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Seaweed Aquaculture

An assessment of the legal and management structure on seaweed farming in Iceland

Summary:

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2 Introduction

Lately, seaweed cultivation in Europe, has been gaining recognition among environmental scientists, within the food and the cosmetics industry, as well as within the sectors of renewable energy, agriculture, new material research and more, for being a sustainable, healthy, and environmentally friendly product. However, whereas a specific and target-orientated law regulates other aquacultures, such as finfish farming, seaweed cultivation often lacks specific regulations and falls instead under more general and vaguely formulated law. A reason is that seaweed cultivation is most often only implemented on a pilot or small commercial scale but very seldom on a large and commercial scale. Thus, the seaweed cultivation sector is still in the early stages of development in Europe and more in-depth and widespread knowledge is needed in order to raise awareness among public authorities and other relevant stakeholders and to build capacity to eventually exhaust its potential benefits and close the legislative gap.
Projects, such as GRASS (Growing Algae Sustainably in the Baltic Sea) as well as its associated partner project SUSCULT (Sustainable Cultivation of Seaweed), that are based on transnational working groups, are pursuing the mentioned goals.

Within the SUSCULT project, this report at hand aims to reveal legislative gaps of seaweed cultivation in the project partner states (Finland, Sweden, Estonia, Norway, Iceland and Denmark) with a focus on Iceland, where a pilot seaweed cultivation plant concurrently with the outlining of this report is being established.
Besides revealing the legislative gaps, this report also includes forward looking statements of practitioners as well as of politicians regarding the future of seaweed cultivation and its biggest chances and challenges with the focus on legislation.

3 Background

Seaweed, or also called macroalgae, are large marine benthic plants. The term "seaweed" has no taxonomic value but includes the three groups of common large algae such as brown algae (*Phaeophyceae*, red algae (*Rhodophyceae*) and green algae (*Chlorophyceae*). Among these three groups, the red algae are often referred to simply as kelp (Mouritsen, 2013). Seaweeds contain a huge variety of species; it is estimated that there exist close to 10'000 different species. As most seaweeds consist of a root-like structure, the so-called holdfast that works like an anchorage, as well as of a stem and leaf-like blades they often look like plants. However, contrary to plants, algae can pass through life stages that differ so much from each other that it sometimes can be hard to designate the different manifestations of the different life stages to one species (Mouritsen, 2013).
Seaweeds have a long history and fossils of earliest relatives of modern-day seaweeds can be traced 1.6 billion years back, which implies that they are highly resilient organisms (Osterloff, 2020).
Due to their rich composition of macronutrients, such as sodium, calcium, magnesium, potassium, chlorine, sulphur, phosphorus, and micronutrients as iodine, iron, zinc, copper, selenium, molybdenum, fluoride, manganese, boron, nickel and cobalt, as well as B12-, A- and K-vitamins, seaweeds are a well-known food source that has been utilized throughout the world for centuries (Ferdouse, Lovstad Holdt, Smith, Murua, & Yang, 2018). Besides human food, coastal communities have used seaweeds as a source of fertiliser and cattle feed. However, over the past decades, new algae-biomass-based applications such as feed and food supplements,

nutraceuticals, pharmaceuticals, biofuels, biomaterials and bioremediation have been developing (The European Commission's Knowledge Centre for Bioeconomy, 2019).

3.1 Seaweed production

The diversification in the market for these resources and the increasing demand for such products has led to sharp increase of the global output of seaweed over the last decade (2006 – 2016) (Ferdouse, Lovstad Holdt, Smith, Murua, & Yang, 2018). Whereas in 2005 globally seaweed production totalled 14.7 million tonnes, in 2015 the production had more than doubled to 30.4 million tonnes. Thereof, only a very small part is harvested from the wild whereas the large part is produced in aquacultures (fig. 1).

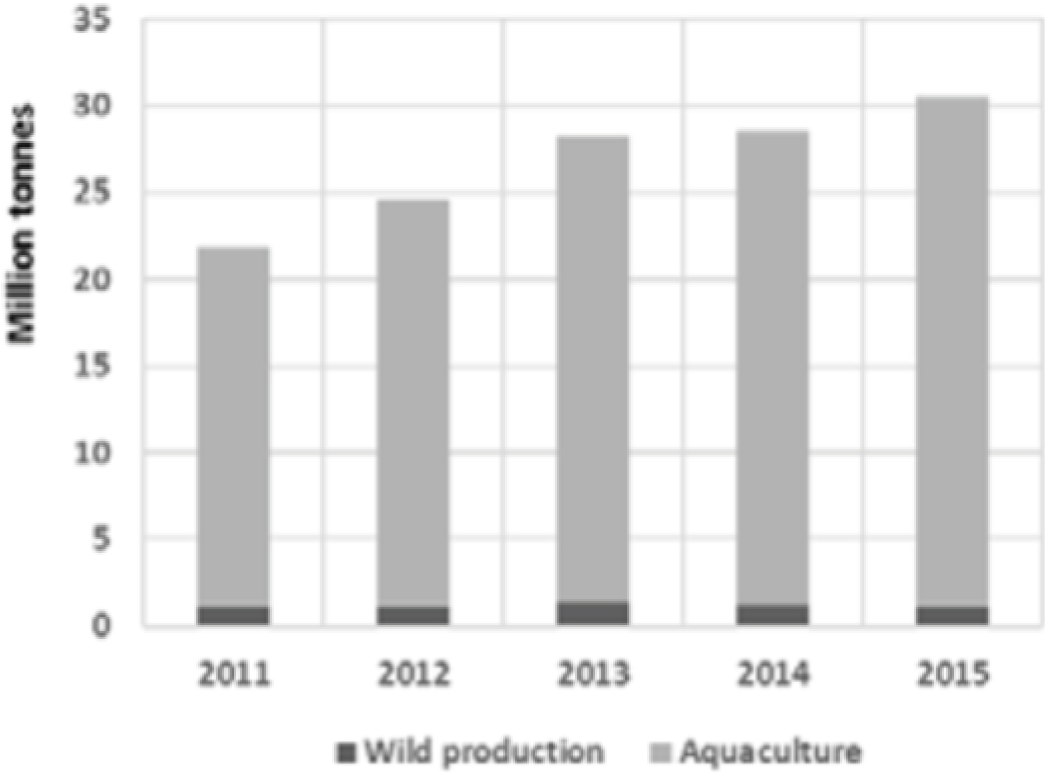


*Figure SEQ Figure * ARABIC 1: Production of seaweed, 2011 – 2015 CITATION Fer18 \l 2055 (Ferdouse, Lovstad Holdt, Smith, Murua, & Yang, 2018)*

