Ensuring environmental safety – necessary monitoring practices for seaweed cultivation and harvesting in the Baltic Sea

Report for the "Safe Seaweed Coalition" project "BalticSeaSafe", Deliverable O.1

By Ieva Bārda, Anda Ikauniece, Aurelija Armoškaite, Efthalia Arvaniti, Francisco R. Barboza, Alexander Jüterbock, Sophie Koch, Jonne Kotta, Anu Lähteenmäki-Uutela, Rafael Meichßner, Esther Robbe, Kristian Spilling, Tim Staufenberger, Eva Strothotte, Martin Wahl

BalticSeaSafe is co-funded by Global Seaweed Safety Coalition

December 2022

Baltic Sea Safe project

Baltic Seaweed Biosafety or BalticSeaSafe is a 16-months project (January 2022 – April 2023) funded by Global Seaweed Safety Coalition. BalticSeaSafe project is coordinated by SUBMARINER Network for Blue Growth EEIG, with partners Finnish Environmental Institute & Latvian Institute of Aquatic Ecology. Website: https://www.submariner-network.eu/BSS

BalticSeaSafe aims for creating a well justified guidance, resulting in recommendations and position papers on environmental monitoring and license conditions for **cultivation of seaweed in the Baltic Sea with regard to environmental safety.** The work is building on the work of Baltic GRASS project (Interreg BSR) and its recommendation for future actions.

BalticSeaSafe will raise awareness on environmental benefits and risks of algae cultivation in the Baltic Sea region, especially in matters of biohazard. In the last 10 years, Baltic Sea Region actors incl. politicians, authorities, entrepreneurs, consumers are very much preoccupied with eutrophication and future measures to improve environmental status of the Baltic Sea.

BalticSeaSafe will also build capacities among policy makers in suggesting a fair unified and coherent licensing regulation reflecting the real risks and also industry's needs. Currently, licensing for setting up new farms is an important barrier for algae investors and entrepreneurs. A new standardised licensing process can effectively unlock investments in algae, by including algae in the maritime spatial plans and allocating areas suitable for algae farming, and also develop a process that is robust, fair, functional and effective.

Project outputs

Workshop 1	The 1st workshop will focus at the most important environmental risks and biohazards related to the upscaling of seaweed farming specifically for the Baltic Sea. The workshop participants will be representatives of academia, consultancies, NGOs, environmental authorities and seaweed farmers as well as other entrepreneurs interested in seaweed The workshop discussion will lead to Ouput 1 (May 2022).
Output 1	A report with recommendations for necessary data collection and monitoring practices at the seaweed farms (December 2022). Contribution to monitoring strategies – environmental policy
Workshop 2	The 2nd workshop will focus on the regulatory issues for seaweed cultivation in the Baltic Sea, especially on licensing procedures and permit requirements. The workshop participants will include environmental researchers, permit-issuing authorities, ministries, maritime spatial planning experts, legal scholars, and farmers. The discussion of the second workshop will lead to the formulation of Output 2.
Output 2	A second report on possible developments in standardizing licensing and environmental assessments in the region (March 2023). Contribution to environmental assessment criteria - environmental policy
Output 3	A position paper on necessary adaptations in environmental legislation. Contribution to environmental legislation aspects - environmental policy (March 2023).

