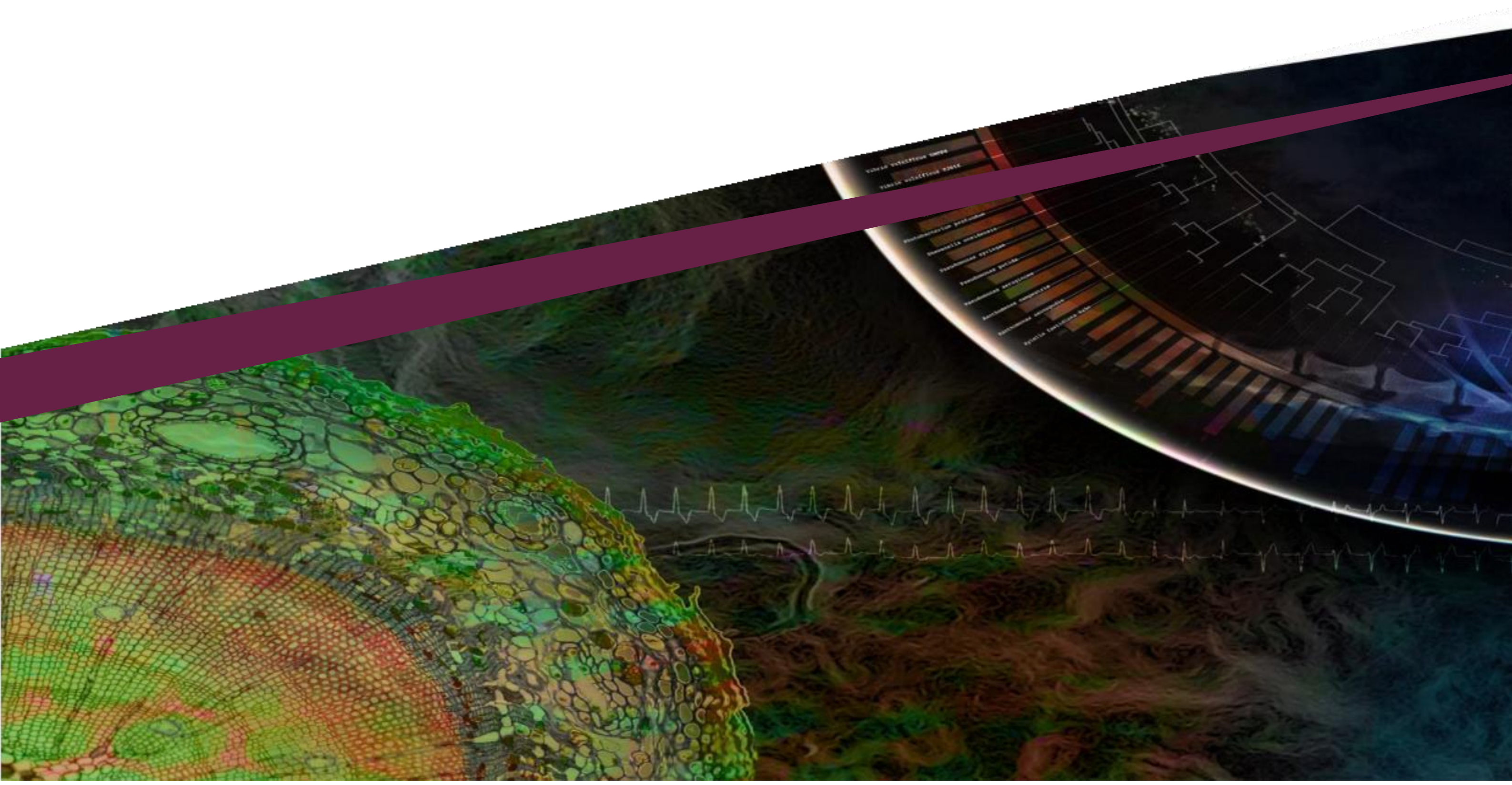
Nordic Sea vegetables as a future edible crop

– is it sustainable and safe?

Patrik Zettergren



Nordic sea vegetables as a future edible crop

Is it sustainable and safe?

Nordisk tång som en framtida gröda

hållbarhet och livsmedelssäkerhet

Patrik Zettergren

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Foreword

After reading the master's program in agroecology, I have gotten a deeper understanding of the multifaceted and complex issues of producing food in a sustainable way. Also, my understanding of the three parts of sustainability that all is of equal importance for something to be sustainable and last over time, ecological, economic, and social sustainability and what that means in the setting of food production systems. With my academic background in culinary arts and ecology, I carried with me the parts of system thinking when it comes to questions about food production that were a red thread throughout the program. The system thinking when it comes to working with questions regarding sustainability is essential because of the complex interactions in the many different parts that food production affects. However, agroecology must have a strong base in the ecology because if the connection between the ecosystems and the interactions between ecosystems and human activities is overlooked, the sustainability work will not progress in any way, the same thing can be said about the social and economic sustainability, but that is in my perspective more important when it comes to continuity.

I hope that the future of food production is moving more and more towards agroecological systems and that the mentality changes so that we see ourselves and the effect humans have as part of the ecosystems we are in. In the following thesis, I try to explore and understand a relatively new production area with a great potential for sustainable products, aquaculture, more specifically, growing sea vegetables in marine environments.

Abstract

As the population continues to grow, so does the need for sustainable food sources. In recent years the production of sea vegetables has been getting more and more attention in the Nordic countries. The cultivation of seaweed can be connected to several of Sweden's national sustainability goals. Food production, in general, is connected to all but two of the national sustainability goals. Two sustainability goals are more closely connected to the production of sea vegetables, and these are the goal of "oceans in balance and a living coastline" and the goal of "limited climate impact". In this master thesis, the seaweed farmers of Sweden were interviewed in order to gather information from the people and catch viewpoints and social data that cannot be measured. The lack of knowledge and information in this new area is one of many points of view that were presented. There is a need for further research about sea vegetables. Furthermore, the contents of healthy or potentially harmful elements in edible seaweeds are still uncertain and need to be considered and further researched. Sea vegetables generally have a high content of iodine and salt. Eating more than 10g of dry seaweed per day is not recommended. It is doubtful that seaweed could be the central part of a meal, but it could add a lot of taste, texture, vitamins and nutritional value to a meal. Sea vegetables are a term commonly used for seaweeds cultivated seaweed, this term will be used to differentiate between wild occurring seaweed.

Keywords: Algae, food, sustainability, future crops, Nordic countries.

Table of contents

1. Introduction

As part of the Swedish efforts toward a sustainable society, there are 16 national sustainability goals. The goals are developed for the Swedish setting and what needs to be done to achieve a future where the next generation can live as sustainably as possible (Sveriges miljömål n.d). In the current time, the need to change to more climate-friendly approaches in many parts of society is getting more urgent. Sustainable food production is an area that needs attention. One area that has recently been getting more and more attention from both the food industry and researchers is farming sea vegetable in the coastal areas for food and an extensive array of other materials. The food system in Sweden affects 14 of the 16 goals. The only areas with no connection to food production are a safe radioactive environment and a grand mountain environment (Nilsson, 2010). The affected goals are listed in appendix 1.

