GRASS

Growing Macroalgae Sustainably in the Baltic Sea
September 2021

Output 4.3.1

Handbook for Public Authorities

A handbook to build capacities of public authorities on macroalgae cultivation, harvesting and applications in the Baltic Sea region.

Foreword

Macroalgae production is an upcoming sector for growing biomass for producing food, consumables such as plastics and energy without competing for arable land, depleting fresh water and using non-renewable fertiliser. However, the sector is still in its infancy in the Baltic Sea Region and there is a lack of in-depth and wide-spread knowledge on the potential benefits of macroalgae production. To deal with this challenge, GRASS aims to raise awareness and build capacity on macroalgae cultivation, harvesting and use among public authorities and other relevant stakeholders across the region. Public authorities, ministries, planning regions and counties play a crucial role in promoting macroalgae as they are the main legislative bodies that also control much of national and regional funding.

The aim of Group of Activities (GoA) 4.3 "*Training material and capacity building activities for public authorities and practitioners*" is to build capacities of public authorities in the BSR to understand sustainable macroalgae cultivation, harvesting and use. To ensure environmental sustainability and mitigate risk in future investments, the main technology transfer activities under GRASS have been held at the regional level, tailored to particular regional circumstances and needs with regards to environmental and ecological aspects, MSP, regulation, value chain development and capacities (of stakeholders and infrastructure). These activities were brought together, showcased and discussed at the final GRASS international conference (GoA 3.3), which highlighted successful developments from macroalgae production and harvesting in the BSR.

Figure 1: Photo of Bladderwrack (Fucus vesiculosus) courtesy of Paul Levesley

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1. MSP synergies and conflicts

The GRASS ODSS Tool

Sustainable cultivation and harvest of macroalgae will play a key role in meeting the goals of blue growth initiatives in the coming years. However, other maritime activities (e.g. energy, conservation, shipping and tourism) are also expected to increase. To secure space for macroalgae cultivation, spatial planners need to know which environmental variables drive biomass production as well as where productive areas are located. First, the Estonian Marine Institute, University of Tartu pooled together all available data on environmental proxies and macroalgal production to quantify their relationships, as well as to predict macroalgae production at the Baltic Sea scale. Second, they built a similar model for macroalgal beach cast (or beach wrack) to predict potential beach cast production at the Baltic Sea scale. The resulting maps are useful for maritime spatial planning because they enable identification of the most suitable areas for macroalgae farming and/or beach-cast harvesting. From the range of suitable sites, it is then possible to identify areas that allow long-term cultivation whilst considering trade-offs and possible conflicts with existing industries (fisheries, shipping routes etc). Information is open access through the user-friendly ODSS online platform at http://www.sea.ee/bbg-odss/Map/MapMain. This tool guides public authorities and private actors interested in licensing, setting up, investing in or funding a farm in their region, either as an environmental tool (e.g. ecosystem services, nutrient removal) or as a macroalgae business.

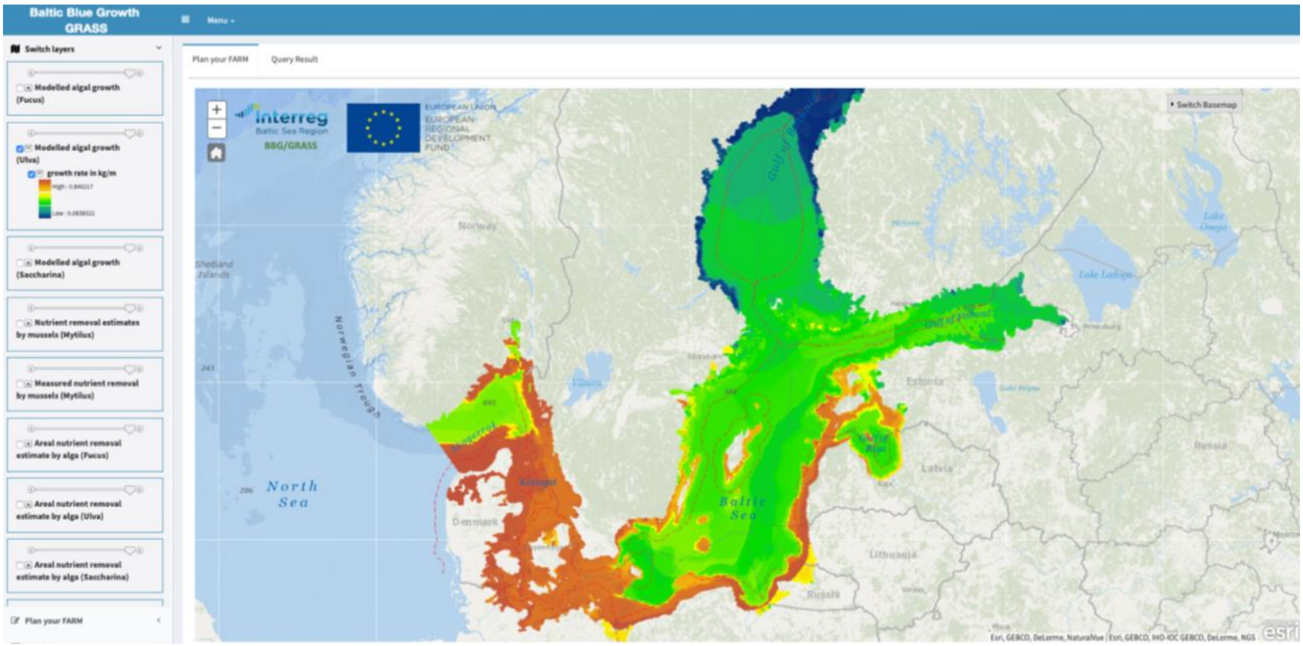

Figure 1: Screenshot of the GRASS ODSS Tool developed by the Estonian Marine Institute, University of Tartu

The modelling of macroalgal and beach cast production potential has shown that macroalgae can be successfully farmed and harvested in much of the Baltic Sea, providing cultivation methods are adapted to the local conditions. With this activity the GRASS partners aim to close the environmental gap for macroalgae production. The ODSS tool fulfils this goal by linking maps of suitable cultivation sites and beach cast harvest with important environmental variables, indicating the environmental health of the Baltic Sea as well as different human uses. The tool is intended for use by regional and national public authorities such as environmental and planning agencies. Other target groups are practitioners, research institutes and NGOs in the field of sustainable blue growth.

Maps illustrating MSP approach to best available sites for macroalgae cultivation and harvesting in the Baltic Sea

The maps developed under Group of Activities 3.1 of the GRASS project are open access files available for download on the GRASS homepage. The maps are broken down into specific Baltic countries, and show multiple layers of MSP data, including the production potential per species (*Fucus* and *Ulva* separately); areas of synergetic co-existence (such as potential co-location with offshore energy); areas of potential competition and areas of conflict. Figure 2 below is a good example of these layers indicating suitable locations for cultivation sites within the given criteria. These maps can therefore be used by regional practitioners to narrow down their options and find the optimal location to streamline the licensing process. Being open access, the maps can also be used by practitioners and public authorities alike as a reference in licensing and survey discussions.

