# Historical changes in macroalgal communities in Hardangerfjorden

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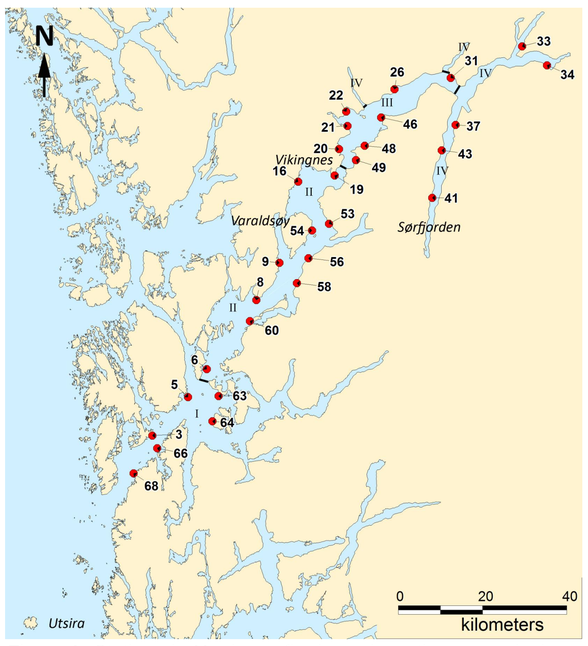
## Methods

In order to study the changes in the macroalgal flora in Hardangerfjorden, material were collected at 22 sites previously investigated in 1955-1960 during summer 2008-2009. Algal flora were collected by the use of the same methods as in the previous studies, hand collection in the intertidal zone and dredging and diving in the subtidal zone. Additionally ROV video-recordings were performed at 21 sites to study the abundance of kelp and urchins during summer 2009, winter and summer 2010 (Figure 1).



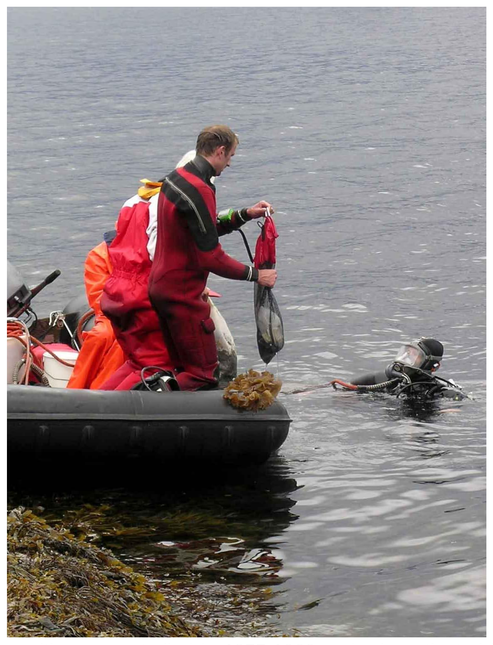



Figure 1. Stations in Hardangerfjorden, where the macroalgal communities were studied in 1955-1960 and reinvestigated in 2008-2009 and 2010 (videotransect only). The termographic station of IMR is located at Ytre Utsira. I= outer fjord area, II= intermediate fjord area, III= inner fjord area, IV= fjord branches.

## Results

Temporal differences in the macroalgal communities were increasing with distance to the fjord head and were most pronounced in the fjord branches (Figure 2).

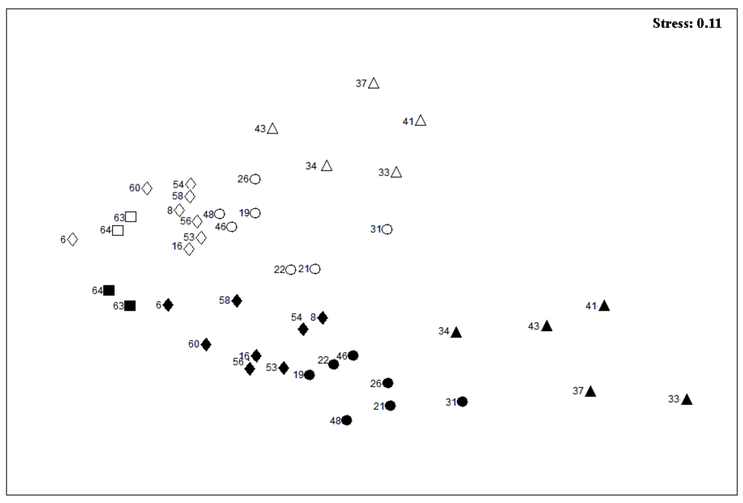



Figure 2. Two-dimensional MDS (non-parametric multi-dimensional scaling) ordination showing Bray-Curtis similarities for 22 sites where the macro algal community in Hardangerfjorden where investigated by intertidal sampling and dredging in 1955-1960 and in 2008-2009. Filled shapes = 1955-1960, open shapes = 2008-2009. Squares = outer fjord area diamond = intermediate fjord area, circle = inner fjord area, triangle = fjord branches.