1.1. Sustainable food production

As the population is growing, the need for more food produced in a sustainable way is getting more and more critical. With the growing world population, there is a need for arable land to grow crops, but there also is a need for more housing, and other land uses. After World War 2, the farming systems developed due to more advanced techniques and industrialisation have the upside of giving a lot of yield per hectare and lower food prices (Gliessman, 2014). The big yields of the industrialised food systems come with the downsides of being highly dependent on inputs like fertilisers, pesticides, herbicides, and fossil fuels. The input dependency, together with the streamlining of the production system with extensive monocultures, are the cause of significant problems like pollution of the environment (water pollution, greenhouse gas emissions, eutrophication, acidification), erosion of soils, losses of biodiversity and depletion of natural resources. The industrialised farming systems are less resilient to diseases, pests and climate change. If farming instead is managed within the boundaries of the local stable ecosystem parameters, it would be more stable and more resilient (Gliessman 2014). It is not uncommon to find the harmful effects of industrialised farming systems in areas not directly connected to the farms (Nilsson, 2010). When there is a need to move away from the industrialised high-yielding systems, and at the same time, the demand for food is increasing with the population growth, there is a need to look at alternative sustainable food sources.

Algae are a source of vitamins, minerals, proteins, and fatty acids (Kovač et al., 2013). In parts of the world, it is not uncommon for algae to be used in nutrition and cooking. Farming seaweed in coastal areas or microalgae in closed growing systems does not need arable land and can be looked at as additional food and feed sources (Alagarsamy et al., 2022). Human activities such as the industrialised production of nitrogen fertiliser and other agricultural processes have changed the nitrogen cycle in a significant way. More nitrogen from the atmosphere is converted into reactive forms from human activities than all the terrestrial processes combined (Rockström et al., 2009). Most of the plant available nitrogen is used within food production as fertilisation. Much of this nitrogen ends up in the surrounding environment and accumulates in waterways and coastal zones, leading to pollution and eutrophication (Rockström et al., 2009). Part of this nitrogen that ends up in the coastal zones can be accumulated by seaweed, preventing eutrophication in the coastal areas.

1.2. Macroalgae and microalgae

Algae are classified as thallophytes, meaning they are plants lacking roots, stems and leaves. They are phototrophic and contain chlorophyll (Sambamurty, 2006). Some algae are large multicellular organisms and can grow to sizes over 30 meters (macroalgae), while some are unicellular and microscopic (microalgae). The different between the classification macroalgae and microalgae are that the microalgae are unicellular organism while the macroalgae are multicellular organism. Different species of algae can be found in almost all of the earth's habitats. They are the most common primary producers and are essential for binding carbon dioxide and producing oxygen and organic materials from sunlight (Kovač et al., 2013; Sambamurty, 2006). Some microalgae species have a remarkably high protein content; an example of this is dried *spirulina* biomass. Spirulina contains all the essential amino acids, and about 68% of the biomass is protein; this is more than any land-grown protein-rich plants and even more than three times more protein content than beef (Kovač et al., 2013). Other algae have higher contents of fatty acids or a lot of fibre, e.g. the agar-producing species commonly used in cooking and the food industry as a gelling or thickening agent.

The main classification of algae is based on five main criteria:

- photosynthetic pigments
- the type of stored energy or reserved foods
- the nature of the cell wall
- types of flagella and details of cell structure

Within the classification system, there are 11 different classes of algae (Sambamurty, 2006). The photosynthetic pigments in algae give a variety of colours. The primary pigments are chlorophylls, carotenoids and biliproteins. The reserve foods are how the algae store the energy they gather from photosynthesis. Some classes of algae form starch like that in higher plants. Other classes form polysaccharides, proteinaceous cyanophycean granules, floridoside and mannoglycerate (Sambamurty, 2006). Several algae also produce fat. Cell walls are mostly made of cellulose, but there are also classes of algae where the cell walls contain alginic acid or mucopeptide. In Bacillariophycaea, the cell walls are silicified (Sambamurty 2006). Two classes have no flagella, and in those who have, the number and placement decide which class the algae belong to.

About 90% of algae are aquatic, meaning that they live in fresh or salt water (Sambamurty, 2006). Several macroalgae are already cultivated as crops in parts of the world, mainly in Asia. Species of *Porphyra* are a commonly accruing marine crop plant known as nori (Sambamurty, 2006). Other commercially cultivated species are *Eucheuma* spp, *Laminaria japonica,* and *Undaria pinnatifida.* However, in the Nordic countries, the only sea vegetable grown on a commercial scale is *Saccharina latissima* or sugar kelp, as it is also called. Sea vegetables are a term commonly used for seaweeds produced by humans (cultivated seaweed). Henceforth in this thesis, this term will be used to differentiate between wild occurring seaweed, used not only for foodstuff but for other purposes as well, and cultivated sea vegetables used not only for foodstuff but for other purposes as well (Lipkin, 1985; Chapman & Chapman, 1980).

1.2.1. Culinary values of algae

In cuisines and food cultures worldwide, humans have enjoyed hundreds of species of algae as food some of the more common examples of these are listed in Table 1. Sea vegetables and seaweeds have had a unique and vital role in the coastal parts of Asia, the British Isles and places like Iceland and Hawaii, where the algae are part of the few native edibles (McGee, 2004). Examples of how sea vegetables are used in different cuisines are that in Japan, they are often used to make seaweed wrappers or in salads and soups. In China, they serve as a vegetable, while the Irish mash them up in porridge or use them to thicken desserts (McGee, 2004).

Table l. *Some of the edible algae, and traditional usage, as presented in McGee (2004).*

	Scientific Name	**Use**
Green Algae		
Sea lettuce	*Ulva lactuca*	Raw salads, soups
Sea grapes	*Caulerpa racemose*	Peppery; eaten fresh or sugar-coated
Awonori	*Enteromorpha*, *Monostrena* species	Powdered condiment
Red algae		
Nori, laver	*Porphyra* spp	Oatmeal mush, sushi wrappers or fried sheets
Agar, tengusa	*Gracilara* spp	Branching stems; raw, salted, pickled, gelling agent for moulded sweets
Irish moss, carrageen	*Chondrus crispus*	Thickening agent for desserts (carrageenan)
Dulse, sea parsley	*Palmaria palmata*	With potatoes, milk, soup, and bread
Brown algae		
Kelp, kombu	*Laminaria* spp	Soup base (dashi), salads, fried
Wakame	*Undaria* spp	Miso soup, salads
Hiziki	*Hizikaia fusiformis*	Vegetable, soups, "tea"

Edible seaweed plays an important role when it comes to the understanding of human taste. In 1908 a chemist named Kikunae Ikeda discovered that the surface of *Laminaria* species was so rich in monosodium glutamate (also known as MSG) that it formed crystals on the surface of dried kombu (McGee, 2004). The *laminaria* species have been used for over a thousand years in Japanese cuisine as a soup base, and they have cultivated as sea vegetables since the 17th century. Kikunae Ikeda discovered that the monosodium glutamate from *Laminaria* provided a different taste than the known standard tastes; sweet, sour, salty, and bitter. He then gave the new taste the name umami and pointed out that this is a taste that also can be found in other foodstuffs, like cheese or meats (McGee, 2004). MSG was considered to be a taste enhancer in the west until 2001 when biologist Charles Zuker at the University of California and colleagues proved that humans and other animals have taste receptors for monosodium glutamate (McGee, 2004).

1.3. Sea vegetables and beneficial environmental effects

Blue carbon is the organic carbon captured and stored by the coastal and ocean ecosystems (Yong et al., 2022). Many countries are implementing more coastal blue carbon initiatives to mitigate climate change and reduce atmospheric carbon (Yong et al., 2022). Both natural seaweed communities and sea vegetable production sites act as significant carbon sinks and provide many ecosystem services (Chung et al., 2017). Even the artificial sea vegetable production sites still provide many of the same ecosystem services as the natural kelp forest. Examples of services include providing a source of food for smaller aquatic animals, providing shelter as nursing grounds, increasing biodiversity, and regulating the nutrients and carbon oxide in the surrounding water (Chung et al., 2017).