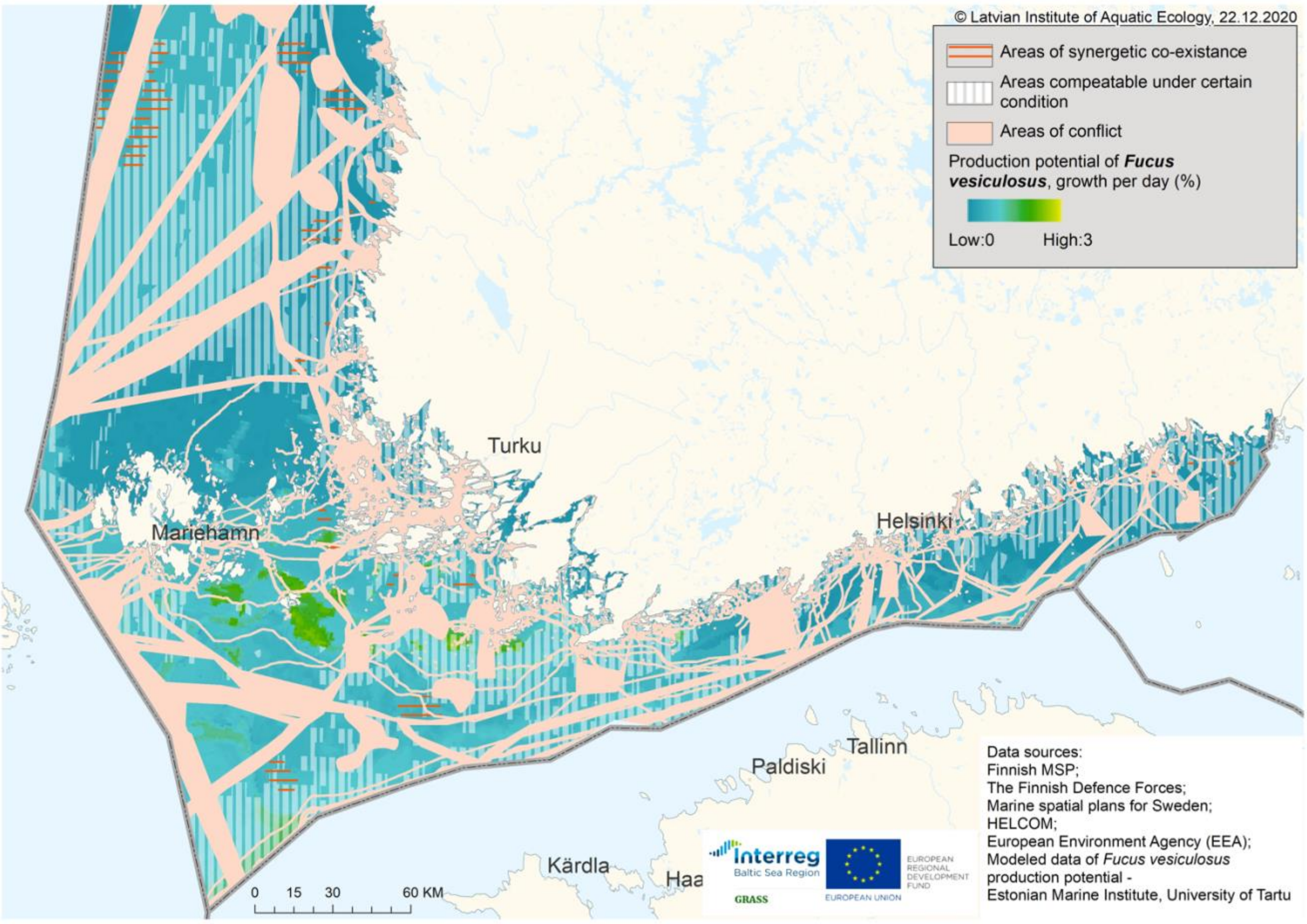

Figure 2: Example of the MSP maps developed by the Latvian Institute of Aquatic Ecology under the GRASS project

The Legislative Landscape on Macroalgae Cultivation

In Europe, cultivation (or aquaculture) of macroalgae is still at an early stage, as is the legislation. The EU and individual European countries lack seaweed-specific legislation, apart from the EU rules on organic seaweed (see below). The main EU legislations related to seaweed aquaculture are the Maritime Spatial Planning Directive 2014/89/EU, the Marine Strategy Framework Directive 2008/56/EC, the Water Framework Directive 2000/60/EC, the Alien Species Regulation 2014/1143/EU along with the Regulation on Aliens Species in Aquaculture 2007/708/EC, the Habitats Directive 92/43/EEC and the Regulation on Organic Production 2018/848/EU. Barbier and collaborators (2019) summarise the mentioned EU regulations and appoint the main challenges of applying these legislations on seaweed aquaculture as described below.

Maritime Spatial Planning Directive

According to the Maritime Spatial Planning Directive (MSPD) 2014/89/EU, each EU Member State needs to have Maritime Spatial Plans (MSP) based on an ecosystem approach to promote sustainable economic development and ecological protection. The development of seaweed aquaculture must be based on good management of space use, by promoting maximum production with minimum impact on the environment and coordinated with other maritime activities (Barbier et al. 2019).

Good Environmental Status

The Marine Strategy Framework Directive (MSFD) 2008/56/EC declares that member states must establish and implement a program of measures to achieve or maintain Good Environmental Status (GES) of the marine areas by 2020. Thus, aquaculture development should not negatively affect biodiversity and intertidal ecosystems, should not contribute to the introduction of invasive species, and should not contribute to eutrophication of coastal areas or the open sea (Barbier et al. 2019). Similarly, for inland surface, transitional, coastal and ground water, the Water Framework Directive (WFD) 2000/60/EC establishes a framework for the protection and enhancement of good status.

Alien Species Regulation

Aquaculture development should not negatively affect biodiversity or increase eutrophication (Barbier et al. 2019). The goal of the Alien Species Regulation 1143/2014 EU is the prevention and management of the introduction and spread of invasive alien species. There is a special regulation 708/2007 for protecting aquatic habitats from the use of alien and locally absent species in aquaculture. According to Barbier et al. (2019), the list of invasive alien species needs to be harmonized in the EU specifically concerning alien species that have long been used in aquaculture.

Habitats Directive and Biodiversity

The goal of the Habitats Directive (92/43/EEC) on the conservation of natural habitats and wild fauna and flora is to promote biodiversity by protecting natural habitats and species, contributing to the sustainable development of ecosystems at the EU level. Natural habitat types of community interest include coastal and halophytic habitats, specifically open seas and tidal areas with reefs. Thereupon, aquaculture development should be compatible with the protection of natural habitats and biodiversity (Barbier et al. 2019).

Environmental Impact Assessments

The Environmental Impact Assessment Directive 2011/92/EU and its amendment 2014/52/EU lay down the procedure for conducting environmental impact assessments of private and public granted projects such as aquaculture before activities begin. In the category of fish farming there is no mention of seaweed, but large-scale operations might require impact assessments.

Organic Seaweed

Organic seaweed has its own regulatory category. The Commission Regulation 2009/710/EC lays down detailed rules on organic seaweed production. The Regulation on Organic Production 2018/848/EU on organic production and labelling of organic products applies, defining the production rules for algae, including harvesting of natural stocks as well as their cultivation (see *Part III: Production rules for algae and aquaculture animals, 2. Requirements for algae*). The collection of wild algae and parts thereof is considered as organic production provided a) the growing areas are suitable from a health point of view and are of high ecological status as defined by Directive 2000/60/EC and b) the collection does not affect significantly the stability of the natural ecosystem or the maintenance of the species in the collection area. Furthermore, the amounts collected should not cause a significant impact on the state of the aquatic environment. Organic algae aquaculture at sea shall only utilize nutrients naturally occurring in the environment, or from organic aquaculture animal production, preferably located nearby as part of an Integrated Multi-Trophic Aquaculture (IMTA) system. Culture density or operational intensity shall be recorded and shall maintain the integrity of the aquatic environment by ensuring that the maximum quantity (environmental carrying capacity) of algae which can be supported without negative effects on the environment is not exceeded. Ropes and other equipment used for growing algae shall be re-used or recycled where possible.

Conclusion

The MSP tools developed in the GRASS project provide a baseline for stakeholders throughout the Baltic Sea region to identify and evaluate possible cultivation sites together with public authorities. Being modelled on the best available scientific data, users of the tools can quickly and easily gain an overview of the most suitable cultivation sites, and which sites could compete with other users of the sea. Not only that, but the potential for synergies in the form of co-location with offshore energy should be pursued where possible as an efficient use of marine resources. Besides efficient use of marine space, co-location has the potential to bring additional benefits in terms of streamlining the licensing process and sharing of resources, reducing both costs and emissions whilst opening the door to further collaborations such as tourism. In terms of legislation, practitioners and authorities have the challenge of providing evidence that macroalgae cultivation will cause no harm to the surrounding environment. Since macroalgae cultivation is largely considered to be ecologically benign, with an increasing body of evidence of beneficial ecosystem services from existing seaweed farms, the licensing process is likely to be met with less apprehension in the future. However, to upscale the Baltic macroalgae industry in a short space of time, public authorities should consider a separate licensing process dedicated to low-trophic species (e.g. macroalgae, bivalves, gastropods, crustaceans and echinoderms) which require zero inputs (I.e. fish feed) which otherwise leads to nutrient loading and ultimately eutrophication of the Baltic Sea.

