and McLachlan, 1992).

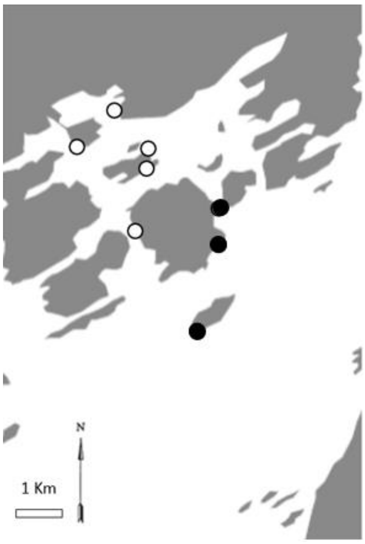
D. contorta was mainly identified in May, except for individuals from one site in August.

Site: Identified from all eight sites.

Previous findings: Larsen (1995) identified individuals from all eight sites. Klavestad (1978) reported the species from Gåsøya.

Permanent collection: Slide nr. 25.

Family: Furcellariaceae



Cf. *Furcellaria lumbricalis* (Hudson) J.V. Lamouroux

Description: Thalli are bushy dark red-brown to greenish purple, with slender, regularly dichotomously branched fronds attached by a fibrous holdfast of tangled branched stolons, terete except for at the dichotomies, with firm and cartilaginous texture (Bird and McLachlan, 1992).

The species can be confused with *Polyides rotunda.* Vegetative *P. rotunda* closely resembles *Furcellaria lumbricalis*. However, *F. lumbricalis* has a fibrous holdfast and greenish colour (Bird and McLachlan, 1992).

F. lumbricalis was identified in May and August.

Site: Identified from Gåsøya, Flisbukta and Lille Ostsund

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

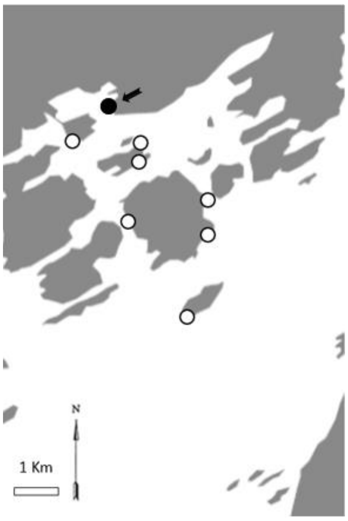
Permanent collection: no.

Order: Gracilariales

Family: Gracilariaceae

Gracilaria gracilis (Stackhouse) Steentoft, L.M. Irvine & Farnham

Description: Thalli consisting of one or more erect fronds, terete throughout, very elastic, attached by a discoid holdfast, dark brownish-purple to green in colour, tapering towards the apices, and repeatedly subdichotomously or irregularly branched (Dixon and Irvine, 1977)



The species is sometimes confused with *Cordylecladia erecta, Cystoclonium purpureum.* However, *C. erecta* is bright red and consists of several fronds arising from an expanded basal disc, and there are also differences in the tetrasporangial sori and cystocarps. *C. purpureum* has a branched holdfast, also zonate tetrasporangia and embedded cystocarp. (Dixon and Irvine, 1977).

G. gracilis was only identified once in August.

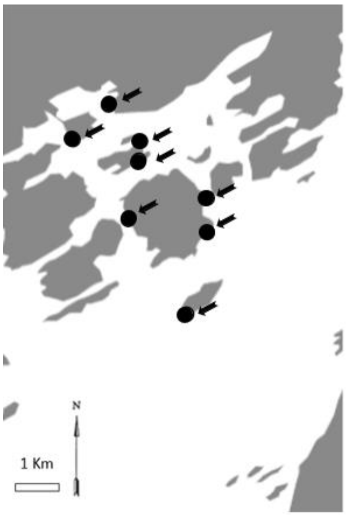
Site: Identified from Høvikodden.

Previous findings: Larsen (1995) identified *G. verrucosa (= G. gracilis)* from Høvikodden. Grenager (1957) reported *Gracilaria* from Kadettangen and Store Ostsund. Klavestad (1978) found *Gracilaria* on four localities in the Bærum basin, including Kalvøya, Høvikodden and Borøya Nord.

<u>Permanent collection:</u> Slide nr. 27.

Order: Hildenbrandiales

Family: Hildenbrandiaceae



Hildenbrandia rubra (Sommerfelt) Meneghini

<u>Description:</u> Thalli are rose red to dark red or nearly black, encrusting, indefinitely large, outline usually irregular, with smooth surface. (Irvine et al., 1994).

The species was identified in May and August.

<u>Site:</u> Identified from all eight sites.

<u>Previous findings:</u> Larsen (1995) identified individuals from all eight sites. Klavestad (1978) reported the species as regular in the area except for the inner harbour areas.

<u>Permanent collection:</u> no.