The temporal differences were mainly cause by increased species richness at sites, in particular increased abundance of southern species (Figure 3) and an increased number of red algal taxa at sites (Figure 4).

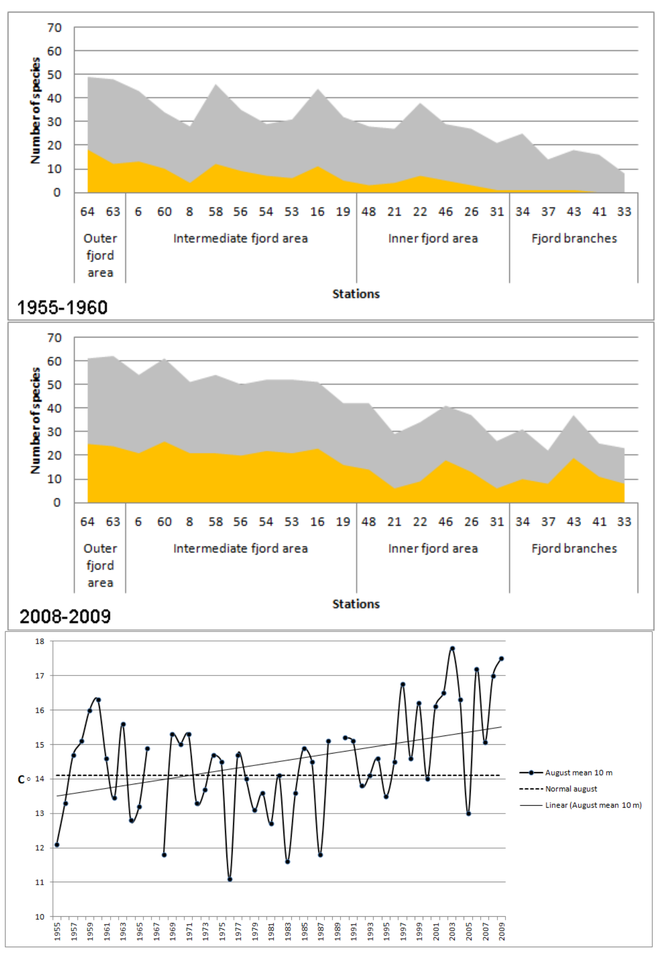



Figure 3.
Above: Rare southern species with increased abundance in the Hardangerfjord, *Acrothrix gracilis.* Foto: Vivian Husa

Top left: number of southern species (yellow) and pansectorial species (grey) on stations registered in 1955-1960 and in 2008-2009. The stations are ranked from outer fjord area (Stn 64) to inner part of fjord branches (Stn 33).

Bottom left: Mean seawater temperatures recorded at 10 m at Ytre Utsira in August (warmest month) in the period 1955-2009. Normal seawater temperatures in August (shown as dotted line) are mean seawater temperature in the period 1936-1993 (Aure & Strand 2001).

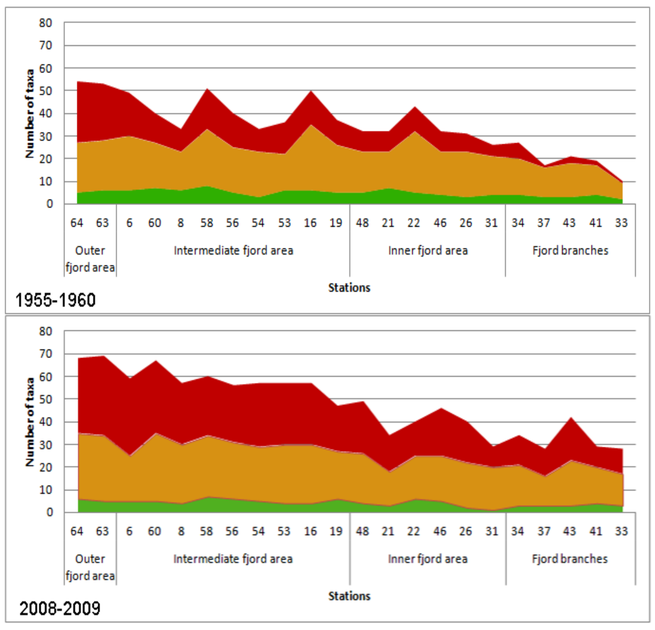



Figure 4. Above: Phycodrys rubens, red alga with increased geographical abundance in inner and middle part of the fjord.
Left: Number of taxa recorded at stations in Hardangerfjorden in 1955-1960 and 2008-2009. The stations are organized going inwards the fjord from the left. The figure also shows distribution of taxa in algal groups in the respective studies. Red area = red algal taxa, brown area= brown algal taxa, green area = green algal taxa. The stations are ranked from outer fjord area (Stn 64) to inner part of fjord branches (Stn 33).