In 2015 the main producers of wild harvested seaweed was Chile with an annual production of 345'704 tonnes, followed by China (261'770 tonnes) Norway (147'391 tonnes) and Japan with 93'300 tonnes per year (Ferdouse, Lovstad Holdt, Smith, Murua, & Yang, 2018). On a global scale, the part of seaweed harvested from the wild makes a small part. On a European scale, all major quantities of seaweed are harvested only from the wild. Besides Norway, also Ireland, France, Iceland, Spain and Portugal produce in the same way considerable amounts (Ferdouse, Lovstad Holdt, Smith, Murua, & Yang, 2018).
However, when it comes to seaweed cultivation, European countries play a clearly less significant role. Main producers of farmed seaweed are Asian countries with China, Indonesia, Korea, and the Philippines and Japan ahead (Ferdouse, Lovstad Holdt, Smith, Murua, & Yang, 2018).

Seaweed Production in Iceland

According to a report by FAO from 1976, in the past, the seaweed resources of Iceland were believed to be among the largest underexploited algal resources in the world. This accounted especially for the brown algae. "In summary", they wrote, "whilst opportunities for the economic expansion of the area's resources of red seaweeds may be relatively limited, a very considerable underexploited potential appears to exist for greater use of the brown algae, particularly in Iceland. (Naylor, 1976). Still today despite the rising global demand for seaweed, there is still only one company, Thorverk, in all Iceland that produces seaweed on a commercial level. Annually, Iceland produces around 18'000 tons or two percent of total world production.

While harvesting of seaweed from the wild has a long tradition Iceland, the cultivation of seaweed is new to Iceland. Besides some more or less successful initial trials of seaweed farming, the first seaweed cultivation pilot plant will be established within the framework of the SUSCULT project.

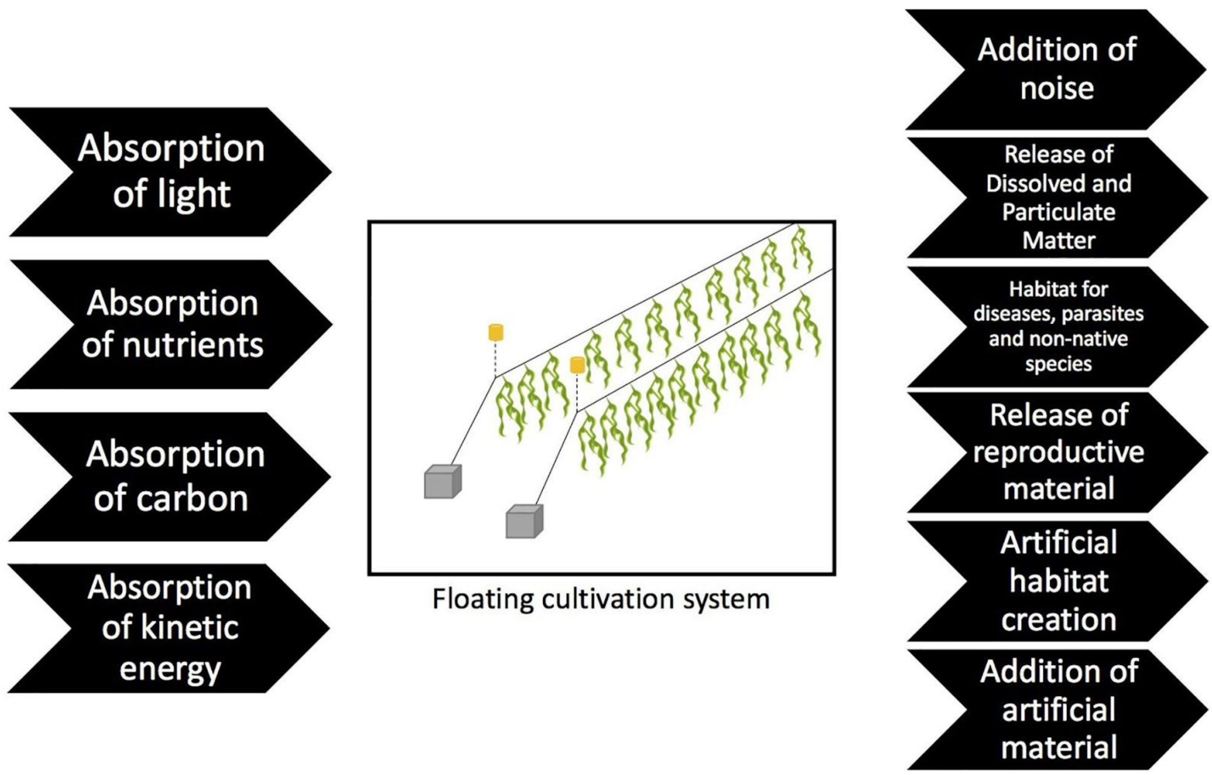
3.2 Challenges and chances of seaweed cultivation