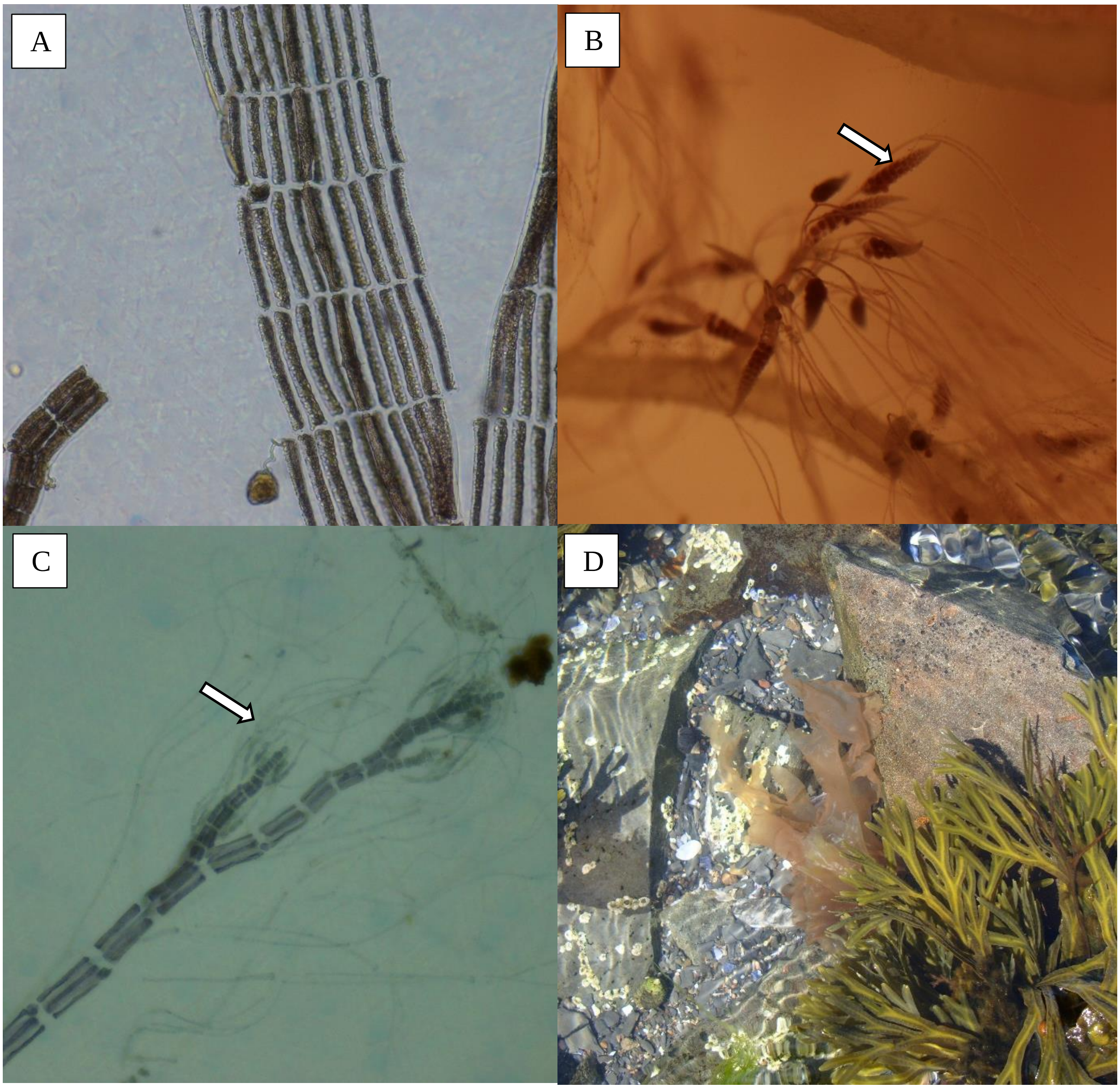


Plate 2. A: *Vertebrata fucoides* prepared with a weak acid to display the periaxial cells. B: *Dasya baillouviana* with arrow pointing at a tetrasporangial stichidia. C: *Leptosiphonia fibrillosa* with arrow pointing at trichoblasts. D: *Porphyra umbilicalis*.

3.2.4 Cyanobacteria and Plantae

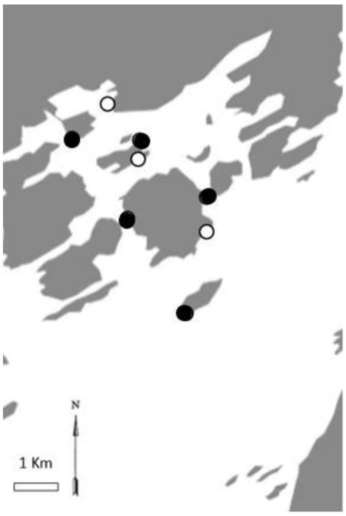
Phylum: Cyanobacteria

Class: Cyanophyceae

Order: Nostocales

Family: Rivulariaceae

Rivularia atra Roth ex Bornet & Flahault



Description: Colonies of rounded shapes, with trichomes radially arranged, partially surrounded by a gelatinous sheet.

The species was mainly identified in August.

Site: Identified from Gåsøya, Store Ostsund, Kalvøya, Borøya Nord and Lille Ostsund.

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

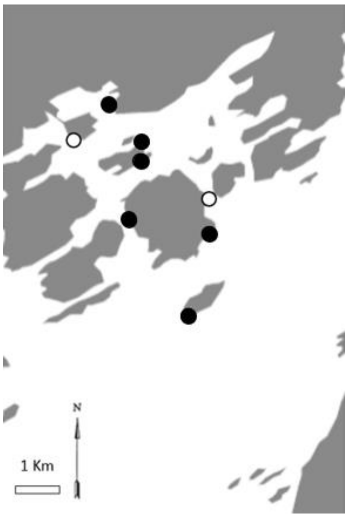
Permanent collection: Slide nr. 49.

Phylum: Plantae

Class: Monocots

Order: Alismatales

Family: Zosteraceae



Zostera marina Linnaeus

Description: Leaves are long, hair-like blades, light green in colour. The rhizomatous plant has rhizomes that grow horizontally through soft substrate. The plant is monoecious.

The species was identified in May and August.

Site: Identified from Gåsøya, Flisbukta, Store Ostsund, Høvikodden, Borøya Nord and Borøya Sør.

Previous findings: There is no previous identification by Larsen (1995), Grenager (1957) or Klavestad (1978) from any of the eight sites.

Permanent collection: Slide nr. 50.

4. Discussion

4.1 The environmental status of algal communities in the Bærum basin

The main hypothesis can in some ways be rejected. However, this is primarily due to the decreased biodiversity observed in 2018. The reduction in biodiversity is a known effect of eutrophication (Diaz and Rosenberg, 2008, Connell et al., 2014, Filbee-Dexter and Wernberg, 2018) Moreover, there have been improvements in the presence of some species and negative changes in others, which at this point is difficult to align in order of significance with regards to environmental status. Yet, the reduced presence of *Fucus distichus* subsp. *Evanescens* may indicate reduced eutrophication. Especially since the presence of the wrack species that indicate good environmental health remains relatively unchanged, with only slight expansions of *Fucus spiralis* and recession of *Fucus serratus* and *Fucus vesiculosus*. However, I also observed a massive increase in the presence of the invasive red algae *Dasya baillouviana*, which will be discussed in further detail in section 4.2.

