Interreg
Kofinanziert von der Europäischen Union
Deutschland – Danmark

MACRO ALGAE

Resources of the Future from the Sea

ECOSYSTEM SERVICES & HIDDEN POTENTIAL

ALGAE FOOD

This information brochure was produced as part of the Interreg Germany-Denmark project AlgaeFood. Interreg is an EU funding programme that supports cross-border cooperation between Germany and Denmark. The aim of the three-year project is to increase awareness of algae as a healthy food ingredient and as an essential component of aquatic ecosystems.

Our goals

1

Identify regional algal species that
- are suitable for consumption,
- can be harvested sustainably, and
- can be used economically.

2

Increase awareness and social acceptance of tasty algae-based foods.

3

Motivate and enable people to cook with algae, e.g. through cooking workshops and activities in schools.

Coastal Research & Management

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MACROALGAE:
RESOURCES OF THE FUTURE FROM THE SEA
ECOSYSTEM SERVICES & HIDDEN POTENTIAL

ALGAE FOOD

WHAT ARE ALGAE?

Algae are true survival artists and belong to the most diverse groups of organisms in the water. Worldwide, scientists estimate the number of algal species at almost **500,000** – an enormous biological diversity found in nearly all waters on Earth.

The majority of these species are so-called **microalgae**: tiny, often single-celled organisms found in fresh and salt water. They usually float freely in the water, form the foundation of the food chain and are responsible for a significant share of global oxygen production – more than all tropical rainforests combined.

Equally fascinating are the multicellular **macroalgae**, which also include the typical “seaweeds”. Around **10,000 species** have been described so far. In contrast to their microscopic relatives, they can grow several metres in length. They live predominantly in the saline coastal waters of the oceans. Particularly impressive are the large brown algal species that form dense **kelp forests** – diverse underwater forests that serve as habitat, a food source and oxygen producers for numerous marine animals.

This diversity can also be discovered in our local waters: in the **Baltic Sea** there are about **200 different macro-algal species**, while the overall more species-rich **North Sea** hosts around **350 species**.

Photo 1: Algae zoning: green algae, brown algae, red algae

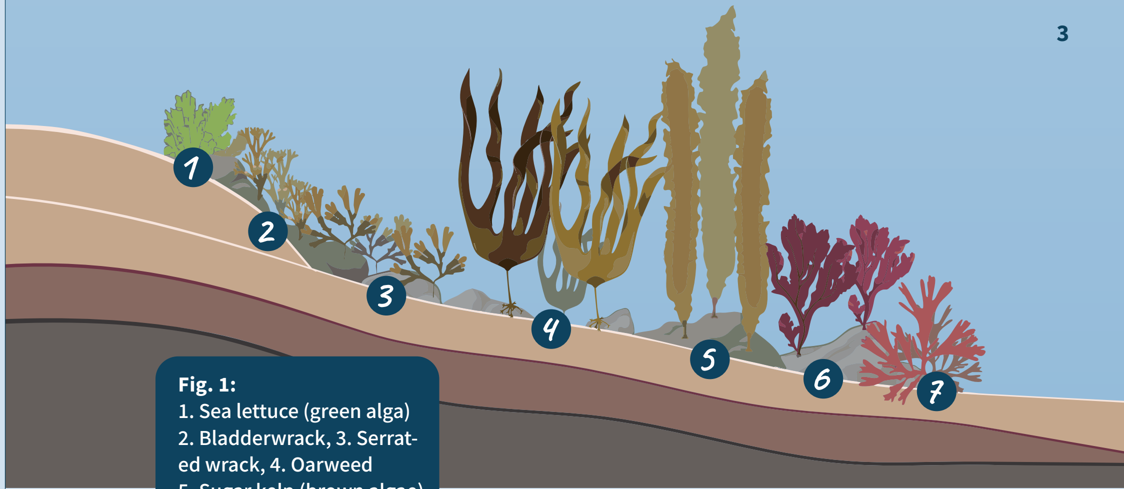


Fig. 1:
1. Sea lettuce (green alga)
2. Bladderwrack, 3. Serrated wrack, 4. Oarweed
5. Sugar kelp (brown algae)
6. Red dulse, 7. Sea sorrel (red algae)

Along our local coasts you can easily distinguish the three major groups of marine algae with the naked eye. Their group affiliation is often recognisable simply by their colour, because the different pigments they use for photosynthesis determine not only their appearance but also the water depths in which they can thrive, depending on how far the light penetrates the water and the alga’s composition of pigments or “chromophores” (such as phycobilins, chlorophylls and carotenoids, which absorb or reflect different colours).