Seaweed communities provide a range of important ecosystem services. The cultivation of seaweeds or also the so-called seaweed aquaculture beds (SABs) provide many of the services associated with natural seaweed communities, such as coastal defence, formation of habitats for important species, carbon sequestration and more (Chung, Sondak, & Beardall, The future of seaweed aquaculture in a rapidly changing world, 2017). Seaweed not only plays an environmentally important role but also supports human wellbeing in regards to pharmaceutical and cosmetic care as well as to being an important direct and also indirect food source in terms of agricultural appliances. Products of seaweed aquaculture additionally can be used in innovative ways such as bioplastics, or biorefinery products as a replacement of non-renewable resources (e.g. gas, coal and oil) (Barbier, et al., 2019). Moreover, seaweed aquaculture generates jobs. Summarizing, seaweed aquaculture can be seen as an innovative and sustainable business from an environmental as well as from a cultural and economic perspective. However, careless or inappropriate handling and management of seaweed aquaculture might also lead to environmentally, social and economic disadvantages. The more important it is that a well thought through legal and management structure does exist. This accounts also for a future seaweed farming sector in Iceland. Subsequently a brief overview of the chances and challenges of seaweed aquaculture in regards to the environment, society and economy with a focus on Iceland is given.

Seaweed farming in Iceland from an environmental perspective:

In order to develop an environmentally sustainable seaweed aquaculture it is crucial to ensure that commercial aquaculture has minimal adverse effects on the environment. To achieve this goal, Kim et al. (2017) suggest to farm seaweed within Integrated Multi-Trophic-Aquaculture (IMTA) systems. IMTA systems fed aquacultures, such as for example fish or shrimp are combined with extractive aquacultures as for example seaweed. This combination of different species leads to a more balanced ecosystem in which neither a scarcity of nutrients nor too high levels of nutrients should occur. Growing seaweed in IMTAs could be an interesting concept for Iceland, as in the last few years net fish farming has been growing fast in this country. With this growing sector also environmentally related concerns have

been rising. Among others, one reason is the high level of nutrients fish farms can lead to, which can trigger harmful algal blooms and can contribute to excessive growth of nuisance or opportunistic macroalgae (Kim, Yarish, Hwang, Park, & Kim, 2017). Seaweeds in turn take up nitrogen, phosphorus and carbon dioxide, which they use for growth and energy production. Therefore, seaweed aquacultures in combination with net fish aquaculture can help to reduce nutrient-levels, as by harvesting the seaweeds also the nutrients are being removed from the water. Thereby, the bioextractive potential of seaweed is considerable; it is estimated that on a global level, seaweed aquaculture could remove approximately 30% of the introduced nitrogen if seaweeds were farmed in 0.03% of the ocean surface area (Bjerregaard, et al., 2020).
However, other environmental problems that open fish net farming can lead to, such as genetic pollution through escaping fish, is not solved by combining fish farms with seaweed aquaculture. Therefore, a total replacement of fish farms by seaweed aquaculture would be needed. However, seaweed aquacultures are not free either from environmental risks, this accounts especially if seaweed is produced on a large scale (> 50 x 200 m lines) (Campbell, et al., 2019). Thereby, different drivers of environmental change, such as the absorption of light, nutrients, carbon, kinetic energy as well as the addition of artificial material and noise and the release of organic matter as well as changes in habitat and species interaction, play an important role (Fig. 2) (Campbell, et al., 2019).



Seaweed aquacultures can, for example, lead to benthic shading by reducing light that and affects understory algae and underlying habitats containing autotrophic organisms, such as pelagic phytoplankton, and benthic macroalgae. Furthermore, Campbell, et al. (2019) suggest to avoid maerl beds and seagrass communities when considering possible sites for seaweed aquaculture as such species are afforded a high level of protection (in Europe) and may be sensitive to shading effects and other disturbance (Campbell, et al., 2019). Negative effects of seaweed aquaculture due to its light reducing effect was shown on the example of a large scale seaweed farm in the Yellow Sea in China (Sanggou Bay), where the shading caused suppression of the abundance of phytoplankton during the growing season, which in turn affected the marine food web in this place (Shi, et al., 2011).

Not only can a decrease in light but also nutrients, caused by seaweed farms, lead to negative impacts of oceanic habitats. While, on a global scale, there is rather a problem of too high levels of nutrients in the Oceans (Dybas, 2005), locally, seaweed aquacultures can lead to a nutrient removal that results in concentrations which fall below that required for natural primary productivity (Campbell, et al., 2019). Seaweed not only does absorb nutrients such as phosphorus and nitrogen, but also carbon. Therefore, seaweed aquaculture has been experiencing a rising interest in connection with the climate change debate. As seaweed aquacultures release carbon that are buried in sediments or exported to the deep sea, they act as CO_2 sinks. Furthermore the crop can also be used for biofuel production with a potential CO_2 mitigation capacity, in terms of avoided emissions from fossil fuels, of about 1'500 tons CO_2 per square kilometre and year (Duarte, Wu, Xiao, Bruhn, & Krause-Jensen, 2017).

On the other hand, seaweed aquacultures not only do deprive sources from the water but also add substances to the water, such as dissolved and particular organic matter (DOM and POM) resulting from wave action and decomposition. Organic matter drift of large-scale aquaculture and its interaction with benthic environments is not yet understood well but it is assumed that large amounts of material decomposing in depositional areas might lead to sedimentary anoxia and hypoxia in bottom waters, together with enhanced sediment nutrient fluxes. This might account particularly for areas with long water residence times (Campbell, et al., 2019).

Besides effects on light, nutrients and carbon, seaweed aquacultures also do have an impact on natural currents with a tendency to dampen and altering them, which in turn cause a microclimate within the aquaculture sites (Campbell, et al., 2019). Observations showed that although total tidal exchange volume remains unchanged, there is a reduction in tidal flow at the surface where seaweed is suspended, which causes the maximum flow point to occur below the suspended kelp fronds. This could have implications for the benthic and pelagic habitats below, which would experience altered flow dynamics resulting from changes surface boundary conditions. Alterations to water flow can have impacts on the cultivation carrying capacity of water body through potential reduction in water exchange necessary for maintaining levels of nutrients required for growth (Shi, et al., 2011). Therefore, Campbell, et al. (2019) suggest that "careful consideration must be given to the siting of cultivation projects in areas and at times where alterations of natural hydrodynamics could result in significant changes to marine chemistry, sediment transport and associated biological communities". This accounts especially for siting in areas important for water exchange, such as the entrance to enclosed water bodies. However, Campbell, et al. (2019) stresses that this accounts especially for large scale aquacultures, whereas for small-scale projects, these effects of altered currents most likely does not have negative impacts on the environment.