Table of Contents

Introduction **1**

I. Assessing the environmental impacts of macroalgae cultivation **2**

1) Scale 3

2) Location 4

3) Method of cultivation and harvest 5

4) Additional global aspects 5

II. Compilation of positive and negative impacts of macroalgal farms on the Baltic Sea ecosystem **6**

III. Environmental monitoring requirements for macroalgal cultivation in the Baltic Sea **7**

IV. Environmental monitoring for wild macroalgae harvesting in the Baltic Sea **10**

V. Conclusions **10**

References **11**

Introduction

While only a handful of SMEs cultivate or harvest macroalgae in the Baltic Sea, the goal and direction towards wider sustainable use of macroalgae as a resource is well defined in the European Union (e.g., EU4Algae[1]; Algae Initiative by European Commission, 2022[2]). The Baltic Sea is a young brackish marginal sea characterized by a pronounced salinity gradient from south-west to north-east and clear seasonal changes in temperature and nutrient availability. Therefore, the Baltic Sea allows the cultivation of a limited number of macroalgae species. In addition, the Baltic Sea is under high anthropogenic pressure due to human activities both on land and at sea, including maritime industries, coastal urbanization and tourism, and fertilizer inputs by agriculture and forestry. There is an utmost need to restore the degraded ecosystems of the Baltic Sea and here, macroalgal cultivation is a promising circular economy solution to locally achieve nutrient reduction (Kotta et al., 2022). However, for this potential to be unlocked, the safety of upscaling has to be assured. Therefore, macroalgal cultivation must follow clear monitoring and control frameworks to avoid unnecessary damage to the fragile and valuable habitats of the Baltic Sea. Indeed, lessons learned in other parts of the world provide the possibility to choose low-risk

[1] https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1727

[2] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12780-Blue-bioeconomy-towards-a-strong-and-sustainable-EU-algae-sector_en

solutions for seaweed aquaculture in the Baltic (Campbell et al., 2019, Tonk et al., 2021, Banach et al., 2022).

The goal of this report is to review the current knowledge and identify the necessary procedures and monitoring practices when starting or expanding a seaweed farm in the Baltic Sea. The suggestions are provided considering the variability of the Baltic Sea environment. Seaweed cultivation is known to improve ecosystem functionality and safeguard several ecosystem services (e.g. Kotta et al., 2022). In the text, we distinguish cultivation from wild harvesting practices. Collecting beach wrack is out of the scope of this report, as it is regulated by terrestrial procedures of biowaste management.

I. Assessing the environmental impacts of macroalgae cultivation

Recent cultivation activities in the Baltic Sea region have focused on the cultivation of brown macroalgae – *Saccharina latissima* is the only species of macroalgae commercially cultivated in the westernmost regions of the Baltic (Campbell et al., 2019; van Oirschot et al., 2017; Weinberger et al., 2019; Visch et al., 2020). However, several ongoing pilot projects are in place for testing techniques (i.e., infrastructure survivability) and cultivation feasibility in the given local conditions to start the sea-based cultivation across the Baltic Sea, particularly in the south-western parts. The algae in the focus are red algae *Furcellaria lumbricalis* (Est-Agar, 2019), green algae *Ulva* spp. (Brzeska-Roszczyk et al., 2017; Suutari et al., 2017; Christiansen, 2018), brown algae *Fucus* spp. (Meichßner et al., 2020; 2021a; b) and *Chorda filum* (Meichßner et al., unpublished data). The cultivation and nutrient removal potential of *Saccharina*, *Ulva* and *Fucus* farms were modeled for the whole Baltic Sea region by Kotta et al. (2022) based on a large collection of recent measurements of macroalgal growth and the statistical relationships between environmental variables (e.g. salinity, temperature, light, nutrient availability, water exchange, etc.) and macroalgal growth yield.

Procedures for establishing a macroalgal farm will in most cases require obtaining a license and national regulations and procedures vary (Camarena-Gómez et al 2022). The level of information submitted when applying for a license is not harmonized across the Baltic Sea region and not even on a national level, e.g., across German federal states.

European Union law (e.g., 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, the Environmental Impact Assessment (EIA) Directive 2014/52/EU, and the Regulation on Organic Production 2018/848/EU) dictates a set of common farm management principles, though. These follow the rule of least negative impact possible to natural habitats and species, and therefore require localization of the farm that: a) minimizes damage to sensitive environments; b) uses seed sources that maintain the genetic diversity of wild stocks; c) does not cultivate non-native species; d) has biosecurity measures to control the spread of diseases, parasites, and non-natives in place; e) uses no fertilization; f) has well-maintained infrastructure; g) has minimal conflicts with other maritime activities (recreation, ship traffic) (Campbell et.al., 2019). Still, the coordination and harmonization between all regulatory acts are not fully present.