When the atmospheric carbon increases, so do the carbon dioxide that dissolves in the water, driving changes in the aquatic environments. The rising carbon dioxide level affects the temperature, circulation, nutrient supply, oxygen content and ocean acidification, which can have a wide range of biological effects. All the changes can potentially affect the performance of sea vegetables and seaweeds and impact productivity (Chung et al., 2017). Even if the research about sea vegetables as a resource has been around for a while, the subject of sea vegetables' contribution to blue carbon and climate change mitigation is relatively recent (Yong et al., 2022). The way carbon is stored in the sea by seaweed or sea vegetables is that dissolved carbon dioxide in the water is used in photosynthesis by the seaweed or sea vegetables. Parts of the produced biomass will be lost due to fragmentation, the parts that come loose will float either onto the shore or out in the ocean, where they will sink to the bottom, and the carbon will be sequestered in the deep ocean prior to the calcification process.

1.4. Social and economic aspects of sea vegetable production

In 2016 the estimated value of the global production of sea vegetables was 11.6 billion USD. Most of this production is done in Asia (van den Burg et al., 2021). Van den Burg et al. (2021) calculated using economic modelling that the cost for sea vegetables in the Nordic Sea is approximately 1 850 euro per tonne of dry product. Cultivation of sea vegetables and offshore wind farms have been researched to see the economic benefits of combining the two systems. One of the main hindrances for offshore wind farms is operation costs and upkeep (25-30% of the total lifecycle cost). The study shows that reducing these costs is possible by about 10% when combined with sea vegetable production or other offshore aquaculture sectors (van den Burg et al., 2021). Human activities affect the social and natural environments creating problems in different global systems. In our time is, the anthropogenic effects a significant threat created by human population growth (Chung et al., 2017). A large majority of the human population lives in coastal areas and near water; this greatly affects the coastal and oceanic environments. The coastal environments are especially vulnerable to climate change, pollution and eutrophication caused by human activities and other stresses (Chung et al., 2017). If sea vegetable production is increased, it could provide work opportunities and at the same time mitigate some of the anthropogenic emissions. Hasselström et al (2018) argue that for the cultural and recreation aspect of the areas used for sea vegetable farming could be disturbed by the production, however the main part of sea vegetable farming are happening in the low season for tourism.

1.5. Conditions needed for sea vegetable production

When establishing a sea vegetable farm, there are a few things to consider, such as the water salinity, level of exposure, water depth, type of sea bottom, and competing or collaborative activities in the area (Franzén et al. n.d). The environmental condition is essential to optimise growth and yield. Medium exposure is proven to have the best effect on growth. High exposure to waves and currents continuously changes water and provides nutrients to the sea vegetables but can cause damage and tear of parts of the sea vegetables. Another thing to consider is the ice coverage, which can affect the time the sea vegetables take to mature, and there is a possibility that the ice could damage the ropes and equipment used to secure the farm in place. If the place is too shallow, in combination with soft bottoms, provides a risk that sediments from the bottom settle on the sea vegetable, reducing the sunlight that reaches the sea vegetable and inhibiting its growth. Soft bottoms also make it difficult to secure the system to the bottom. In deep waters, there can be a problem with nutrient deficiency because the nutrients accumulate at the bottom of the sea and will only reach the surface waters in areas of a natural surge. According to Weinberger et al. (2020), the recommended depths to grow seaweed are 2 – 50 meters on hard bottoms. Establishing a growing site might also have competitive or collaborative effects with other activities in the area. If the sea vegetable field is placed over where seaweed is growing naturally, the field will cast shade and compete with the natural vegetation on the bottom. At the same time, it could provide shelter for smaller fish and aquatic animals (Franzén et al. n.d).

The growing systems can be divided into two phases (Fig.2). In the first phase, fertile seaweed plants are collected and cultivated in a tank on land where they release spores. The spores are allowed to germinate, and the small sea vegetable plants are attached to a small rope (Fig 2a). In the second phase (Fig. 2b), the small rope is attached to a bigger rope that is put in the sea at about 1-1,5m below the water surface, where the sea vegetables grow to the desired size before harvesting, for example as illustrated in Fig. 2a (van Oirschot et al 2017; Campbell et al. 2019).

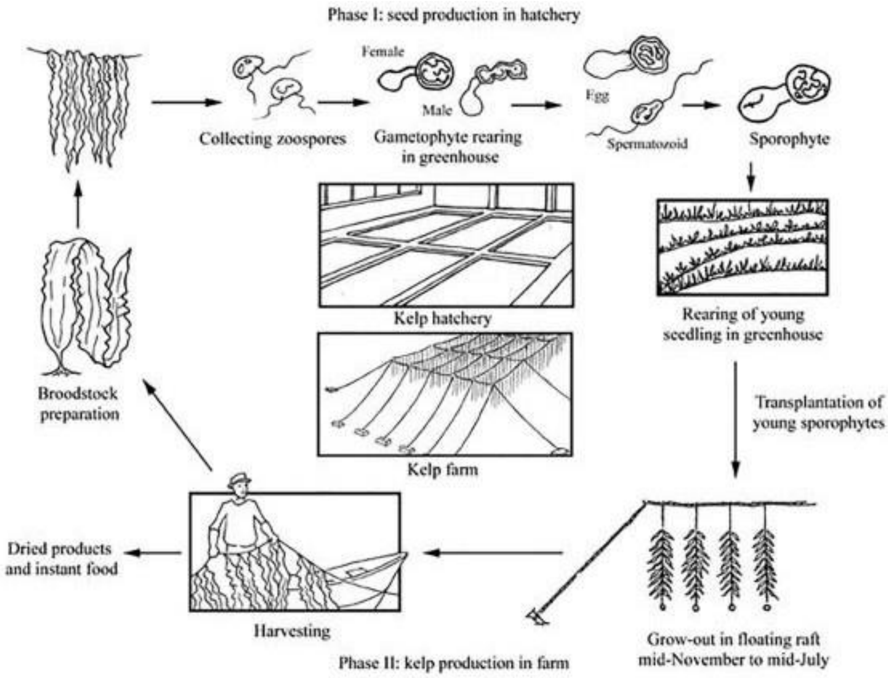

Fig 2a shows the two phases in the growing systems. (Picture from Campbell et al. 2019)