This is a qualitative study, and the presence and number of algae taxa does not represent the abundance or biomass of each species. It is possible that the abundance of certain species may have changed, which would certainly impact the evaluation of the algal communities. For instance, eutrophication or other drivers of ecological change may have had a large impact on vegetation loss, making the environmental status worse than it appears when only looking at presence or biodiversity.

The sites with the lowest biodiversity in 2018 had some clear commonalities. They were close to the city and river of Sandvika, which increases the chance of eutrophication (Figure 5). They also had some of the lowest fetch (Table 2). All of which could possibly explain the lower biodiversity (Kaiser et al., 2011, Lundsør et al., 2018, Filbee-Dexter and Wernberg, 2018). Yet, the sites with the largest decline in biodiversity compared to 1993-94 did not have any obvious commonalities shared by all. For instance, Gåsøya (Site1), is a high fetch site located on the outskirts of the Bærum basin. This site had a large reduction in algal taxa which could indicate a reduction of biodiversity outside of the Bærum basin. Yet, the well-exposed nearby site of Flisbukta (Site 2) showed very little change, and Store Ostsund (Site 3) had a significant increase in biodiversity (Figure 17).

The results from Store Ostsund of Larsen's (1995) investigation are questionable. All the samples identified from Store Ostsund (Site 3) in 1993-94 were only sampled in June, August or September, which might explain the low biodiversity and total absence of green algae (Figure 17). It is highly unlikely that Larsen (1995) was unable to identify a single alga during his spring sampling of Store Ostsund. Larsen (1995) writes that his focus during the spring was “typical spring algae” and species within the family fucaceae. One may question why he did not list a single fucoid species from that site during the spring. It appears, as though the site was not sampled during the spring, which may explain the distinctly low number of taxa and subsequently separation observed in the nMDS-analysis (Figure 18). Similarly, the site with the second lowest biodiversity, Kalvøya (Site 4), only had three out of 14 algal taxa collected during the spring, none of which were within the family fucaceae.

In contrast, Borøya Sør (Site 7) which had the third highest number of total taxa of the 1993-94 investigation (figure 17), had none of the algal taxa collected during spring. This goes against my initial assumption regarding a lack of spring sampling heavily influencing the number of taxa observed from Store Ostsund. However, Borøya Sør had the lowest biodiversity of all the eight sites in 2018. Larsen (1995) describes the site as having rich vegetation in the littoral zone with areas of continues vegetation as far as five meters deep, which is far from what I observed in 2018. It is possible that Larsen (1995) and I visited different areas on the southside of Borøya, since the sites were only located using large points on a map, rather than exact coordinates. Olsen (2008) also expressed unexpected differences from Borøya Sør, when comparing with Larsen (1995), though this study only investigated *Dasya baillouviana* and *Sargassum muticum*. Moreover, the point on Olsen’s (2008) map was located far towards the western part of Borøya Sør compared to the map I used, which might be were Larsen (1995) collected samples. I have listed the exact coordinates of my sampling areas to avoid this issue in the future (see appendix 3).

All sites that stood out in the nMDS-analysis are particularly sheltered having some of the lowest fetch (Table 2) compared to the rest. Lille Ostsund (Site 8) does also have low fetch, but unlike site 3,4,5 and 7, this site has a direct connection with the open parts of the Oslofjord (Figure 5), which may explain why this site had higher biodiversity than the other low-fetch sites. When inspecting the map of the Bærum basin, it seems probable that sites 3,4,5 and 7 might have some of the highest influence from the Sandvika river (Figure 5).

4.2 Presence of macrophytes between 1993-94 and 2018

4.2.1 The five fucoid species

In contrast to annual algal species, perennial fucoid species are more resilient to small and short-lasting changes, making them more suited for indicating long-lasting trends. The differences in presence of macroalgae between this and Larsen's (1995) investigation is not enough to indicate a trend. However, numerous investigations from the area regarding the five fucoid species (*Ascophyllum nodosum*, *Fucus distichus* subsp. *evanescens*, *Fucus vesiculosus*, *Fucus serratus* and *Fucus spiralis*) can support the changes observed between 1993-94 and 2018.

Initially, Gran (1897) described *A. nodosum* as common in the inner Oslofjord, and recorded individuals as far north as Bygdøy in 1893-94 (Gran, 1897). Later, Grenager (1957) recorded *A. nodosum* from only 3 out of 57 sites in the inner Oslofjord, and Klavestad (1967) reported individuals even further out. Rueness (1973) found no individuals inside Nesoddtangen in the early 1970s. It was suggested that *A. nodosum* was being outcompeted by fast-growing opportunistic algae species (Bokn and Lein, 1978). According to NIVA's monitoring program, the species kept receding from 1974 until the last investigation in 2013 (Kroglund et al., 2017). The species was at that time only found in modest quantities in the southernmost parts of the inner Oslofjord, apart from being reported as "scattered" from the north tip of Nesoddtangen and a few sites in the inner parts of Bunnefjorden (Kroglund et al., 2017). Later investigations by Norconsult from 2015-2017, revealed that the species had receded even further, though only slightly (Lundsør et al., 2018). Ultimately, no individuals of *A. nodosum* have been recorded in the Bærum basin since the 1970s (Kroglund et al., 2017, Lundsør et al., 2018), supporting the fact that neither I nor Larsen (1995) identified the species.

