Netherlands Food and Consumer Product Safety Authority
Ministry of Agriculture, Fisheries, Food Security and Nature

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To the Minister of Agriculture, Fisheries, Food Security and Nature, the State Secretary for Youth, Prevention and Sport and the Inspector General of the Netherlands Food and Consumer Product Safety Authority

Advice from the Director of the Office for Risk Assessment and Research regarding the assessment of seaweed; food safety and nature

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Date
16 October 2025

Our reference
2025-01007090

Background

Seaweed is seen as an important source of alternative proteins for a sustainable food system and food security. The cultivation of seaweed is therefore encouraged by the European Union (EU). The Dutch government is also encouraging (research of) the cultivation of seaweed in Dutch waters. The Social Innovation Program Seaweed for Food and Feed', launched in 2017 and funded by the former Ministry of Agriculture, Nature and Food Quality (LNV), aimed to develop multifunctional seaweed farms in the North Sea. The LNV vision on food from sea and great waters also mentions a future for the cultivation of seaweed. In the National Protein Strategy, seaweed is explicitly mentioned as an alternative protein source.

In China, Japan and Korea there is a long history of eating seaweed. In Europe, seaweed is eaten much less, but this has increased sharply in recent years. The introduction of Asian cuisine, particularly sushi from Japan, has led to an increase in seaweed consumption in Europe. This is further reinforced by the fact that seaweed is increasingly seen as a natural, healthy and locally produced food. The consumption of seaweed and seaweed products is also increasing in the Netherlands.

However, seaweed may be contaminated with contaminants that may pose a risk to food safety. Common contaminants are heavy metals. In addition, seaweed may contain high concentrations of iodine. In Recommendation (EU) 2018/464[1], the European Commission calls for monitoring of the presence of a number of (heavy) metals and iodine in seaweed, halophytes (plants growing on high salinity soils) and products based on seaweed. The occurrence of contaminants and iodine in seaweed is determined by the environment in which the seaweed grows, the seaweed species and the age of the seaweed at harvest. In broad terms, higher levels of contaminants are found in brown seaweeds than in green seaweeds and red seaweeds. Environmental factors such as the estuary of a river (with possible upstream discharges of contaminants) or agricultural and industrial activities nearby can thus affect the quality and food safety of the harvested seaweed.

Also, the cultivation of seaweed in open water can have adverse effects on the natural ecosystem, such as disturbance of the marine ecosystem, the arise of pests and diseases that can spread to wild seaweed populations and the introduction, establishment and spread of alien seaweed species or other alien

[1] Recommendation (EU) 2018/464 on the monitoring of metals and iodine in seaweed, halophytes and products based on seaweed.

species associated with the seaweed. In addition, the cultivation of seaweed can contribute to the establishment and spread of alien species for which seaweed aquaculture is a suitable habitat.

In the Netherlands, seaweed is still grown to a limited extent compared to Asia or other European countries such as Norway. Despite the fact that the cultivation of seaweed in Dutch waters is stimulated by the government, not all the risks resulting from this cultivation are yet in the picture.

Approach

This risk assessment of the seaweed production chain aims to identify the hazards and assess the risks to public health and nature in the Netherlands associated with the cultivation and consumption of seaweed in the Netherlands.

The questions that BuRO has formulated on its own initiative are:

1. Are there any risks to the health of consumers from the consumption of seaweed grown in the Netherlands and/or from the consumption of seaweed products on the Dutch market?

2. Are there any risks to nature in the Netherlands due to the introduction, establishment and spread of alien species as a result of the cultivation of seaweed in Dutch waters?

For these risk assessments, a number of studies were carried out on behalf of BuRO and a number on behalf of LVVN. With regard to food safety, Wageningen Food Safety Research (WFSR), Wageningen Food & Biobased Research (WFBR) and the National Institute for Public Health and the Environment (RIVM) carried out a series of studies (from 2018 to 2025). GiMaRIS, in collaboration with Wageningen Marine Research (WMR), conducted three studies on alien species to identify the risks to nature (2019, 2020 and 2025). Based on these reports and additional literature, BuRO has performed the risk assessment.

In order to assess the risks to public health (food safety) and nature (alien species), BuRO follows four steps in the risk assessment. This methodology is based on that of the Codex Alimentarius and EFSA's methodology. The four steps are as follows:

1 Hazard identification: identification of potential hazards
2 Hazard characterisation: description of possible effects of the hazards
3 Exposure assessment: Estimation of the extent to which the hazard occurs and causes an effect
4 Risk characterisation: conclusion on risk, based on hazard characterisation and exposure assessment.

The substantiation describes in detail each of these four steps for the food safety risk assessment and for the assessment of risks to nature.

Scope

This risk assessment assesses the risks to two public interests: public health and nature. The public health assessment is limited to food safety. The nature assessment is limited to the risks of introduction, establishment and spread of alien species (including invasive alien species) to nature (biodiversity and aquatic ecosystem) in the Netherlands. The public interests of animal health (seaweed as an ingredient in animal feed), product safety (seaweed as an ingredient in

consumer products) and 'plant' health (possible diseases and pests of seaweed) are not taken into account.

Findings

Public health risks – food safety

- Most seaweed does not belong to the plants and is therefore not a product of plant origin. This applies to certain specific requirements of the food hygiene legislation (Regulation (EEC) No. (EC) No 852/2004) not in principle for seaweed.

Chemical

- The literature shows that the levels of contaminants in seaweed depend, among other things, on the type of seaweed, the cultivation location and the season in which it is harvested.
- The literature shows that the levels of iodine and (heavy) metals in seaweed can be influenced by the processing and preparation of seaweed. This depends, among other things, on the type of seaweed and the combination of the different processing and preparation steps.
- The presence of inorganic arsenic, lead, iodine and PFAS in fresh unprocessed seaweed grown in the Netherlands is so high that it poses a risk to consumer health if the seaweed was consumed without further processing or preparation steps.
- The processing of seaweed prior to consumption (such as washing, blanching, drying, salting, fermenting) is expected to reduce the presence of chemical hazards. The risks associated with the consumption of processed seaweed are therefore assessed as low.
- There is no European legislation yet on maximum levels for different contaminants in seaweed (products). The European Commission is now working on setting maximum levels for iodine and metals in seaweed.

Microbiological

- Data on the presence of pathogenic microorganisms on seaweed (products) are very limited. Available data show that:
  - environment-related pathogenic bacteria (including *B. cereus* and *Vibrio* spp.) are regularly found on seaweed and that
  - pathogens originating from humans and/or animals are only occasionally found on seaweed (products).
- Data on the presence of viruses and parasites on seaweed are missing. However, seaweed does not appear to be a plausible route of exposure for these microorganisms, with the exception of norovirus.
- Global cases of disease due to the consumption of seaweed are mainly associated with pathogens originating from humans and/or animals (in particular *Salmonella*, STEC and norovirus) and not with environment-related pathogens.
- Despite the lack of data on the presence of *C. botulinum* on seaweed, BuRO assessed that this environment-related pathogen is a relevant hazard for seaweed (products).
- Processing affects the presence of microbiological hazards on seaweed (products). It is unclear to what extent these processes achieve a sufficient degree of reduction to ensure the safety of the product.
- As regards human and/or animal pathogens, the risk of consumption of raw seaweed compared to fishery products is lower than that of molluscs and is

likely to be compared to the risk of consumption of raw fish. Thus, the assessment is that the probability of contracting an contamination through consumption of seaweed will be low to very low.
- Control of the microbiological food safety risk of seaweed lies in particular in preventing contamination of the seaweed cultivation area with micro-organisms of human and/or animal origin (in particular via sewage water).

Physical

- Data on the presence of foreign objects and micro- and nanoplastics in seaweed (products) are very limited. Therefore, it is not possible to perform a risk assessment.
- Seaweed rinsing is an important way to remove foreign objects and micro- and nanoplastics, except for barnacles that need to be removed mechanically.