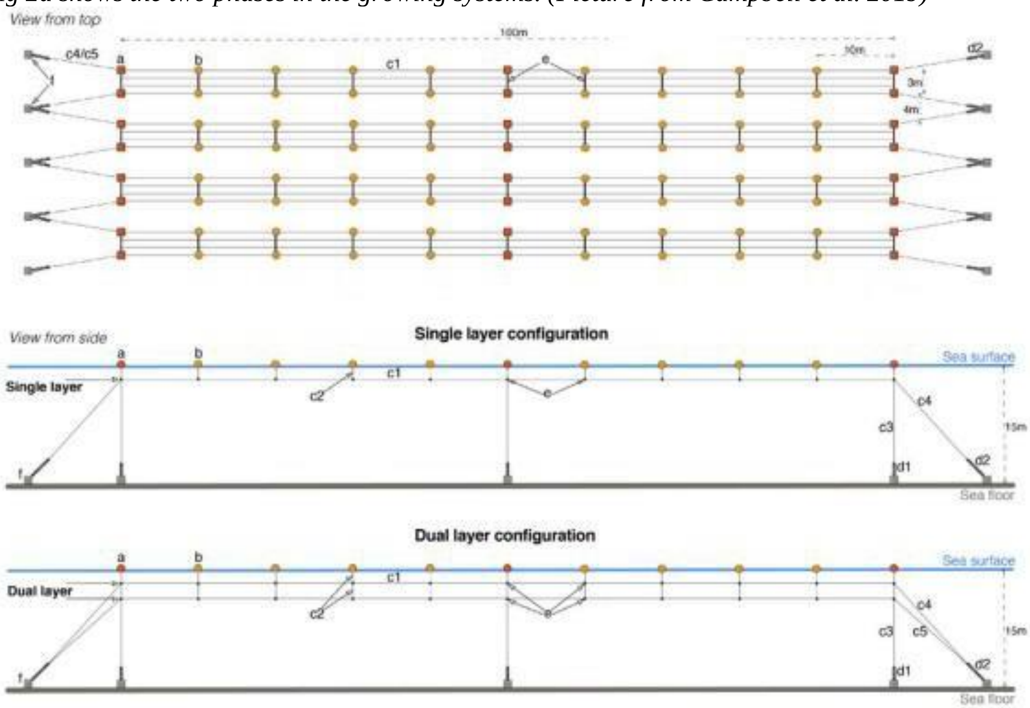

Fig 1b. representation over how a cultivation could look like from above and from the side. The single- and double-layer subsystems look identical from above, but the difference can be viewed from the side. Components are (a) Marker buoys, (b) small buoys, (c) PP rope (longline), (d) steel chain, (e) strip strengthens and (f) concrete anchors. (Picture from van Oirschot et al. 2017)

1.6. Nordic production of seaweeds

There are about 300 species of seaweed that are of economic interest globally (Kersen et al., 2017). Depending on different parameters, such as temperature and salinity of the water, there are limitations regarding which species can be grown in different places (Sambamurty 2006). Despite the large number of algal species of economic interest, there are only about 37 species of algae cultivated in the world. There is a potential to expand the number of cultivated species and create a bigger market for products made from sea vegetables (Kersten et al., 2017).

Today only *Saccharina latissima* (sugar kelp) is cultivated in the Nordic, and it needs a salinity over 16 PSU (Practical Salinity Unit); this means that it is not possible to cultivate *Saccharina latissima* on the east coast of Sweden or in the brackish water of the Baltic Sea (Weinberger et al. 2020). Thus, the Swedish farmers are limited to the west coast of Sweden, compared to Norway and Denmark, which have a larger coastline towards the Nordic Sea and, therefore, more area suitable for cultivating sugar kelp. Only a few species of seaweed live in the Baltic Sea due to unfavourable conditions such as low salinity in the waters. The unfavourable conditions and the few species that can grow there are believed to be one of the reasons that there has not been any significant culture of growing sea vegetables in the Baltic Sea historically. However, in the early 1940s, harvesting of a seaweed called *Furcellia lumbricalis* started in the Baltic Sea; this seaweed was and is still used for phycocolloids and as other food additives, among other things. However, *Furcellia lumbricalis* is characterised as relatively slow growing, and in some areas, it was harvested to extinction in 1950-1960. In other areas, it disappeared because of higher emissions rates from wastewater treatment plants and other activities before the 1980s, when measures to limit the runoff into the Baltic Sea were taken. However, it takes a long time to reduce eutrophication in an ecosystem. The current harvesting of *Furcellaria lumbricalis* in the Baltic Sea is restricted to Estonia (Weinberger et al., 2020).

1.7. Nutritional value of sea vegetables

Sea vegetables are one of the few vegetative sources of vitamin B12 and are, therefore, important to a growing vegan community. Sea vegetables contain various antioxidants and vitamins such as A, B, C and E (MacArtain et al. 2007). Especially *Ulva lactuca* has been highlighted considering vitamin B12. This sea vegetable has been suggested as a food supplement for elderly and strict vegetarians for its rich content of vitamins. *Ulva lactuca* contains approximately 5µg of vitamin B12 in 8g of dry product which is sufficient to meet the vitamin B12 daily recommended intake of 2µg/day for an adult (Susanti et al 2022; MacArtain et al 2007; Livsmedesverket 2022e). There is ongoing research to understand how to best extract the complex, water-soluble molecule vitamin B12 from *U. lactuca* (Susanti et al., 2022).

Sea vegetables are a source of essential vitamins and minerals at levels that would complement and increase diversity in an otherwise balanced diet if consumed regularly. Some sea vegetables, such as *Porphyra spp* (Nori), have a relatively high protein content, up to 49% of the dry weight. However, the levels of protein vary a lot depending on species and harvest season (MacArtain et al., 2007). Sea vegetables are abundant in trace elements and minerals compared to plants produced on land (MacArtain et al., 2007; Susanti et al., 2022).

The two ways it is possible to buy seaweed grown in Sweden commonly are dried and blanched and frozen. The nutritional value of *Saccharina latissima* is presented below in both its dried form and the blanched and frozen form (Table 2). In addition to the information presented below, it should be mentioned that in one student experiment where they examined the content of B12, very low amounts of this vitamin were found in the Swedish-grown sugar kelp (Johansson & Hevelius 2021).

Table 2: Blanched and dried *Saccharina latissima* Nutritional value and mineral content per 100g in blanched product and for 5g in dry product.
From: [20201229-Produktblad hemsida.pptx (webflow.com)]() (2021-09-20)

Nutritional value	Blanched per 100g	Dried per 5g
Energy	24 kcal	13 kcal
Protein	1,12g	0,5g
Carbohydrate	4,44g	2,7g
Fat	0,16g	0,02g
Salt	0,29g	0,4g
Mineral content		
Calcium	200mg	85mg
Magnesuim	92mg	34mg
Iodine	1,3mg	11,5mg
Iron	3,4mg	0,7mg
Zink	0,7mg	0,2mg

1.8. Human health risks with Sea vegetables

According to Banu and Umamageswari (2011), consuming edible sea vegetables is safe for humans when the intake is under 10g of dry weight per day (approximately 80-85% of the fresh weight is lost when the sea vegetables are dried) . Thus, very high amounts of sea vegetables should not be consumed. Despite these, seaweeds have many benefits as a food and can be considered one of nature's most complete and balanced nutrient sources when harvested in clean waters (Banu and Umamageswari., 2011). However, seaweed is grown in coastal areas, and the seawater cannot be considered clean waters. Therefore it has been recommended to keep track of metals like Arsenic (As), Aluminium (Al), Lead (Pb) and Cadmium (Cd) in edible seaweeds (Rubio Armendáriz et al. 2014).

Like every other food, if the intake is excessive, sea vegetables can have harmful effects to humans (Bharath et al., 2022). They can contain high levels of salt and iodine, which are substances humans need, but a high concentration in a diet can lead to health problems. Algae also can contain organic and inorganic arsenic and other heavy metals that they absorb from the waters they grow in (Bharath et al., 2022).

Algae are known bioindicators of eutrophication in marine environments because algae have an excellent capacity for accumulating and absorbing polluting macronutrients and trace elements (Paz et al., 2019a; Murai et al., 2021). Excessive intake of certain mineral nutrients (Magnesium Mg, Calcium Ca, Potassium K, Sodium Na) can negatively impact health. A high intake of Ca can cause hypercalcemia. A high intake of Na is related to high blood pressure (hypertension). Too much K can lead to hyperkalemia, vomiting, and weakness. Mg overdoses cause hypermagnesemia with diarrhoea and vomiting (Paz et al. 2019a). When it comes to the trace elements (Iron Fe, Copper Cu, Manganese Mn, Cobalt Co, Chromium Cr, Zinc Zn, Boron B, Barium Ba, Lithium Li, Molybdenum Mo, Nickel Ni, Strontium Sr, Vanadium V) may also have different harmful effects on humans health if the intake is excessive (Paz et al. 2019a; Murai et al. 2021).