However, not all fucoid species indicate good environmental status. The species *F. distichus* subsp. *evanescens* was first recorded from Drøbak in the inner Oslofjord, during the 1890s (Simmons, 1898). At around the same time, the two native species, *A. nodosum* and *F. vesiculosus* commonly inhabited the area (Gran, 1897). Furthermore, Gran (1897) found no evidence of *F. distichus* subsp. *evanescens* in his investigations during 1893-1894. Thereafter, the species was listed as "scattered", but "locally very abundant" in some areas of the inner Oslofjord, in the 1940s (Sundene, 1953). The species spread even further (Klavestad, 1967), and by the 1970s *F. distichus* subsp. *evanescens* was recorded as one of the most common wrack species in many areas of the inner Oslofjord (Kroglund et al., 2017). Furthermore, the increased presence of *F. distichus* subsp. *evanescens* observed was occurring just after the increase in sewage pollution observed in the inner Oslofjord from 1900 to 1970 (Bergstøl et al., 1981, Kroglund et al., 2017). Moreover, during the same period there was a significant decline in the relative abundance and presence of four wrack species that do indicate good environmental status; *A. nodosum, F. vesiculosus, F. spiralis and F.serratus* (Sundene, 1953, Grenager, 1957, Rueness, 1973, Klavestad, 1978, Kroglund et al., 2017). It was suggested that *F. distichus* subsp. *evanescens* was outcompeting the other fucoid species, due to its opportunistic nature and subsequently competitive edge in moderately polluted waters (Russell and Fielding, 1974). This is because the species grows fast and becomes fertile early, allowing establishment before the green algae take over during spring.

During the 1980s, when the new VEAS treatment plant was built, the trend started to shift. The NIVA monitoring program supports Larsen's (1995) findings, as *F. distichus* subsp. *evanescens* was recorded as "dominant" from most of the sites in the Bærum basin, during the 1990s to the year 2000 (Kroglund et al., 2017). Later, during 2011-2013, NIVA recorded significant improvements as the species was only recorded as "dominant" in the harbour areas close to the city of Oslo (Kroglund et al., 2017). During the same period, the species was recorded as "scattered" to "not registered" in the Bærum basin, with the exception of Gåsøya were the species was recorded as "common" (Kroglund et al., 2017). Then, from 2015-2017 the presence of *F. distichus* subsp. *evanescens* was relatively unchanged with recordings from Gåsøya, Flisbukta, Kalvøya and Lille Ostsund (Lundsør et al., 2018). This supports the decreased presence I observed compared with Larsens (1995). However, in contrast to the investigations spanning 2011-2016, the species was only identified from the inner sites in 2018.

Bokn et al. (1992) found that the abundance and presence of the fucoid species, apart from *F. distichus* subsp. *evanescens* had improved in areas around Oslo, which at that time were less influenced by sewage pollution. NIVA evaluated the environmental status of some of the sites in the Bærum basin, based on the abundance of the five wrack species, between 1998-2000 and 2011-2013. Gåsøya showed a "slight improvement", two sites close to Store Ostsund were "improved", Kalvøya and Høvikodden remained unchanged, Borøya Nord and a site close to Flisbukta was "slightly worse", and Lille Ostsund was "worse" (Kroglund et al., 2017). Overall, the abundance of the five wrack species in the Bærum basin remained relatively unchanged between these two periods.

F. spiralis is the only of the five original fucoid species that has continually expanded since the 1900s, in Vestfjorden. However, the species did not generally grow far into the Bærum Basin, during 2011-2014 (Kroglund et al., 2017). Yet, the 2018 report from Norconsult identified, in 2017, the species from all the same sites as I did, apart from Lille Ostsund (Lundsør et al., 2018). Moreover, the same report also identified the exact same presence of *F. vesiculosus* and *F. serratus* that I found (Lundsør et al., 2018), supporting the change I observed.

4.2.2 Other species

Larsen (1995) identified the species *Bangia atropurpurea* (Mertens ex Roth) C. Agardh from Gåsøya in May 1995. The species was taken out from the comparison since it was the only species in Larsen's (1995) dataset, of the Bærum basin, listed as recorded in 1995. Also, Larsen (1995) mentions nowhere that he collected samples during the year 1995. Nevertheless, I did not identify the species from any of the eight sites, in 2018. This is likely due to the summer of 2018 being exceptionally warm, resulting in the early disappearance of the species in spring and the late arrival in autumn. Furthermore, the species prefers being regularly humidified by ocean sprays. Therefor I find it reasonable that the species was found exclusively on Gåsøya, by Larsen (1995).

The invasive red algae *Dasya baillouviana* has increased its presence from only Borøya Sør in 1993-94 to all but Høvikodden in 2018. Prior, Olsen (2008) only recorded the species from 9 of 33 sites, including Borøya Nord from the Bærum basin, during her investigation in 2005 to 2006. Another study, identified the species from Nesodden in 2015 (Rinde et al., 2017). However, only one site from Nesodden, Vollen and Frogn was investigated in the inner Oslofjord. The species originates from the Mediterranean and has likely dispersed northward due to the warming climate. The ecological impacts of this species are still unclear. Yet, the species is regarded as a potential risk to biological diversity (Rinde et al., 2017).

Eelgrass *(Zostera marina)* will not compete with macroalgae for substrate, since *Z. marina* only grows on soft bottom and macroalgae on hard bottom. However, I still find it odd that eelgrass was not mentioned in Larsen's (1995) study. Eelgrass has been monitored in the inner Oslofjord by Havforskningsinstituttet since around the 1950s, with some sites around the Bærum basin area. (Espeland and Knutsen, 2019) Eelgrass fields play a vital structural and functional role in many coastal areas, much like the wrack and kelp species (Boström et al., 2014) Similarly, eelgrasses can also be used as environmental indicators since they too are sensitive to eutrophication and will reflect and integrate water quality over longer time periods (Krause-Jensen et al., 2008). *Z. marina* was identified from all but Kalvøya and Lille Ostsund of the eight sites located in the Bærum basin. Still, eelgrass can also be found very close to the site located on Kalvøya. The eelgrass appeared to thrive better than most macroalgae in the diversity poor areas of this study, including Høvikodden and Borøya Sør. According to a report from Havforskningsinstituttet, there is some indication of a downward trend in sites with pure eelgrass fields, during the last ten years in the inner Oslofjord (Espeland and Knutsen, 2019). However, there was large year to year variations, and the sites inhabiting a combination of eelgrass and macroalgae increased during the same period. The report also observed a significant increase in the presence of eelgrass in the outer Oslofjord (Espeland and Knutsen, 2019).

