Guidelines for undertaking Environmental Impact Assessments for macroalgae cultivation and harvest projects (GoA 2.3.)

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1 Introduction and aim

These guidelines aim to inform the local authorities, cultivators, and harvesters of the potential environmental impacts of macroalgae cultivation and harvest in the Baltic Sea.

The guidelines briefly describe the current environmental management requirements regarding macroalgae cultivation and the Environmental Impact Assessment process in Europe. They also suggest criteria for evaluation of cultivation and harvest proposal and outline the expected environmental risks and benefits associated with longline 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”.

2 Macroalgae cultivation and harvest in the Baltic Sea

Meanwhile the global seaweed industry relies on aquaculture, around 99% of the macroalgae biomass harvested in Europe are harvested from wild stocks growing on the coasts of the Atlantic and the North Sea (Monogail et al., 2017). The growing interest in developing the blue bioeconomy and concern over resource overexploitation has meant that European nations have been increasingly looking for ways to sustainably harvest macroalgae and develop macroalgae cultivation and harvest methods in the European seas. Due to the low salinity and temperatures, only a few of the commonly harvested and used species are native to the Baltic Sea. Therefore, there are only a handful of examples of macroalgae cultivation and harvest project in the region.

As it stands, *Saccharina latissima* is currently the only species of macroalgae commercially cultivated in the Baltic (Campbell et al., 2019; van Oirschot et al., 2017; Weinberger et al., 2019; Visch et al., 2020). This is done using longline systems - anchored long-lines suspended by buoys approximately 1-2 m below the surface. However, several ongoing pilot projects testing techniques for cultivation at the sea of *Furcellaria lumbricalis* (Est-Agar, 2019)*, Ulva spp.* (Brzeska-Roszczyk et al., 2017; Christiansen, 2018) and *Fucus* (Meichssner et al., 2020) across the Baltic, particularly in the south-west.

The harvest of loose-lying *Furcellaria lumbricalis* for commercial uses has a long history in the Baltic. However, it is now mostly found in the West Estonian Archipelago Sea area where it is continued to be harvested using bottom trawlers for the extraction of furcellaran – a thickening agent used in food and cosmetics production (Weinberger et al., 2019).

Some Baltic sea coastline zones are abundant with beach wrack, which is a mix of various seagrasses and macroalgae. Coastal municipalities are responsible for removing the beach cast algae accordance with European legislation (Directive (EU) 2006/7/EC) concerning the quality of bathing waters in tourist beaches, but also to please tourists (Chubarenko et al., 2021). The wrack, are most often seen as a nuisance, contaminated and unusable as a raw resource. Because it cannot be dumped into landfill, it is either collected and deposited back into the sea or pushed up or down the coastline and left to decompose away from tourist visited beaches (Chubarenko et al., 2021).

3 Environmental Impact Assessments for macroalgae cultivation and harvest

The Environmental Impact Assessment (EIA) assesses of the potential significant biophysical or any other impacts of projects, plans or programmes. The EIA aims to inform the decision maker, or anyone else interested, of the consequences of the proposal and to identify mitigation measures that will minimize any significant environmental impacts. EIAs are part of the licensing procedure for plans, projects, and programmes, and are an EU wide requirement regulated by the EIA Directive (Directive 2011/92/EU). The EIA processes vary slightly from country to country, however the main stages are the same (See Figure 1).

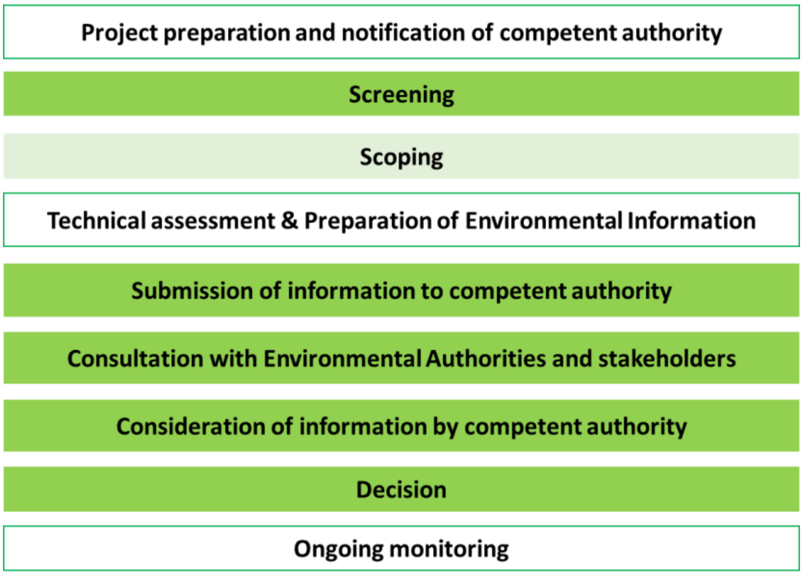

Figure 1 Stages of the EIA process. Stages in dark green – mandatory for EU states, white– part of good EIA practice, light green – not mandatory, but must be present in some form (adopted from European Commission Guidance on EIA 2001).