Not only the right selection of the site seems crucial to minimalize negative impacts seaweed aquaculture on the environment, but also the choice and handling of the artificial materials needed for the farming of seaweed, such as moorings, lines and floats. While on the farm itself, theses material will not have a negative impact on the environment, they can cause damage in case the get lost from the farm. Such debris from seaweed aquacultures, as from any other kind of aquaculture, may contribute to existing environmental pollution issues such as increasing levels of plastics in

(marine) food webs. Moreover, it can cause mortality of marine fauna by entanglement. In these regards, the choice of material can be crucial as for example moorings and lines that have low tension and poor visibility leading to reduced avoidance (Benjamins, et al., 2014). However, much more of importance is a save, stable and well-designed infrastructure to avoid material loss in general. Campbell, et al. (2019) suggests that licensing authorities should pay particular attention on this matter.
Similar to fish farms, seaweed aquaculture can lead to a reduction in genetic diversity associated with the domestication of wild seaweed species. Such decrease in genetic diversity can lead to crops that are more susceptible to abiotic stressors, diseases and parasites (Valero, Guillemin, Jacquemin, Gachon, & Badis, 2017). On the other hand, non-native species can be introduced through aquacultures, as it was for example the case in 1983, when the brown kelp, *U. pinnafida*, native to Asia, was introduce to the French Atlantic coast for commercial cultivation. Even though, it was believed that it could not reproduce, the species spread widely in the local environment. In this respect, Campbell stresses the importance of providing more clarity of which target cultivation species are permitted throughout Europe (including Iceland) to ensure comparable approaches across neighbouring countries. Genetically and phenotypically distinct species might impact wild seaweed populations through direct competition as well as through hybridization with natural stands (Valero, Guillemin, Jacquemin, Gachon, & Badis, 2017). Therefore, breeders must, according to Campbell, et al. (2019), "focus on strategies that optimize the selection of desirable traits, whilst maintaining the domesticates evolutionally potential to ensure good yield in variable environmental conditions whilst reducing impacts on natural populations".

Altogether, the establishment of a seaweed aquaculture, as any other aquaculture, lead to an alteration of the physical and biological conditions as well as chemical composition of the site. How far-reaching these changes are, depends on the scale of the aquaculture. However, there is, according to Campbell, et al. (2019), a gap of knowledge on the dependency of environmental changes in regards to the scale. Furthermore, Campbell, et al (2019) stresses the importance on prioritizing research and monitoring objectives in order to support future managers and decision makers. This accounts especially for countries, such as Iceland and most other European coastal states, where seaweed aquaculture is a fast growing sector but at the same time still is in the fledgling stage and accordingly, the legal framework still needs to be incorporated.

<u>Seaweed farming in Iceland from a social perspective</u>
Aquaculture in general is nothing new to Iceland, but stretches back more than a century (Ministry of Industries and Innovation Iceland, 2020). First aquaculture experiments in Iceland took place in the 1950s with on-land as well as ocean ranching of Atlantic salmon. Due to fluctuating salmon prices and rough weather conditions that made ocean-based fish farming rather difficult, aquaculture developed rather slow and with difficulties. From the 90s on, experiments with other species took place, such as Sea bass, Tilapia, abalones (using geothermal water), sea cucumbers, Senegal sole, lumpfish, Rainbow trout and Arctic char (Ministry of Industries and Innovation Iceland, 2020). Since the last decade, there has been a significant growth in aquaculture in Iceland and fish farming activities have quadrupled. Today, the three main species produced in Iceland in aquacultures are Salmon, Arctic char and Rainbow trout. In 2018, Iceland produced a total of 19'000

tonnes farmed fish (Statistics Iceland, 2019). However, the four biggest companies in the industry, which control nearly all of the operating licences issued in Iceland, are majority owned of fully owned by Norwegian investors and existing companies in the Norwegian salmon industry. For some reason, companies (with only very few exceptions) in the Icelandic fisheries and fish-processing sector do not participate as investors and shareholders in the build-up of the sea fish farming industry in Iceland and therefore have mostly not added into their fish production (Bjarnason, 2019). In this regards, aquaculture in Iceland can be seen as a rather two-edged-sword from a social point of view. The same accounts also for the aquaculture of seaweed. Even though Iceland, as an insular state with seaweed growing wild in its waters, there is a whole list of foreign seaweed farming companies serving Iceland (Xprt Agriculture, 2020). There has not been a commercially operating seaweed aquaculture in Iceland yet. Accordingly, there is still research needed to gain technical and management knowledge in regards of seaweed farming in Iceland. Besides technical understanding, there is also a gap of knowledge in regards to social acceptance of seaweed aquaculture in Iceland. Results from a case study in Sweden (study site size: 100 m x 200 m) showed that seaweed cultivation led to an improvement or at least to a non-affection of ecosystem services. However, much more delicate were the cultural services that were likely to be negatively affected by the seaweed aquaculture and led to controversies that may prevent to a sustainable future expansion of the sector (Hasselström, Visch, Gröndahl, Nylund, & Pavia, 2018). According to the authors of the study, a holistic ecosystem services assessment for seaweed cultivation must contain also a social perspective, including an analysis of the impacts on cultural heritage, cognitive benefits, human well-being and recreation. Furthermore, they suggest that "the local contexts is key to the degree of impacts on cultural services […]. However, competition for space and negative impacts on the aesthetics and natural heritage of coastal and marine areas can be expected generally". Therefore, when building up the legal framework for seaweed aquacultures, also the public opinion needs to be taken into account (for example in regards to the study site choice) (Hasselström, Visch, Gröndahl, Nylund, & Pavia, 2018). Accordingly, future success or failure of building up a seaweed aquaculture sector in Iceland and the enforcement of a widely accepted legal framework not only depends on a technical and environmental issues but on the Icelandic society and how the participation process of the public is handled.