4.3 Other drivers of ecological change

There are several simultaneously-acting processes, in addition to eutrophication, that may explain the presence and diversity of macroalgae, in the Bærum basin. Moreover, these drivers can induce gradual changes and are sometimes specific for certain systems, making them difficult to separate into order of significance (Filbee-Dexter and Wernberg, 2018).

4.3.1 Abiotic

4.3.1.1 Turbidity and sludge

The vertical distribution of macroalgae is highly dependent on the penetration of light (visibility), which depends on the amounts of particles suspended in the water (turbidity) (Lundsør et al., 2018). The low visibility observed in 2016-2018 (Lundsør et al., 2018), may have influenced the number and presence of algal taxa observed from Kalvøya (Site 4), Høvikodden (Site 5), and Borøya Sør (Site 7). These sites exhibited the absolute lowest number of algal taxa in 2018 and gave the impression of being the most barren, during snorkelling. Furthermore, I find it probable that the massive construction effort of the Sandvika Fjordpark, may have influenced the turbidity of the surrounding water. About 40.000 truckloads of rocks, dirt and sand was used to expand the Kadettangen peninsula, which was finished in 2019, according to Sandvikaby.no. However, I was unfortunately unable to access to the NGI end report (NGI –Norges Geotekniske Institutt (2018). Kadettangen Fjordpark. NGI Sluttrapport for miljøoppfølging av utfylling ved Kadettangen, 6. juni 2018).

4.3.1.2 Ice scouring

Ice scouring happens when sea ice scrapes along the seafloor or coastline, which may affect the presence or vertical distribution of macroalgae in the littoral zone (Sundene, 1953, Klavestad, 1967, Bokn et al., 1992, Fredriksen and Røst Kile, 2012). Ice scouring is especially significant in the Arctic (Fredriksen and Røst Kile, 2012), and the severity of this phenomenon appear to be related to the relationship between tidal amplitude and sea ice thickness (Ellis and Wilce, 1961). The Bærum basin is often covered with ice and could be susceptible to ice scouring, though not likely to the extent observed in the arctic. Still, the degree of which this affected the macroalgae in this study is unclear.

4.3.1.3 Temperature and salinity

Temperature and salinity are two important factors influencing eutrophication and algal growth (Yang et al., 2008) There have been several studies on the impact of temperature on macroalgae distribution, especially kelp. There is strong evidence supporting the notion that increasing temperatures has played an important part in many coastal areas shifting to turf (Filbee-Dexter and Wernberg, 2018). Climate change (increased temperature) and eutrophication was suggested by Moy and Christie (2012) to be the two main drivers that synergistically lead to the largescale disappearance of sugerkelp (*Saccharina latissima*) forests in southern Norway, observed from 2002. Also, during the extraordinary warm summer of 1966, Klavestad (1978) detected an increase in the abundance of specific green algae species, in the Oslofjord. Moreover, In Western Australia, experimental canopy-removal of kelp showed that kelp in warmer areas recovered slower due to increased turf growth (Wernberg et al., 2010). However, in most areas displaying turfs algae shift, significantly large amount of kelp was lost before the temperature reached mortality thresholds. This suggest that the change was caused by multiple stressors rather than temperature alone (Filbee-Dexter and Wernberg, 2018).

I mentioned in the introduction that the summer of 2018 was significantly warmer than usual, with an average temperature of 2.7 degrees above normal, in Southeast Norway, according to Meterologisk Institutt (Grinde et al., 2018b). Yet, the temperature deviations during Larsen's (1995) investigations in 1993 and 1994 were both close to normal, even slightly colder in 1993 (Grinde et al., 2018b). The same is true for the water temperature, observed from Steilene (Figure 3). It seems probable that the exceptionally high temperatures observed in 2018 may have affected the presence of algae in the Bærum basin, contributing to the slightly lowered number of total taxa of this study compared to Larsen's (1995) investigation. Especially, since the shallow bay areas of the Bærum basin get particularly hot (Figure 4).

4.3.1.4 Acidification and carbon dioxide

There is some experimental evidence suggesting that ocean acidification could stimulate growth of turfs, due to carbon enrichment (Connell and Russell, 2010). Subsequently, leaving herbivores unable to compensate for the increased growth rates (Mertens et al., 2015).

4.3.2 Biotic

4.3.2.1 Grazing

Biological interactions, such as algal grazing by herbivores snails, isopods and sea urchins, may influence algal distribution and presence (Lein, 1980, Christie et al., 2009). For instance, ephemeral (short-lived) green algae and fucoid germlings appear to be highly susceptible to grazing (Lein, 1980, Lubchenco, 1983). Moreover, some fucoid species appear to vary in their vulnerability to grazing, which may influence abundance of these specific fucoid species. (Barker and Chapman, 1990). While snorkelling, none of the eight sites appeared to have significantly large numbers of sea urchins or isopods. However, many sites had large numbers of gastropods, including *Littorina littorea.* The species has been shown to negatively influence the amount of green algae, including *Ulva compressa* and *Blidingia minima* in the inner Oslofjord (Lein, 1980). *Ulva compressa* was only found on the exposed sites of Gåsøya and Flisbukta, which were visually less populated by *Littorina littorea.* Still, the species *Ulva intestinalis* and *Blidingia minima* was also found on many of the inner highly snail-populated sites. Larsen (1995) also found these species on both the sheltered and exposed sites. Furthermore, it is possible that the seemingly low number of snails observed from Gåsøya and Flisbukta were mainly due to increased cover by vegetation.