For some projects EIA is considered mandatory whilst for others, including aquaculture "Intensive fish farming" projects, national authorities decide whether EIA is required during the screening process employing a set of predefined criteria (Directive 2011/92/EU, Annex II and III). In practice, EIA is only applied to large scale, intensive fish farming projects, and because the majority of aquaculture projects are small scale full EIAs are relatively rare (FAO 2009). Meanwhile 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.

This is an issue, as the lack of formal procedures for cultivation projects and lack of understanding and regulation of risks creates uncertainty for developers (Wood et al., 2017) which could contribute towards the slow growth of the sector. Further, when it comes to wild harvest, national and local authorities and coastal communities across the world have begun voicing concerns that the rate and volume of harvest in some areas is unsustainable and may be causing damage to the ecosystems (Monogail et al., 2017).

4 Assessment Screening Criteria

It is up to the member states to determine whether cultivation involves intensive techniques and interpret the screening criteria and set thresholds. In most cases, the area occupied, production volume, intensity, method, and species cultivated are considered when screening fish and shellfish aquaculture proposals (FAO 2009; European Commission, 2016). However, the nature of fish, shellfish and macroalgae cultivation is very different and so are the environmental impacts.

Although there is still limited evidence, studies seem to suggest that small-medium size macroalgae cultivation has very few, insignificant negative effects on the environment. In most cases, it is even seen as beneficial for the marine ecosystem. However, the degree of impact depends on the method of cultivation, scale, and site location.

Experience of an unregulated harvest of wild-grown loose lying *Furcellaria* in southern Baltic has shown that it can lead to overexploitation and considerable reduction of stocks (Naylor 1976). Similarly, frequent, geographically insensitive harvest of beach cast macroalgae can disrupt the functioning of coastal ecosystems. Therefore, in addition to scale and location, screening wild-grown algae harvest proposals should also consider the frequency of the activity and the species harvested.

Based on the existing EIA Directive Annex III screening criteria and the findings of the assessment of ecological impacts of macroalgae cultivation in the Baltic Sea region conducted as part of the GRASS project the following criteria have been identified to support the screening process:

1) Scale

The extent of impacts of activities will vary according to the size of the infrastructure used to cultivate, the volume of macroalgae grown or gathered.

Small scale manual gathering, or cultivation activities are unlikely to have significant impacts and are considered a traditional, culturally important activity and are unlikely to require EIA. However, large scale projects, are much more likely to influence the ecosystem as is the presence of multiple small-medium size sites, thus should be assessed in more detail.

Suspended longline cultivation sites are generally considered small-medium size when they range between 1 to 50 × 200 m lines and large - above 50 × 200 m lines (Marine Scotland 2017).

2) Location of project

Ecosystems are not all equally sensitive to the different stressors caused by human activities. The environment's sensitivity must be taken this into account when choosing the location for a macroalgae cultivation site or harvest of wild-grown algae. In particular, the effects on the biophysical environment of proposals in or in the proximity of marine protected areas should be assessed.

3) Method of cultivation and harvest

The method used to cultivate, or 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. However, most methods are likely to physically alter the ecosystem to a certain extent, as is the harvest of algae via mechanical means.

Wild harvest specific criteria:

Wild grown macroalgae are a resource, but they are also an essential part of the coastal and marine ecosystems. Therefore, in addition to the above, it is also important to consider:

4) **The abundance and importance of the harvested species** in the ecosystem to prevent overexploitation of stocks.
5) **Frequency of harvest** to make sure that time is given for plant regeneration and recovery of the areas.
6) **Timing** – beach wrack plays an important part in coastal ecosystems, particularly during certain times of the year, for instance during bird nesting season.

5 Expected Environmental Impacts

Studies of environmental impacts of macroalgae cultivation and harvest suggest that the benefits tend to outweigh the risks, if the scale (volume of harvest and surface occupied), location, species cultivated, and frequency of harvest are considered with respect to geographical sensitivity[1].