<u>Seaweed farming in Iceland from an economic perspective</u>

In 2019, a new economic report by the company "Iceland Ocean Cluster" (IOC) was released that predict a major change of the marine economy in Iceland. Among fish farming, food technology, crustacean shells and marine biotechnology, also algae and seaweed will belong to the fastest growing sectors within the marine industry. On a global perspective, the seaweed industry is experiencing consistent and significant growth. This is also mirrored in the value of world seaweed production that has doubled over the period from 2010 and 2016 from US$ 3 to US$ 6 billion (Chung, Sondak, & Beardall, The furture of seaweed aquaculture in a rapicla changing world, 2017).

Iceland has not been jumping up on this growing market fully yet, but is getting ready for it. There are approximately 15 companies and start-ups now that are utilizing seaweed in their products and research. Additionally, there is also the fact that there is already the existing company Thorverk, located in the Westfjords of Iceland that is equipped to harvest and process seaweed. Other Icelandic companies, such as Algae Nattúra, Taramar, Zeto and Marinox, already have been using wild harvested seaweed by Thorverk to create skincare products. Seaweed in Iceland is also used in food products, animal feed and as fertilizer and pharmaceuticals (Fig. 3).

Figure 3: Current seaweed use in Iceland and future opportunities. (Garland, 2020)

Besides the ongoing SUSCULT field experiments on ocean-based seaweed aquaculture, there are experiments on land-based seaweed cultivation. Under these aspects, Iceland is about to establish a small seaweed industry that, according to an analysis by IOC, "presents significant opportunities for continued innovation and developments that would create more value". In this regards, there is a good chance that in the near future, seaweed can contribute to a diversification of Iceland's maritime industries in a way that is both economically significant and (if well managed and regulated) environmentally sound (Garland, 2020).

4 Legal framework of seaweed aquaculture – Actual Situation

From the chapters ahead, it can be concluded that seaweed aquaculture is a fast growing sector and is undergoing global expansion. In Europe, seaweed production mostly is still in its infancy. Well-managed, seaweed aquaculture can add value to ecosystem services and create new jobs. However, as any other rapid expansion of any industry, the fast development of the seaweed aquaculture sector can result in unforeseen ecological and socio-economic impacts (Cottier-Cook, et al., 2016). This account particularly for early stages in new geographical areas, where policies to regulate and manage the industry are not fully established, as it is the case in Iceland. Ecological and societal consequences can include disease outbreaks, introduction of non-indigenous pests and pathogens and reduction in the genetic diversity of native seaweed stocks. Such consequences in turn can lead to further-reaching effects as for example the decline of a certain crops their areas of origination and associated losses (Cottier-Cook, et al., 2016). But not only a clear regulation in regards to prevent genetic instability, the outbreak of diseases or the introduction of non-native species is needed, but also in regards to a site selection process. This is getting particularly important, as there is an increase in demand for contaminant-free edible seaweeds, with a high level of traceability being reported. (Cottier-Cook, et al., 2016). Accordingly, Cottier-Cook, et al (2016), stress the

importance of setting up a legislative framework under the comprehension of Marine Spatial Planning.
Cottier-Cook, et al. (2016) list following eight paramount recommendations in their policy brief that are essential components of establishing the balance between economic growth and ocean health and of which all legal framework regarding seaweed aquaculture should be based on:

- **Establishment of centres of research excellence** in order to develop and identify new indigenous cultivars, specifically chosen for their disease resistance, high yields and ability to meet consumer preferences and in order to minimize the risk of disease outbreaks.
- **Establishment of national seed banks**, which are responsible for maintaining a high health status of seed stock and where seaweed farmers following a disease outbreak can hold disease-resistant strains for use.
- **Maintenance of the genetic diversity in wild stocks** by preventing the introduction of non-indigenous species and encouraging the development of local cultivars.
- **Exercising the precautionary approach** when introducing new or non-indigenous cultivars to the marine environment.
- **Focusing on development and enhancement of biosecurity programmes** through capacity building, including training in quarantine procedures and farm management practices and incentivise the development of diagnostics to rapidly detect diseases and non–indigenous species, to enable adaptive risk management and better evaluation measures to be taken.
- **Incentivising of long-term investment in the industry,** potentially through part-government funded insurance policies to safeguard the business against natural disasters and disease outbreaks.
- **Incentivising of the integration of seaweed and other extractive species with fin-fish in IMTA systems** to both reduce the eutrophication of the water column and benthic enrichment effects of fin-fish aquaculture and to minimise space used for aquaculture purposes in coastal zone.
- **Development of assessment tools for evaluation spatial planning issues in relation to aquaculture (including seaweed)** and to enable risk-based analysis of spatial management options to support the licencing process and facilitate future investments in infrastructure / insurance schemes to ensure the sustainable growth of this industry.

These policy recommendations exceed a legislative framework that only focuses on the technical and practical issues by far, but represent much more a holistic approach (including ecological as well as economic and social aspects) that aims a long-term sustainable setup and management of the seaweed aquaculture sector.
In the following chapters, the existing framework of European countries will be assessed by using the recommendations of the list above as guiding principles.