2. Technological platforms for cultivation, harvesting and storage of macroalgae in the BSR, spatial requirements and equipment

Environmental challenges of macroalgae cultivation and harvest

It is well known that macroalgae need nutrients for growth and can assimilate them from the surrounding environment. This is an important quality of macroalgae that could help over time to decrease the levels of phosphorus and nitrate in the Baltic marine environment. The environmental conditions necessary for growing macroalgae vary among species. However, the key variables determining their growth are levels of sunlight, nutrients, salinity, and temperature. Due to the difference in these factors in the Baltic Sea the availability of wild grown, beach cast macroalgae and the possibility to cultivate currently commercially viable species varies12. Because of the environmental constraints, there are currently only a few types of macroalgae being cultivated and harvested in the Baltic1 and only a hand full of methods being applied2. The GRASS report 2.3.1 *(Report on ecological impacts of macroalgae cultivation in the Baltic Sea region*) summarises the environmental challenges and, most importantly, the benefits of macroalgae cultivation in the Baltic Sea. The report concludes that macroalgae serve as carbon and nutrient sinks and their cultivation and harvest could mitigate the local effects of eutrophication and improve water quality which would regulate the occurrence of harmful algal blooms (Campbell et al., 2019; Duarte et al., 2017). Further, that suspended macroalgae cultivation using long-line systems at a small or medium scale is unlikely to have any significant negative impacts on marine ecosystems, if cultivation does not spatially overlap with sensitive or protected habitats. Large-scale cultivation or harvesting activities should take place with more caution. Large long-line installations may introduce stressors over large areas for prolonged periods of time – shading extensive areas of the seabed and affecting communities of organisms underneath the installation and within the water column. The report also suggests criteria for evaluation of cultivation and harvest proposals, outlining the expected environmental risks and benefits associated with long-line cultivation of macroalgae in the Baltic Sea as well as harvesting of wild grown, loose lying macroalgae and beach cast wracks. These guidelines have been put together following the European regulations regarding environmental Impact Assessments (EIA) using the most up to date scientific knowledge of the environmental impacts of macroalgae cultivation and harvesting in the Baltic Sea region. Further and more detailed information about the environmental impacts of macroalgae cultivation can be found in the GRASS project "Report on ecological impacts of macroalgae cultivation in the Baltic Sea region".

Technological platforms for cultivation, harvesting and storage of macroalgae in the BSR

Environmentally sustainable and robust technology is critical in the upscaling of macroalgae production in the BSR. The technology required depends largely on the method of production, whether it be offshore cultivation on long-lines, land-based recirculating aquaculture systems (RAS) or harvest of beach cast either by hand or with heavy machinery. The development of these technologies should take place with the further use of the biomass in mind, since the various stakeholders along the value chain will have different quality requirements, such as low sand content, low epiphytic growth, or suitability for further processing such as drying or fermentation. All of these factors can be addressed with dedicated technological developments to ensure a high level of quality, maximise production and minimise waste. The spatial requirements will also differ depending on the method of production, with different stakeholders, regulations and cost considerations. The tools provided by the GRASS project provide practitioners and authorities with the knowledge and understanding to anticipate potential production volumes and nutrient removal both offshore and from beach cast. This data could be further expanded to include regulations, spatial requirements and equipment for land-based systems in the future.

Dedicated Technology & Equipment for Macroalgae Production

While existing industries and manufacturers can meet many of the demands for macroalgae cultivation and harvesting, they usually need to be adapted or customised to meet practitioners' needs. With macroalgae production earmarked by the EU for upscaling in the near future, there is considerable scope for this market niche to be exploited by manufacturers from marine engineering to beach cast removal to RAS technology, as well as further processing technologies along the value chain from biorefinery to biodigestion, with corresponding job opportunities and skills development. In terms of technological platforms, a dedicated macroalgae hub would accelerate technological development by connecting practitioners with manufacturers and processors, which would enable them to meet each other's needs and co-develop scalable solutions.

Methods of macroalgal production in the Baltic Sea

The GRASS project's lead partners KTH analysed three different production tracks; cultivation, wild harvest and beach cast collection. These were examined through a survey among the project partners within the GRASS project, together with a literature study.

Species with economic potential

Seven potential production macroalgae species were identified for cultivation in the region. Cultivation is already ongoing in the Western Baltic Sea region on the Swedish west coast where cultivations of *Saccharina latissima*, *Laminaria digitata* and *Ulva sp*. are established. Land-based and small-scale coastal cultivations exist in the Baltic Sea region but with limited production because of low salinity, which inhibits high production of true marine species such as *Saccharina latissima*. *Furcellaria lumbricalis* is the only macroalgae species wild harvested in the region. In Estonia, an unattached form of the species is harvested each year in a limited amount. Four beach cast projects were reported within GRASS (Latvia (2), Russia and Sweden), but small-scale projects of beach cast collection occur in several parts of the region.

Species cultivation techniques

As *Sacchcarina latissima* and *Laminaria digitata* are experimentally and commercially cultivated in Sweden and Denmark, the cultivation techniques, based mainly on long-line technology dedicated for these species exist and are well described in the literature. The experience in cultivation of macroalgae in the Baltic Proper and adjacent basins is limited to few experimental initiatives. Based on the findings from these initiatives and on the scientific literature, we assumed that sufficient knowledge exists to plan at least experimental farms of *Fucus vesiculosus* and *Ulva intestinalis* in the Baltic Sea. Based on the results from FucoSan project, we propose fucus farms which rely on vegetative fragments of thalli as a 'seeding' material, placed in the experimental infrastructure consisting of floating baskets and cultivated throughout the year. For *Ulva intestinalis* we suggest the farm based on the long-line technique - using lines with planted spores, suspended shallow below the water's surface and located in the shallow coastal zone, most preferably in areas characterised with high nutrient concentration. Due to seasonality, it is possible to cultivate *U. intestinalis* 5-6 months per year.

Production challenges

Production challenges identified by the project partners include demanding environmental conditions, legislation obstacles, lack of know-how and high labour costs. To overcome these challenges, the GRASS partners suggest that more focus and effort is put on research and development of production systems in the Baltic Sea. The precautionary principle must provide the framework in harvesting of *Furcellaria lumbricalis*, and sustainability aspects must also be considered for beach cast harvest in the region. To accommodate growth of sustainable macroalgae production systems for cultivation, harvesting and collection, we need knowledge transfer and capacities to support the development of technology, legislation and policies in this area.

Pathways to sustainable production

Potential pathways towards establishing a sustainable macroalgae industry in the Baltic Sea call for addressing and overcoming several production-oriented challenges. An interdisciplinary approach combining environmental, technological and social/economic aspects of the challenges is crucial. It can be illustrated by a potential chain effect of events starting with building up knowledge of environmental effects from macroalgae production (cultivation, harvesting and collection). Such knowledge could serve as sustainability guidance for policy-makers, thus simplifying permitting processes for macroalgae production. A more straightforward permitting process could, in turn, secure or expand economic subsidies, increase investments in technological development and other critical challenges. Discovering connections between the different production challenges - including environmental, social, economic and technical aspects - could provide momentum for the development of macroalgae production in the Baltic Sea Region. The following tangible steps are recommended:

For the Western Baltic Sea Region we recommend further development and streamlining of the relatively mature production technology for *Saccharina latissima*, *Laminaria digitata* and *Ulva sp.,* as these are the only commercially cultivated species in the offshore area to date.

Key Messages and Recommendations

- There is an urgent need for more research and knowledge of life-cycles, cultivation techniques and product value chains for alternative species in open sea cultivation in the region, such as *Furcellaria lumbricalis*, *Fucus vesiculosus*. *Ulva sp*., *Chorda filum*, etc. This is especially important for the Baltic Sea (Eastern Baltic Sea Region) since species with mature cultivation techniques and infrastructure found in other areas are lacking in the Baltic Sea. “New” production systems must therefore be developed before establishment is possible in the region.
- Land-based systems are available or under development already today for several species in the region such as *Fucus vesiculosus*, *Ulva sp*., *Saccharina latissima*. However, infrastructure, technology and cost efficiency need to be improved for these systems to be commercially viable. Land-based systems are advantageous by being less region-specific and by producing macroalgae biomass of a high quality.
- Wild harvest of *Furcellaria lumbricalis* needs systemic analysis of environmental effects to assure that sustainable methods are applied. Research on cultivation techniques for *Furcellaria* aquaculture should also be promoted.
- The management systems for beach cast in the Baltic Sea Region are formed locally but the challenges are similar. In order to achieve sustainable paths forward, emphasis should be placed on identifying sustainable levels of collection with regards to the effects on marine ecosystems, terrestrial effects from beach cast removal (e.g. erosion), as well as environmental effects from the use of beach cast as biogas or fertiliser, with agri- and horticultural use currently being the most common applications.
- Gather and share knowledge to build capacities and competences to support the development of legislation and policies which accommodate growth of sustainable macroalgae production systems for cultivation, harvesting and collection.