The main benefits of harvest and cultivation include capture and removal of nutrients and hazardous substances:

- Nutrients – as macroalgae grow, they accumulate large amounts of nutrients removing them from the surrounding environment. The nutrients are stored within their tissue, and once the algae are harvested, they are removed from the marine environment (Campbell et al., 2019). Increased abundance of macroalgae during cultivation also increases competition for dissolved nutrients, which reduces nutrient availability for phytoplankton and reducing the occurrence of harmful algal blooms (Jiang et al., 2020).
- Hazardous substances – in addition to nutrients, algae also absorb other substances (heavy metal ions, such as zinc and cadmium, iodine, and pesticides) from their surroundings some of which are considered hazardous at high concentrations (Rönnberg et al. 1990; Greger et al.,2006; Rubio et al., 2017). Although this may

[1] 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".

compromise the algae uses, the harvest of algae from waters polluted with heavy metals leaves the marine environment a safer place for living organisms.

5.1 Mechanical harvest of beach cast

The removal of beach cast macroalgae is socio-economically and environmentally beneficial – it presents a potential of nutrient reduction, organic material for soil fertilisation, and improves the attractiveness and safety of beaches for tourists (Chubarenko et al., 2021).

However, the frequent removal of beach cast in large volumes may disrupt coastal wildlife as beach cast is an important source of food and refuge from predators for invertebrates and microorganisms (Dugan et al., 2008). Studies show that frequent harvest is likely to negatively affect the biodiversity of sandy beach communities - invertebrate abundance and in turn, species higher up the food chain, such as birds (Baltijas Krasti 2018; Dugan et al., 2008). Further, harvest during nesting season may deprive seabirds of nesting grounds (Schultz-Zehden and Matczak 2012; Baltijas Krasti 2018). Therefore, bird nesting habits must be considered when picking harvest location and time.

To remove large quantities of beach cast a range of different tractors, grabbers and heavy machinery equipped with specialised forks are used. The machinery is used to pick and load the algae onto trucks transporting algae to a different location. The use of machinery has the potential to have a physically alter the beach. Tractors and other heavy machinery are likely to leave wheel marks, which may affect the beach’s aesthetic quality. Some machines may also remove stones from the beach or shallow water, protecting the coast from erosion and sand drift. Machinery is also likely to create noise pollution, which may drive wildlife and tourists away (Evaluation of machines for the collection of algae 2012).

5.2 Bottom trawling for loose lying algae

The harvest of wild resources inflicts various degrees of change and inevitably has ecological implications for the target and any associated species. Two of the main concerns with wild harvest are overexploitation of the resource and use of environmentally damaging harvesting techniques (Monagail et al., 2017).

To manage stocks sustainably and prevent negative ecological responses, algae populations stocks are monitored, and a population-adjusted quota is set by the state in the countries where commercial harvest of wild-grown algae is widely practised, for instance, Scotland and Norway. Currently, the only loose lying macroalgae harvested from the wild for commercial purposes in the Baltic is *Furcellaria lumbricalis*. It is found on the soft bottom habitats in the West Estonian Archipelago Sea and is harvested by bottom trawling (Weinberger et al., 2019). To maintain stocks, the ecological status of *Furcellaria lumbricalis* has been monitored regularly and official harvest quotas set by the state in Estonia (Weinberger et al., 2019). Harvest of any other species elsewhere in the Baltic should also take a similar precautionary approach.

Abrasion and scouring of the seabed, suspension of the bottom substrate, extraction of other than target species, and structural damage of wrecks are associated with trawling methods of all kinds (Sahlin and Tjensvoll 2018). The significance of these impacts depends on the seabed type and habitats and species present, as well as the type of gear used, strengths of trawling and time of the year.

5.3 Cultivation and harvest using longline systems

The environmental impacts of cultivation and harvest using longlines at sea depends on the scale and location of the installation and vary throughout the different phases of the project life cycle.

Physical alteration of the environment

Light conditions

When cultivated using longlines, macroalgae are suspended at the top of the water column and can physically block the light for living organisms underneath the installation and increases competition for light among mobile species within the water column (Phillips 1990; Campbell et al., 2019).