4.3.2.1 Competition of substrate

There are multiple species that will compete with fucoid species for substrate, including blue mussels, oysters and other fucoid species (Russell and Fielding, 1974, Moy, 1985). Moy (1985) found that blue mussels *Mytilus edulis* negatively influenced *F. serratus* distribution in the littoral zone of the inner Oslofjord. Blue mussel densities were particularly high in the Oslofjord before 1985 due to the increased nutrient supply. Moreover, the substrate competition imposed by the thick mats of blue mussels may have contributed to the historical declines in fucoid abundance in the inner Oslofjord (Bokn and Lein, 1978, Klavestad, 1978).

The invasive pacific oyster (*Crassostrea gigas*) was identified in Norway for the first time in 2005, and is now categorized as a high risk to biological diversity (Rinde et al., 2017). Since then it has spread rapidly and can now found in many areas of the inner Oslofjord, including the Bærum basin. The species was found scattered on most of the eight sites in this study. However, the significance of their presence on the distribution or presence of macroalgae in this study is unclear.

As mentioned earlier, invasive species such as *F. distichus* subsp. *evanescens* may compete with other macroalgae species (Russell and Fielding, 1974).

4.4 Troubleshooting

4.4.1 Comparing data with previous investigations

It can be somewhat problematic to directly compare the qualitative data of this study with some of the previous studies in the area. Differences in collection methods, depth, transect widths, species identification, seasons, number and location of sites limit the comparability between some of the different investigations done throughout the years. However, the part of Larsen’s (1995) investigation concerning the Bærum basin was replicated as accurately as possible, with regards to these variables, making the two studies well suited for a comparison.

4.4.2 Year to year variations

Several species, including *Erythrotrichia carnea* (Sundene, 1953), *Pylaiella littoralis, Bryopsis plumosa, Petalonia facia* and *Enteromorpha* sp. (Klavestad, 1978), *Fucus vesiculosus* and *Fucus spiralis* (Bokn, 1979) have in the past shown year to year variations in the Oslofjord. These types of year to year variations can be accounted for by collecting samples over several years. Unfortunately, this was not possible for this study, which therefore only gives a momentary snapshot of the conditions in the Bærum basin.

The optimal scenario when comparing two studies would be, among other things, that they have collected samples at similar seasons for the same amount of years. However, in the case of Larsen's (1994) investigation, the two years of sampling had to be collectively compared with my one-year sampling period, in order to account for the seasonal variations. This is because each year of Larsen's (1995) study represented different seasons (autumn in 1993 and spring and summer in 1994).

4.4.3 Environmental indicators

There is no group of organisms that will act flawlessly as an environmental indicator in all situations, and macroalgae is no exception. The lack of one or a few sensitive macroalgae species does not necessarily imply pollution. As discussed above, the distribution and presence of macroalgae are influenced by several factors. Moreover, it is important to consider that wrack species are perennial and sometimes take years to show changes when exposed to eutrophication. Bokn et al. (2003) found that certain wrack species used two and a half years to show sign of eutrophication. Additionally, it is difficult to separate the effect of eutrophication and reduced PSU. However, large changes in biodiversity and percentages of sensitive or tolerant species are in some situations a very good indication of eutrophication. Especially, when investigated over several years, or compared with other similar studies. Also, information from both population- and community-based indices should, if possible, be used when assessing ecosystem conditions (McCormick and Cairns, 1994). Standardized protocols for sampling and interpretation would also be highly beneficial, as it makes comparisons much more reliable and universal. Overall, I believe macroalgae is one of the more assessable and reliable indicators of eutrophication.

5 Conclusion

This study found that the total number of algal taxa has slightly reduced from 64 to 54 taxa, since Larsen's (1995) investigation in 1993-94. Yet, the decline was mainly within the green and red algae groups. The largest decline in taxa was served from Gåsøya (Site 1), Høvikodden (Site 5), Borøya Sør (Site 7) and Lille Ostsund (Site 8), though the reason why remains unclear. However, it was mainly green algae that reduced from site 5 and site 8. The low fetch sites; Kalvøya (Site 4), Høvikodden (Site 5), Borøya Sør (Site 7) and Lille Ostsund (Site 8) were clearly the most barren and had low diversity in 2018.

There has been a clear reduction in the presence of the unwanted and eutrophication-tolerant species *Fucus distichus* subsp. *evanescens* between the two studies. Yet, the presence of the wrack species that indicate good environmental health remains relatively unchanged, with only slight expansion of *Fucus spiralis* and recession of *Fucus serratus* and *Fucus vesiculosus*. The native wrack species *Ascophyllum nodosum* is still absent from the area. Moreover, the presence of the invasive red algae species *Dasya baillouviana* has expanded throughout the entirety of the Bærum basin, apart from Høvikodden, in 2018.

It is from this investigation unclear which drivers have had the largest impact on macroalgae biodiversity and presence. However, the hot summer of 2018 might have influenced the result. Overall, the environmental status of the algal communities within the Bærum basin does not appear to have improved since 1994-94. Still, further investigations entailing both qualitative and quantitative data, should be compared with this study too broaden the knowledge of their environmental status. Changes in macroalgae communities will be important when assessing future risk and impact of increased human activity, in the area. If both global warming and the supply of nitrogen and phosphorus continue to increase, as the human population grows, the Bærum basin is at risk of returning to the foul condition observed around the middle of the 1900s. This would undoubtedly affect the many animals that depend on these communities, potentially resulting in the collapse of these ecosystems.