Risks to nature – alien species

- Alien seaweed species pose a risk to nature, including in the Netherlands.
- If the cultivated seaweed species is already common in the area of cultivation and locally collected starting material is used, cultivation of the alien seaweed will in all likelihood not increase the impact on nature and therefore not pose an additional risk to nature.
- Cultivation of an alien seaweed species can pose a risk to nature if the species is not yet present in the area or is not abundant in the area, but also if the starting material is not collected locally.
- If the starting material for seaweed cultivation does not come from the area itself, alien species, including species that pose a risk to nature, can hitchhike with the seaweed and thus be spread.
- There is a sharp increase in the number of new alien seaweed species in Dutch waters. Many of these species belong to groups of species that are farmed and/or wild harvested (elsewhere).
- There are indications that starting material is used that has not been collected locally but is taken from other areas.
- Without DNA determination, it is difficult to identify a species from the following genera: *Ulva*, *Gracilaria* and *Porphyra*/*Neopyropia*/*Pyropia,* because they are morphologically (based on external characteristics) difficult to distinguish. As a result, instead of a native species, an (invasive) alien species can possibly be grown unintentionally

- The Marine Strategy states that the cultivation of alien seaweed species and improved native seaweed species (i.e. cultivars or hybrids) in the open sea in the Netherlands is considered undesirable, also due to the precautionary principle.
- The Alien Species in Aquaculture Regulation applies to the cultivation of seaweed. This Regulation regulates the introduction of alien species into the Netherlands in order to prevent the introduction of species that may pose a risk when grown in open aquaculture facilities. The cultivation of certain cultivars and hybrids is also regulated by this Regulation.
- It is currently unclear who is responsible for granting authorisations for the cultivation of seaweed under the Alien Species in Aquaculture Regulation. There is also currently no supervision or enforcement of this Regulation by the NVWA or any other supervisory authority.
- There are situations that do not fall within the scope of the Regulation, but may pose a risk, such as research with alien seaweed species in open facilities, the cultivation of alien species that occur elsewhere in the Netherlands, but are not or hardly present in the area concerned, or the cultivation of seaweed

(natural populations, cultivars or hybrids) with other characteristics than the seaweed that occurs in the area concerned. The latter may concern both alien and native seaweeds.
- If the permit does not specify the Latin name for the seaweed species, the introduction of alien species may sometimes be inadvertently allowed.

Answers to the questions

1. Are there any risks to the health of consumers from the consumption of seaweed grown in the Netherlands and/or from the consumption of seaweed products on the Dutch market?

Risks to public health (food safety) can be caused by chemical, microbiological or physical hazards in food. All three types of hazards can be present in/on seaweed grown or consumed in the Netherlands. The processing of seaweed prior to consumption (such as washing, blanching, drying, salting, fermenting) is expected to reduce the presence of both chemical, microbiological and physical hazards. The risks associated with the consumption of processed seaweed are therefore assessed as low.

2. Are there any risks to nature in the Netherlands due to the introduction, establishment and spread of alien species as a result of the cultivation of seaweed in Dutch waters?

Alien seaweed species can have an impact on nature (biodiversity and ecosystem). Activities involving alien seaweed species in open water or open aquaculture facilities, such as cultivation and research, therefore pose a risk to nature. Alien seaweed species that are eligible for cultivation are usually species that grow quickly and are more likely to have a negative impact on nature. In addition, the use of non-locally collected starting material − regardless whether the seaweed species is alien or native − poses a risk to nature. When seaweed is moved to another area, other (alien) species may hitchhike. This may result in the the establishment of alien species in the Netherlands, or the spread of alien species to other parts of the country. Among the species that may hitchhike are also alien species with an impact on nature

Advice from BuRO

To the Minister of LVVN

Legislation and policy

- Make sure that a location-specific permit is required for
  - the cultivation of all alien seaweed species
  - the cultivation of new cultivars and hybrids
  - the movement of alien and native seaweed species, both from abroad to the Netherlands and within the Netherlands.
- Ensure that research with alien seaweed species is also regulated.

Permit grants and supervision

- Ensure that a permit to grow an alien seaweed species, a new cultivar or hybrid is only granted after a risk assessment showing that cultivation does not have or does not increase the impact on nature and does not pose an additional risk to nature in the Netherlands and nearby countries.
- Ensure that a permit for the movement of an alien or native seaweed species is only granted if a prior risk assessment shows that no harmful alien species can hitchhike with the seaweed.

- When granting a permit, make sure that all species (native and alien) are indicated in the permit with their official Latin name and include in the permit conditions for those genera whose species are not easily distinguishable from each other that the identity of the seaweed must be verified by DNA analyses.
- Ensure that the authority or authorities responsible for authorising and supervising aquaculture of native and alien seaweed species are clearly identified and that these tasks are carried out.

To the State Secretary for Youth, Prevention and Sport

- Ensure that seaweed is explicitly included in food hygiene legislation.
- Support the setting of European maximum levels for contaminants in seaweed and seaweed products.

To the Inspector General of the NVWA

- Work in consultation with the Ministry of LVVN to clarify the supervisory tasks in the field of seaweed.

Yours sincerely,

Prof. Dr. Dick T.H.M. Sijm
Director of the Office for Risk Assessment and Research

Summary of risk assessment

A detailed description (including literature references) of the risk assessment can be found in the accompanying substantiation.

Seaweed

Seaweeds are also called macroalgae and occur in the sea or in brackish water. Although seaweeds are often considered plants, taxonomically most seaweeds are not plants. In the text they are called plants for readability. Seaweeds can be divided into three main groups: green seaweeds, red seaweeds and brown seaweeds. They grow in the wild on hard substrate, for example rocks, or soft substrate such as mud and sand. Seaweed is also cultivated in saltwater basins on land or in open water (aquaculture). Expectations for seaweed cultivation are high due to the potential of sustainable production of (plant based) food, (biobased) products and (bio) fuels.

In 2022, more than 37.6 million tonnes of seaweed (wet weight) were produced worldwide. Most of them (around 80%) were intended for human consumption. More than 97% of global production took place in Asia.

There are more than 12,000 species of seaweed, of which only a fraction (approximately 200) is of commercial value and around ten species are intensively cultivated worldwide. In the North Sea, the Southwest Delta and Wadden Sea there are 195 native seaweed species. In addition, various alien seaweed species are present, including species that are not native to Europe.

Seaweed farming

Until the mid-1960s, wild harvest was the most important way of harvesting seaweed worldwide. Research into the life cycle of seaweed has led to the development of seaweed aquaculture. Aquaculture has been growing enormously since the 1990s, supplying more than 95% of world seaweed production since 2011, with China and Indonesia as the largest producers.

Unlike Asian production, wild harvest is the most important in Europe (>98%). Aquaculture in Europe takes place mainly in Ireland, Norway and France, with the main species being *Saccharina japonica* and species from *Euchema* spp. and *Gracilaria* spp.. These are hundreds of thousands of tonnes of seaweed per year out of tens of millions of tonnes produced worldwide.

Seaweed cultivation in the Netherlands has not been around that long. A number of seaweed farmers have been active since the '10s of the 21st century. Seaweed is grown on lines in the Wadden Sea, in saltwater basins on land and in open waters of the North Sea and the Eastern Scheldt. In addition, wild seaweed is harvested in the Wadden Sea and the Eastern Scheldt. Most seaweed farmed in the Netherlands is intended for human consumption. A large part of the farming of seaweed is still in the experimental phase.

Around 30 different species of seaweed are grown and/or wild harvested in European countries around the North Sea (Netherlands, France, Ireland, United Kingdom, Denmark). Half of these species are native to the Netherlands or are alien species that have already established here. The other half of the species wash ashore in the Netherlands. These species are almost all native to other parts of northwestern Europe.

Seaweeds grown in the Netherlands are several species of sea lettuce (*Ulva* spp.), sugar kelp (*Saccharina latissima*), oarweed (*Laminaria digitata*), wakame (*Undaria pinnatifida*), Japanese wireweed *(Sargassum muticum*), Agardh's red weed (*Agardhiella subulata*) and dulse (*Palmaria palmata*). The most commonly grown species are sugar kelp and the various species of sea lettuce.

Intern gebruik

Seaweed production chain

For this risk assessment, the seaweed chain is described and divided into four stages (see Figure 1).