According to Kumar and Sharma (2021), there are some risks to eating seaweed, and there have been some recorded cases of iodine-induced goitre (an enlarged thyroid gland that can be associated with a thyroid gland that is not functioning correctly) that are related to high consumption of edible seaweed. The Swedish Food Agency (2021) recommends an iodine intake of 150µg for persons over ten years old, adults and teenagers.

Seaweeds can also contain the heavy metal arsenic in the form of arsenosugars. In the human body, arsenosugars can be metabolised into different arsenic compounds, among others, the substance thio-DMA, which is a known toxic metabolite, was found in individuals that ate 10g (dry weight) of sea vegetable in a study made by Taylor et al. (2017). It has been suggested that the arsenosugars content in edible sea vegetables should be analysed even though it does not give a complete picture of the risk related to the consumption of sea vegetables (Murai et al., 2021).

In this study, analyse of the contents of the elements aluminium, lead, arsenic, and cadmium were conducted to compare the Nordic Sea sea vegetables products to the imported ones mainly produced in Asian countries. There are some unclarities regarding the harmful impact of the element aluminium. It has been reported to accumulate in the brain in humans and possibly lead to impairment of memory, Parkinson's disease or Alzheimer's (Hardisson et al. 2017). Parallel with this knowledge, there is no recommended maximum intake of this element by the Swedish food agency. It can, however, be a good idea to keep track of the aluminium content in sea vegetables as it is one of the foods that could have a relatively high concentration of aluminium (Hardisson et al. 2017). In addition, the sea vegetables produced in the Nordics can be considered a food source currently under development and will soon reach ordinary Swedish consumers.

1.8.1. Aluminium (Al)

Aluminium is the most common metal found in the ground, meaning that this element is all around in small amounts. Large amounts of aluminium can negatively affect the reproductive system and development of the central nervous system in studies made on animals. Fertile women and people with impaired kidney function can be sensitive to high aluminium intakes. EFSA have a temporary highest recommended intake of aluminium, which is 1 mg per kilogram body weight and week. This intake is safe for even the most sensitive consumers and is about 300 times less than the exposure that caused the negative effects in animal trials (Livsmedelsverket 2022a).

Aluminium can accumulate in the body, and long-term exposure to aluminium leads to toxic effects (Hardisson et al. 2017).

1.8.2. Arsenic (As)

Arsenic is a naturally occurring element found in bedrock and the soil. Arsenic has two main forms, organic and non-organic; it is the non-organic form that is most harmful to humans and is an established carcinogen in humans. The risk depends on how much of the substance an individual is exposed to. Some groups are more sensitive to exposure to arsenic, e.g., small children.

The Swedish food agency's current restriction to non-organic arsenic is limited to rice, and it is limited to 0.2 µg per kg product (Livsmedelsverket 2022b). Sea vegetables contain arsenic in primarily an organic form called arsenosugars. Less is known about the organic forms of arsenic and the effects it could have on humans (Taylor et al. 2017).

1.8.3. Cadmium (Cd)

Cadmium is a metallic element that is in soils in different concentrations. Even if the amounts of cadmium that people are exposed to through food are low, it is still important to minimise the exposure when possible. The most common sources of cadmium in Sweden are grains and potatoes. These sources contain relatively low amounts of cadmium, but because they are consumed in large amounts, they provide a lot of the total amount of cadmium. Types of foods like liver, kidney, brown meat from crabs and some mushrooms are known to contain relatively large amounts of cadmium. Cadmium remains in the human body over a long time and accumulates in the kidneys, long exposure can damage the kidneys, and it could also increase the risk of bone fractures. People with less iron in the blood are more sensitive to cadmium (Livsmedelsverket 2022c).

1.8.4. Lead (Pb)

Lead is a neurotoxic metal that accumulates in the body and can damage the central nervous system even in very low doses. Fetus and developing children are extra sensitive to lead (Paz et al. 2019b). The liver, kidney, and parts of shellfish can contain high amounts of lead; however, lead is found in most foods in small amounts. The overall exposure to lead has decreased over the last two decades, mainly because of the switch to non-lead gasoline. However, the levels of lead in the blood are still too high, which is a reason to reduce the amount of lead that the industry is releasing into the environment and to lower the maximum amount of lead allowed in foodstuffs (Livsmedelsverket 2022d).

2. Aim and research questions.

This paper aims to give an overview of sea vegetables as food from a Swedish perspective and its benefits and risks through an agroecological lens.
The research questions are:

Which seaweeds are suitable for growth under Swedish conditions?

Is large-scale production of seaweeds sustainable under Nordic conditions?
Which are the experiences and future needs of commercial seaweed producers in Sweden?
How is the nutritional content of seaweeds, with a specific focus on the selected elements Al, As, Cd and Pb

2.1. Limitations

This study is limited to sea vegetables, thus cultivated seaweeds grown in marine environments.

3. Material and methods

This study was made in three parts, one literature review to give an overview of the knowledge within the area. The second is an interview with people working with sea vegetables in Sweden today. Finally, an analysis of selected metal content in sea vegetables was also performed to compare Swedish produce with imported products.

3.1. Literature

The literature used in this study was obtained from the Web of Science database. The search words were "seaweed, toxicology, aluminium, protein, sustainability, crops, food, environmental, edible, kelp, sea vegetables, allergy, organism, Baltic and cultivation" in different configurations. Besides this, also published books on the subject were included.

3.2. Interview

A semi-structured interview was performed with active farmers of seaweed in Sweden to gather information about growing sea vegetables, mainly for food purposes. When it came to gathering information through questions, two main things were considered. The first one is structuration which is how open the questions are to interpretation and answer based on interpretation and the individuals previous experience. The second is standardisation, how much responsibility the interviewer has, how the questions are worded and in what order the questions are presented (Patel & Davidsson 2011). In this study, the questions had a low standardisation and a low structuration, so-called open questions, which gives an opportunity for a depth in the answers given, based upon previous experience and interpretation. The questions were worked out before the interview was conducted, and the interviewer had them as a guide during the interviews (Appendix 2). The persons included in the interview are individuals who work with sea vegetables for human consumption in Sweden. No personal data were collected about the interviewees. The persons chosen for the interview are all located along the Swedish west coast, and in total, five different sea vegetable farmers were interviewed. The interviews were partly done online using the video chat platform zoom and phone calls, and partly face-to-face interviews were made in Swedish, the native language of all the interviewees. The collected data from the interviews were transcribed and compiled, and the material was shortened to sentences of importance. These sentences were processed and translated into the result presented below.

3.3. Analysis of selected harmful elements

The two types of seaweed used for analysis were Sugar kelp (*S. latissima*) from Sweden and Ito-wakame (*Undaria pinnatifida*) from South Korea. The reason for using two different species is availability. Sugar kelp is not a commonly used sea vegetable in Asia and is unavailable in shops. Ito-Wakame is a sea vegetable easily available and used for similar cooking purposes as *S. latissima*. The *Undaria pinnatifida* was obtained from a local store, and *Saccharina latissima* was ordered from one of the Swedish commercial sea vegetable farmers. Six replicates of each kind of seaweed were analysed, and all samples were dry from the producers. The samples were sent to Eurofins for analysis of Al, As, Cd, and Pb. The method SS-EN ISO 17294-2:2016 /SS- EN 13805:2014 was used.