Greenalgae appear bright green because chlorophyll dominates – the same pigment found in land plants. For effective photosynthesis, they need lots of light and relatively high levels of nutrients. They therefore prefer shallow waters directly below the waterline, where sunlight can still penetrate unhindered.

Brown algae, which include well-known species such as kelp or bladderwrack, possess brown pigments such as fucoxanthin in addition to chlorophyll. These pigments allow them to carry out photosynthesis efficiently even in lower-light conditions. Brown algae therefore colonise the middle depth zones, below the green algae.

Red algae, in turn, are recognisable by their reddish to violet colours, which come from the pigment phycoerythrin. This pigment is particularly light-sensitive and enables red algae to use even the weaker light available at greater depths. They are therefore often found in the lowest algal zone and can grow – depending on water clarity – down to depths of about 20 metres or more.

This zonation is not only a fascinating example of ecological niche formation, but also a good indicator of how algal growth is linked to the light conditions in their habitat – and how they have adapted and evolved over time.

ALGAL SPECIES IN THE BALTIC SEA

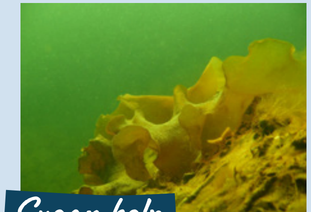
With unique properties for people & marine life

Bladderwrack

(Fucus vesiculosus)
Bladderwrack is a perennial brown alga common in the North and Baltic Seas. Its fronds are 10–30 cm long and are characterised by the gas-filled bladders on the blades, which give the alga buoyancy in the water. It is used as a dietary supplement and in medicine.

Serrated wrack

(Fucus serratus)
Serrated wrack often grows in the same places as bladderwrack. It is closely related to bladderwrack but has no bladders. Instead, the ends of its blades are serrated like a saw. Its properties are currently being researched, but in Ireland is traditionally used in thalassotherapy as an exfoliating body scrub.



Sugar kelp

(Saccharina latissima)
The blades of sugar kelp are amber-coloured, can grow several metres long and have a wavy edge. Its components are mainly used in cosmetics, but also in food.

Oarweed

(Laminaria digitata)
Oarweed is a perennial brown alga that can grow from one to several metres long. Its alginates are used primarily as thickeners in the food industry and as substrates in medicine.

Sea lace

(Chorda filum)
Sea lace can grow over 2 m long and is an annual brown alga. Initial cultivation trials in the Baltic Sea have been successful. Its properties are currently being researched.

Sea lettuce

(Ulva lactuca)
Sea lettuce is a green alga and the fastest-growing marine alga. Ulva is used as a nutrient filter for aquaculture effluent. There is initial research into the medical use of its components (ulvans). It is also a traditional food in Ireland and France.

Red dulse

(Palmaria palmata)
Red dulse is relatively rare in the Baltic Sea but more common in the North Sea and the Atlantic. Dulse is a very popular superfood due in part to its nickname “bacon of the sea”.

Sea sorrel

(Delesseria sanguinea)
The first cultivation of sea sorrel took place in 2010 at the Baltic Sea reef off Nienhagen. The pharmacological properties of this red alga are of particular interest and are being researched.

Furcellaria

(Furcellaria lumbricalis)
Furcellaria is widely used in Estonia as a gelling agent in sweets and jams. It contains valuable substances for cosmetics and biostimulants, as well as for medical research.

WHAT CAN ALGAE DO?