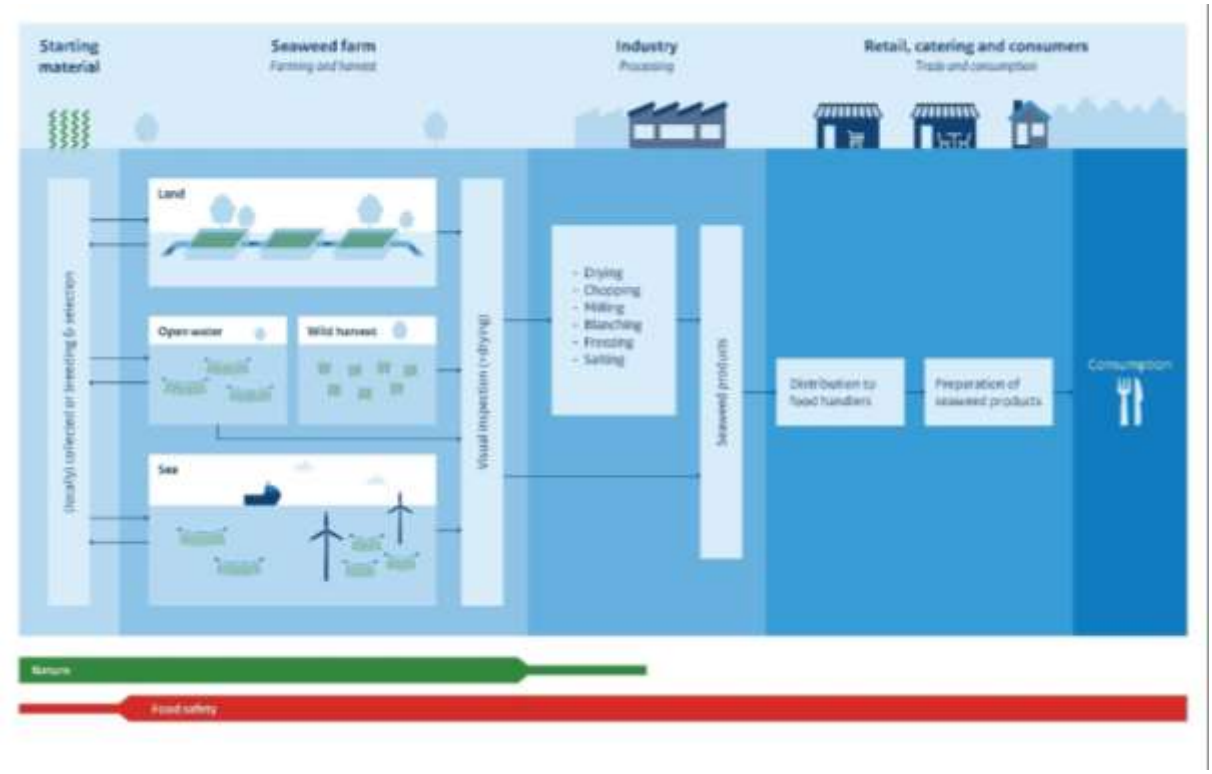

Figure 1 The seaweed production chain in the Netherlands in four stages. Imports of seaweed and seaweed products are not included in the figure.

Stage starting material

Dutch seaweed farmers reported in 2019 that they use seaweed collected along the Dutch coast as starting material. There is one company in the Netherlands that grows specific inoculum for seaweed farming, including inoculum from alien species. The company gets seaweed from Ireland, Norway and other places in Europe. This is used as the starting material from which inoculum is grown, which is then sold to farmers in the country of origin.

Stage cultivation and harvesting

The cultivation of seaweed can take place in different ways: on lines or nets in open water or in basins. In open water systems, seaweed grows from lines, with the lines hanging horizontally and/or vertically in the water. In the Netherlands, the possibility to cultivate seaweed in wind farms in the North Sea is being investigated.

Harvesting is done by moving along the lines with a boat and cutting off the seaweed, or by bringing in the entire line. When seaweed is partially harvested, it grows again and can therefore, depending on the species, be harvested several times a year. A number of companies in the Netherlands have permission to harvest wild seaweed in the Wadden Sea and the Eastern Scheldt.

In the Netherlands, seaweed cultivation also takes place on land in various basins made of plastic or concrete. These can be covered or open basins, which are filled with local seawater by a pipeline. Sometimes these are closed systems, sometimes there is a connection to open water via a drain.

Stage processing

After harvesting seaweed in open water, the seaweed is brought ashore with the help of boats for further processing. Common processing practices are: a visual check for unwanted objects, washing (rinsing) to remove, among other things, salt and impurities and then centrifugation.

Before the seaweed is stored, it is usually first dried in the air or dried by centrifugation with or without simultaneous heating.

Further possible processing steps are milling, freezing, fermenting, blanching or salting. After one or more of these steps, seaweed can be added as an ingredient to foods or sold as a 100% seaweed product.

Stage trade and consumption

The vast majority of seaweed products on the Dutch market consist of imported products from Asia, especially from China and Japan. The total imports (from countries inside and outside the EU) to the Netherlands in the period from 2017 to 2022 are over 3 million kg dry weight seaweed. Total imports in the same period amounted to almost 50 million kg dry weight seaweed for the EU as a whole.

There is a wide range of seaweed based foods with a wide range of products. There are products that consist entirely of seaweed, such as seaweed sheets that are used for sushi, for example, and products in which seaweed is only used in small quantities as a seasoning (e.g. seasoning mixes). In, among others, seaweed burgers, seaweed wraps and various seaweed pasta, the percentages of seaweed range from a few percent to more than 50%. Dried seaweed products are the most common. They are used as a garnish or as a (partial) replacement of flour in pasta, bread and other cereal products. Fresh seaweed is added to salads, mixed in fruit shakes, or cooked with rice and beans.

Preparation steps for the consumption of seaweed are soaking (hydration) and/or washing and/or heating (blanching, cooking, frying).

A number of seaweed products are available based on seaweed grown in the Netherlands, such as the Dutch Weed Burger and Sea Nuggets with seaweed from the Eastern Scheldt. Also restaurants have more and more seaweed on the menu; there are seaweed farmers who deliver directly to restaurants, without the intervention of a trader.

In order to gain a better insight into seaweed consumption in the Netherlands, RIVM, commissioned by BuRO, carried out a survey by means of a questionnaire survey among a representative sample of the Dutch population. RIVM concluded that a quarter of the participants regularly eat seaweed (products) and that seaweed (products) is eaten in all levels of society. Most seaweed is eaten in the form of chips/kroepoek with seaweed, noodles based on seaweed, seaweed spaghetti, wraps with seaweed and seaweed salad.

Public health risks – food safety

Introduction

Risks to public health (food safety) can be caused by chemical, microbiological or physical hazards in food. These three types of food safety hazards are highlighted in this chain assessment. Chemical hazards in food can be chemicals that enter food from the environment (e.g. environmental contaminants), are added to it (e.g. food additives), or are formed during processing of food (process contaminants). Microbiological hazards of a food are disease causing microorganisms (pathogens) that can be transmitted to humans via food. These include bacteria, viruses and parasites. Physical hazards in food are foreign objects that may inadvertently be present in a food. These are foreign objects such as stones, glass, animal material, plant material (including wood), metal and plastics (including micro- and nanoplastics).

Scope

This risk assessment is about seaweed as food. It does not include food supplements with seaweed as an ingredient, nor food raw materials prepared from seaweed (such as mannitol and alginates) and seaweed harvested by consumers themselves. Also, the presence of potential allergens in the cultivated seaweed has not been considered and antibiotic resistance is not part of this risk assessment. In the chemical risk assessment, the assessment takes place per individual compound. Finally, no cost/benefit analysis has been made for the consumption of seaweed.

Approach

Various sources have been used by BuRO to assess the chemical, microbiological and physical risks to public health associated with the consumption of seaweed. Wageningen Food Safety Research (WFSR) has carried out literature research into chemical hazards to food safety with regard to the consumption of seaweed or seaweed products, Wageningen Food & Biobased Research (WFBR) has carried out literature research into the microbiological hazards. BuRO has carried out additional literature research, also for physical hazards. In addition, other sources (such as the RASFF system) have been consulted.