Statistical analyses were carried out using Minitab version 2018, and data were tested for significant differences ($p<0.05$) using a t-test.

4. Result

4.1. Which seaweeds are suitable for growth under Nordic conditions?

Right now, in Sweden, the only species grown commercially are *Saccharina latissima* or sugar kelp. Because of the demand for a salinity level above 15PSU, it is only possible to grow this on the west coast of Sweden. Species like *Furcellaria lumbricalis, Chorda filum, Palmaria palmata* and *Ulva lactura* and *Ulva intestinalis* are suitable to grow under Swedish conditions. However, there are currently no working systems for these types of algae developed yet (Franzén et al. n.d). *Furcellaria lumbricalis* are a species harvest to be used as an additive in food and the cultivation of this species could be suitable on the east coast of Sweden because it is a species that can grow in lower salinity and brackish water (Weinberger et al. 2020). *Chorda filum* are a species that also are grows in brackish waters and is suitable to use as food since it is an annual and fast growing species (Franzen et al. n.d). *Palma palmata* are a red algae that already exists, wild growing, in the Baltic sea and it established on the worlds food market were it is used for food, feed and biofuel (Franzen et al n.d). Ulva spp. Are also already used in different cuisines and is a family of algae that growing systems are develop and tried out in different places of the world (Franzen et al n.d).

4.2. Is large-scale production of sea vegetables sustainable under Nordic conditions?

There are different things to consider when assessing the environmental risks of growing sea vegetables, e.g., scale and siting (Campbell et al. 2019). There are similar legislation and policies throughout Europe that set some common management principles. Included in the policies are siting that minimises damage to sensitive environments; seeds that maintain the genetic diversity of wild stocks; a ban on cultivating non-native species; biosecurity measures to control the eventual spread of diseases, parasites, and non-native species; no fertilisation; and a well-maintained infrastructure (Campbell et al. 2019). Some local variation in the policies is to be expected within different countries. An example is the cultivation of non-native species (like *U. pinnatifida*) at a location where this species has already established (Campbell et al., 2019). It is possible to grow *Saccharina latissima* at a large scale in the Nordic waters towards the Atlantic Ocean, where the salinity is high enough. The limit is somewhere close to Bornholm, where the saltiness becomes lower than 16PSU, and the growth is already significantly reduced (Weinberger et al., 2020). However, as mentioned above, there are other sea vegetables suitable to grow in the brackish waters of the Baltic Sea. However, suitable cultivation systems are not yet developed, and this is a current hindrance to making commercial production possible.

4.2.1. Light

Photosynthetic active radiation (PAR) light is needed for the photosynthetic algae to grow. Therefore, the growing systems need to be placed at an optimal depth for the right amount of light to reach the sea vegetables. The growing system is causing shade on the bottom under the growing system. However, this is not a big problem for the autotrophic species that grow underneath the fields (Campbell et. al., 2019). Visch et al (2020) found that the reduction in light irradiance is 40% at 5m below the sea vegetable, right before harvest when the biomass is the largest. Bottom growing primary producers could be sensitive to shading, but there have been studies that shows that even a 18ha kelp farm doesn’t affect the seagrass that grows underneath the farm (Walls et al 2017). It is still necessary to consider shading effects and what is present underneath the site when choosing a growing site, especially in areas where Mearl beds and seagrass communities are present. Since the type of sea vegetable that is grown on what site should be a local one to not introduce an new species to an ecosystem is the type of algae already suitable for the conditions in the local area.

4.2.2. Nutrients

When the sea vegetables grow, they absorb nutrients from the surrounding water. The flow of nutrients must be continuous, so the water must flow through the cultivation. The nutrient in the water comes from a range of natural marine and atmospheric sources. In addition, more nutrients are added from anthropogenic sources such as agriculture and urban wastewater (Campbell et al. 2019). In a model made by Aldridge et al. 2012, it was calculated that a hypothetical farm at $20km^2$, a large-scale farm, would require about 480 tons of nitrogen per year if the production is estimated to be 20tons per hectare of dry weight. This calculation suggests a potential to reduce the local nitrogen resources with a large-scale seaweed farm. It is unlikely to achieve nitrogen depletion with these systems, for the anthropogenic sources of nitrogen can be high, e.g., 7500tons nitrogen was estimated to be released by salmon farming outside of Scotland in 2010 (Aldridge et al. 2012). The nitrogen released from a common salmon farm is considerably more than a small to medium sea vegetable farm can absorb (Campbell et al. 2019). Nutrient sequestration is most likely to be effected positively by sea vegetable farming (Hasselstöm et al 2018).

4.2.3. Ecosystem

The importance of kelp forests for different animal species is one argument for cultivation rather than wild harvest. Natural occurring seaweed is considered habitats for invertebrate macrofauna that support a diversity of fish that feed on these (Campbell et al., 2019, Hasselstöm et al 2018). Larger sea vegetable cultivation sites are likely to provide additional habitat for different invertebrate and fish species. The cultivation sites will act as fish aggregating places due to the feed and shelter the sea vegetables will provide. Creating sea vegetable habitats via cultivation could support positive changes to the local ecosystems, providing shelter and increased food resources in the same way as naturally occurring seaweed would (Campbell et al., 2019). More research is needed to determine if the cultivation of sea vegetables will attract marine mammals or other bigger species. Currently, there is limited evidence in the matter, and it is most likely to be connected to specific locations and species (Campbell et al., 2019). In a study made by Visch et al (2020) they shown that a kelp farm did not have any negative effects on the surrounding area, it did have a slightly positive effect. The bottom underneath the farming area were not affected by the sea vegetable production when it comes to oxygen uptake (Visch et al 2020). Sea vegetable farming have the potential to provide various ecological services when they are run properly. But according to Bhuyan (2023) the sea vegetable farm could be a centre for infections.

It is important, when cultivating sea vegetables in open waters that invasive species are avoided, and that the native species to the area are chosen to cultivate to not disturbed the pre-existing ecosystem. It is important to monitor and evaluate risks in the growing industry of sea vegetable farming (Bhuyan 2023; Campbell et al 2019). When the farming is run properly it is suitable for the Nordic conditions because the suitable species for sea vegetable farming should only be already existing ones, so if there are edible seaweeds present in the area it could benefit from sea vegetable cultivation.

4.3. Interview results-commercial sea vegetable producers in Sweden

The interview indicates an increased interest in seaweed in the Nordic countries, which will increase even more in the near future. The farmers expected this to be a fast-growing area in the Nordic countries, because of the recent interest by consumers and researchers in the area of sea vegetables grown in the Nordic countries. The harvested sea vegetable could be used as part of a meal, an ingredient, or a spice more than a staple food itself. This is mainly because of the high iodine content that limits how much sea vegetables are safe to eat in a day. Sea vegetables will become a more common additive in different food products in the future, there is a need for more sustainable products within the food industry and sea vegetables have a role to play here. The growers also pointed out that the sea vegetables could be used for a lot more than food, e. g., biofuels, bioplastics, pharmaceuticals, cosmetics, fertilisers, animal feed, textiles, or other packing materials. The large diversity of products that could be made from seaweed and an increased interest in sustainable food is expected to lead to an increased demand for seaweeds. For the coastal villages and municipalities, it was pointed out that increased cultivation could have a role to play when it comes to providing more work opportunities, especially during the winter season when the sea vegetables are grown, and the tourist industry is off-season. The cultivation of sea vegetables was also suggested to be a tool to learn more about interactions that happen in the ocean and lead to a greater understanding and a higher respect for the marine ecosystems in the local population. It was pointed out that seaweed is a new addition to Nordic cuisine, and this can cause it to take some time before it is generally used as food.