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Appendix 1: Taxonomic matrix of 2018

Taxonomic overview of identified taxa in 2018. X= identified

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**
CHLOROPHYTA								
Ulvophyceae								
Cladophorales								
Bryopsidales								
Bryopsidaceae								
Bryopsis hypnoides J.V. Lamouroux		**X**						
Cladophoraceae								
Chaetomorpha cf. *linum* (O.F. Müller) Kützing				**X**		**X**	**X**	
Cladophora cf. *albida* (Nees) Kützing					**X**	**X**	**X**	
Cladophora rupestris (Linnaeus) Kützing	**X**							
Cladophora spp.	**X**	**X**	**X**	**X**	**X**	**X**		**X**
Rhizoclonium tortuosum (Dillwyn) Kützing	**X**	**X**	**X**					**X**
Ulotrichales								
Monostromataceae								
Monostroma grevillei (Thuret) Wittrock	**X**			**X**				
Ulotrichaceae								
Urospora wormskioldii (Mertens) Rosenvinge					**X**			
Ulvales								
Kornmanniaceae								
Blidingia minima (Nägeli ex Kützing) Kylin	**X**	**X**	**X**			**X**		
Ulvaceae								
Ulva cf. *linza* Linnaeus						**X**		
Ulva cf. *torta.* (Mertens) Trevisan	**X**			**X**				

Ulva compressa Linnaeus	**X**	**X**						
Ulva flexuosa Wulfen			**X**		**X**	**X**		
Ulva intestinalis Linnaeus	**X**	**X**	**X**	**X**		**X**		
Ulva prolifera O.F. Müller	**X**		**X**	**X**		**X**		
Ulvellaceae								
Ulvella viridis (Reinke) R. Nielsen						**X**		
OCHROPHYTA								
Phaeophyceae								
Chordales								
Chordaceae								
Chorda filum (Linnaeus) Stackhouse	**X**							
Desmarestiales								
Desmarestiaceae								
Desmarestia viridis (O.F. Müller) J.V. Lamouroux			**X**					**X**
Ectocarpales								
Chordariaceae								
Dictyosiphon foeniculaceus (Hudson) Greville	**X**	**X**	**X**					**X**
Elachista fucicola (Velley) Areschoug	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Spermatochnus paradoxus (Roth) Kützing		**X**	**X**					
Ectocarpaceae								
Ectocarpus fasciculatus Harvey	**X**		**X**					
Ectocarpus siliculosus (Dillwyn) Lyngbye	**X**	**X**	**X**	**X**	**X**	**X**		
Ectocarpus sp.		**X**						**X**
Spongonema tomentosum (Hudson) Kützing	**X**	**X**						
Acinetosporaceae								
Pogotrichum filiforme Reinke						**X**		
Pylaiella littoralis (Linnaeus) Kjellman	**X**					**X**	**X**	**X**

Scytosiphonaceae								
Scytosiphon lomentaria (Lyngbye) Link			**X**					
Fucales								
Fucaceae								
Fucus distichus subsp. *evanescens* (C. Agardh) H.T. Powell			**X**	**X**	**X**			
Fucus serratus Linnaeus	**X**	**X**						**X**
Fucus spiralis Linnaeus	**X**	**X**	**X**			**X**		**X**
Fucus vesiculosus (Linnaeus)	**X**	**X**	**X**	**X**		**X**	**X**	**X**
Sargassaceae								
Sargassum muticum (Yendo) Fensholt	**X**	**X**						
Laminariales								
Laminariaceae								
Saccharina latissima (Linnaeus) C.E. Lane, C. Mayes, Druehl & G.W. Saunders		**X**						
Sphacelariales								
Sphacelariaceae								
Sphacelaria cirrosa (Roth) C. Agardh	**X**	**X**	**X**	**X**	**X**		**X**	**X**
Stschapoviales								
Halosiphonaceae								
Halosiphon tomentosus (Lyngbye) Jaasund	**X**							
RHODOPHYTA								
Bangiophyceae								
Bangiales								
Bangiaceae								
Porphyra umbilicalis Kützing	**X**							
Compsopogonophyceae								
Erythropeltales								

Erythrotrichiaceae								
Erythrotrichia carnea (Dillwyn) J. Agardh		**X**						
Florideophyceae								
Acrochaetiales								
Acrochaetiacea								
Acrochaetium spp.	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Ahnfeltiales								
Ahnfeltiaceae								
Ahnfeltia plicata (Hudson) Fries						**X**		**X**
Ceramiales								
Ceramiaceae								
Ceramium tenuicorne (Kützing) Waern	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Ceramium virgatum Roth	**X**	**X**						
Callithamniaceae								
Callithamnion corymbosum (Smith) Lyngbye	**X**	**X**	**X**			**X**		
Rhodomelaceae								
Carradoriella elongata (Hudson) A.M. Savoie & G.W. Saunders	**X**	**X**		**X**	**X**	**X**	**X**	
Leptosiphonia fibrillosa (Agardh) A.M. Savoie & G.W. Saunders	**X**	**X**				**X**		
Vertebrata fucoides (Hudson) Kuntze	**X**	**X**	**X**		**X**	**X**	**X**	
Delesseriaceae								
Dasya baillouviana (S.G. Gmelin) Montagne	**X**	**X**	**X**	**X**		**X**	**X**	**X**
Corallinales								
Lithothamniaceae								
Phymatolithon lenormandii (Areschoug) W.H. Adey		**X**						
Gigartinales								

Gigartinaceae								
Chondrus crispus Stackhouse	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Polyidaceae								
Polyides rotunda (Hudson) Gaillon	**X**							
Dumontiaceae								
Dumontia contorta (S.G. Gmelin) Ruprecht	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Furcellariaceae								
cf. *Furcellaria lumbricalis* (Hudson) J.V. Lamouroux	**X**	**X**						**X**
Gracilariales								
Gracilariaceae								
Gracilaria gracilis (Stackhouse) Steentoft, L.M. Irvine & Farnham					**X**			
Hildenbrandiales								
Hildenbrandiaceae								
Hildenbrandia rubra (Sommerfelt) Meneghini	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
CYANOBACTERIA								
Cyanophyceae								
Nostocales								
Rivulariaceae								
Rivularia atra Roth ex Bornet & Flahault	**X**		**X**	**X**		**X**		**X**
PLANTAE								
Monocots								
Alismatales								
Zosteraceae								
Zostera marina	**X**	**X**	**X**		**X**	**X**	**X**	

Appendix 2: Matrix used in nMDS-analysis.