An analysis of the presence of kelp and urchins in the subtidal zone in 2008-2009 showed that the community at stations had a high similarity with the recordings in 1955-1960. *Laminaria* spp. (Figure 5) and *Saccharina latissima* (Figure 6) were most abundant in the outermost part of Hardangerfjorden during both investigations, and that both genera had a similar depth distribution and showed a sporadic occurrence towards the innermost part of the fjord in both studies. Kelp abundance were strongly regulated by urchin grazing (*Echinus acutus*), resulting in a lower limit for kelp growth at 3-5 meters except from in the outermost area (Figure 7).

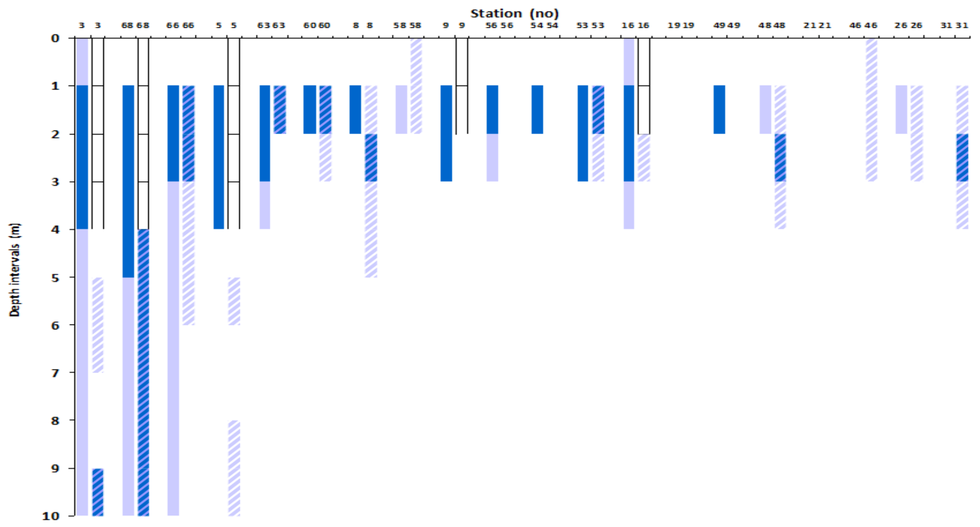



Figure 5. Estimated abundance of *Laminaria* spp. at depth down to 10 m at 20 stations. Solid columns show data compiled from Fig. 27 in Jorde & Klavestad (1963), and hatched columns represent results from the present investigation. Distribution data of L. hyperborea and L. digitata from Figure 27 in Jorde and Klavestad (1963) are combined. Dark blue represents dense occurrence of Laminaria spp. and light blue scattered occurrence. White boxes represent depth intervals without observations. The stations are ranked from outer to inner part of Hardangerfjorden, with Stn. 3 being the outermost one.

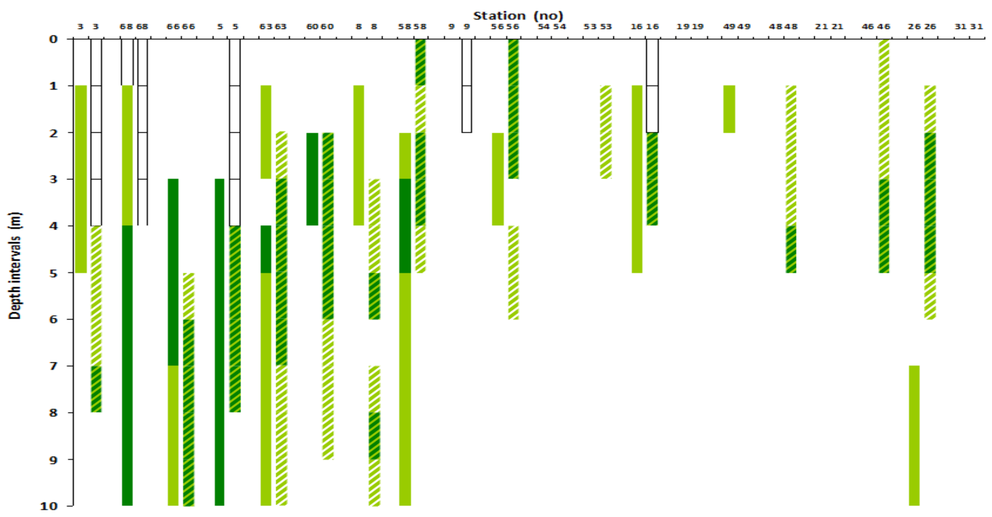



Figure 6. Estimated abundance of *Saccharina latissima* in depth intervals to 10 m at 20 stations. Solid columns show data compiled from Fig. 27 in Jorde & Klavestad (1963), and hatched columns represent results from the present investigation. Dark blue represents dense occurrence of S. latissima and light blue represents scattered kelps. White boxes represent depth intervals without observations. The stations are ranked from outer to inner part of Hardangerfjorden, with Stn. 3 being the outermost one.

Figure 7. *Echinus acutus* in Hardangerfjorden. Foto: Erling Svensen