Furthermore, chemical analyses have been carried out by WFSR on seaweed grown in the Netherlands (2018 to 2025) and limited microbiological research has been carried out on seaweed products available on the Dutch market (2019 to 2021). These studies form the basis for the assessment of the risks of seaweed consumption for food safety in the Netherlands.

The assessment of chemical hazards is based on seaweed grown in the Netherlands. Useful chemical analyses of imported seaweed products on the Dutch market were not available. EFSA's risk assessment was used for the assessment of seaweed products for the European market. The assessment of microbiological hazards is mainly based on literature data, supplemented by microbiological examination of seaweed products on the Dutch market; data on the microbiological quality of seaweed grown in the Netherlands are not available. As regards microbiological food safety, no full risk assessment has been performed due to the lack of sufficient quantitative data, the assessment is qualitative and focuses in particular on exposure and related risk of contamination. A comparison has been made with fishery products to characterise the risk. The assessment of the physical hazards is, in the absence of Dutch data, based entirely on the literature.

European and Dutch laws and regulations

Food should not be placed on the market if it is unsafe. Food is considered to be unsafe if it is injurious to health or unfit for human consumption (General Food Regulation (ALV) (Regulation (EC) No 178/2002)[2]. The responsibility for food safety lies with food producers (food business operators).

In addition, the regulation on the hygiene of foodstuffs lays down requirements for primary production (Regulation (EEC) No. (EC) 852/2004)[3]. This includes the production of seaweed. It is unclear whether seaweed products fall under the specific plant product requirements in this legislation, as strictly speaking most seaweeds are not plants.

Whether a particular type of seaweed is considered a novel food and is covered by Novel Food Regulation (EU) 2015/2283)[4] should be considered per species and/or per product. This is determined by the history of consumption. In 2021, the European Union's Joint Research Centre (JRC) published a technical report providing a comprehensive overview of the novel food status of seaweeds.

Regulation (EU) 2023/915[5] does notset maximum levels for certain contaminants in seaweed. The European Commission is working to establish maximum levels for iodine and metals in seaweed. For a number of heavy metals and iodine, maximum limits (ML) have been established at European level in food additives (E-numbers) based on seaweed (Regulation (EC) No 1333/2008)[6] and for mercury substances in algae and prokaryotic organisms (Regulation (EC) No 396/2005)[7]. As there is virtually no European legislation on other contaminants in seaweed, a number of countries have

3 Regulation (EC) No 852/2004 on the hygiene of foodstuffs
4 Regulation (EU) 2015/2283 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001
5 Regulation (EU) 2023/915 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006
6 Regulation (EC) No 1333/2008 on food additives
7 Regulation (EC) No 396/2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EC

set national maximum levels. There is currently no specific national legislation in the Netherlands for chemical contaminants in seaweed.

In the EU, no specific microbiological criteria for seaweed are included in the legislation. However, a food safety criterion for *L. monocytogenes (Regulation* (EC) No 2073/2073)[8] applies to ready-to-eat foods. In the Netherlands, national legislation lays down microbiological food safety criteria for food and beverages that are no longer heated for consumption by the end user (ready-to-eat foods) (Wbbl)[9]. In the Netherlands there is currently no specific national legislation for microbiological food safety of seaweed. There are a number of European countries (Denmark, France, Norway) where this is the case, or where the seaweed sector itself has drawn up guidelines.

Risk assessment of chemical hazards

Seaweed grown in the Netherlands (various species of *Ulva* and *Saccharina latissima,* abbreviated to sea lettuce and sugar kelp) has been analysed for iodine, heavy metals (including metalloids) and other contaminants. Based on the measured levels in seaweed and the consumption of seaweed in the Netherlands, the exposure of Dutch consumers has been estimated for all contaminants and iodine. This leads to the conclusion of the risk of the consumption of seaweed farmed in the Netherlands.

Seaweed (sea lettuce and sugar kelp) grown in the Netherlands contains iodine, (heavy) metals (arsenic, cadmium, mercury, lead and nickel) and other contaminants (dioxins (including dibenzofurans), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), poly- and perfluoroalkyl substances (PFAS) and algae toxins (cyanotoxins)). Mineral oils, plant protection products and radioactivity were not found in any of the samples analysed. The literature shows that the degree of presence of iodine and contaminants in seaweed may differ. This depends, among other things, on the type of seaweed and the processing steps that follow after the harvest. Processing seaweed generally leads to a decrease in the presence of iodine and contaminants. The size of the decrease varies per substance and depends on, among other things, the type of seaweed and the (combination of) processing steps. This combination of factors means that no single reduction rate can be applied in the risk assessment.

Research by RIVM showed that the 95th percentile of the consumption distribution (P95 consumption) of raw (fresh) wet seaweed by adult seaweed users was more than 90 grams per day. Of dried seaweed, the P95 consumption was over 13 grams per day. On the basis of these P95 consumption data, BuRO concludes that daily consumption of large quantities of raw (fresh) wet or dry seaweed (sea lettuce and sugar kelp) grown in the Netherlands may lead to a risk to consumer health due to the presence of iodine, lead, inorganic arsenic and PFAS. A worst-case scenario, because the possible decreases of (heavy) metals and iodine due to the processing and/or preparation steps are not included.

In addition, there are a number of other uncertainties that need to be taken into account when interpreting this conclusion, such as the determined levels of contaminants and iodine, the calculated total PFAS-levels and the consumption data for Dutch consumers.

Excessive intake of iodine can lead to a disruption of thyroid function. However, a deficiency of iodine can also lead to disruption of thyroid function and therefore to growth retardation in children. The iodine intake of Dutch adults is (just) sufficient. The Dutch iodine intake comes mainly from iodized salt added to bread. A decrease in salt intake could lead to an iodine deficiency in consumers. To prevent shortages, seaweed is mentioned as a possible iodine-rich food. When seaweed is consumed as an iodine source, there is a risk of an excessive intake of iodine, as this risk assessment confirms.

In addition, the consumption of raw (fresh) wet and dry seaweed grown in the Netherlands can have a (substantial) contribution to the total intake of various heavy metals via food. It should be noted that the intake of cadmium, mercury, arsenic and lead via food generally leads to exposure

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8 Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs
9 Commodities Act Decree on the Preparation and Treatment of Foodstuffs

around the health limit value. Consumption of seaweed grown in the Netherlands contributes (extra) to this.

An EFSA-study on seaweed based products shows that the consumption of seaweed, seaweed-based products and halophytes can have a major contribution to the intake of iodine and heavy metals (especially cadmium) for consumers who eat seaweed.

The intake of dioxins, dibenzofurans and DL-PCBs as well as PFAS from food and drinking water, causes a large part of the European and Dutch population to exceed the health-based guidance value. Consumption of seaweed grown in the Netherlands contributes (extra) to this.

Risk assessment of microbiological hazards

On seaweed bacterial genera occur that contain human pathogenic species. The sources consulted show that there is very limited data on those pathogenic species themselves on seaweed (products). Almost nothing is known about the occurrence of viruses and parasites on or in seaweed (products). The microbiological studies carried out are often based on a small number of samples. For that reason, failure to find a pathogen on seaweed or seaweed products is not evidence that that pathogen could not occur on seaweed. In order to obtain a better picture of the microbiological risk of seaweed than is possible on the basis of data on seaweed itself, in this risk assessment it was also examined whether it is plausible that pathogens that can be transmitted to humans via food play a role in the food safety of seaweed and in particular of seaweed that is present in the Netherlands. Contaminations that occur during further processing are not specific to seaweed and are therefore not included in this risk assessment.

The hazard identification a number of bacterial genera whose pathogenic species are only opportunistic pathogens. These genera have been assessed as irrelevant. This is because these pathogens do not pose a risk to the general (healthy) population. The identification also shows pathogens that rarely cause infections or where it mainly concerns hospital-related infections and where food is not (always) the route of infection, these pathogens have also been assessed as not relevant. It has been concluded that these bacteria are not of importance for the general food safety of seaweed. Although *Aeromonas* spp. are common on seaweed and *Aeromonas* is sometimes considered an emerging pathogen, this pathogen has not been taken into account, as the role of food in exposure is unclear.

