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Seaweed as a potential biomass for symbiosis

This brief is a part of the Blue Green Bio Lab Tool Kit, that represents the findings in the Blue Green Bio Lab project. The project targets the urgent challenges of reducing nutrients to waters of the Baltic Sea Region, limiting greenhouse gas emissions, and enhancing European self-supply with food, feed, and energy. Together, aquaculture, agriculture and industry can provide solutions to these challenges through industrial symbiosis based on the sustainable exploitation of local blue and green biomasses initially grown and/or harvested with the objective to produce positive ecosystem services. The Blue Green Bio Lab project is co-financed by Inter-Reg Baltic Sea Region with partners in Denmark, Latvia, and Sweden.

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Description of seaweed species

Seaweed or macroalgae is the visible underwater vegetation in the sea and freshwater, composed of several groups of species. The species composition, size of plants, abundance and biomass depends on the salinity, turbidity and bottom substrate in the location where the seaweed is growing. All seaweed, however, will require a certain amount of light and nutrient content in the water for building biomass. In the Baltic Sea where the gradient of salinity is present in a southern-northern direction, species composition and dimensions change quite substantially. The coastal underwater habitats of Denmark, Germany and southern Sweden are inhabited by quite large (up to 2-3 m long) brown algae Saccharina latisima (sugar kelp) and Laminaria digitata (oar weed). Further east and north at the coasts from Lithuania to Finland the red algae Furcellaria lumbricalis and brown algae Fucus vesiculosus (bladderwrack) are 4-5 times smaller in size. In the Baltic Sea there are more than 300 seaweed species near the Danish coasts, though only seven species have been found suitable for cultivation. This brief will describe the five best investigated perennial species.

Sugar kelp is the target species for cultivation in Europe and several parts of the world, and thus also in the Baltic Sea south-western areas (Picture 1). The optimal salinity for the kelp is around 25 per mille and in natural conditions it grows, attached to rocks. Sugar kelp thrives in areas with good water exchange but without excessive wave exposure. In Denmark, up to 16 tons (wet weight) of sugar kelp have been produced annually in recent years by two commercial producers. Sugar kelp can be used as a sweetener and thickener in the food industry, as nutriceutical, in cosmetic products, as an additive to feed and as source of biomass for energy production as well.

Picture 1. Danish production line of sugar kelp in Horsens fjord, photo: Teis Boderskov.

Oar weed shows similar requirements of salinity and water exchange as sugar kelp but is more sensitive to higher temperatures. It tolerates a higher flexibility of salinity levels but grows slower than sugar kelp.

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The cultivation of oar weed does not yet exist on an industrial scale.

Bladderwrack is one of the dominant species of the coastal ecosystems in the Baltic Sea. It forms a canopy and therefore is also a keystone species for ecosystem structure and functioning in the Baltic Sea Region. Bladderwrack covers large areas from the surface down to around 10 meters depth in more open areas and 2–4 meters depth in nutrient enriched areas. Danish waters contain large populations of this Fucus species, for example the population of Fucus species in the Kattegat alone is estimated at approx. 82,000 tonnes of biomass. However, in many Baltic Sea areas from Poland to Finland bladderwrack belts have been decreasing due to diminished water transparency and dominance of annual algae. Cultivation of bladderwrack is currently at the experimental stage. Bladderwrack has healing properties and is used for digestion problems. It can be consumed fresh or cooked.

Red algæ (Furcellaria lumbricalis) grows on rocks to a depth of about 8-12 metres, but can also grow in large floating mats, which are easier to harvest (Picture 2). It is also an important habitat-forming seaweed, as its belts provide spawning habitat for many fish species, herring being the most important in the Baltic Sea.

Picture 2. Furcellaria lumbricalis in the Baltic Sea, Estonian waters. Photo: Tiit Hunt.

F.lumbricalis life-span is up to 10 years and it tolerates salinities down to 3.6 practical salinity units. F. lumbricalis forms monotypic dense meadows in the central and northern Baltic Sea. The floating type of Furcellaria nowadays inhabits only habitats with soft bottoms near western Estonia where it produces about 100,000-150,000 tons of wet weight every year. Of this amount about 2000 tons are harvested by bottom trawling. Furcellaria is used for production of agar in food industry, it contains natural red colorant phycoerythrin possible to use in cosmetics.

Sea lettuce (Ulva sp.) is a fast-growing green macroalgae. Sea lettuce are often the dominant species in the specific seaweed blooms called green tides. Due to its high growth rates and tolerance to varying salinity (6-30 PSU), sea lettuce is suitable for farming in nutrient-rich wastewater sources from for example fish farming. There have been attempts to cultivate two species of sea lettuce (Ulva lactuca and Ulva intestinalis) within the Baltic Sea Region in pilot and experimental projects. However, currently the land-based cultivation seems the most viable option. In areas of the Baltic Sea where green tides occur, sea lettuce can be harvested. Ulva sp. is considered one of the most usable seaweeds- in food with high protein and carbohydrate content, agriculture, pharmacology and medicine.

Climate and environmental goals in the Baltic Sea Region

The European Commission has foreseen wider cultivation and use of seaweed for food, feed, energy, and material production in a carbon neutral and circular way as recently adopted in the Algae Initiative. Member countries are encouraged to develop novel and sustainable ways for the use of seaweed resources as a part of European Green Deal and Farm to Fork strategy, calling for climate neutrality by 2050. The Commission has identified 23 actions, which aim to improve business environments, increase social awareness and acceptance of algae and algae-based products by consumers, and close the knowledge, research, and technology gaps. Actions include development of standards for algal products and strengthening the market, facilitation of access to marine space for seaweed farming, and conducting studies to gain better knowledge on seaweed climate change mitigation opportunities and the role of seaweed as blue carbon sinks.