Environmental Impact Assessment (EIA) Directive 2014/52/EU is typically applied to large-scale, industrial fish farming projects, but because most aquaculture projects are small-scale, for semi-subsistence purposes, full EIAs are relatively rare (FAO 2009). While permitting procedures and EIA screening criteria for fish and shellfish aquaculture exist (European Commission 2016; Wood et al., 2017), they are yet to be interpreted and developed for macroalgae cultivation and harvesting in the Baltic Sea region (*GRASS,* 2021a). To select and apply the most appropriate parameters for the EIA in the Baltic Sea, several workshops were held where macroalgae practitioners and researchers from the Baltic Sea and outside regions participated, sharing their experience and knowledge on the topic discussed here. Synthesis of the workshop outcomes with EIA Directive Annex III screening criteria is the result we propose to support the decision process on whether EIA is necessary for macroalgae cultivation and harvesting:

1) Scale

Small-scale cultivation and harvesting activities are unlikely to have significant environmental impacts. Thus, EIA most probably will not be required. However, large-scale projects are much more likely to influence the surrounding ecosystem, and thus should be assessed in more detail than small to medium size projects. Such negative impacts involve for instance shading, nutrient uptake, spread of reproductive material (maybe even non-native or genetically modified), introduction of (non) synthetic, input of litter, noise disturbance, etc. (Tonk et al., 2021).

The scale of longline cultivation site can be categorized by the area occupied (e.g., Marine Scotland 2017), while other options include the amount of produced biomass and biomass produced per area. In the Baltic Sea, currently only an experience from the Kiel Bay IMTA farm exists. Here, together with mussels and fish also macroalgae are growing, and a yield – amount of produced fish biomass – has been considered as a threshold to define farm size, not the farm dimensions. If the annual yield is less than 50 t, the farm has been considered as small, and no EIA is required (Ministerium für Wirtschaft, Arbeit, Verkehr und Technologie Schleswig-Holstein, 2016). As there are no farms licensed in the Baltic Sea yet for commercial cultivation of macroalgae alone, we cannot yet suggest either precise yield or density values for a reliable threshold. Still, based on this experience, we suggest fewer requirements for obtaining EIA for farms only cultivating macroalgae.

To understand the limits of upscaling, carrying capacity studies are underway, focusing on the extend of seaweed cultivation possible without causing negative impacts or surpassing limits of unacceptable change (Kotta et al., 2022).

2) Location

The location of a farm should be in accordance with a country's maritime spatial plan (MSP). In the ideal case, the seaweed farming would have specifically designated areas in the MSP. Furthermore, interactions between macroalgae cultivation and other maritime sectors as off-shore wind park, research, aquaculture and opportunities for co-location should be considered during the implementation of macroalgae cultivation areas in MSPs (Armoškaite et al, 2021). In addition, it should be considered that in several Baltic Sea countries, hard bottom areas are scarce and mostly designated as protected habitats. Therefore, at least in Germany, Poland and Latvia, hard bottom substrates will not be accepted as sites for seaweed farming.

For the Baltic Sea, the modeled Pan-Baltic patterns of macroalgae production potential are publicly available through an online Operational Decision Support System (ODSS) that provides stakeholders a basis to identify suitable areas for macroalgae cultivation and harvesting (http://www.sea.ee/bbg-odss/Map/MapMain). In the portal, users can, for example, select the map of modeled *Fucus* or *Ulva* growth potential and display the results across the Baltic Sea. The user can then draw a theoretical farm area polygon and acquire variables (e.g. algal growth rate, water temperature and salinity) for that area (GRASS, 2021 b).