Pathogens included in this risk assessment based on the hazard identification and selection followed are *Bacillus cereus*, *Campylobacter jejuni*, *Clostridium botulinum*, *Listeria monocytogenes*, *Salmonella*, *Shigella* spp., STEC (pathogens *E. coli*), *Staphylococcus aureus*, *Vibrio* spp., norovirus (NoV), hepatitis A virus (HAV), hepatitis E virus (HEV), rotavirus, *Cryptosporidium* spp., *Giardia* spp. and *Toxoplasma gondii*.

Of these pathogens, the main route of introduction has been investigated and whether the pathogen poses a risk to public health through consumption of seaweed (from the Netherlands). Contamination with pathogenic microorganisms during processing of the product or by sick personnel (harvesting, processing, food preparation) is not specific to seaweed and is not part of this assessment. This assessment focuses on the hazards introduced at the primary stage − during cultivation.

The risk assessment is limited to exposure (probability) and does not address the severity of infection (effect).

During the cultivation phase, seaweed can become infected with pathogens that occur in the seawater. These can be pathogens that are naturally present in seawater or the seabed or that end up in the water by humans and/or animals. The environment-related pathogens *Vibrio* spp. and *B. cereus* are regularly found on seaweed. By analogy, it is expected that the environment-related pathogen *C. botulinum* may also occur on seaweed. It has been assessed that any microbiological hazards from the environment that may be present on seaweed do not appear to contribute significantly to the risk to human health (population level) or to consumers (consumption level). However, *C. botulinum* is a relevant hazard because it is likely to occur naturally on seaweed and there are storage conditions in the chain that may be beneficial for growth of *C. botulinum* (among other things, modified atmosphere packaging (MAP)).

The assessment shows that seaweed does not play a role in human exposure to parasites. Also, viruses other than norovirus do not seem to play a role in exposure, especially for seaweed grown in the Netherlands.

Seaweed may become infected with pathogenic micro-organisms during harvest by hand contact (e.g. *Staphylococcus* spp.). From the risk assessment it follows that this is not a major source of contamination.

Seaweed can undergo various processing steps (e.g. washing, blanching, drying, salting, fermenting). These steps can have a germ-reducing effect, with the degree of reduction depending on the process, the type of seaweed and the pathogen. It is unclear whether these processes provide an adequate germ reduction for any pathogenic microorganisms present on seaweed.

Although seaweed is consumed on a regular basis in other countries (especially in Asia), there have been few outbreaks described (worldwide 14 outbreaks in the period up to and including September 2023). In some cases, it mainly concerns contamination by pathogens originating from human and/or animal. Relevant are in particular *Salmonella*, STEC and norovirus. These pathogens fish, crustaceans and molluscs turns out that the main pathway of introduction of these microorganisms is the proximity of a sewage discharge point or overflow to the cultivating area. These pathogens may also end up in the water as a result of run-off from agricultural land or recreation. It has been assessed that the microbiological safety of seaweed is mainly determined by human and/or animal pathogens and that the microbiological quality of the water in which the seaweed is grown is crucial in this respect. It must be avoided that this water becomes contaminated with pathogenic micro-organisms from humans and/or animals (via sewage water, run off of agricultural land, recreation).

The occurrence of pathogenic micro-organisms on seaweed cannot be properly estimated on the basis of available data. As a result, the risk characterisation has a high degree of uncertainty. It was therefore decided to compare the risk of seaweed consumption with a product group with a known risk. For the purpose of the risk assessment, a comparison was therefore made, as an indication, with the risk of the consumption of fish, crustaceans and molluscs previously assessed by BuRO (BuRO, 2022). After all, products from the fish, crustacean and molluscs supply chain come from the same environment (seawater) and partly have the same hazards. For the situation in the Netherlands, BuRO assessed that the probability of contracting a *Vibrio* infection (symptomatic) due to consumption of fishery products (in particular molluscs) is currently low. For infection with *Salmonella* and STEC, that probability was assessed as low and very low, respectively. Viruses mainly play a role in molluscs and viruses that are involved in molluscs-related outbreaks are mainly NoV, but also HAV. Exposure to HEV via this route does not play a role and HAV is not endemic in the Netherlands. The risk of the protozoan parasites *Cryptosporidium* spp., *Giardia* spp. and *T. gondii* via consumption of fishery products is estimated to be limited. Although no estimate of the probability of infection was given (BuRO, 2022), it is estimated to be very low based on the available data. However, compared to fishery products, seaweed − like fish − does not seem to accumulate micro-organisms, as filter-feeding molluscs can. Possible exception to this could be *Vibrio* spp. BuRO has assessed that the probability of contracting infection by pathogenic microorganisms through consumption of seaweed is very likely to be lower than the probability of becoming ill by these pathogens through consumption of molluscs (oyster, mussels) and that the probability is likely to be comparable to the risk of these pathogens through consumption of raw fish. As a result, the chance of contracting an infection through consumption of seaweed will be low to very low.

Risk assessment of physical hazards

Physical hazards occur as foreign objects in seaweed and seaweed products and can pose a health risk to consumers. The main physical hazards in seaweed are (pieces of) crustaceans and small stones to which the spores of seaweed attach to grow. Furthermore, there are sea animals that can attach to the surface (including barnacles) or fibers from the lines on which the seaweed grows can end up in the harvested batch of seaweed. Micro- and nanoplastics, which are widely present in the sea, also attach easily to seaweed.

These physical hazards can remain undetected during processing or consumption of fresh seaweed, especially when only traditional detection methods such as metal detection are used. In particular, in the case of fresh seaweed, foreign objects may reach the consumer.

There is no safe limit to consumer exposure to foreign objects for the risk assessment of physical hazards caused by foreign objects. In practice, this means that seaweed and seaweed products must be free of foreign objects when they reach the consumer. Data on the occurrence of foreign objects in seaweed (products) are very limited. Therefore, it is not possible to perform a risk assessment.

Given the lack of information on the effects of micro- and nanoplastics on humans and the lack of quantitative data on the occurrence of plastic particles smaller than 10 µm in seaweed, a risk assessment of this hazard is currently not possible.

The main method of removing foreign objects and micro- and nanoplastics that have come with the harvest of seaweed is rinsing, although the removal of the barnacles often have to be done mechanically. Also the micro- and nanoplastics that are enclosed by the seaweed will not be removed by rinsing.

Uncertainties

The food safety risk assessment could not be performed entirely on the basis of data on seaweed grown in the Netherlands. Microbiological and physical data for Dutch seaweed were missing, so the microbiological and physical risk assessment was done on the basis of international literature data.

The chemical risk assessment is based on data on freshly grown seaweed in the Netherlands and Dutch consumption data of seaweed. The reducing effects of seaweed processing have not been taken into account. Furthermore, no distinction was made in the location of sampling, sampling spot in the seaweed bed and the moment of sampling. The sampled sea lettuce has not been determined by species, and could potentially be different species of sea lettuce. In addition, representative consumption data for children and adolescents are lacking, so it was not possible to assess the risk for this group.

Risks to nature– alien species

Introduction

When assessing the risks to Dutch nature, the focus of this risk assessment is on alien species and the effects of these species on biodiversity and the aquatic ecosystem in the Netherlands. Alien species are species that do not occur naturally in the Netherlands. In this case, the Netherlands refers to Dutch marine and brackish waters: the Dutch section of the North Sea, the Dutch section of the Wadden Sea and the Southwest Delta. Alien species can be harmful to Dutch nature, but also to human health, safety and the economy. When an alien species adversely affects or threatens biodiversity and related ecosystem services, it is referred to as an invasive alien species.

Scope

This risk assessment concerns potential risks to Dutch nature due to the introduction, establishment and spread of alien species (seaweeds or other organisms) as a result of seaweed cultivation. These can be alien seaweed species that are deliberately brought to the Netherlands for seaweed cultivation, alien seaweed species that have previously been introduced by other human activities and alien species that naturally wash ashore. It can also be alien species that occur within the cultivated seaweed. The species are alien to the Netherlands. They may be alien or native to other parts of Northwest Europe. This risk assessment does not address possible other impacts of seaweed farming on nature, such as disruption of ecosystems during seaweed farming and/or harvesting, or reduced nutrient availability to other organisms. This risk assessment also does not address the risks to nature in nearby countries. The conditions in these countries do not always correspond to those in the Netherlands.