3. Skills

Seaweed for Blue Growth

Macroalgae offer a means to increase food security, jobs and income while decreasing the nutrient load to eutrophic coastal areas and mitigating the eutrophication effects (Campbell et.al., 2019). For these reasons, macroalgae cultivation and harvesting is seen as a socially, economically, and environmentally sustainable maritime activity, the development of which would support the EU blue growth strategy and blue bioeconomy initiatives.

Building competences of public authorities

This handbook aims to guide decision-makers on how to regulate novel blue biomass solutions in the Baltic Sea region. Legal regulation should provide possibilities for both blue growth and for environmental protection. Novel blue biomass solutions include macroalgae cultivation, mussel farming and reed and fish biomass removal from the sea. The aim of the European Union's Blue Growth strategy is to harness the untapped potential of oceans, seas and coasts for jobs and growth in a sustainable way (European Commission 2012, 2020). The European Green Deal underlines that the blue economy must be able to protect and restore nature and fight climate change in addition to providing economic growth and employment (EU 2020). For the blue economy to be environmentally sustainable, it must comply with EU environmental law requirements stemming from the EU Water Framework Directive (WFD 2000/60/EC), Marine Strategy Framework Directive (MSFD 2008/56/EC) and Habitats Directive (92/43/EEC).

Licensing aquaculture activities can be a long and tedious process for entrepreneurs, in some cases taking several years. The lack of specific seaweed legislation is one of the main obstacles for seaweed aquaculture. The authorities must understand what seaweed is, and the benefits that it can generate. Having a specific regulation on seaweed aquaculture may accelerate the licensing process, which would benefit all the interested parties including authorities, entrepreneurs and stakeholders. The development and improvement of the seaweed market by promoting the industry through workshops, stakeholder meetings and conferences help to increase the interest of authorities regulating seaweed-related activities. Awareness-raising and pilot farms are also needed to gain attention from politicians and administrators. Governments may refer to global standards, mainly the ASC-MSC Seafood Standard (Aquaculture Stewardship Council and Marine Stewardship Council 2018) in determining the rules for sustainable macroalgae business, however their association with capture fisheries and fish aquaculture tend to obfuscate many of the beneficial aspects of macroalgae cultivation and harvest.

Beyond building capacities of public authorities, the GRASS project can build skills and awareness among consumers, too. Currently, seaweed products are appearing more and more often on the retail market of the Baltic Sea Region (e.g. health food stores) in the form of salads, dried products, as well as a number of innovative multi-ingredient products. There is also a wide availability of dietary supplements based on seaweed. Seaweed products are quite well known to consumers in the Baltic Sea Region. Thanks to surveys conducted during GRASS project, 26% of consumers in the Baltic Sea Region were found to have already eaten seaweed, but only as an ingredient of sushi, while nearly every fourth (23%) consumer has already tried seaweed also in other forms (e.g. salads, soups, snacks). Over 30% of consumers in the region believe that seaweed is food with particularly high pro-health values. Combining this data with the preference of Baltic consumers for local (or regional) products, it must be determined that seaweed food products have great market potential. Algae can constitute new sources of functional compounds for the food chain but also could be useful in various industries as valuable raw material for:

- cosmetics and cosmetology industry,
- medical and pharmaceutical industry,
- agriculture (fertilizers, bio-stimulants),
- biofuel production,
- many other industrial applications.

Preliminary calculations show that the production of macroalgae in the south-east of the Baltic Sea: Poland, Latvia, Estonia is quite cost-intensive. Depending on the adopted input parameters, the production cost of 1 kg of fresh *Ulva* varies from 0.23 €/kg, with the optimistic assumption of efficiency of 87t/ha, up to 1.0 €/kg, assuming the pessimistic version of the yield of 9.8t / ha. The estimated unit cost of producing 1 kg of fresh Fucus is ca 2.34 €/kg. Starting the cultivation of seaweed in the Baltic Sea Region, from the market point of view, would be a response to the growing consumer demand for new, pro-health products of aquatic origin, also in line with the trend of reduced demand for animal products. Production in the Region would make it possible to offer a local, ultra-fresh product. From a socio-economic point of view, local cultivation of seaweed would contribute to increasing added value in the Region (replacing imported products), promoting employment (including people leaving sea fishing) and better utilizing the potential of fish processing plants. From an environmental point of view, the cultivation of seaweed, especially fast-growing seaweed (like U. intestinalis), offers a unique opportunity to reduce water eutrophication while accumulating CO2.

The main problems and threats to the start of macroalgae cultivation in the main part of the Baltic Sea (except its western part) are: the inability to estimate the market absorption capacity for new species, practically absent in the food market of the Region (such as U. intestinalis); lack of proven in practice technologies for the cultivation of *U. intestinalis* and *F. vesiculosus* in Baltic conditions; legal and legislative barriers - especially for first market entrants; finally - the lack of public funding for the aquatic environmental services that will be provided by seaweed farms.

4. Funding and investment

The tools developed under the GRASS project guide public authorities interested in setting up, investing in or funding a farm in their region as well as private actors who want to get involved in the macroalgae industry. The findings show that a more straightforward permit process could, in turn, secure or expand economic subsidies and increase investments in technological development, and other critical challenges. Discovering connections between different production challenges - including environmental, social, economic and technical aspects - could provide momentum for the development of macroalgae production in the Baltic Sea Region.

Novel blue biomass solutions should be officially recognised as a nutrient mitigation tool. This could provide incentives to support these solutions and their use as nutrient offsetting/compensation measures in relation to economic activities (see Submariner 2019). However, at the same time the environmental impacts of these solutions, such as large-scale macroalgal cultivation, must be monitored, since they may disturb marine ecosystems (Suutari et al. 2016). An extensive assessment on their total environmental and socio-economic footprint should be conducted. ECONOMIC INCENTIVES are needed to develop infrastructure for the blue biomass solutions (see Suutari et al. 2016). There could be payments for the ecosystem services they provide. While different public funding schemes are available for the purpose, payment schemes could also be based on markets for ecosystem services either under the polluter pays or beneficiaries pay principle (Schultz-Zehden et al. 2019).

From an environmental point of view, the cultivation of seaweed, especially fast-growing seaweed (like U. intestinalis), offers a unique opportunity to reduce water eutrophication while accumulating CO2. The main problems and threats to the start of macroalgae cultivation in the main part of the Baltic Sea (except its western part) are: the inability to estimate the market absorption capacity for new species, practically absent in the food market of the Region (such as U. intestinalis); lack of proven in practice technologies for the cultivation of *U. intestinalis* and *F. vesiculosus* in Baltic conditions; legal and legislative barriers - especially for first market entrants; finally - the lack of public funding for the water-environmental services that will be provided by seaweed farms.

Potential pathways towards establishing a sustainable macroalgae industry in the Baltic Sea calls for addressing and overcoming several production-oriented challenges. An interdisciplinary approach combining environmental, technological and social/economic aspects of the challenges is crucial. It can be illustrated by a potential chain effect of events starting with building up knowledge of environmental effects from macroalgae production (cultivation, harvesting and collection). Such knowledge could serve as sustainability guidance for policy makers; and thus, simplify permit processes for macroalgae production. A more straightforward permit process could, in turn, secure or expand economic subsidies and increase investments in technological development, and other critical challenges.

5. Permits and licensing procedures

Legal barriers

It should be emphasised that there are legal barriers but also opportunities for the cultivation and harvesting of macroalgae. The legal aspects can be divided to: (1) spatial conflicts and synergies with other maritime users according to Marine Spatial Plans; (2) regulations related to environmental law, usually requiring permissions from several different authorities; and (3) regulations related to food and feed ingredients, mainly regarding limits on harmful substances, labelling and the introduction of novel foods onto the market.

Building capacities of public authorities

As mentioned above, potential pathways towards establishing a sustainable macroalgae industry in the Baltic Sea call for addressing and overcoming several production-oriented challenges. An interdisciplinary approach combining environmental, technological and social/economic aspects of the challenges is crucial. It can be illustrated by a potential chain effect of events starting with building up knowledge of environmental effects from macroalgae production (cultivation, harvesting and collection). Such knowledge could serve as sustainability guidance for policy makers; and thus, simplify permit processes for macroalgae production. A more straightforward permit process could, in turn, secure or expand economic subsidies and increase investments in technological development, and other critical challenges.