4.1 A look cross Iceland's border – assessment of the legislation on seaweed aquaculture in the EU and of national legislation of European countries

Currently, there is no specific European legislation existing for seaweed aquaculture. However, there do exist several regulations and recommendations that apply to seaweeds (Barbier, et al., 2019). As an example for such regulations that also relate to seaweed aquaculture are as an example Alien Species Regulation, food-related regulations (e.g. EU Regulation 2015/2283, EU recommendation 2018/464) and maritime habitat and marine resource managing regulations (e.g. Fisheries Policy, Maritime Spatial Planning Directive, Water Framework Directive, Marine Strategy Framework Directive, Habitats Directive). An overview of the different EU legislations that also apply to seaweed aquaculture is given in figure 4.

*Figure SEQ Figure * ARABIC 4: Different EU legislations that were not specifically established for seaweeds aquaculture but also includes seaweed aquaculture CITATION Bar19 \l 2055 (Barbier, et al., 2019).*

Barbier, et al. (2019) provide a good overview on the content of the mentioned EU regulations and recommendations and how they apply to seaweed aquaculture and with additional indications of gaps and appointments of the biggest challenges in the context to seaweed aquaculture (tab. 1).

Table 1: List provided by Barbier, et al. (2019), of the directives and political initiatives related to seaweed aquaculture and the main associated challenges within the EU.

Directive / Political initiative	Specification	Objectives	Topics related to seawe aquaculture
Habitats Directive on the conservation of natural habitats and wild fauna and flora	(92/43/EEC)	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 se and tidal areas with reefs
Marine Strategy Framework Directive establishing a framework for community action in the field of marine environmental policy	(MSFD) (2008/56/EC, CD 2017/848)	Achieve and maintain Good Environmental Status of the EU marine environment by 2020	Descriptor 1 (Biodiversity): Benthic habitats including ro and biogenic reefs. Descriptor 2 (Invasive speci including macroalgae. Descriptor 5 (Eutrophication with criteria on macroalgae (opportunistic macroalgae a macrophyte communities). Descriptor 6 (Sea-floor integrity) considering the structure and functioning of intertidal ecosystems.
Water Framework Directive stablishing a framework or the protection and enhancement of good status of inland surface, transitional, coastal and ground water	(WFD) 200/60/EC	Achieve Good status of waters by maintaining a framework of biological and physicochemical quality elements at a certain level of quality status	Macrophytes and phytobenthos are one of the three biological quality elements assessed under th WFD. Nutrient enrichment is one of the non-biological quality elements assessed under the WFD.

Maritime Spatial Planning Directive establishing a framework for the planning of multiple uses of maritime and coastal areas.	2014/89/EU	Application of an ecosystem-based integrated approach to spatial planning of the maritime environment, ensuring the sustainable economic development and ecological protection of maritime and coastal areas.	The use of maritime space f multiple purposes (e.g. ecosystem and biodiversity conservation, aquaculture installations and sustainable management of coastal resources) requires integrate planning of space usage by potentially competing activiti
Common Fisheries Policy setting out rules for the management of fishing fleets while ensuring the conservation of fish stocks	Various documents and articles such as Art. 11, 15 and 45 of the EU regulation No. 1380/2013 and more.	Ensure environmental and socioeconomic sustainability and the safety of fishing and aquaculture activities.	In order to boost the development and competitiveness of the aquaculture sector, and in recognition of the potential o aquatic farming in the EU, a cooperation process was launched at the Union level based on Strategic Guidelin and Multiannual national strategic plans for aquacultu (including aquatic plants).
Alien Species Regulation on the prevention and management of the introduction and spread of invasive alien species	1143/2014/EU	Ensure that the species listed as invasive alien species of Union concern are not brought, kept, bred, transported, placed on the market, used or exchanged, allowed to reproduce, grow, be cultivated or released into the environment.	This regulation does not ap to species listed in Annex IV Regulation 708/207 when us in aquaculture.

Regulation concerning the use of alien and locally absent species in aquaculture	708/2007	Develop a framework at the Union level to ensure adequate protection of aquatic habitats from the use of alien and locally absent species in aquaculture.	The regulation should cover aquaculture activities, all a and locally absent organis farmed, and all forms aquaculture. Activities rela to the use of certain a species long cultivated aquaculture should ben from different limitations.
Directive on the assessment of the effects of certain public and private projects on the environment	2011/92 EU and its amendment 2014/52/EU	Establish and harmonise procedures for environmental impact assessment EIA of private and public projects, contributing to high-level protection of the environment and human health.	A complete assessment of a project's likely effects on the environment should be carri out before it being granted consent. Aquaculture is included in Annex II, listing t projects that might be subjected to EIA depending Member States judgement.
Regulation on compliance measures for users from the Nagoya Protocol	511/2014	The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their utilisation in the Union is a treaty adopted by the Convention on Biological Diversity. This regulation aims to create a framework to increase cooperation between stakeholders involved in access to and benefit sharing for genetic resources.	Any genetic resource (mean genetic material, i.e. any pla material containing functiona units of heredity) and traditional knowledge associated with genetic resources used shall be accessed in accordance wit the terms of the regulation.
Regulation on novel foods	2015/2283	Establish updated rules for novel food, amending Regulation 1169/2011 and repealing Regulations 258/97 and 1852/2001. Consider the developments in Union law and scientific and technological progress.	This regulation applies to no foods. The term "novel food" applies to all the seaweed species produced for food (o food supplements) that were not used for human

			consumption to a significant degree within the Union befo 15 may 1997.
EU recommendation on the monitoring of metals and iodine in seaweed, halophytes and products based on seaweed.	2018/464	To monitor the concentrations of arsenic, cadmium, iodine, lead and mercury in seaweeds and halophytes in order to establish maximum levels.	The Member States, in collaboration with food and feed business operators, should monitor, during the years 2018, 2019 and 2020, the presence of arsenic, cadmium, iodine, lead and mercury in seaweed, halophytes and products bas on seaweed, and report thes values to EFSA.