Approach

To assess the risks posed by the introduction, establishment and spread of alien species, GiMaRIS researchers were commissioned by BuRO to analyse the ecological impact of alien seaweed species on nature (desk research, 2025). They also inventoried the seaweed species farmed in the Netherlands (field research, 2019) or potentially suitable for cultivation in Dutch wind farms (desk research in collaboration with WMR, 2019). In addition, they inventoried other species found in

Dutch seaweed cultivation (field research, 2019). They then determined which cultivated seaweed species and other species found are alien to the Netherlands and estimated whether these alien species could have an impact on Dutch nature. In addition, they assessed the extent to which the seaweed cultivation activities such as these took place in the Netherlands in 2019, and the future cultivation of seaweed in wind farms in the North Sea, increase the chance of introduction, establishment and spread of these alien species and the impact of these species on nature. Subsequently, in 2025, the origin of the starting material used for seaweed cultivation was re-examined (desk research, 2025).

BuRO has made an inventory of the existing laws and regulations applicable to seaweed cultivation and related to possible risks of alien species.

European and Dutch laws and regulations

European legislation on alien species consists of the Marine Strategy Framework Directive (2008/56/EG[10]) (MSFD), the Regulation on invasive alien species ((EU)1143/2014[11]) and the Regulation on alien species in aquaculture ((EC)708/2007[12]). The MSFD states that the number of 'non-indigenous species' (or alien species) newly introduced by human activities should be minimised and, where possible, reduced to zero. The core of the invasive alien species Regulation is a list of invasive alien species that are of concern to the European Union. Species on this list may not be intentionally released into the environment and may not be propagated, grown, used or sold. This so-called Union list includes one marine seaweed species (*Rugulopteryx okamurae*) (Implementing Regulation (EU)2022/1203[13]). This species occurs in seawater with a relatively high temperature, such as in the south of France and Spain. This species is currently not relevant for the Netherlands, but due to the changing climate this could change in the future.

The European Regulation on alien species in aquaculture contains rules for the introduction in the Netherlands of alien (seaweed) species used in aquaculture including potentially hitchhiking alien species. This Regulation has been implemented in the Netherlands [14,] so that alien species may only be introduced in the Netherlands for cultivation in an open aquaculture facility if this presents a 'low' risk and a permit has been granted. However, alien species already present in the Netherlands do not fall within the scope of this Regulation. This also applies to species that have only recently been found in the Netherlands. No authorisation is required for the cultivation of these species on the basis of this Regulation. Even if these species are not yet or hardly present in the area where they will be grown and the cultivation of these species may therefore pose a risk to nature. It is also unclear whether research involving alien species in an open aquaculture facility falls within the scope of the Regulation.

Some artificially obtained cultivars and hybrids are covered by the scope of the Regulation. As it is not known how certain provisions in the European Regulation are interpreted, it is unclear for other artificially obtained cultivars and hybrids whether they are within the scope of the Regulation. In addition, cultivars and hybrids can also be developed that do not fall within the scope of the Regulation, but may pose a risk to nature when grown in an open aquaculture facility. For example, when seaweed species are bred with properties that increase the likelihood of invasiveness, such as faster growth or being able to survive exposed conditions at sea.

For authorisation in general, the use of Latin names for the species for which authorisation is granted is important. If common names or Latin names for groups of species are used, there is a chance that cultivation of alien species may be inadvertently authorised. Under a permit for the cultivation of 'sea lettuce', various native sea lettuce species, but also the alien southern sea

10 Directive 2008/56/EC establishing a framework for Community action in the field of marine environmental policy
11 Regulation (EU) No 1143/2014 on the prevention and management of the introduction and spread of invasive alien species
12 Regulation (EC) No 708/2007 on the use of alien and locally absent species in aquaculture
13 Implementing Regulation (EU) 2022/1203 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern
14 Order of the Minister of Agriculture, Nature and Food Quality of 17 December 2008, No. TRCJZ/2008/3516, laying down rules for the use of alien and locally absent species in aquaculture (Regulation on the use of alien and locally absent species in aquaculture).
Government Gazette 2008, No 252

lettuce (*Ulva australis*) could be grown. A similar situation arises in the case of an authorisation to cultivate '*Ulva*'. Under such a permit, all 388 *Ulva* species would be allowed to be grown, while only 16 *Ulva* species are native to the Netherlands.

It is currently unclear who is responsible for granting permits to grow alien seaweed under the Alien Species in Aquaculture Regulation. According to the Ministry of Agriculture, Fisheries, Food Security and Nature (LVVN), this is the Netherlands Enterprise Agency (RVO), but RVO indicates that they do not grant these permits. The General Inspection Service (now the Netherlands Food and Consumer Product Safety Authority (NVWA)) is responsible for supervising and enforcement of this regulation. At present, the NVWA does not monitor compliance with this Regulation.

In line with the European Marine Strategy Framework Directive, the Dutch Marine Strategy 2022-2027 describes measures to achieve a good environmental status with regard to alien species: a minimum number of newly introduced alien species. This strategy states that initiatives concerning the cultivation of alien seaweed species and improved native seaweed species (i.e. cultivars or hybrids) in the open sea are considered undesirable also due to the precautionary principle. The Dutch policy for marine alien species is based on prevention and is fully committed to preventing introduction, because marine species are difficult to control and mitigate after establishment.

The Environment and Planning Act ('Omgevingswet')[15] of the Netherlands, contains rules to protect nature and the environment. An environmental impact assessment is mandatory for certain activities, but not for the propagation or cultivation of seaweed. There are also rules to protect plant and animal species, Natura 2000 sites and special national nature conservation areas. For example, various activities with potential consequences for naturally occurring wild plants and animals (so-called flora and fauna activities) are subject to authorisation. This applies, for example, to the deliberate disturbance, capture or killing of protected species. Activities that may have adverse effects on Natura 2000 sites and special national nature conservation areas are also subject to authorisation. They may only be carried out if they do not have deteriorating or significantly disturbing disruptive effects, or do not adversely affect the integrity of the site (taking into account the conservation objectives). This also applies to seaweed cultivation activities. In practice, all seaweed cultivation activities will require a Natura 2000 assessment, because the areas where seaweed can be grown are Natura 2000 areas or could affect Natura 2000 areas. For activities within the so-called exclusive economic zone of the North Sea and in the part of the territorial sea that does not belong to a province, a permit is granted by the Ministry of LVVN and Rijkswaterstaat is responsible for supervising and enforcement. For activities in other areas, a permit is granted by the province and the province is also responsible for supervision and enforcement.

Risk assessment of alien species

Alien seaweed species can change the area in which they are introduced if they establish in the area. They can be so dominant that they displace other species. Also, seaweed species that form large plants can change the flow and sedimentation in an area. This affects the species that live in the area and can also change the hydromorphological characteristics of the area. Some seaweed species contain substances that are harmful to fish that eat it. In other species, the plants degrade so rapidly that acidification can occur and the oxygen content in the water may drop sharply. This particularly occurs in closed inland waters. Due to the deterioration of water quality, this has a negative effect on the achievement of the WFD objectives. If the oxygen level becomes too low, this also leads to death in all kinds of species. Especially benthic species that live on and in the seabed and extract nutrients from the sediment or filter the water, such as worms and molluscs bivalves, are sensitive to this.

In general, alien seaweeds have a negative impact on the native seaweeds present in an area. Other native species can also be negatively impacted by seaweeds. Among the species that may be affected by alien seaweed species are also characteristic species for habitat types in the Southwest Delta and Wadden Sea. These characteristic species serve as a quality indicator for these Natura 2000 sites. However, in some cases, alien seaweeds have a positive effect on native species, for

15 Act of 23 March 2016 laying down rules on the protection and use of the physical environment (Environment Act)

example when the seaweed provides shelter from predators and currents, or when the seaweed creates additional settlement opportunities.