SPECIES	**GROUP**	**Site_118**	**Site_218**	**Site_318**	**Site_418**	**Site_518**	**Site_618**	**Site_718**	**Site_818**	**Site_193-94**	**Site_293-94**	**Site_393-94**	**Site_493-94**	**Site_593-94**	**Site_693-94**	**Site_793-94**	**Site_893-94**
*Acrochaetium*_spp.	Red	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1	1
Acrosiphonia_arcta	Green	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ahnfeltia_plicata	Red	0	0	0	0	0	1	0	1	1	1	0	0	0	1	0	0
Blidingia_marginata	Green	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Blidingia_minima	Green	1	1	1	0	0	1	0	0	1	1	0	0	1	1	1	1
Bryopsis_hypnoides	Green	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Callithamnion_corymbosum	Red	1	1	1	0	0	1	0	0	1	0	0	0	0	0	1	0
Carradoriella_elongata	Red	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0
Ceramium_tenuicorne	Red	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
Ceramium_virgatum	Red	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceramium_cimbricum	Red	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ceramium_nodulosum	Red	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0
Ceramium_strictum	Red	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1
Cf._*Furcellaria_lumbricalis*	Red	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
*Chaetomorpha*_cf._*linum*	Green	0	0	0	1	0	1	1	0	0	1	0	0	1	1	0	0
Chaetomorpha_ligustica	Green	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
Chondrus_crispus	Red	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0
Chorda_filum	Brown	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chordaria_flagelliformis	Brown	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
*Cladophora*_cf._*albida*	Green	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0
Cladophora_rupestris	Green	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Cladophora*_spp.	Green	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0
*Cladophora*_cf._*sericea*	Green	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1
*Cladophora*_cf._*vagabunda*	Green	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Codium_fragile	Green	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Dasya_baillouviana	Red	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	0
Desmarestia_viridis	Brown	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0
Dictyosiphon_foeniculaceus	Brown	1	1	1	0	0	0	0	1	1	1	1	0	0	1	0	1
Dumontia_contorta	Red	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ectocarpus_fasciculatus	Brown	1	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
Ectocarpus_siliculosus	Brown	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0
*Ectocarpus*_spp.	Brown	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0
Elachista_fucicola	Brown	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Erythrotrichia_carnea	Red	0	1	0	0	0	0	0	0	1	1	0	0	1	1	1	1
*Fucus_distichus*_subsp. *evanescens*	Brown	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1
Fucus_serratus	Brown	1	1	0	0	0	0	0	1	1	1	0	0	1	1	0	1
Fucus_spiralis	Brown	1	1	1	0	0	1	0	1	1	1	0	0	0	0	0	1
Fucus_vesiculosus	Brown	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Gayralia_oxysperma	Green	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gracilaria_gracilis	Red	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Halosiphon_tomentosus	Brown	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Hildenbrandia_rubra	Red	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Leptosiphonia_fibrillosa	Red	1	1	0	0	0	1	0	0	1	1	0	0	0	0	1	0

Melanothamnus_harveyi	Red	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1
Monostroma_grevillei	Green	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0
Nemalion_helminthoides	Red	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Petalonia_fascia	Brown	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Phymatolithon_lenormandii	Red	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pilayella_littoralis	Brown	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0
Pogotrichum_filiforme	Brown	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Polysiphonia_hemisphaerica	Red	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
Polyides_rotunda	Red	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
*Porphyra*_cf_*purpurea*	Red	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
Porphyra_umbilicalis	Red	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Punctaria_tenuissima	Brown	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
*Pyropia*_cf._*leucosticta*	Red	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0
Ralfsia_verrucosa	Brown	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
Rhizoclonium_tortuosum	Green	1	1	1	0	0	0	0	1	1	1	0	0	0	1	0	0
Rhodomela_confervoides	Red	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Rivularia_atra	Cyano	1	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0
Saccharina_latissima	Brown	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum_muticum	Brown	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scytosiphon_lomentaria	Brown	0	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0
Spermatochnus_paradoxus	Brown	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphacelaria_cirrosa	Brown	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	0
Spongomorpha_aeruginosa	Green	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Spongonema_tomentosum	Brown	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Stragularia_clavata	Brown	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0
Striaria_attenuata	Brown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Stylonema_alsidii	Red	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
*Ulothrix*_cf._*flacca*	Green	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1
*Ulothrix*_cf._*implexa*	Green	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
*Ulva*_cf._*linza*	Green	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
*Ulva*_cf._*torta.*	Green	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ulva_compressa	Green	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulva_flexuosa	Green	0	0	1	0	1	1	0	0	1	0	0	0	0	0	1	0
Ulva_intestinalis	Green	1	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1
Ulva_lactuca	Green	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Ulva_prolifera	Green	1	0	1	1	0	1	0	0	1	1	0	0	1	1	0	1
*Ulva*_spp.	Green	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1
Ulvella_viridis	Green	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Urospora_penicilliformis	Green	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Urospora_wormskioldii	Green	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Vertebrata_fucoides	Red	1	1	1	0	1	1	1	0	1	0	0	0	1	1	1	0
Zostera_marina	Higher_Plant	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0

Appendix 3: Site coordinates

SITE NR.	NAMES	COORDINATES
1	Gåsøya	59°50'55.1"N 10°34'40.3"E
2	Flisbukta	59°51'51.0"N 10°35'16.2"E
3	Store Ostsund	59°51'58.3"N 10°33'24.8"E
4	Kalvøya	59°52'52.2"N 10°32'19.1"E
5	Høvikodden	59°53'18.6"N 10°33'02.8"E
6	Borøya Nord	59°52'53.4"N 10°33'46.0"E
7	Borøya Sør	59°52'42.4"N 10°33'45.8"E
8	Lille Ostsund	59°52'15.9"N 10°35'12.1"E