Seaweed is not the same as fish

The general aquaculture and fishing permit procedures and the general environmental and water laws apply to seaweed cultivation. However, there are some exceptions: Estonia, Iceland, Norway, Germany and Russia have rules on wild seaweed harvesting and Denmark and Norway have specific seaweed permits. Because the environmental impacts of seaweed cultivation differ entirely from (or in fact counteract) those of fish aquaculture, entrepreneurs, researchers, and regulatory authorities must come together for setting up good regulatory practices that specifically apply to seaweed cultivation. Regulatory collaboration and/or benchmarking between countries is preferable. All Baltic states may want to sign and endorse the UN Global Compact Seaweed Manifesto (2020), which is the first global memorandum of understanding on seaweed.

Biomass solutions as tools for blue growth

The WFD, MSFD and BSAP all require countries to reduce eutrophication of the Baltic Sea. To achieve that, it is important to not only to reduce nutrient inflow but to also develop nutrient uptake and removal as a mitigation strategy. Thus, the WFD, MSFD and BSAP allow and even support blue biomass solutions as far as they contribute to the achievement of the environmental objectives (see Schultz-Zehden et al. 2019). Considering the reconciliation of blue growth and the environmental objectives in the Baltic Sea, the relationship between fish farming and the novel blue biomass solutions provides a concrete example. Regarding fish farming, both open-net rearing units and recirculating systems, cause nutrient flows to the sea. Therefore, it is uncertain whether any new or continued permits can be granted for fish farming in areas that have not achieved the environmental objectives of WFD and MSFD (see Soininen et al. 2019). To allow permitting, EU Member States may consider different measures, such as biomass solutions (i.e. macroalgae, sea grass or similar) to remove nutrients from the sea (EU 2017).

Authorisation of blue biomass solutions

Public authorisation relates to novel blue biomass solutions in two ways. First, these solutions usually require a permit due to their need of marine operation area. Second, they can be supported as environmental measures through the permitting of other activities such as fish farming. TO MAKE the permitting of the blue biomass solutions work, these solutions should be integrated into planning instruments. Maritime spatial planning as well as the river basin management plans and marine strategies provide a platform for the permitting process to locate and permit the blue biomass activities and, in general, to reconcile them with other uses of marine environment. Second, the largely positive environmental impacts of the blue biomass solutions should guide the permitting process and required environmental assessments.

The lack of understanding of the environmental impacts of novel blue biomass solutions (e.g. mussels and seaweed farming) may cause lengthy permitting processes. Public and private sectors should work together to help with the knowledge gap concerning these solutions and provide sufficient information, such as recommendations and guidelines, to the authorities. WHEN PERMITTING fish farming or other activities causing nutrient loading to the sea, blue biomass solutions should be considered as environmental measures that may help with mitigating or offsetting their impacts. States could help develop trading schemes that consider the ecosystem services that blue biomass activities provide and consider the cumulative impacts of different activities (EU 2016; Belinskij et al. 2018).

6. Political environment, regulations, and financial support

The political context

The European and national regulations on macroalgae cultivation and macroalgae products must protect consumers and the environment while not discouraging sustainable innovation. The licensing procedures for macroalgae cultivation in the sea are a central regulatory issue. Permitting is based on environmental and water law. For EU Member States, the Maritime Spatial Planning Directive 2014/89/EU, the Water Framework Directive 2000/50/EC, the Marine Strategy Framework Directive 2008/56/EC, and the Habitats Directive 92/43/EEC are central. Multi-use of the sea and synergies between sectors can be promoted through maritime spatial planning, such as co-locating macroalgae cultivation with offshore wind farms. As an opposite to fish aquaculture, macroalgae cultivation can potentially improve water quality by reducing nutrient loads in the ecosystem. Macroalgae can be part of Integrated Multi-Trophic Aquaculture (IMTA) systems, where macroalgae can offset nutrients released from fish or mussel farming.

<u>The path to harmonised regulation</u>

Macroalgae cultivation is a new activity in the Baltic Sea region, and the Baltic Sea countries do not have specific regulations on the activity. In many countries, several different authorities are involved in aquaculture licensing, and the procedure is time-consuming. One-stop shops for macroalgae cultivation and IMTA permits are needed, even in federal countries if possible.

> A joint statement from the ministries and permitting authorities ex-pressing a favourable attitude towards macroalgae farms would encourage the business.

The regulations on macroalgae products are another critical issue for the development of this industry. Improving and clarifying the European rules on macroalgae products is mainly a task for the EU. The novel food status (Regulation 2015/83/EU) of some edible macroalgae species has not yet been evaluated and clarified. Uniform safety rules are needed regarding heavy metals and toxins in macroalgae foods (under Commission Regulation 2006/1881). Fishery-based product labelling rules (Regulation 2013/1379/EU) are not suitable for macroalgae products, especially since health claim substantiation (Regulation 2006/1924/EU) is demanding for any food company. Markets for macroalgae products are also shaped by more general regulatory instruments impacting either the supply of macroalgae products or their demand.

> Many macroalgae products have their added value in replacing more resource intensive, larger-carbon footprint and less healthy alternatives such as meat or soy. A regulatory framework that adds weight to sustainability criteria will work in their favour.

Key Messages and Recommendations

- **Recognising macroalgae cultivation** and wild harvesting as a compensation measure for nutrient and carbon emissions promotes innovation in multi-trophic biocircular systems. In addition to selling the biomass, algal biomass producers could receive income through tradeable offsets.*
- **Public procurement rules** that add weight to environmental criteria broaden the markets for eco-innovative products. European procurement policies are based on European and national laws, but concrete procurement criteria are decided at the level of individual procurement units.
- **Tax schemes** that add weight to environmental criteria benefit sustainable products. The EU sets the amount of possible VAT rate categories (a Member State can have three), whereas tax rates are decided at Member State level.
- **Trade agreements** between the EU and other countries or trade blocks may adopt criteria that favour sustainable products while blocking or limiting the imports of unsustainable products.
- **Removing subsidies** from the production of competing, high-carbon raw materials lowers the relative prices of more sustainable products.

7. Product value chains, markets and stakeholders for a blue, circular bioeconomy

Cost efficiency of Baltic macroalgae production

Preliminary calculations show that the production of macroalgae in the south-east of the Baltic Sea: Poland, Latvia, Estonia is quite cost-intensive. Depending on the adopted input parameters, the production cost of 1 kg of fresh *Ulva* varies from 0.23 €/kg, with the optimistic assumption of efficiency of 87t/ha, up to 1.0 €/kg, assuming the pessimistic version of the yield of 9.8t / ha. The estimated unit cost of producing 1 kg of fresh *Fucus* is ca 2.34 €/kg.

Societal Value

Starting the cultivation of seaweed in the Baltic Sea Region, from the market point of view, would be a response to the growing consumer demand for new, pro-health products of aquatic origin, also in line with the trend of reduced demand for animal products. Production in the region would make it possible to offer a local, ultra-fresh product. From a socio-economic point of view, local cultivation of seaweed would contribute to wider societal value in the region: replacing imported products; stimulating employment (including people leaving sea fishing) or conversion of fish processing plants.

Baltic market barriers

From an environmental point of view, the cultivation of seaweed, especially fast-growing seaweed (like *U. intestinalis*), offers a unique opportunity to reduce water eutrophication while accumulating CO_2. The main obstacles to the establishment of macroalgae cultivation in the Baltic Proper (i.e. the Eastern Baltic) are: the inability to estimate the market absorption capacity for new species, practically absent in the food market of the region (such as *U. intestinalis)*; lack of proven in practice technologies for the cultivation of *U. intestinalis* and *F. vesiculosus* in Baltic conditions; legal and legislative barriers - especially for new market entrants; finally - the lack of public funding for the ecosystem services that provided by seaweed farms. The report 4.1 (*Macroalgae value chains relevant for BSR, showcasing macroalgae business models for blue bioeconomy products and market analysis)* synthetically collects the available knowledge about the production possibilities and the seaweed market in the Baltic Sea Region, carried out by the National Fisheries Marine Research Institute of Poland as part of the GRASS project.