The described locational issues are mostly relevant for nearshore locations where seaweed farming activities are currently focused. We are aware of intentions to develop macroalgal cultivation at offshore locations. Closest to the Baltic Sea is a pilot site which combines an offshore wind research platform and offshore aquaculture (mussels and seaweed), established in the German North Sea by Horizon 2020 project UNITED[3]. During the setup of the pilot site, it has already appeared that for offshore locations, the monitoring requirements are different from nearshore locations, e.g., monitoring of marine mammals is requested. Studies of sharing offshore structures with wind farms to construct mooring systems for macroalgae cultivation have been developed (Buck and Grote 2019) in some areas and have been tested in Danish waters. Offshore location allows for larger dimensions, if not conflicting with other sea uses. In that case, the size of the farm will be relevant for environmental impacts in any location. Many potential negative impacts a farm could have can be minimized or even excluded by selecting an appropriate cultivation site, like choosing a site which is not too shallow to prevent the shading effects to impact other benthic communities, a site with enough currents and nutrient availability to prevent nutrient depletion, a site not located in breeding grounds of vulnerable species to avoid disturbance and

[3] https://www.h2020united.eu

entanglement (Campbell et al 2019, Wood et al. 2017 Tonk et al 2019, Banach et al. 2022).

3) Method of cultivation and harvest

The method used to cultivate and harvest algae will also determine the type and degree of impact on the environment. Cultivation methods differ; they are developed and selected depending on the type of algae cultivated and the environmental condition of farm locations. In the Baltic Sea, commercial cultivation of seaweed is currently done by longline systems – anchored long-lines suspended by buoys approximately 1-2 m below the surface. Experimental systems such as nets and cages have been tried at the pilot studies, but upscaling to industrial scale is still awaited. It should be noted though that nets and cages hold a higher risk of possible entanglement and injuries of wild fauna. The commercial harvesting of macroalgae is performed with a harvester vessel or a smaller boat in the coastal areas. Regardless of the method of cultivation and harvesting, the range of possible negative impacts of activities will be, as mentioned above, closely related to the size of the farm.

4) Additional global aspects

In addition to the European Union legal requirements including EIA requirements, another rules system for farming marine organisms is the Aquaculture Stewardship Council (ASC) – a leading private certification system for farmed seafood. Developed jointly by two certification programmes – ASC and Marine Stewardship Council (MSC) – the ASC-MSC Seaweed Standard sets strict requirements for responsible cultivation (Aquaculture Stewardship Council, 2022). By promoting environmentally sustainable and socially responsible use of seaweed resources, the standard encourages seafood producers to minimize the negative environmental and social impacts of aquaculture, which is in line with EU requirements regarding environmental risks. The Seaweed Standard consists of a set of five principles, each with defined performance indicators. Most relevant for data and monitoring purposes are the first two:

- Sustainable wild populations – harvest without depleting the populations, assess stock status, harvest strategy and the genetic impact of the assessment site on the wild stock;
- Environmental impacts – the structure, productivity, function and diversity of the ecosystem should be maintained;

The rest of the principles include effective management, social responsibility, and community relations and interactions.

II. Compilation of positive and negative impacts of macroalgal farms on the Baltic Sea ecosystem

Macroalgal farms can have positive effects on the Baltic Sea environment that can even counteract the negative consequences, especially if farms are small to medium size. For example, the deployment of a macroalgal farm can remove nutrients, reduce symptoms of eutrophication, and can increase biodiversity by attracting fish, birds and mammals, and smaller benthic animals. Based on these and other ecosystem functions provided by macroalgae we have compiled both positive and negative impacts of seaweed farms that are specific for the Baltic Sea coastal area (Table 1).