Not all alien seaweed species have an impact on nature. However, alien seaweed species that are eligible for farming or wild harvest are usually fast growing species. Many of these species are therefore likely to have a negative impact on nature. Because alien seaweed species grown in open water can disperse without human intervention, there can be an impact not only on nature in the area where the seaweed is grown, but also on areas further away. If alien seaweed is grown on a larger scale, seaweed may disperse over larger distances and settle in larger quantities, increasing the chance of establishment and spread, and the risk to nature.

Alien species in cultivation

In 2019, the species present at ten Dutch seaweed farms (including wild harvest of seaweed) and one breeder of starting material were inventoried. A total of 64 seaweed species, 15 of which are alien, have been found. In addition, 61 animal species have been found, 20 of which are alien. The seaweed and animal species that are alien to the Netherlands are almost all also alien to other parts of Europe. The only exception is *Palmaria palmata* (dulse) which is native to other parts of northwestern Europe. Both the found alien seaweed species and the found alien animal species (including a number of ascidians, crustaceans and molluscs) have an impact on Dutch nature. Among the seaweed species found are invasive alien seaweed species such as *Undaria pinnatifida* (Wakame), *Sargassum muticum* (Japanese wireweed), *Gracilaria vermiculophylla* and *Grateloupia turuturu,* all of which can significantly change an ecosystem. All alien seaweed species found had already established in the area where the seaweed was grown. Five of the 15 found alien seaweed species were grown: Agardh's red weed (*Agardhiella subulata*), Japanese wireweed (*Sargassum muticum*), southern sea lettuce (*Ulva australis),* wakame (*Undaria pinnatifida*) and dulse (*Palmaria palmata)* (the latter was found only in a quarantine basin at a breeder of starting material).

In addition, the North Sea Farmers Foundation has proposed species for cultivation within wind farms in the North Sea. Among the species that may be cultivated within five years, four were alien species: the aforementioned wakame and dulse, and winged kelp (*Alaria esculenta*) and thongweed (*Himanthalia elongata*). With the exception of wakame, these species are native to other parts of northwestern Europe. The North Sea Farmers Foundation also proposed two genera: *Ulva* with 388 species and *Gracilaria* with 285 species. These two genera were not included in the risk assessment. As the characteristics and the occurrence of the species within these genera is very different, their potential impact is also very different. Therefore, it is not possible to assess the risk of these genera as a whole.

All seven alien seaweed species that are already grown or have been proposed for cultivation in wind farms in the North Sea have a negative impact on native seaweed species in the Netherlands, but also elsewhere. In addition, they can also have a negative impact on native animal species. Wakame, Japanese wireweed, winged kelp and thongweed form large plants that change the flow and sedimentation in an area and thus indirectly affect the species that occur there. This can also alter the hydromorphological characteristics of the area. Southern sea lettuce grows so fast that it displaces other species. The same applies to Agardh's red weed, which covers sediments and displaces the species living there. In addition, the plants of Agardh's red weed die at the end of the growing season and then degrade quickly. Especially in closed inland waterways, this may cause the oxygen content in the water to drop sharply. If the oxygen level becomes too low, this leads to death in all kinds of species.

All seven alien seaweed species have a negative impact on other species that occur in the area where they are present and thus pose a risk to nature. Whether cultivation of a species increases its impact and thus poses an additional risk to nature depends on the specific situation.

Dulse, winged kelp and thongweed are native to other parts of Northwest Europe and regularly wash ashore on the North Sea coast, but plants attached to substrate have not been found. This shows that these species cannot (easily) establish in Dutch waters. Possibly this is because the Netherlands does not have a rocky coast with strong currents. Because these species cannot establish here, there is little chance that these species will have an impact on nature if they were grown in wind farms in the North Sea. In addition, these species could also establish naturally in wind farms. Cultivation of these species in wind farms therefore poses no additional risk to nature when locally or upstream collected starting material is used.

Japanese wireweed and southern sea lettuce are already common along the entire Dutch coast and in the Southwest Delta. Agardh's red weed is widespread in the Eastern Scheldt. Since these species have already established themselves in the areas where they are grown and are common there, the impact of these species on nature is unlikely to increase due to current seaweed farming activities. The cultivation of these species therefore does not pose an additional risk to nature provided that locally collected starting material is used.

Wakame is found in a few places in the Netherlands, but only grows in relatively sheltered places. Wakame is very common in the Eastern Scheldt. Cultivation of wakame in the Eastern Scheldt will therefore in all likelihood not increase the impact that this species has on nature as long as starting material from the immediate vicinity of the facility is used. If wakame were to be grown in wind farms in the North Sea, the species is not expected to disperse over long distances, as wakame is usually harvested before spores have formed, and the spores and leaves of wakame sink quite quickly. Although some individuals could reach the Wadden Sea, this will in all likelihood not increase its impact on nature, because there is already a wakame population near the marina of Terschelling and wakame also occurs further north in the Wadden Sea. The cultivation of wakame in the Eastern Scheldt or in wind farms in the North Sea therefore poses no additional risk to nature provided that the starting material for cultivation comes from the immediate vicinity of the facility and therefore only grows in relatively sheltered places.

Starting material

The cultivation of alien seaweed species with an impact on Dutch nature does not always pose an additional risk. Whether an alien seaweed species has already established itself in the area where it is intended to be grown and the extent to which the species is present there determines to a large extent whether cultivation poses an additional risk to nature. If an alien seaweed species is already widespread in the area and is a common species there, cultivation will generally not increase the impact of the seaweed on nature. However, it is important that the starting material is collected locally. If this is not the case, the seaweed grown may have different properties and could have a greater impact on nature than the seaweed already present in the area. In this case cultivation could pose an additional risk to nature.

Starting material from other locations, cultivars or hybrids, may have different properties than the seaweed population in the area itself. There is a continuous search for seaweed plants and populations with properties beneficial for seaweed cultivation, and cultivars or hybrids with these properties are actively developed. Properties that allow the seaweed to grow faster, grow in other places, or withstand conditions at sea are beneficial for seaweed cultivation because they increase production or allow the seaweed to be grown in more places. At the same time, these properties can increase the risk to nature. For example, the wakame that occurs in the Netherlands only grows in relatively sheltered places, but there are also populations, cultivars and a hybrid between winged kelp and wakame, which can establish in places with strong currents and waves (exposed conditions). If this wakame was used as a starting material for cultivation, the impact of wakame and therefore the risk to nature would greatly increase, because it can grow in more places and will therefore have an impact in more places than the wakame that now occurs in the Netherlands. Comparably, if the cultivation of dulse, winged kelp and thongweed were to use starting material from populations or cultivars that can establish themselves in Dutch waters, the cultivation will greatly increase the risk to nature.

In 2019, the starting material used by Dutch seaweed farms was collected locally. In 2025, we examined whether this is still the case. There are several indications that starting material now also comes from other places. For example, seaweed species are offered for sale on the internet that are said to be grown in the Eastern Scheldt or harvested there (wild harvest), but previously did not occur there. The sharp increase in the number of new alien seaweed species is also an indication of the use of starting material from abroad. Since 1996, two or three new alien seaweed species have been found in the Netherlands every five years. However, 15 new alien seaweed species have already been found in the past four years. The efforts to detect new alien species have increased from 2009 onwards, but more intensive monitoring does not provide a good explanation for this increase. The number of new alien seaweed species has only recently increased significantly and has also increased much more than other groups of organisms. Shipping also does not provide a good explanation for the sudden increase in the number of new seaweed species, because other groups of organisms that, like seaweed, can be transported by vessels (through

biofouling) have not increased to the same extent. In addition, it is striking that nine of these species belong to groups known to be cultivated: sea lettuce (*Ulva* spp.) and nori (*Porphyra* spp., *Neopyropia* spp. and *Pyropia* spp.). Because these alien species have now been found in the Netherlands, any cultivation of these species no longer requires a permit under the Alien Species in Aquaculture Regulation. *Ulva* species are grown in the Netherlands and the possibilities for cultivation in the Netherlands of species that can be used as nori are being investigated. In both groups, the species are difficult to tell apart based on their appearance and native species also occur in the Netherlands. In groups whose species are morphologically difficult to distinguish, such as *Ulva* spp., *Porphyra* spp./*Neopyropia* spp./*Pyropia* spp. and *Gracilaria* spp., it is often not clear without DNA analysis which species is grown, so an (invasive) alien species might be grown unintentionally.