Socio-economic dimension of the development of the production and the use of macroalgae in the Baltic Sea Region

We can only talk about the socio-economic impact of the local seaweed industry on the Baltic Sea Region based on the assumptions made regarding the scale of future seaweed cultivation. There is no such assumption in any official policy documents for the Baltic Sea Region. Therefore, we estimate the socio-economic impact in this factsheet based on an ambitious, proprietary strategic vision (described on page 3). We show that the use of 3,480 ha of Baltic Sea waters for the cultivation of fast-growing seaweed such as *Ulva intestinalis* can have significant positive environmental effects, such as significant nutrient reduction in the eutrophied waters of the Baltic Sea and significant accumulation of CO_2. By contrast, some negative impacts on the environment (seabed, landscape) are much smaller than the obtained benefits (see page 2). The development of the consumption of seaweed, regardless of whether it is based on local production or – as at present – imported raw materials, has a positive effect on the health of the society. The versatile positive health benefits of seaweed have been scientifically proven. This is especially important in the face of the growing demand for vegan products. The development of the seaweed sector and at least partial replacement of imported raw materials with local production translates into the multiplication of the added value in the Region per unit of seaweed products used. At the same time, the project demonstrated that biorefining is the most comprehensive and future-proof option for processing seaweed raw materials. The development of local production of seaweed is an opportunity to use human potential, especially the competences of fishermen leaving the Baltic fishery, as a result of the reduction in fishing opportunities every year (see page 6). There are several strong research centers dealing with seaweed in the Baltic Sea Region. However, there are few initiatives focused on practical implementation so far. Therefore, the implementation of any ambitious plan should be preceded first by conducting experiments on a semi-industrial scale in the Baltic Proper, as the available literature data regarding the productivity of macroalgae such as *Ulva intestinalis* come from different years and show large divergences.

Conclusion

Seaweed's potential stems one the one hand from its ecosystem services as a primary producer supporting species fundamental to marine ecosystems, reversing the negative effects of human induced climate change and ocean acidification. On the other hand, it has enormous potential to meet multiple market entry points along the value chain, be it neutra-/pharmaceuticals, cosmetics, food ingredients, animal feed, bioplastics, fertiliser or biogas. For the full value chain to be further developed, companies need to develop new products using algal biomass, or replace environmentally unsound materials (such as fossil-based plastics, meat or soy) with bio-based alternatives. To fully exploit the full value chain, those companies also need to work together to ensure all their needs are met, and processes are continually optimised. Many new products will come from start-ups and SMEs, but pressure needs to be applied to larger companies to convert their infrastructure to use bio-based feedstocks. As mentioned, this can come in the form of subsidies, tax schemes and public procurement rules which incentivise the transition and ultimately open up new markets in a knock-on effect. In terms of what this means for the transition to a circular economy, consumers have a key role to play: by sticking to the mantra of 'think global, buy local', and being prepared to spend slightly more for locally produced products, they will essentially 'vote' for the Baltic seaweed industry with their money. To make this choice obvious to the average consumer, clever marketing should be applied to new products, be it labelling, certification or clustering/associations, so that products are instantly recognisable as "Baltic biomass". To this end, companies and producers should work together and pool their resources in order to succeed. Furthermore, Life Cycle Assessments should also be applied to new products so that stakeholders can understand the full journey of a product, including its socio-economic and environmental inputs and outputs. Incentivising primary production of raw materials in the EU results in wider societal value in the form of job opportunities, improved skills and competences, resilience to economic shocks and of course multiple environmental benefits, providing a blueprint for a truly sustainable circular industry.

8. Analysis of benefits, risks and opportunities at a regional, national and at transnational level of the BSR of macroalgae cultivation, harvesting and use, considering environmental, ecological, regulatory and socio-economic aspects

Macroalgae production is an upcoming sector for growing biomass for producing food, consumables such as plastics and energy without competing for arable land, depleting fresh water and using non-renewable fertiliser. However, the sector is still in its infancy in the Baltic Sea Region and there is a lack of in-depth and wide-spread knowledge on the potential benefits of macroalgae production. To deal with this challenge, GRASS aims to raise awareness and build capacity on macroalgae cultivation, harvesting and use among public authorities and other relevant stakeholders across the region. Public authorities, ministries, planning regions and counties play a crucial role in promoting macroalgae as they are the main legislative bodies that also control much of national and regional funding.

Benefits

As we have seen in the GRASS project and from research worldwide, macroalgae cultivation and harvesting has the potential to bring many ecological and socioeconomic benefits to water bodies such as the Baltic Sea and its coastal communities. Macroalgae biomass is a rich source of bioactive products. Relevant macroalgae end uses include medicinal products, food (direct consumption, food ingredients, supplements, and additives), feed and feed additives, cosmetics, bioplastics, fertilizers and agricultural biostimulants, and biofuels/biogas. Due to their high protein content, favourable amino acids, antioxidants and vitamins, macroalgae have many benefits for humans (SAPEA 2017). MOST IMPORTANTLY, macroalgae do not need land, fertilizers or freshwater in their production. Macroalgae production can mitigate the effects of eutrophication and enhance water quality through nutrient uptake. Algae production mitigates climate change through binding CO_2 in algal biomass. According to Seaweed for Europe (2020), 27,300 hectares of macroalgae farms can take up 20,000 tons of nitrogen, 2,000 tons of phosphorus and 5.4 million tons CO_2e. In sum, macroalgae can have a significant role in reaching various sustainable development goals related to food security, human health, and planetary health, in addition to providing opportunities for sustainable blue economic growth.

a) Sustainable Use of Resources

No agricultural land: Unlike soy or other imported crops commonly used in food and animal feed, macroalgae has the benefit of not requiring agricultural land. It also grows much faster than land-based plants, in some cases by a few centimetres per day. While much of terrestrial space is and will be increasingly designated to farmland or urbanisation, the marine domain is still relatively under-used. Of course, there are major users of marine areas such as offshore energy, shipping lanes, tourism and leisure activities, marine cultural heritage sites and aquaculture sites. As the GRASS mapping exercises have shown, there is ample opportunity for effective location or even co-location of macroalgae production with other industries in many coastal areas of the Baltic Sea Region.

No freshwater inputs: The other major benefit of biomass generated from macroalgae is the fact that it does not require freshwater inputs. With extreme weather events such as heatwaves and droughts becoming a yearly occurrence throughout Europe, the demand for freshwater in the summer months is becoming a major international issue and will continue to do so for decades to come. By creating new value chains derived from marine or brackish biomass, dependence – and ultimately the associated risks – will be mitigated in the long term. It is vital that this transition starts as soon as possible to provide resources for an increasing global population from sources not dependent on freshwater inputs.

No fertiliser: Just as with freshwater, macroalgae does not require additional fertiliser to stimulate growth (as with land plants). The nutrients required for growth (e.g. nitrogen and phosphorous) come from the surrounding water body in the form of dissolved nutrients. Much of the nutrient loading (and resulting eutrophication) of the Baltic Sea stems from agricultural run-off and sewage storm surges. Macroalgae therefore provides a crucial ecosystem service by absorbing the excess nutrients, thereby cleaning, oxygenating and deacidifying the Baltic Sea, which in turns improves habitat conditions for other marine life.

b) Water Quality

Macroalgae's natural ability to take up excess nutrients (particularly nitrogen and phosphorous) make it a low-cost and efficient method to bring the Baltic Sea to a Good Environmental Status under the EU Water Framework Directive. Macroalgae oxygenates surrounding waters. Hypoxia, or low oxygen levels in bottom waters, is a chronic problem in the Baltic Sea resulting from excess nutrient loading caused by human activity and agricultural run-off. This is turn triggers algal blooms in the summer months, which sink to the sea floor and decay, using up oxygen in the process. This, coupled with low water exchange characteristic of the Baltic Sea, creates a layer of anoxic conditions which consequently result in benthic dead zones. Macroalgae can also play a role in deacidification of the Baltic Sea through the uptake of carbon. Ocean acidification is a problem caused by excess carbon dioxide in the atmosphere from human activity, which is then absorbed by water bodies and in turn lowers pH levels, which are critical to the survival of many aquatic species. At the same time, increased cultivation will naturally suppress the occurrence of algal blooms (e.g. *Furcellaria*) along the Baltic coast, which is a costly nuisance to most local authorities and negatively affects tourism in the summer months. Alongside cultivation, improved harvesting and processing techniques of the excess algal biomass from the Baltic can turn a waste resource into a useful raw material, be it for fertiliser, building materials or biogas.

c) Biodiversity

Not only water quality, but biodiversity has been scientifically proven to be boosted by the increased presence of macroalgae, as it is a primary producer, providing habitat and shelter for juvenile fish, countless invertebrates and plankton species. These form the basis of the food chain and support all higher trophic levels such as cod. While the same principles of biodiversity support mechanisms (e.g. introduction of honeybees, insect hotels etc.) are well-known on land, they have yet to be widely applied in marine environments in the Baltic.