Table 1. The most relevant ecosystem functions and impacts of macroalgal farms

Macroalgae farm's effect on:	Negative effects	Positive effects
Hydrodynamics/sediment dynamics		
Water currents	- Increased sedimentation, suspended load and deposition of seaweed fragments - Affected local hydrodynamic movements, reduced water flow	- Additional food source for benthic organisms
Wave actions	- Reduced wave power - Increased sedimentation and suspended particle load	- Coastal protection/ protection around infrastructure of the farm
Water quality		
Nutrients	- Risk of nutrient depletion if the farm is too big and/or the water exchange is too low	- Uptake of inorganic nutrients - Act as biofilter in cases of IMTA - Competition for dissolved nutrients with phytoplankton, and opportunistic filamentous algae, thus especially seen as positive impact in the eutrophic Baltic Sea - Eutrophication mitigation
Pollution		- Reducing pollution in the surrounding environment by uptake of hazardous substances within their cells
Provision of habitats for marine life		
Illumination	- Possibility of benthic shading effects on underlying or surrounding habitats	- Creating seaweed "forests" in the places where it is not growing naturally, e.g. at sandy/gravel habitats.

Other	- Physical obstacles for fauna - Attraction of grazers, disease or other pests - Displacement of wild populations - Spreading of non-native species - Spreading of genetically modified species - Spreading of reproductive material, creating an imbalance to the native distribution of species)	- Act as nursery places, provide shelter and food, a refuge from predators for fish and other organisms, thus increasing biodiversity - Attract marine mammals and seabirds

It should be emphasized that impact level at the offshore farms can differ substantially. E.g., hydrodynamics and sediment dynamics most likely will not be affected in the offshore locations. Also impact on benthic habitats will be vague, if at all due to larger depth, and illumination for benthic animals will not be influenced

A quantitative estimation of both types of impacts requires additional knowledge and measurements, as the current recorded evidence of seaweed farming does not cover the Baltic Sea explicitly. The nearest examples are from the Kiel, IMTA farm (Rößner et al., 2014) and the Swedish west coast (Hasselstrom et al., 2018, 2020), providing information on the mostly positive effects of kelp cultivation.

Besides the ecosystem function of seaweed, the cultivation structure itself has an impact, which should be minimized: anchoring disturbed the seabed temporarily, littering of microplastics through the cultivation ropes, possible input of (non-)synthetic substances by the boats and structure, noise disturbance through the engines and chains (Tonk et al. 2019, Campbell 2019, Banach et al. 2022). At the same time, anchoring can also provide a positive effect by creating a new or additional substrate for a variety of benthic organisms, i.e., serving as an artificial reef, as it was recorded in the Kiel Farm[4].

III. Environmental monitoring requirements for macroalgal cultivation in the Baltic Sea

Environmental monitoring in the Baltic Sea is based on commitments of the countries around the Baltic Sea under the Helsinki Convention (HELCOM). The goal of this monitoring is to follow the status of the Baltic Sea, and data collection does not include all parameters to assess the impacts of macroalgae cultivation. Also, no additional standardized and unified monitoring requirements for seaweed aquaculture exist in

[4] https://www.dbu.de/123artikel24819_.html

the Baltic Sea region. Based on the expert and practitioner experience, monitoring requirements vary from country to country.

Having listed typical positive and negative impacts (Table 1) on the surrounding ecosystem and considering that seaweed cultivation is seen as the most environmentally friendly of all aquaculture types, we propose the information on the following variables to be requested by licensing authorities before the farm deployment and during regular monitoring at the coastal areas, summarized as Table 2. We assume that the coming years will bring more information on the effects of macroalgal farms at the offshore locations of the Baltic Sea where both technologies and monitoring requirements would be different from the nearshore. If in the future seaweed farms start to have large-scale category, we would recommend modelling the possible impacts of a farm in the foreseen location as the first step (Campbell et al, 2019).