Some of the EU regulations and recommendations that apply to seaweed aquaculture that are mentioned in the list of Barbier, et al (2019), meet the recommendations that are, according to Cottier-Cook, et al (2016), essential for a sustainable legal framework in relation to seaweed aquaculture. For example is the Alien Species Regulation (1143/2014/EU) associated with Cottier-Cook's, et al. demand for "Exercising the precautionary approach when introducing new or non-indigenous cultivars to the marine environment" as well as for "focusing on development and enhancement of biosecurity programmes in order to detect […] non-indigenous species […]." when establishing legal framework on seaweed aquaculture. However, there is still a gap in regards to the harmonization across member States on listed invasive alien species. Another example is the attempt of the EU to create a framework to increase the cooperation between stakeholders involved in access to and benefit for genetic resources (regulation on compliance for users from Nagoya Protocol, 511/2014), which meets partially Cottier-Cook's, et al (2016) recommendation for the establishment of national seed banks. However, also this regulation still needs to be fully developed, as clarification is needed in regards to the situation of cultivated genera and the protection of genetic resources.
Overall, when comparing the existing regulation and legal framework of the EU with the paramount recommendations of Cottier-Cook, et al (2016), for the establishment of a legal framework on seaweed aquaculture, it gets clear that there is still a major gap in practically applicable regulations in the EU. This is in accord with the Cottier-Cook, et al. (2016), who stresses the need of setting up a strong and reasoned legal framework on seaweed aquaculture and does not only account for the EU itself but also for national legislations of European countries.
Many of the European countries where seaweed is farmed do not yet have specific regulations for seaweed aquaculture. This, for example, accounts for Norway, France (besides an official list of authorised seaweed species), Spain and Portugal. Seaweed aquaculture activities are regulated by the framework for aquaculture in general. This leads to (Barbier, et al., 2019):

- complicate and long-time taking licensing processes,
- non-sustainable seaweed farming due to a lack of clarity about the legislation for organic and sustainable certification as well as due to a lack of standardisation of seaweed farms and cultivation technologies, as it is the case for fish farms, to prevent damages of the farms themselves as well as of the environment.
- a lack of well-educated personnel (in regards to scaling up, understanding the market, solid knowledgebase of environmental impact) due to a lack of regulations that require professionals
- a lack of the availability of marine space for seaweed aquaculture a lack of social acceptability due to a lack of clear regulations and transparency

In Denmark, one of the biggest issues regarding legislation of seaweed aquaculture is the division of responsibility for mariculture crops and mussels and finfish; while seaweed cultivation sites are handled by the Danish Coastal Authorities (DCA), finfish and mussel cultivation is handled by the Danish Agricultural Agency (DAA).
This leads to difficulties in the licensing process, especially when it comes to IMTAs (Barbier, et al., 2019).

Similarly complicated is the situation in Spain, where aquaculture is mainly regulated by regional governments. This also leads to regional inconsistencies and therefore to, again, complicate and regionally varying licensing-processes. Moreover, these differences in legal factors as well as the gap of a general legal framework lead to difficulties in the definition of the spatial distribution or areas with suitable conditions for seaweed aquaculture (Barbier, et al., 2019).

Also in Germany does not exist a consistent legal framework that is valid for the whole country. Depending on site and cultivation technique, different legal fields come into effect (AFC Consulting Group AG, 2017).

Other countries, such as Scotland, are a step further and already established some initial seaweed specific regulations. The Scottish government published a "Seaweed Cultivation Policy Statement (SCPS), with the goal "to help facilitate the growth of the sector by setting out Scottish Government policy on the suitability of seaweed cultivation in different scenarios […] and to provide greater certainty for the industry, while ensuring that activities which may have an environmental impact are understood and mitigated" (Scottish Government, 2017).

The SCPS covers commercial seaweed cultivation development size and the development of IMTA and includes following seven policies:

- Policy 1:
  In principle, the Scottish Government is supportive of small-medium farm seaweed cultivation 0-50 x 200 m lines), subject to regulatory consideration; the General Policies set out in Chapter 4 of Scotland's' National Marine Plan; and any other relevant policies within that Plan. Applications for such seaweed farms should demonstrate that mitigation measures have been considered to prevent adverse environmental impacts, and set out how these will be delivered.
- Policy 2:
  Only species native to the area where seaweed cultivation will take place should be cultivated, to minimise the risk from non-native species.
- Policy 3:
  Where seaweed is grown for human consumption, cultivators should site farms away from sewage outfalls and other potential sources of pollution.
- Policy 4:
  Equipment used in seaweed cultivation should be fit for purpose to withstand damage from adverse weather conditions.
- Policy 5:
  Other marine users and activities should be considered in the siting of farms.
- Policy 6:
  Small-medium size farming (0-50 X 200 m lines) is unlikely to be spatially limited, and may be located anywhere in Scotland, subject to agreement and appropriate local conditions.
- Policy 7:
  The Scottish Government is supportive of IMTA.

These policies go partially in line with some of the eight paramount recommendations of Cottier-Cook, et al. (2016), such as "exercising the precautionary approach in regards to alien species" and "incentivising of the integration of seaweed in IMTA systems". However, more vaguely, other recommendations by Cottier-Cook, et al (2016), such as "development of assessment tools for evaluation spatial planning issues in relation to seaweed aquaculture" are considered within the SCPS (Policy 5 is partially related to the mentioned recommendation regarding assessment tools for spatial planning).

Summarizing, Barbier, et al (2019) list recommendations on European legislation and regulations that are in accord with the recommendations listed in the policy brief by Cottier-Cook, et al. (2016). Namely Barbier, et al (2019) address, among others, following gaps within the European legislation:

- A lack of a framework for IMTA systems, which is necessary for the development of ecosystem-based management approaches to aquaculture.
- A lack of a framework for guiding offshore aquaculture spatial organisation, which maximises production by the selection of optimal sites while minimising impacts.
- A lack of a list of alien species of economic interest in Europe and a lack of an assessment of the risk for the environment of these alien species. Species of potential risk need to be included in the list of species of Union concern.
- A lack of simple, transparent and efficient national licensing procedures.
- A lack of standardised production and distribution of seaweed products on a European scale.
- A lack of an updated list of seaweed species that are authorised as food in Europe that help to facilitate the work of seaweed companies and to improve the social acceptance of seaweed as food and therefore of the establishment of seaweed farms.