Also, the complicated process of getting the correct permits to start a cultivation in Sweden was mentioned as a hindrance for new farmers willing to start a smaller cultivation. Right now, the farmers are requesting more knowledge and facts about Nordic seaweed, the heavy metal contents, and the potential risks or benefits of eating seaweed. Another hindrance could be the competition along the coastline. A lot of area are already used for different purposes, such as military practices or other things.

Finally, the Seaweed farmers emphasised that when seaweed is cultivated in the ocean, nothing is added to the water. Everything that the sea vegetables needs are already in the water, all the nutrients, sunlight and, of course, water. The cultivations have shown to benefit the local areas in which they are grown, according to the farmers the surrounding area are more involved in the cultivation of sea vegetables, it have in some cases ben beneficial for the locals were some other people living close to the farms have begun to develop their own products from the sea vegetables. They bind free nutrients in the water and mitigate eutrophication while giving shelter to smaller fish and other animals. Since this still can be considered a new type of cultivation in these areas, it is important to further investigate potential risks or benefits of these types of cultivation both to the local areas they are in and as a food item.

4.4. Concentration of selected elements

The concentration of four selected elements in food samples of two seaweed species was determined. Significant differences between the seaweeds in the concentration of Al, Cd and Pb were observed (Table 3).

Table 3. The elements aluminium, Arsenic, cadmium, and lead were determined in *Saccharina latissimia* and *Undaria pinnatifida* (mg kg^{-1} dry weight). Mean ± standard deviation is shown, n=6.

Element	*S. latissima*	*U. pinnatifida*
Al	411.7±31.9a*	89.3±19.0b
As	38.3±13.8a	35.0±1.4a
Cd	0.3±0.02a	2.0±0.5b
Pb	0.4±0.06a	1.5±0.1b

*Values within rows followed by different letters are significantly different ($p \leq 0.05$).

5. Discussion

There are several positive aspects considering the increased production of sea vegetables in Sweden. Potentially, it can assist in taking care of the nutrients from traditional farming systems that have leached out in the sea, and as it does not need arable land, it will not compete for land use. Seaweed and algae produce a wide range of substances that can be used for a lot of different things. Some algae reproduce in a short amount of time and are a remarkable source of biomass and the substances they produce. The cultivation of sea vegetables could benefit the sustainability work in Sweden and, at the same time, be part of a new market for an array of sustainable products.

The sustainability work done in Sweden is important not only for the obvious reasons of creating a safe and habitable future but also for setting a good example and leading the sustainable development towards success in Agenda 2030 (Naturvårdsverket 2021). The environmental work needs to be done on a larger scale and at a faster pace, as Sweden is still not reaching 15 out of the 16 national sustainability goals (Naturvårdsverket 2021). Out of the 16 national sustainability goals, some of them could possibly benefit from seaweed cultivation. One of them is "Oceans in balance and a living coastline", and increased sea vegetable cultivation could be beneficial by mitigating eutrophication and giving shelter for small fish and other animals (Campbell et al 2019). Within this goal also, the living coastline is emphasised. Increased seaweed cultivation has the possibility to provide work opportunities for the people who live or who want to live close to the coast. The cultivation of sea vegetables also affects the goal of "Limited climate impact" by taking up the nutrients in seawater and binding carbon dioxide through photosynthesis. Other national sustainability goals connected to the cultivation of seaweed are "No eutrophication" and "A rich plant and animal life" for the same reasons as previously discussed. The recent evaluation of how the work on all these climate goals is currently proceeding shows that the goal for "Limited climate impact" and "A rich plant and animal life" is going the wrong way; we are getting further from the goal rather than working towards this goal. When it comes to the goals "No eutrophication" and "Oceans in balance and a living coastline", the situation is not getting worse, but it is not getting better either (Natrurvårdsverket 2021). Here it is clear that more efforts are needed, and that sea vegetable production may be an additional tool. However, the impact that increased sea vegetable cultivation could have on mitigating the climate impact is harder to say since that is mostly about mitigating the greenhouse gas in the atmosphere, and how much the carbon and nitrogen uptake effects the overall GHG in the atmosphere is hard to estimate. But even a slight improvement made in many places at the same time could make a difference, and the carbon and nitrogen in the sea vegetables can also end up in the atmosphere depending on how the sea vegetables are used post production.

Interviews were deemed appropriate for this study because a qualitative interview aims to discover and identify properties and conditions within a subject (Patel & Davidsson 2011). All Swedish seaweed farmers were part of the interview, so from a Swedish perspective, the interview has good coverage and gives an insight into how seaweed cultivation is perceived from the farmer's point of view. A hindrance that was discussed in the interviews was the uncertainty about the effects on human health that sea vegetables could have. Questions like "are there a big health benefit to consuming sea vegetables, or could it be potentially harmful to consume" were raised; this shows that the knowledge about sea vegetables as a food source is lacking and further research on the subject is needed. The previous research on this topic also concludes the lacking of knowledge in the area. Even if it is established that there is a significant content of heavy metals in the seaweed, not a lot is known about how the human body absorb these, as an example - arsenic is not necessarily harmful to the human body as it does not absorb the organic forms of this metal (Taylor et al. 2017). It is still a good idea to do continuous tests of the seaweed to see if the content is getting higher or lower in the seaweeds, both to get an overview of potentially harmful content in the food itself but also to be used as an indicator of the eutrophication levels in the sea (Rubio Armendáriz et al. 2014; Taylor et al. 2017; Murai et al. 2020; Paz et al. 2019a; Kumar et al. 2021). Another potential risk is allergies to seaweed if there is an increased presence on the market and increased exposure to consumers. One case of seaweed allergy presented by Thomas et al. (2019), this case is considered the first case of seaweed allergy. However, there could be other cases that are either misdiagnosed as seafood or shellfish allergies (Thomas et al 2019).

When it comes to the risks of eating seaweed, the literature seems to agree that there should not be any problems for any healthy human to eat seaweed as long as the consumption is not overwhelming. Considering that sea vegetables rarely can be harvested in completely clean waters and are rich in elements that can be considered harmful to humans if overconsumed, it is debatable if sea vegetables can be considered a complete and balanced food source because it is only deemed safe if consumed in amounts less than 10g dry weight per person and day. There were high levels of aluminium in the samples collected in this study, which could be considered a prohibiting factor to introducing larger amounts of sea vegetables into a diet (Hardisson et al. 2017).

In addition, as previously pointed out, sea vegetable cultivations are not competing with land use because the cultivation takes place in the sea. However, there is some competition in the coastal areas that could cause other types of conflict. Pressures on the marine environment are increasing as a result of the expansion of offshore energy, fishing, aquaculture, dredging, mineral extraction, shipping and the need to meet the national and international goals of biodiversity conservation (Douvere and Ehler 2007). As the pressures increase, so does the potential for conflict. One other thing that is also something to consider in the spacial uses near the coast is military activities. In the interview, that was one of the things that were raised as a potential conflict of marine areas.

Aquaculture within offshore wind farms provides one of the multiple possibilities for better use of marine space and creates opportunities for innovations (Röckmann et al. 2017). In Sweden, outside of the cost of Halland, there are plans to combine a largescale wind farm with sea vegetable farming (Åkergren 2022). The combination of wind farms and sea vegetable production is expected to provide new work opportunities and better use of the marine area. The combination of the two systems has been discussed in previous studies and is deemed a good idea and provides several benefits to sustainability (Röckmann et al. 2017; van de Burg et al. 2021). From a social sustainability perspective, combining wind farms and sea vegetable cultivation provides work opportunities. From an economic perspective, the profits from sea vegetables can be used to partly pay for the costs of upkeeping the wind farm (van de Burg et el 2021).