Table 2. Variables suggested for environmental permits and regular monitoring

Criteria	Variables	*Parameters required before installation/for permits*	*Monitoring requirements*
Scale	Currently, all seaweed farms in the Baltic Sea are small-scale, therefore, no specific requirements on this criterion.		
Location of farm	**Sediment dynamics**		
	- sediment transport intensities and pathways	X	
	Water purification/ regulation		
	- Inorganic P, N content in the water column	X	1 time per year *
	- pH, oxygen concentration, temperature at the surface and 1m above the bottom	X	1 time per year *
Method of cultivation and cultivated species	**Sediment dynamics**		
	- Inorganic P, N and organic content in the sediments	X	1 time per year *
	Marine flora and fauna		
	- sea-floor integrity:		
	bottom coverage,	X	
	benthic macroinvertebrate and macroalgae species	X	1 time per year **

	composition, including non-native species, - marine mammals - presence and spread of diseases, pathogen bacteria and parasites	X	1 time per year *

*- inside and outside farm after full cultivation scale has been reached

** - inside and outside farm after full cultivation scale has been reached, and afterwards every 2nd year

In addition, we would also suggest having joint actions between researchers, fisherman and farmers, wind-park companies or those producing seaweed to ensure the exchange of knowledge and data. To enhance the collection of necessary data for seaweed farms, student research projects and other scientific initiatives (e.g., citizen science) could contribute to the monitoring of seaweed farms. Considering the importance of seaweed cultivation in the provision of valuable ecosystem services, the national or local systems of monitoring could include macroalgal farms in their surveys.

IV. Environmental monitoring for wild macroalgae harvesting in the Baltic Sea

Wild grown macroalgae are a biological resource with economic value, but they are also an essential part of the coastal and marine ecosystems, and therefore should be treated with caution. The harvest of loose-lying *Furcellaria lumbricalis* for commercial uses has a long history in the Baltic. Today it is mostly occurring in the West Estonian Archipelago Sea area where *F. lumbricalis* is harvested by bottom trawlers for the extraction of furcellaran. To maintain the stock, the ecological status of *F. lumbricalis* is already monitored regularly, and official harvest quotas are set in Estonia (Weinberger et al., 2019). We suggest taking a similar precautionary approach when harvesting any other macroalgae species elsewhere in the Baltic Sea. The following criteria should be considered:

1) the spatial extent and biomass of the harvested species in the ecosystem to prevent overexploitation of stocks,
2) annual production potential of the harvested species to prevent overexploitation of stocks,
3) frequency of harvest to make sure that time is given for plant regeneration and recovery of the areas,
4) timing of the harvest –particularly during certain times of the year/season.

V. Conclusions

Although empirical evidence still is scarce, the presence of macroalgal farms in the Baltic Sea would provide opportunities for ecosystem improvement by securing several important functions. Measurements and information are urgently needed to assess the impacts quantitively, and to decide upon the most effective and sustainable ways of seaweed farming in the Baltic Sea. Licensing of macroalgal cultivation should be based on the evaluation of positive and negative environmental impacts of operations. Full EIA should not usually be required from small and medium-sized farms. Regular monitoring requirements should be based on real risks and not be overly burdensome for operators. For harvesting, quotas should be set based on the ecological status of the harvesting area. Harmonization of national and Baltic-wide licensing procedures should be supported and promoted.

References

Aquaculture Stewardship Council, 2022. Joint standard for environmentally sustainable and socially responsible seaweed production. https://www.asc-aqua.org/what-we-do/our-standards/seaweed-standard/

Armoškaité A., Bārda I., Andersone I., Bonnevie I.M., Ikauniece A., Kotta J., Kõivupuu A., Lees L., Psuty I., Strāķe S., Sprukta S., Szymanek L., von Thenen M., Schrøder L., Sten Hansen H., 2021. Considerations of Use-Use Interactions between Macroalgae Cultivation and Other Maritime Sectors: An Eastern Baltic MSP Case Study. Sustainability (Switzerland) 13 (24),13888 https://doi.org/10.3390/su132413888

Banach JL, Koch SJI, Hoffmans Y, van den Burg SWK. Seaweed Value Chain Stakeholder Perspectives for Food and Environmental Safety Hazards. Foods. 2022 May 23;11(10):1514. doi: 10.3390/foods11101514. PMID: 35627084; PMCID: PMC9141909.