4.2 Assessment of the legislation on seaweed aquaculture in Iceland

As it is the case in most other countries in Europe, there is also no specific legal framework on seaweed aquaculture in Iceland. Seaweed aquaculture in Iceland is regulated within other laws that may apply to seaweed as well, such as the Act on the Management of Marine Resources (lög um umgengni um nytjastofna sjávar), the Fisheries Management Act (lög um stjórn fiskveiðda), the Fishing Fees Management Act (lög um veiðigjald), the Marine and Coastal planning act (lög um skipulag haf- og strandsvæða), the act on aquaculture (lög um fiskeldi) and the environmental impact assessment act (lög um mat á umheverfisáhrifum).
However, recently some of the acts were extended and adjusted in order to include sections that regulate seaweed aquaculture related concerns. In this relation, on June 14, 2017, following legal changes came in force:

- **The Act on the Management of Marine Resources** was amended with two new paragraphs:
  § 9 that rules the handling of bycatch was amended by paragraph 3: "when acquiring seaweed, it is not obligatory to separate by-catch, but the Minister

may issue instructions in a regulation on how to monitor its registration and inspection of catch.
§ 10 that rules the landing procedure was amended by an additional paragraph saying, "the captain of a vessel that transports seaweed to the port of landing shall keep the catch specified so that the catch can be transferred to the correct vessel in the Directorate of Fisheries Catch Registration System".

- **The Fisheries Management Act** was amended with several new paragraphs and articles:
  § 2 that defines commercial stocks and Iceland's exclusive fishing zones was amended with the declarative that "the utilization of marine vegetation shall, in addition to provisions in this Act, be in accordance with the nature Conservation Act (No. 60/2013) and the Act on the Protection of Breiðafjörður (No. 54/1995).
  § 3 about limitations on catches was amended with five new paragraphs that say 1) "the Marine Research Institute and the Icelandic Institute of Natural History shall conduct research and monitoring of marine vegetation and related ecosystems", 2) "The Marine Research Institute shall advise the government on the utilization of marine vegetation, and shall seek the opinion of the Icelandic Institute of Natural History on its advice", 3) "advice, research and monitoring of the utilization of marine vegetation shall take into account Article 2. Act on Nature Conservation on conservation objectives for habitats, ecosystems and species and on the Act on the protection of Breiðafjörður", 4) "the Marine Research Institute and the Icelandic Institute of Natural History shall outline a monitoring plan for the utilization of marine vegetation that will be part of the monitoring of key aspects of Icelandic nature in accordance with the first and second paragraphs", 5) "the provisions of the first and second paragraphs [already existing paragraphs on catch limitations] do not apply to seaweed".
  § 15 a (Permit to obtain seaweed), § 15b and § 15c were added.
  § 15 and § 15 b only refer to harvesting seaweed from the wild (regulations of permits and authorization). In § 15 a seaweed aquaculture activities are explicitly excluded from these regulations. § 15 c rules the authorization and financing of the seaweed drying process and therefore only refers indirectly to seaweed growing process itself. However, the last paragraph could be of interest also for the seaweed aquaculture as it states that a simplified licencing process is possible for applicants that want to set up a new seaweed-processing sector within an area affected by depopulation and monotonous economy.
  § 24 about the licensing for coastal fishing is with the amendment also binding "for the acquisition of seaweed".
  Any other amendments of the Fisheries Management Act only refer to wild seaweed harvest and does not apply to seaweed aquaculture.
- All amendments of the **Fishing Fees Management Act** only refer to the wild harvesting of seaweed and do not apply for seaweed aquaculture.

Possible impacts of the actual legal situation on Seaweed aquaculture in Iceland

All amendments made within the existing legal framework do mainly apply to wild seaweed harvesting and only marginally to seaweed aquaculture. Hence, there is

currently no strait forward and clear legislation on seaweed aquaculture existing in Iceland. Policymakers will need to apply existing law on seaweed aquaculture. However, this might lead to inconsistencies within a potentially fast growing sector. Although the legal situation for seaweed aquaculture in Iceland is therefore similar to most other European countries, Iceland in contrary to most European coastal states additionally is lacking an integrated management framework on Marine Spatial Planning (Sullivan, 2011). This, in combination with a lack of a legal framework on seaweed aquaculture, might make a future-directed and sustainable regulation of seaweed aquaculture difficult. As mentioned by Barbier, et al. (2019), a lack of transparency and clarity in legislation can lead to social unacceptance of seaweed farms. This may also account for Iceland, even though Icelanders ever since have been depending on the sea for survival.
If Iceland does not establish a legal framework for seaweed aquaculture, it might get difficult to keep up with a growing sector that is interesting from an economic as well as from a social and ecological point of view. As a result, as it is the case in other European countries, the licensing process for seaweed aquacultures might get very slow, ineffective and complicated. Or, as another consequence, seaweed aquacultures might, due to a lack of an applicable legislation, be licensed in a non-sustainable way that can lead to economic (coast-inefficient), ecological (harmful to the environment) or also social (depopulation, loss of job opportunities, unacceptance of seaweed aquacultures) failure.

As the establishment of a new legal framework for a whole new sector that in addition does include a variety of factors related to the (marine) environment, the economy, the tourism, health etc., can take a lot of time, a first step could be the outline of a policy statement on seaweed aquaculture by the Icelandic government (according to the example of the Scottish Seaweed Cultivation Policy Statement).
As there is also still a lack of knowledge on seaweed aquaculture, it would be probable sensible to include the support of related research in such a Policy statement.

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5 The future of seaweed farming in Iceland

5.1 From a practitioner's point of view

Interview Gunnar Ólafsson
Interview Peter Krost

5.2 From a politician's point of view

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6 Conclusion

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