The future is most likely going to be different in several ways, depending on what choices humans make right now regarding development of more sustainable technique or ways of living. The choices humans make daily are essential for the environment, not only when it comes to production but the food system as a whole, including a farm-to-waste view. The development of new technologies is possible as part of a solution regarding the environmental impact of food. However, for this to have an effect, changes in behaviour in food consumption are needed (Björklund et al. 2008). One important first step can be that more people are involved in food production and are closer in different ways to the production; this would result in more awareness of how the food system works and make it easier to make climate-smart choices. At the same time, research about agriculture and food production is a complex issue because every farm or production site is unique (Nilsson 2010). Sea vegetables might have a role to play in the future food system but not as the main part of a meal, but more as a part of a food product or as a side dish; this is because of the content of iodine and possible harmful heavy metals. More research and innovation are needed if sea vegetables are going to be a more significant part of the food system.

If seaweed is proven to be a safe and nutritional food, a fast and big response to the Nordic food market could be expected according to the recent increased interest from consumers together with products that are more available than before. The area of sea vegetables can still be considered new in the Nordics, and there is potential in the area to produce food and other materials; this is something that some of the farmers mentioned in the interview and there are ongoing studies in many of these areas. An example is Prussi et al. (2021), who study the possibilities of manufacturing aviation fuel from microalgae. In the Nordic countries, the species that is cultivated is sugar kelp. There is, however, a possibility that there is a market for more species to be cultivated, especially in the Baltic Sea. The inner parts of the Baltic Sea are generally seen as areas where the cultivation of sea vegetables is less than optimal, but there are still species that are suitable to grow in this area aswell. Mainly because of the water's low salinity, only a few species of seaweed can grow there. Some projects are looking to grow species such as *Furcellaria*, for example, extracting different substances mainly used as a thickening agent for food or out of this seaweed. There are also other ongoing projects and trials to develop methods and find suitable species to grow in the Baltic Sea (Weinberger et al. 2020).

Working towards a sustainable future and national and international sustainability goals need to be more intense than ever. The work being done right now is not doing enough to have the impact needed to achieve the sustainability goals successfully. There is a complexity involved when it comes to questions regarding sustainability, often are, the problems abstract and not in immediate connection to the source. Because of this, food production and the environment are challenging issues to tackle (Björklund et al. 2008). With a growing world population, it is crucial to start adopting more environmentally friendly ways of producing different foods. The need to look at new food production techniques is becoming more important now than it has been. It can be expected that the work locally with sustainability goals and resilient food systems will be more challenging because of a more unstable environment caused by climate change. Even though algae are not suitable for a main product in a meal, it has a lot of nutritional value to add to different food products or as parts of meals. It is also possible to extract different specific nutrients from algae (MacArtain et al., 2007; Susanti et al., 2022).

6. Conclusion and critical reflection

It can be concluded that increased cultivation of sea vegetables has the potential to assist in sustainable development in Sweden. Right now, there are only one species cultivated in the Nordic countries. However, there are efforts to be made with other species as well, which means that we could, in the near future, see more species of seaweed as part of Nordic cuisine. This new foodstuff has some culinary value when added to cuisine. However, it is unlikely that it will significantly impact the food system because of the recommended daily intake of 10g. Growing sea vegetables is, however, a good idea because of the positive effects it provides in the marine ecosystems and mitigating the eutrophication of the oceans. Sea vegetable production is also considered a new product, and it has a role to play in innovation and development of other sustainable products such as packing, bioplastics or biofuels. Large-scale production of sea vegetables could be considered a raw material like wood that has many different applications more than just food. Different species of sea vegetables have different applications and are suitable for an array of different products and innovations and new work opportunities along the coastline. It must develop techniques to cultivate a larger variety of sea vegetables to keep this area developing.

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Appendix 1

Limited climate impact, this goal is set to limit the greenhouse gas emissions from human activities. Today, agriculture depends on fossil fuels and mineral fertilisers, and some forms of animal farming contribute to greenhouse gas emissions.

Fresh air, this goal is about harmful particles released into the air, diesel used in machines and on-farm activities can release particles in the air.

Only natural acidification, this goal is about eliminating acidification from anthropogenic sources. Using fossil fuels for transport and on-farm activities can lead to acidification of the nearby aquatic environments.

A non-toxic environment, this goal is to minimise the release of toxic elements into the environment. Pesticides, fungicides, and herbicides are toxic elements used in food production. These potentially harmful elements must be used responsibly to minimise release into the environment.

Protective ozone layer, this goal is about to let the ozone layer develop and provide long-term protection against harmful UV radiation. The usage of nitrogen fertiliser can sometimes release nitrous oxide into the atmosphere, and this gas is harmful to the ozone layer.

No eutrophication is about the amount of fertilising elements in the ground, and water should not negatively affect human health, biodiversity, or the possibilities of a multifaceted use of ground and water. Fertilisers in agricultural systems must be used so that they do not lead to eutrophication.

Living lakes and watercourses is a goal about the ecological sustainability of sweet water. Food production, such as fish farming, is leaching a lot of nutrients out into the surrounding environment.

Groundwater of good quality. The groundwater should be a safe and secure source of drinking water and provide a suitable environment for animals and plants in lakes and watercourses, some cases of animal husbandry are known to leach nutrients from manure into the groundwater, and other elements such as fertilisers, pesticides, herbicides and fungicides can also leach into the groundwater and make it unsafe to use.

Oceans in balance and a living coastline. This goal is to make the coastlines and surrounding waters in Sweden to have a long-term sustainable ability to produce and that the existing biodiversity should be preserved. This goal is also about keeping the cultural values of the coastal areas. Production of sea vegetables can be a vital part of reaching this goal, it would keep people in the area all year, and sea vegetable farming has the potential to be a key component of reaching this goal.

Teeming wetlands is about preserving and restoring the wetlands to keep the water-holding capacity and ecological functions of the wetlands. Leakage of nutrients and chemicals from agricultural activities can cause eutrophication and, in other ways, disturb the wetlands and their ecosystems.

Living forests, this goal is to maintain the ecological and cultural values of the forests and woodlands. Deforestation and competition about land areas between forests and agricultural land are an ongoing issue.

A rich agricultural landscape aims to protect the values of biological production and, at the same time, strengthen the biodiversity and cultural values within the agricultural sector.

A good built environment, this goal is about building cities and villages that contribute to a healthy environment for humans, that the nature- and cultural values are developed and reserved, and that buildings should be designed to maintain a long-term responsible usage of ground, water and other resources. A rich plant and animal life; this goal is about maintaining biodiversity both now and in future generations. (Sveriges miljömål n.d; Nilsson 2010)

Appendix 2

Interview guide.

Original question in Swedish inside the parentheses

2. Tell us about seaweed as food? (Berätta om tången som livsmedel?)

3. What is the future for Nordic seaweed? (Vad finns det för framtid för nordisk tång?)

4. What could seaweed contribute to coastal communities? (Vad skulle tången kunna bidra med i kustsamhällen?)

5. Do you see any obstacles with this type of food? (Ser du några hinder med den här typen av livsmedel?)

6. Sustainability or economy. What drives you? (Hållbarhet eller ekonomi. Vad driver er?)

7. The cultivation process? (Odlings processen?)

8. Risks with cultivation for ecosystems or the like, monocultures? (Risker med odling för ekosystem eller liknande, monokulturer?)