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Similar to the European Union's aim for climate neutrality, the Baltic Sea region has a goal to be a climate neutral region in 2050, in accordance with the European Union Strategy for the Baltic Sea Region. The region aims for clear sea waters, rich and healthy wildlife, climate change adaptation, risk prevention and management. The emphasis of the planned actions is on reductions of nutrient emissions, recycling of nutrients, prevention of pollution and strengthening of sustainable and circular bioeconomy.

The Baltic Sea Action Plan, part of the Helsinki Convention, is the central framework for implementation of the mentioned Strategy, holding the overall objective of reaching good environmental status for the Baltic Sea until 2030. Actions and measures are designed to strengthen the overall resilience of the Baltic Sea, thus improving its ability to respond to the effects of climate change. The actions should help to reach the desired state for the marine environment regarding eutrophication when concentrations of nutrients are close to natural levels, meaning the water is clear, algal blooms are at natural levels, plants and animals have natural occurrence and distribution, and oxygen levels are also natural.

HELCOM Baltic Sea Regional strategy for Nutrient Recycling is another tool for improvement of nutrient use and reduction of leakages to the Baltic Sea environment from agriculture. The Nutrient Recycling Strategy aims for closing nutrient cycles, reducing greenhouse gas emissions, improving soil quality and enhancing carbon sequestration. The circular use of nutrients should be safe and secure, based on the best available knowledge and should encourage new business model development together with improved policy coherence. The Strategy has a list of possible measures in the form of a toolbox with ideas for nutrient recycling development in the region.

Climate and environmental goals for Skive Municipality and Zemgale Planning Region

This section looks at the translation of goals at the Baltic Sea level to the local scale, through the objectives and actions of project partner region of the Blue Green Lab project.

Skive Municipality adopted a new climate action plan in 2022 with the goal of a 70% reduction in CO2 emissions by 2030 and climate neutrality by 2050. These climate targets are in accordance with international agreements and with national targets established for greenhouse gas reduction formulated in the Danish Climate Act. To reach the 70% reduction target by 2030, Skive Municipality must half their CO2 emissions per year by 2030, i.e. by 314,000 tonnes CO2/year. If the implementation of the climate action plan is successful, Skive Municipality will achieve:

- 82% reduction in CO2 emissions in 2030 compared to 1990
- 97% reduction in CO2 emissions in 2050 compared to 1990.

The large reduction in CO2 emissions by 2030 in Skive Municipality is expected largely due to the development of the Power-to-X industry (PtX) and the transition of the agricultural sector, especially in terms of land use. PtX production of green fuels such as hydrogen, methanol and green ammonia will reduce emissions in the transport sector. In addition, the expected green transition of the agricultural sector, based on the Danish Agricultural Agreement, aims for a more than 50% reduction in CO2 emissions from land use in Skive Municipality.

The river basin management plans of 2021-2027 are relevant for Skive Municipality to gradually improve the water quality in Skive Fjord, Lovns Bredning, Hjarbæk Fjord and Risgårde Bredning. For Skive Fjord, Risgårde, Lovns Bredning and Bjørnsholm Bugt it is required to reduce 739.5 tonnes of nitrogen/year, while for Hjarbæk Fjord, the reduction requirement is 894.6 tonnes N/year.

Options of biomass use for achieving the climate and environmental goals

Skive Municipality already anticipates ways to use aquatic (meaning blue) biomass, potentially including seaweed, for achieving the climate goals and improving the status of water quality in Skive Fjord. It has already been calculated that blue biomasses could decrease CO2 emissions by 26,000 tons per year by 2050, i.e., about 8% of the total necessary reduction for Skive Municipality. However, reaching climate and environmental goals through the cultivation of various types of seaweed results in some contradictions.

Sugar kelp is already cultivated for research purposes in the Limfjord area (DTU Aqua, 4 ha) and trials have shown that 29.3 kg of nitrogen and 3.91 kg of phosphorus per hectare can be removed. Sugar kelp binds CO_2 during growing, but the capture is not permanent. It should be noted that many seaweeds have a life cycle with the leaf plate shedding in the autumn, and thus also a large part of the carbon bound in the plant. Furthermore, the cultivation of sugar kelp can reduce biodiversity due to shadowing, thereby worsening light conditions in water. Another option could be restoration of eelgrass beds. Eelgrass is a flowering plant, not a seaweed. Eelgrass beds are important ecosystems that provide a range of ecosystem services - bind and retain nutrients, sequester carbon, act as a filter, slowing down water velocity as it passes through an eelgrass bed, thereby settling particles. Eelgrass beds contribute to high biodiversity as they provide habitat for a wide range of animals and plants.

Still, the costs of nutrient removal and CO_2 sequestration through the cultivation of seaweed is quite high and not so area or cost efficient, as they require more space and technology. Therefore, it is recommended to combine cultivation of algae with mussels and investigate options for other macroalgal species. Fast-growing annual seaweed can also be biomass for removal of nutrients, yet technologies for their proper collection and use still need to be developed.

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Project facts

The Blue-Green Biolab project is co-financed by Interreg Baltic Sea Region.

Total budget: 499,399.60 Euro.
Project period: October 2022 - March 2024.

Homepage: https://interreg-baltic.eu/project/blue-green-bio-lab/

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