Habitats most sensitive to shading are rich in seagrasses or macroalgae and are found in areas of stony substrate and shallow waters – areas generally unsuitable for installing cultivation sites. This makes macroalgae cultivation and sensitive seabed habitats overlap unlikely (Campbell et al., 2019). It is also unlikely that small and medium-size cultivation sites will significantly impact the communities within the water column as the movement of species floating or swimming in the water column is ensured by the design of the installation.

The likelihood of impact increases for large cultivation sites. Therefore, a focused monitoring program assessing changes within the water column should be conducted to prevent impacts at larger scales. Further, the seabed underneath the installation should be checked for habitats or species that may be sensitive to the change in light conditions, particularly if the planned site is large or if there are plans for multiple sites in the area.

Introduction of macroalgae to the water column

The introduction of macroalgae to the otherwise structureless water column is likely to create an attractive habitat, and a site of refuge and shelter for a range of invertebrate and fish species (Campbell et al., 2019; Visch et al., 2020). Due to limited cultivation practice, there is little evidence to suggest whether marine mammals and birds will avoid or be attracted to macroalgae cultivation sites in the Baltic Sea. However, it is likely that macroalgae farms will attract fish which may present mammals and birds with foraging opportunities presenting a risk of entanglement. The responses are likely to be location and species-specific and must be evaluated before a cultivation site is chosen and mitigation measures must be put into place to ensure that vulnerable or protected species, such as seals, are safeguarded.

Further, decomposing material deposits on the seafloor may cause oxygen depletion and affect the organisms on the seabed or within the sediment (Sévant et al., 2017). To prevent this, material deposit rates need to be monitored underneath the cultivation site during cultivation and harvest activities.

Introduction of hard substrate

Suspended macroalgae cultivation using longline systems requires anchoring to the seabed. This introduces artificial substrate (Visch et al., 2020); however, because the anchor's footprint is small, they will have little effect on the seabed communities, regardless of the seabed substrate type.

Introduction of structures within the water column

The presence of physical structures and maintenance vessel traffic may interfere with and restrict normal fish and mammal migration routes creating a 'barrier effect' (Campbell et al., 2019). To prevent this, the cultivation site needs to be selected with migration and feeding habits in mind.

Further, suspended cultivation systems also affect the local passage of water currents and waves, and sediment movement (Campbell et al., 2019). The precise impacts will vary from site to site; therefore, an assessment of the following prior and during cultivation has been recommended: water velocity inside and outside the farm; sediment transport pathways; sedimentation rates within and outside farm (upstream and downstream); and identification of potential sediment deposition locations (Wood et al., 2017).

The spread of non-native species, disease and parasites

Although only native species found within the marine environment can be cultivated commercially in the EU, the introduction of macroalgae or their increased presence can support the spread of non-native species – provide them with a place of refuge and a source of food (Campbell et al., 2019). Further, to reduce the potential risk of non-native species introduction, the movement of biofouling associated with maintenance vessels needs to be monitored and managed (Campbell et al., 2019).

To prevent the introduction and spread of disease and pests, precautions must be taken at the project level to limit overcrowding and monoculture, which leads to lack of water exchange, light, and nutrients and ultimately – disease outbreaks (Werner et al., 2004)

Although the risk can never be managed fully, cultivation practices are unlikely to cause significant environmental effects assuming native species are cultivated, and operations are managed to reduce the potential risk.

Noise pollution

It is expected that during cultivation and harvest, there will be an increase in vessel traffic to and from the cultivation site as well as presence of machinery required for the installation and maintenance of the site. Vessel traffic is also likely to increase during installation, and decommissioning stages and occurrence of impulsive sound originating from construction may be expected.

The effects of elevated local noise on marine ecosystems are currently unclear, but some evidence suggests that noise pollution can cause negative environmental impacts. However, the magnitude of the noise of vessel traffic associated with small cultivation sites is unlikely to cause significant ecological changes if the ecosystem is not vulnerable or sensitive.

Larger cultivation projects will require additional consideration during the consenting process as they may present higher risks. To lower the risk of the impact, the location and traffic routes need to be chosen with respect to geographical sensitivity. A noise impact assessment and noise level monitoring should be conducted for larger projects.

6 Further resources and web-links

Project GRASS Growing algae sustainably in the Baltic Sea outputs available online at *https://www.submariner-network.eu/grass*

Project CONTRA Conversion of a Nuisance to a Resource and Asset outputs available online at https://www.beachwrack-contra.eu/

An Operational Decision Support System (ODSS) for the application for the Baltic blue mussel and macroalgal farming
http://www.sea.ee/bbg-odss/Map/MapMain

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