Brzeska-Roszczyk, A., Barańska, A., Kruk-Dowgiałło, L., 2017. A review of the selected methods of macroalgae cultivation in marine waters. Bulletin of the Maritime Institute in Gdańsk. 2017; 32(1): 129-136. DOI: 10.5604/01.3001.0010.6980

Buck, B.H. and B. Grote. 2019. Seaweed in high-energy environments: protocol to move Saccharina cultivation offshore. In: (B. Charrier, T. Wichard and C.R.K. Reddy, eds) Protocols for macroalgae research. CRC Press, Boca Raton. pp. 3–36.

Camarena-Gómez, M.T., Lähteenmäki-Uutela, A., Spilling, K., 2022. Macroalgae production in Northern Europe: Business and government perspectives on how to regulate a novel blue bioeconomy. Aquaculture, 560: 738434

Campbell I., Macleod A., Sahlmann C., Neves L., Funderud J., Øverland M., Hughes AD., Stanley M. 2019. The Environmental Risks Associated with the Development of Seaweed Farming in Europe–- Prioritizing Key Knowledge Gaps. Frontiers in Marine Science. 6:107. doi.org/10.3389/fmars.2019.00107

Christiansen, E.R., 2018. The Potential of Ulva for Bioremediation and for Food and Feed. Master’s Thesis M.Sc.Eng. Biotechnology.

European Commission (to be adopted in 2022) Blue bioeconomy – towards a strong and sustainable EU algae sector.

EU4Algae. A European algae stakeholder platform launched by the European Commission, the European Climate, Infrastructure and Environment Executive Agency (CINEA) and a consortium of sustainability consultants and algae organisations.

FAO. 2009. Environmental impact assessment and monitoring in aquaculture.

GRASS 2021a. (Interreg project - Growing Algae Sustainably in the Baltic Sea) https://www.submariner-network.eu/images/grass/outputs/GoA_23_EIA_guidelines_for_macroalgae_cultivation_and_harvest.pdf

GRASS 2021b. (Interreg project - Growing Algae Sustainably in the Baltic Sea) https://www.submariner-network.eu/images/grass/outputs/GRASS_OA21_pan-Baltic_map_depicting_potential_of_macroalgal_cultivation_and_harvesting.pdf

GRASS 2021c. (Interreg project - Growing Algae Sustainably in the Baltic Sea) https://www.submariner-network.eu/images/grass/outputs/GRASS_22_Macroalgae_Production_Manual-3.pdf

Hasselstrom, L., Thomas, J.B., Cervin, G., Nylund, G.M., Pavia, H., Gröndahl, F., 2020. Socioeconomic prospects of a seaweed bioeconomy in Sweden. Scientific Reports, 10: 1-7,

Hasselstrom, L., Visch, W., Gröndahl, F., Nylund, G.M. Pavia, M., 2018. The impact of seaweed cultivation on ecosystem services–- a case study from the west coast of Sweden. Marine Pollution Bulletin, 133: 53-64

HELCOM, 2013. HELCOM Monitoring and Assessment Strategy. https://helcom.fi/action-areas/monitoring-and-assessment/

Kotta, J.; Raudsepp, U.; Szava-Kovats, R.; Aps, R.; Armoskaite, A.; Barda, I.; Bergström, P.; Futter, M.; Gröndahl, F.; Hargrave, M.; Jakubowska, M.; Jänes, H.; Kaasik, A.; Kraufvelin, P.; Kovaltchouk, N.; Krost, P.; Kulikowski, T.; Kõivupuu, A.; Kotta, I.; Lees, L.; Loite, S.; Maljutenko, I.; Nylund, G.; Paalme, T.; Pavia, H.; Purina, I.; Rahikainen, M.; Sandow, V.; Visch, W.; Yang, B.; Barboza, F. R. 2022. Assessing the potential for sea-based macroalgae cultivation and its application for nutrient removal in the Baltic Sea. STOTEN, 839, 156230.