Macroalgae cultivation in combination with either wind farms or artificial reefs (e.g. decommissioned oil rigs) is one such example of biodiversity support mechanisms that could be applied in the marine environment.

d) Societal value:
As discussed in chapter 7 (Product value chains, markets and stakeholders for a blue, circular bioeconomy), from a market point of view, the cultivation of seaweed in the Baltic Sea Region would be a response to the growing consumer demand for new health products of aquatic origin, also in line with the trend of reduced demand for animal products. Production in the region would make it possible to offer a local, ultra-fresh product. From a socio-economic point of view, local cultivation of seaweed would contribute to wider societal value in the region: replacing imported products; stimulating employment (including people leaving sea fishing) or conversion of fish processing plants. The development of local production of seaweed is an opportunity to use human potential, especially the competences of fishermen leaving the Baltic fishery, as a result of the reduction in fishing opportunities every year (see page 6). There are several strong research centers dealing with seaweed in the Baltic Sea Region. However, there are few initiatives focused on practical implementation so far. Therefore, the implementation of any ambitious plan should be preceded first by conducting experiments on a semi-industrial scale in the Baltic Proper.

e) Economic resilience:
The development of the seaweed sector and at least partial replacement of imported raw materials with local production translates into the multiplication of the added value in the Region per unit of seaweed products used. At the same time, the project demonstrated that biorefining is the most comprehensive and future-proof option for processing seaweed raw materials. European domestic production of macroalgae biomass – while more expensive than imports – will have long term benefits which support a local, circular bioeconomy into the future and guarantee high quality products thanks to European standards. The consumer understanding of the benefits of locally produced products is well-known and accepted, so consumers, as well as the producers and processors are key in early adoption of macroalgae biomass and products. If the benefits are clearly communicated, then consumers will hopefully be willing to pay a little extra to support the establishment and early growth of the industry. Once established, producers and processors can work to drive prices down as processes and technology is further refined.

f) Green Transition:
The European Commission's plan to transition to net zero emissions depends on the so-called 'greening' of the economy, divesting from fossil fuels and investing in environmentally sound and sustainable innovation to replace old infrastructure. The term 'Green Transition' is perhaps indicative of the fact that marine resources are still not adequately considered in the transition to a zero-carbon economy. In terms of terminology, a "blue-green" transition may be more appropriate, since the blue economy has an equal if not greater role to play in the transition to net zero. Though the blue economy is in many ways far behind terrestrial transition schemes, it has huge potential to rapidly provide an abundant source of carbon storage and environmental

remediation as well as production of food, pharmaceuticals, biomaterials, jobs and education. As a primary producer, macroalgae has a vital role to play in all the above-mentioned sectors. By building an industry around macroalgae in an ecosystem-based approach, doors will be opened for complementary raw materials which offer similar ecosystem services and socio-economic gains.

Risks

Diversity and Economies of Scale: An important history lesson to be learned from the agricultural "Green Revolution" of the post-war period is that monocultures are fraught with risks. While monocultures may suit old economies of scale, posterity shows us that disease resistance, dependence on fertiliser, genetic and biodiversity all suffer as a result. *Saccharina latissima* is so far the most cultivated macroalgae species in Europe. While certain applications require large quantities of feedstock inputs, this should not justify "mega-farms" of monocultures occupying huge swathes of marine areas. To avoid the old pitfalls of disease, ecological regime shifts and economic shocks (e.g. through crop failures), the risk should be spread across multiple species, of either macroalgae or other trophic levels. An ecosystem-based approach should therefore be taken to any new farm site, with rigorous, long-term environmental impact assessments undertaken prior to implementation. From a socio-economic perspective, "mega-farms" also have been proven (in agriculture) to only benefit a small number of practitioners, who then receive then lion's share of subsidies, out-compete smaller producers and prevent newcomers from entering the industry. This in turn leads to socioeconomic "monocultures" which, though arguably more efficient, do not represent a fair, resilient nor competitive European economy.

Barriers

a) **Legislation**: As discussed in chapter 1 (MSP Synergies and Conflicts), in terms of legislation, practitioners and authorities have the challenge of providing evidence that macroalgae cultivation will cause no harm to the surrounding environment. Since macroalgae cultivation is largely considered to be ecologically benign, with an increasing body of evidence of beneficial ecosystem services from existing seaweed farms, the licensing process is likely to be met with less apprehension in the future. However, to upscale the Baltic macroalgae industry in a short space of time, public authorities should consider a separate licensing process dedicated to low-trophic species (e.g. macroalgae, bivalves, gastropods, crustaceans and echinoderms) which require zero inputs (I.e. fish feed) which otherwise leads to nutrient loading and ultimately eutrophication of the Baltic Sea.
b) **Awareness**: As outlined in output 3.2.1, awareness-raising and pilot farms are also needed to gain attention from politicians and administrators. Governments may refer to global standards, mainly the ASC-MSC Seafood Standard (Aquaculture Stewardship Council and Marine Stewardship Council 2018) in determining the rules for sustainable macroalgae business, however their association with capture fisheries and fish aquaculture tend to obfuscate many of the beneficial aspects of macroalgae cultivation and harvest.
c) **Markets:** The high cost of labour and technology in Europe are a challenge in making a European seaweed industry economically viable, when raw materials can be sourced for a fraction of the price from overseas. Subsidies are an ideal solution to support the European seaweed industry in those crucial early stages of development. In addition, persuading

consumers and end-users that macroalgae is a valuable resource is another challenge to overcome in the establishment of a European seaweed industry.

d) **Technology**: While Europe, and particularly Baltic countries, have advanced technologies for aquaculture and processing of e.g. bioactive compounds, the technology for harvesting, cultivating and processing of specific macroalgae species is either in its infancy or completely lacking. There is ample potential for technological developments and cross-sectoral collaborations such as industrial symbioses, thus accelerating the transition to a circular bioeconomy.

e) **Spatial Planning**: Another barrier identified in the GRASS project is spatial planning in terms of competition from other marine sectors such as shipping, tourism and fish aquaculture. The GRASS outputs make the first step in approaching this barrier by identifying suitable cultivation sites in the Baltic Sea, as well as harvesting sites via the Operational Decision Support System (ODSS). The next step is to use these outputs to place pilot sites in the water, to better manage the ecological effects and socio-economic interactions with other industries, but also to provide a precedent to be further built upon and inform future actions.

<u>Opportunities</u>

While macroalga hydrocolloid production and traditional macroalga based foods and cosmetics remain big sectors of macroalgae industry, interest towards new products such as macroalgae food supplements and novel macroalgae consumables is evident. Although the diversity of currently used macroalgae species is wide, lack of efficient cultivation technologies has a big impact on the production volumes of different macroalgae species. Harvesting of wild macroalga populations is often unsustainable and utilisation of many macroalgae species is dependent on development of new aquaculture techniques. Diverse selection of sustainably produced macroalgae species would allow the development of novel macroalgae food and feed products and novel high-value phytochemicals. In addition, subsequent cascading extraction of various fractions and raw materials from macroalgae biomass and utilisation of side streams of the hydrocolloid production could bring higher revenue for macroalgae production. However, more research is needed to unlock the potential of macroalgae phytochemicals for different applications. Macroalgae have newly been recognized as potential food and feed ingredient in Europe and in the Baltic Sea countries, where their consumption has traditionally been less compared to other regions. With the increased consumption of imported seaweed products, also the interest towards local seaweeds is starting to rise. The Novel Food law still limits the use of many European macroalgae species as food, although the authorization processes have been developed and simplified. Moreover, the food safety regulation setting limits to harmful contaminants in food suffers from shortcomings concerning the seaweed food products. Maximum levels for arsenic in seaweed foodstuffs have not been established even though high levels of inorganic arsenic in certain macroalgae species may result in the intake of harmful quantities of inorganic arsenic even when relatively small amounts of seaweed are consumed. However, these shortcomings in the regulation have been recognized and are likely to be resolved in the future. The classification of seaweeds as fishery and aquaculture products is noteworthy, since it obligates detailed product labelling and authorization of the species by the national authorities. The limitations and requirements for macroalgae based feed materials are established in the EU feed laws where, depending on the regulation, algal feed materials are either considered as their own feed category with specific safety regulations or covered by common principles applicable to all feed materials.

