Short description of the Norwegian seaweed industry

The algae industry in Norway has long tradition in exploiting natural resources. The seaweed constitute an important part of the ecosystem and are of important commercial value. This article describes the established seaweed industry in Norway.

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Seaweed has been used as manure, feed and food since Norway was first populated. From around 1750, burning of kelp for potash to European soap and glass industry was important for coastal farmers. Between 1800 and 1913 the export of potash increased from 1 500 to 6 000 tons, produced from 150 000 tons of kelp. From 1870, potash was used in iodide production, but in 1933 it was replaced by the “chile-sal-peter”. Norwegian alginate research was established around 1900, partly governmentally supported. Protan AS managed to produce pure alginate acid in 1943 thanks to collaboration with the Norwegian Institute for kelp research (NITT). The production was based on drifted kelp and hand cut *Laminaria digitata*. Since 1963 *Laminaria hyperborea* is the most important raw material, due to mechanization of harvest and high volume. The export of alginate increased from 100 tons in 1954 to 300 tons in 1960. Today Protan AS is named FMC Biopolymer AS and is owned by the FMC Corporation. From 1930, seaweed meal from *Ascorhyllum nodosum* for animal food and fertilizer was an important product from the Norwegian industry. The seaweed was cut by hand, dried on shore and milled. Algea AS, established in 1937, and several companies in the 60s produced seaweed meal and extracts agriculture and human and animal alimentation (Aasland 1997). Algea AS is the only remaining company and is owned by the Italian Valagro Group. Nowadays 180 people are working in the seaweed industry. Around 45 persons harvest seaweed, employed by themselves, the boat company or by the processing company.

Species exploited in Norway

*L. hyperborea* is harvested between Rogaland and Sør-Trøndelag. The annual landings are 150 000 tons, and the firsthand value is under 23 EURO/ton wet weight (w.w.) (FMC Biopolymer AS 2011, pers. comm.). *L. hyperborea* is processed to alginates (5 000 tons/year), used in pharma- and nutra-ceutical products. *A. nodosum* is harvested between Møre og Romsdal and Nordland. The annual landings are 10-20 000 tons, with a firsthand value delivered to fabric of 50 EURO/ton w.w. (Algea AS 2011, pers. comm.). *A. nodosum* is processed to seaweed meal for agricultural, nutraceutical and cosmetic products. Around 140 kg of *Ulva lactuca* is harvested by hand in Rogaland yearly, the firsthand value is 50 EURO/kg w.w. sold to restaurants.

**Identification of harvesting techniques**

Since 1976, *L. hyperborea* is harvested with a seaweed trawl, a 3 m long iron sledge with pinnacles pointing towards the drag direction. The trawl jerks plants larger than 20 cm from the substrate and leave smaller plants for re-growth. The trawl can take up to 1 ton of kelp per drag and up to 150 tons daily. The seaweed is delivered to transport ship, collecting stations or directly to fabric. From the 70’s, *A. nodosum* is harvested either with paddlewheel or water jet driven seaweed cutters, which both leave at least 10 cm of the plant for re-growth (Algea AS pers. comm.). The harvested material is transported in a bags or nets to the fabric.

**Biomass evaluation**

The biomass of *A. nodosum* is estimated around 1,8 mill tons along the Norwegian coast, in densities of 4-7 kg/m² (Steen 2009). The standing stocks of *L. hyperborea* are estimated to be between 50 and 100 mill tons based on a growth area of 5 000-10 000 km² and average densities of 10-15 kg/m² (Steen 2009).
Ecological issues

Harvesting of *L. hyperborea* is estimated to remove 0.3% of the total biomass yearly. On a local scale up to 50% of biomass can be removed (Steen 2005). Re-growth after harvest differs between locations and varies with latitude (Rinde and Sjøtun 2005). The new generation approaches untrawled kelp forest size at 2-4 years (Christie *et al.* 1998). Ecological models indicate that loss of primary and secondary production in trawled areas is up to 98% (Rinde *et al.* 2006). The re-growth of epiphytes is not fulfilled after 5 years, and diversity is not restored before plants reach average age of 7 years (Waage Nielsen *et al.* 2003). Distance to the closest intact, untrawled kelp forest is important for re-colonization of trawled areas (Christie *et al.* 2003). *A. nodosum* is harvested every 4-6th year, to ensure good regrowth and is assumed to have limited recruitment potential and relatively slow re-growth (Steen 2009). Re-growth by generating new branches depends on parts of the plants being left after harvest. The local harvesting efficiency is 60% (Algea AS pers. comm.). Harvesting activity occasionally conflicts with environmental protection, which affects the raw material access. Regional harvesting regulations coordinate these interests for *L. hyperborea*. Since 1970, 50% of the kelp forest between Nord-Møre and Finnmark is assumed to be grazed by sea urchins (Sivertsen 1997). Grazing is estimated to cause a loss of 15M NOK.year⁻¹ for fishermen in the area around Vega (Sakshaug *et al.* 2002). In grazed areas, mostly located to sheltered areas, the kelp forest production is estimated to be 1% of the original production (Norderhaug *et al.* 2008). Sea urchin density is controlled by several factors such as predation and juvenile recruitment.

Aquaculture of algae

Aquaculture trials have been done with *Saccharina latissima* and *Alaria esculenta* to produce ethanol. Several projects investigating algae culture as monoculture, polyculture or in fjord restoration are in progress.

Stakeholders

Industry

- Algea AS harvests *A. nodosum* for production of seaweed meal and extracts. www.algea.com
- Biomar AS produces fish feed for salmon and trout, exploring the use of algae in feed. www.biomar.com
- FMC Biopolymer AS harvests *L. hyperborea* for alginate production. www.fmcbiopolymer.com
- Frode Ljosdal AS harvests *U. lactuca* for sale as food to restaurants.
- Holm fjord AS cultivates sugar kelp to restore the kelp forest in Porsanger fjorden. www.holmfjord.no
- Salmon Group is an aquaculture company exploring integrated aquaculture. www.salmongroup.no
- Seaweed Energy Solutions is exploring cultivation of sugar kelp for biofuel. www.seaweedenergysolutions.com
- Statoil is involved in cultivation projects to produce macroalgae for bioethanol. www.statoil.com

Authorities

The Ministry of Fisheries and Coastal Affairs, the Directorate of Fisheries, the Ministry of the Environment, the Directorate for nature management, the County Governors, the County Authorities, the Norwegian Coastguard, the Norwegian Food safety Authority, the Ministry of Health and Care Services, the Ministry of Agriculture and Food and the Norwegian Agricultural Authority.

Research institutes

- Institute of Marine Research, IMR, is advisory capacity to FKD, and survey *L. hyperborea* harvest. www.imr.no
- Lysefjorden Forsøksstasjon- uses upwelling as source for nutrients in production of macroalgae.
- Norwegian Institute for Agricultural and Environmental Research, BIOFORSK, achieves R&D on cultivation of aquatic plants and the added value of algae products. www.bioforsk.no
- Norwegian Institute for Nature research, NINA, achieves applied ecological research. www.nina.no
- Norwegian Institute for Water Research, NIVA, is modeling distribution of kelp forests. www.niva.no
- Norwegian University of Science and technology, NTNU, achieves alginate research. www.ntnu.no
- SINTEF is achieving R&D in fishery and aquaculture, and in seaweed cultivation projects. www.sintef.no
- University of Bergen, UiB, is doing marine research on marine biodiversity. www.ub.no
- University of Oslo, UiO, is doing marine research on kelp biology and kelp forest ecology. www.uio.no
References
www.fiskeridir.no
www.imr.no
www.ssb.no