When starting material is not collected locally, but is taken from another place, other (alien) species can hitchhike with the seaweed and thus be spread. As a result, new alien species can be introduced in the Netherlands and establish here. It also allows alien species to spread further within the Netherlands. It depends on the specific situation whether this poses a risk to nature. During the inventory carried out in 2019, various alien organisms (a number of ascidians, crustaceans and molluscs) and alien seaweed species were found in the farmed and wild harvested seaweed. All these alien species had already established in the area where the seaweed was grown, so they did not pose an additional risk to nature. However, if alien species that have a negative impact on nature are introduced into an area, this does pose a risk to nature.

Conclusions

Public health - food safety

Risks to public health (food safety) can be caused by chemical, microbiological or physical hazards in food. All three types of hazards can be present on or in seaweed. The degree of presence of the hazards in seaweed can vary and depends, among other things, on the type of seaweed, the area of cultivation, the harvesting season. The processing steps that seaweed undergoes for consumption may further reduce the presence of the hazards. To what extent this happens is unclear.

Seaweed (sea lettuce and sugar kelp) farmed and researched in the Netherlands contains iodine, heavy metals and other contaminants. Based on the measured levels in fresh, unprocessed seaweed and the seaweed consumption of Dutch consumers, BuRO concludes that the daily consumption of this seaweed in large portions of more than 90 grams wet weight or more than 13 grams dry weight may lead to a risk to the health of the consumer due to the presence of iodine, lead, inorganic arsenic and PFAS. Processing seaweed can reduce the levels of contaminants. In particular, by washing seaweed, there appears to be a significant reduction in the levels of iodine, lead and inorganic arsenic. As it is highly plausible that Dutch seaweed is also washed for consumption, risks associated with the consumption of processed seaweed are estimated to be low. An European study by EFSA on seaweed-based foods shows that the consumption of seaweed, seaweed-based products and halophytes by seaweed consumers can make a major contribution to the intake of iodine and heavy metals (notably cadmium). There is no European legislation yet with maximum levels for iodine and contaminants in seaweed (products). The European Commission is now working on setting maximum levels for iodine and metals in seaweed (products).

Seaweed contains a wide variety of micro-organisms, including pathogens naturally occurring in seawater or seabed (notably *Vibrio* spp., *B. cereus* and very likely *C. botulinum*) or pathogens originating from humans and/or animals (notably *Salmonella*, STEC, *L. monocytogenes* and norovirus). The main introduction route of this latter group of microorganisms is the proximity of a sewage discharge point or overflow to the farming or harvesting area. Seaweed does not appear to play a role in human exposure to parasites and viruses (except norovirus). There is still much uncertainty about the germ-reducing effect of various processing steps that seaweed can undergo for consumption. The few outbreaks described in the literature mainly concern contamination by pathogens originating from humans and/or animals (e.g. *Salmonella*, STEC, norovirus). Seaweed, like fish, does not generally seem to accumulate microorganisms, as filter-feeding molluscs can. In the absence of sufficient data on seaweed, a relative risk assessment has been made in relation to the risk of consumption of fish, crustaceans and molluscs. It has been concluded that the risk of

contracting a contamination by pathogenic microorganisms via consumption of seaweed is very likely to be lower than the risk of contamination by these pathogens via consumption of molluscs (oyster, mussels) and is likely to be comparable to the risk of these pathogens via consumption of raw fish. The chance of contracting an contamination through consumption of seaweed is therefore low to very low.

The basis for the risk assessment of the physical hazards caused by foreign objects is that the products must be free of foreign objects. However, a foreign object in food does not directly pose a risk to the consumer. This is related to the size and shape of the objects. The main physical hazards in seaweed are (pieces of) crustaceans and small stones to which the spores of seaweed attach to grow. The main method of removing the foreign objects that came with the harvest of the seaweed is rinsing, although the removal of the barnacles often have to be done mechanically. There is no information of the occurrence of foreign objects in Dutch-farmed seaweed.

Nature – alien species

Alien seaweed species pose a risk to nature. Alien seaweed species that form large plants can radically change the ecosystem because their presence affects the flow and sedimentation in an area. This has an effect on the species present in the area, but also on the hydromorphological characteristics of the area. There are also alien seaweed species that are so dominant that they displace other species and there are species that are degraded so quickly that the oxygen content of the water decreases, which can cause mortality in all kinds of species, especially in closed inland waters. All this can also have a negative impact on the achievement of the conservation objectives set for Natura 2000 sites, as well as on the objectives of the WFD.

Alien seaweed species that are eligible for cultivation are usually fast growing species. Many of these species are therefore likely to have a negative impact on nature. Because seaweed can disperse through currents, there can be an impact not only on the area where the seaweed is grown, but also on areas further away. However, not all alien seaweed species have an impact on nature. In addition, it also depends on the area and the species already present there if and what impact an alien seaweed species will have. An alien seaweed species does not have to have the same impact in all areas in the Netherlands. Also, the impact of an alien seaweed species in nearby countries may be different from its impact in the Netherlands.

There are regulations for the use of alien species in aquaculture, so that alien species that are not yet present in the Netherlands can only be grown in an open aquaculture facility if this presents a 'low' risk and a permit has been issued.

However, this regulation does not apply to alien species that are already present in the Netherlands. Even if the alien species does not or hardly occurs in the area where one wants to grow it and cultivation can therefore pose a risk to nature. Once a species has been found in the Netherlands, no permit is required on the basis of the Alien Species in Aquaculture Regulation. There is a permit requirement for the cultivation of alien species that are not yet present in the Netherlands, but it is unclear who is responsible for granting the permit in the case of seaweed. Also, there is currently no supervision or enforcement of this Regulation by the NVWA or any other supervisory authority.

For authorisation in general, it is important to use the specific Latin name of the species that may be grown. If common names for species, or if Latin names for genera are used, there is a chance that alien species may be grown inadvertently within a permit.

There are several alien seaweed species (Agardh's red weed, Japanese wireweed, southern sea lettuce and wakame) that are farmed or wild harvested in parts of the Netherlands. These alien species have an impact on Dutch nature. However, the current activities do not increase the impact of these seaweed species on nature, as the alien species are already common in the areas where they are grown. The cultivation of these seaweed species in these areas therefore does not pose an additional risk to nature as long as locally collected starting material is used.

The alien seaweed species (dulse, winged kelp, thongweed and wakame) that are potentially suitable for cultivation in wind farms also pose no additional risk to nature when the starting material comes from the immediate vicinity of the wind farm. Japanese wireweed and southern sea lettuce are already common along the entire Dutch coast, and dulse, winged kelp and thongweed cannot establish in the Netherlands. Wakame is found in a few places in the Netherlands. It only

grows here in relatively sheltered places. As long as starting material collected locally is used for cultivation, any individuals of wakame that could reach the Wadden Sea from a wind farm will only grow in relatively sheltered places. Therefore, they will in all likelihood not increase the impact of wakame on nature, partly because there is already a wakame population near the marina in Terschelling and wakame also occurs further north in the Wadden Sea.

However, where starting material of the above species is used for cultivation that is not collected locally, the alien seaweed grown may have different characteristics than the alien seaweed already present in the area. The seaweed grown could have a greater impact on the area. Using starting material from another area therefore poses a risk to nature. Cultivars and hybrids may also have characteristics that differ from the characteristics of the species (native or alien) used for their development. There is a deliberate search for seaweed with properties that are beneficial for seaweed cultivation, because they increase production or ensure that the seaweed can be grown in more places. However, these properties can increase the risk to nature.

The use of starting material from another area also poses a risk to nature, because alien species can hitchhike with the starting material. This may result in the introduction and establishment of these species in the Netherlands, or in their spread to other parts of the Netherlands. Among the species that may hitchhike are also alien species with an impact on nature.

Seaweed farmers previously indicated that the starting material for cultivation was collected locally. The striking increase in the number of alien seaweed species found for the first time in the Netherlands is an indication that this is not always the case anymore. A relatively large number of the new seaweed species belong to groups that are grown elsewhere. It is possible that starting material of alien species has been imported unintentionally, because species from these groups are not or hardly distinguishable from native seaweed species on the basis of their appearance.