Promoting Sustainable Macroalgae Business

Macroalgae, or seaweeds, are simple, plant-like organisms found worldwide. They grow primarily along the coastline, but they can also be found in freshwater ecosystems such as rivers and lakes. Macroalgae are divided into three major groups: green, brown and red algae. The global value of the macroalgae industry is currently more than 6 billion USD (FAO 2019), of which 85% comes from food products for human consumption (FAO 2018). In the last decade, the global cultivation of macroalgae has doubled to an annual production of 32 million tons fresh weight (FW), whereas the harvesting of natural macroalgae has stayed constant at approximately 1 million tons FW per year (FAO 2019). According to Seaweed for Europe Coalition (2020), European seaweed production will have to rapidly expand from present production of 300,000 tons FW (2020) to 8 million tons FW by 2030, to cover 30% of the need of the European seaweed industry, with an estimated market value of €9.3 billion in 2030.

Further research and better regulation

Further research and innovation activities are needed to discover the potential of various algal species, to develop cultivation methods, to ensure product safety, and to respond to consumer needs. Macroalgae should be understood both as a bioeconomy resource and as a potential tool for environmental management. All Baltic states should sign and endorse the UN Global Compact Seaweed Manifesto (2020), which is the first global memorandum of understanding on seaweed.

The European and national regulations on macroalgae cultivation and macroalgae products must protect consumers and the environment while not discouraging sustainable innovation. Governments may refer to global standards, mainly the ASC-MSC Seafood Standard (Aquaculture Stewardship Council and Marine Stewardship Council 2018) in determining the rules for sustainable macroalgae business.

The licensing procedures for macroalgae cultivation in the sea are a central regulatory issue. Permitting is based on environmental and water law. For EU Member States, the Maritime Spatial Planning Directive 2014/89/EU, the Water Framework Directive 2000/50/EC, the Marine Strategy Framework Directive 2008/56/EC, and the Habitats Directive 92/43/EEC are central. Multi-use of sea and synergies between sectors can be promoted through maritime spatial planning: macroalgae cultivation can co-locate for example with offshore wind farms. As an opposite to fish aquaculture, macroalgae cultivation can potentially improve water quality by reducing nutrient loads in the ecosystem. Macroalgae can be part of Integrated Multi-Trophic Aquaculture (IMTA) systems, where macroalgae can offset nutrients released from fish or mussel farming. Macroalgae cultivation is a new activity in the Baltic Sea region, and the Baltic Sea countries do not have specific regulations on the activity. In many countries, several different authorities are involved in aquaculture licensing, and the procedure is time-consuming. One-stop shops for macroalgae cultivation and IMTA permits are needed, even in federal countries if possible. A joint statement from the ministries and permitting authorities ex-pressing a favourable attitude towards macroalgae farms would encourage the business.

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- **Recognising macroalgae** cultivation and wild harvesting as a **compensation measure** for nutrient and carbon emissions promotes innovation in multi-trophic biocircular systems. In addition to selling the biomass, algal biomass producers could receive income through tradeable offsets.
- **Public procurement** rules that add weight to environmental criteria broaden the markets for eco-innovative products. European procurement policies are based on European and national laws, but concrete procurement criteria are decided at the level of individual procurement units.
- **Tax schemes** that add weight to environmental criteria benefit sustainable products. The EU sets the amount of possible VAT rate categories (a Member State can have three), whereas tax rates are decided at Member State level.
- **Trade agreements** between the EU and other countries or trade blocks may adopt criteria that favour sustainable products while blocking or limiting the imports of unsustainable products.
- **Removing subsidies** from the production of competing, high-carbon raw materials lower the relative prices of more sustainable products.

National policy measures needed

Marine and coastal aquaculture in the Baltic Sea comprises of fish farms, mussel farms and algae cultivation. Fish farms are operated on a commercial basis, while mussel farms and algae cultivation, which are two of the novel blue biomass solutions, are currently (2021) mostly pilot-scale research projects (Przedrzymirska et al. 2019). ACCORDING TO the EU, the blue bioeconomy faces many challenges and constraints. Two of these are the complexity of the regulatory and administrative procedures and the lack of reward schemes for the provision of environmental services to the marine ecosystems (EU 2020). THE WATER Framework Directive, Marine Strategy Framework Directive and Baltic Sea Action Plan all support novel blue biomass solutions that enhance the achievement of the good environmental status of the Baltic Sea. However, they also leave a lot of discretion for Member States to regulate the biomass solutions and to reconcile them with the blue growth objectives (see Schultz-Zehden et al. 2019). AT THE national level, the advancement of the novel blue biomass solutions requires different types of policy measures. On the one hand, a lot can be done based on current legal regulation. On the other hand, legislative changes may also be needed.

1. Promote novel blue biomass solutions through maritime spatial planning

One of the bottlenecks of the novel blue biomass solutions is the integration of the different uses of marine areas. Macroalgae cultivation, for example, may require large marine areas of operation and must be integrated with nature conservation areas and other activities such as shipping, fisheries, wind power production, recreational uses and national defence. Some of these uses, e.g. offshore wind energy, may be combined with blue biomass solutions (see Przedrzymirska et al. 2019). Furthermore, space on land is needed for the storage and processing of wet algal material. ONE OF the policy tools to enhance macroalgae and other novel biomass solutions at sea is maritime spatial planning. The main objective of the EU Maritime Spatial Planning Directive (2014/89/EU) is to promote sustainable development and growth in the maritime sector (Art. 5). To achieve this, maritime spatial plans should be able to reduce conflicts between sectors, create synergies and balance the development of a wide range of maritime activities (EU 2016). Maritime spatial planning process can specifically address the novel blue biomass solutions. In addition, regional and local level planning is needed to enable the storage and processing of blue biomasses.

2. Plan how to manage nutrient balances.

The novel blue biomass solutions could benefit from a mass balance approach to evaluate the nitrogen and phosphorus pools at the Baltic Sea level and the national level. In the framework of the Baltic Sea Action Plan, states could consider how to allocate their nutrient targets between different activities and how the novel blue biomass solutions may support synergies between sectors or offset emissions from other activities by removing nutrients from the sea. THE BLUE biomass solutions can also be included in the river basin management plans and marine strategies. In this way, countries may plan in more detail how they can use these solutions as environmental measures to offset nutrient loading resulting from different sea- and land-based activities. TO MITIGATE eutrophication stemming from the fish farming, Member States may consider applying nutrient-neutral schemes and other means to remove nutrients from the sea (EU 2017). National and international nutrient trading schemes and co-location solutions could be enhanced. They could include the development of integrated multitrophic aquaculture systems where fish farms are combined with nutrient extracting species such as macroalgae or shellfish to provide environment remediation in the form of the bio-mitigation of harmful impacts (see EU 2016; Przedrzymirska et al. 2019).

3. Recognise blue biomass solutions as environmental measures

Novel blue biomass solutions should be officially recognised as a nutrient mitigation tool. This could provide incentives to support these solutions and their use as nutrient offsetting/compensation measures in relation to economic activities (see Submariner 2019). However, at the same time the environmental impacts of these solutions, such as large-scale macroalgal cultivation, must be monitored, since they may disturb marine ecosystems (Suutari et al. 2016). An extensive assessment on their total environmental and socio-economic footprint should be conducted. ECONOMIC INCENTIVES are needed to develop infrastructure for the blue biomass solutions (see Suutari et al. 2016). There could be payments for the ecosystem services they provide. While different public funding schemes are available for the purpose, payment schemes could also be based on markets for ecosystem services either under the polluter pays or beneficiaries pay principle (Schultz-Zehden et al. 2019).

4. Make permitting work

Public authorisation relates to novel blue biomass solutions in two ways. First, these solutions usually require a permit due to their need of marine operation area. Second, they can be supported as environmental measures through the permitting of other activities such as fish farming. TO MAKE the permitting of the blue biomass solutions work, these solutions should be integrated into planning instruments. Maritime spatial planning as well as the river basin management plans and marine strategies provide a platform for the permitting process to locate and permit the blue biomass activities and, in general, to reconcile them with other uses of marine environment. Second, the largely positive environmental impacts of the blue biomass solutions should guide the permitting process and required environmental assessments.

Figure 2: Photo of Bladderwrack (Fucus vesiculosus) courtesy of Paul Levesley

Acknowledgements

Finally, the SUBMARINER Network for Blue Growth would like to say thank you to the project partners for their commitment to the GRASS project and their dedication to its overall success.