Marine Scotland. 2017. Seaweed Cultivation Policy Statement, https://www.gov.scot/publications/seaweed-cultivation-policy-statement-2017/

Meichssner, R., Stegmann N., Cosin, A. S., Sachs, D., Bressan, M., Marx, H., Krost, P., Schulz, R., 2020. Control of fouling in the aquaculture of Fucus vesiculosus and Fucus serratus by regular desiccation. Journal of Applied Phycology, 32:4145–4158

Meichssner, R., Krost P., Schulz, R., 2021a. Vegetative aquaculture of Fucus in the Baltic Sea—obtaining low-fertility biomass from attached or unattached populations? Journal of Applied Phycology, 33:1709–1720. https://doi.org/10.1007/s10811-021-02419-x

Meichssner, R., Krost P., Schulz, R., 2021b. Experimental testing of density- and season-dependent growth in vegetative Fucus aquaculture and modelling of growth over one year for different cultivation scenarios. Journal of Applied Phycology, 33:3939-3950.

Ministerium für Wirtschaft, Arbeit, Verkehr und Technologie Schleswig-Holstein verantwortlich, 2016. Entwicklung und Förderung einer nachhaltigen Aquakultur in SchleswigHolstein (Küstengewässer Ostsee). Genehmigungsleitfaden für Investoren. https://www.lksh.de/fileadmin/PDFs/Landwirtschaft/Tier/Genehmigungsleitfaden_fuer_Investoren__Kuestengewaesser_Ostsee_.pdf

Rößner, Y., Krost, P. & Schulz, C. 2014. Increasing seaweed crop yields through organic fertilisation at the nursery stage. J. Appl. Phycol. 26:753-62. DOI 10.1007/s10811-014-0269-7

Strothotte E., 2022. 2nd UNITED Workshop – Aquaculture Multi-Use Offshore: Environment and Biology German Pilot. https://www.h2020united.eu/images/Workshops/WS2/WS2_German_Pilot.pdf

Suutari, M., Leskinen, E., Spilling, K., Kostamo, K., & Seppälä, J. (2017). Nutrient removal by biomass accumulation on artificial substrata in the northern Baltic Sea. Journal of Applied Phycology, 29(3), 1707-1720.

Tonk, L., Jansen, H. M., Poelman, M., Nauta, R. W., Jak, R. G., Tamis, J. E., & Jongbloed, R. H. (2021). Development of a framework and toolbox for measuring and evaluating ecosystem interactions of seaweed aquaculture. (Report / Wageningen Marine Research; No. C069/21). Wageningen Marine Research. https://doi.org/10.18174/553741

van Oirschot R., Thomas, J. B. E., Gröndahl F., Fortuin K.P.J., Brandenburg W., Potting J. 2017. Explorative environmental life cycle assessment for system design of seaweed cultivation and drying. Algal Research. 27. 43–54. doi.org/10.1016/j.algal.2017.07.025

Visch, W., Kononets, M., Hall, P.O.J., Nylund, G.M., Pavia, H. 2020. Environmental impact of kelp (Saccharina latissima) aquaculture. Marine Pollution Bulletin. 155. doi.org/10.1016/j.marpolbul.2020.110962

Weinberger, F., Paalme, T., Wikström, S.A., 2019. Review: Seaweed resources of the Baltic Sea, Kattegat and German and Danish North Sea coasts, Botanica Marina. doi.org/10.1515/bot-2019-0019

Wood, D., Capuzzoa, E., Kirby, D., Mooney-McAuley, K., Kerrison. P. 2017. UK macroalgae aquaculture: What are the key environmental and licensing considerations? Marine Policy. 83. 29–39. doi.org/10.1016/j.marpol.2017.05.021