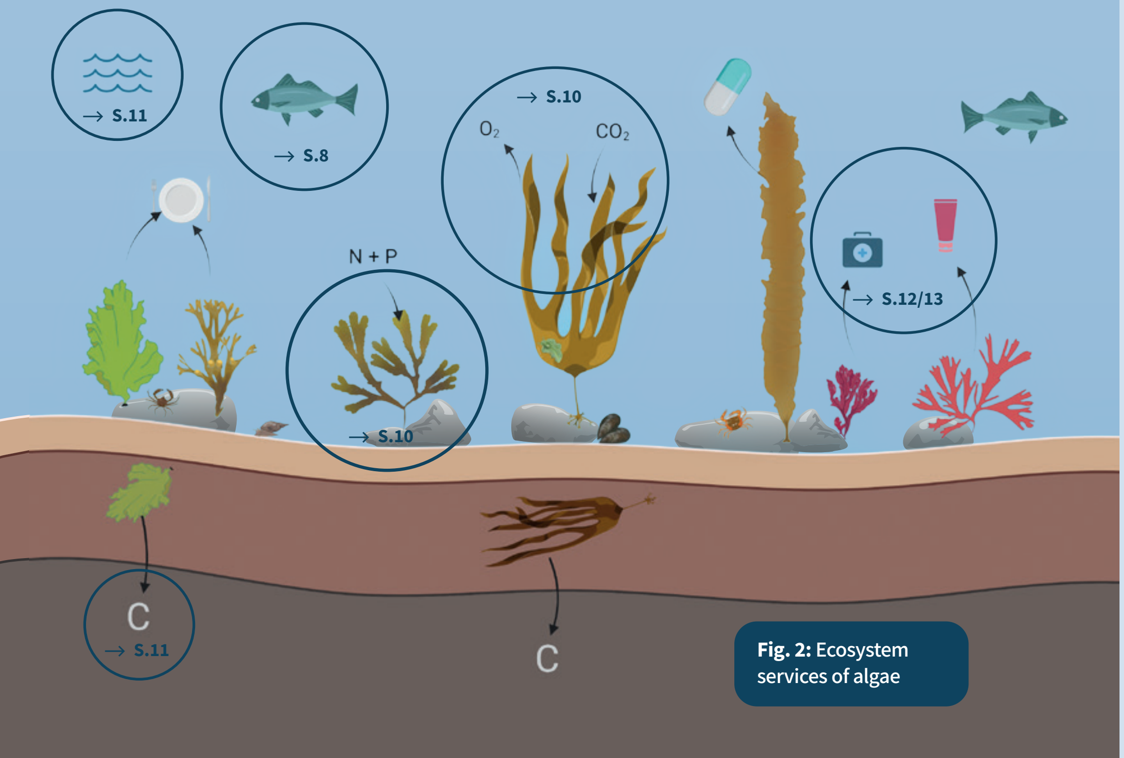


Fig. 2: Ecosystem services of algae

Algae provide us with a wide range of ecosystem services – free of charge:

1. **LEBENSGRUNDLAGE**
   BASIS OF LIFE
   Algae are at the very foundation of the marine food chain. Like land plants, they produce the oxygen essential for life via photosynthesis. Every second breath we take comes from the sea!

2. **ALL-ROUND PROVIDERS**
   Many algae are edible and tasty and they purify our water. They can be used in packaging, textiles, cosmetics, as natural fertiliser, feed additives and building materials. The components of algae are being intensively researched and are promising candidates for medical products and future remedies.

3. **GUARDIANS OF NATURE**
   Algae absorb excess CO_2 and nutrients, regulate chemical processes and the heat balance in the sea. Algal forests, like seagrass meadows, reduce the force of waves and protect inhabited coasts from flooding. They promote and preserve biodiversity in the sea.

4. **“BALM FOR THE SOUL”**
   Algae are not only useful but also beautiful to look at, with their diversity of sizes, shapes and colours. During walks on the beach we breathe in – along with mineral salts – many health-promoting sub-stances released by algae (e.g. polyphenols). On coastal safaris, snorkelling or diving trips we can marvel at species-rich underwater meadows and forests.

ALGAE ARE IMPORTANT **HABITATS**

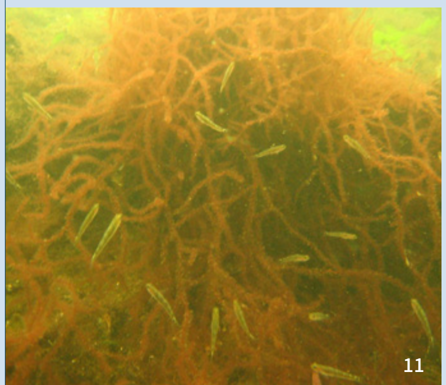
Algae form their own ecosystems and high-quality **BIOTOPES** in all the world's oceans, including the Baltic coast, such as kelp forests and seaweed meadows.

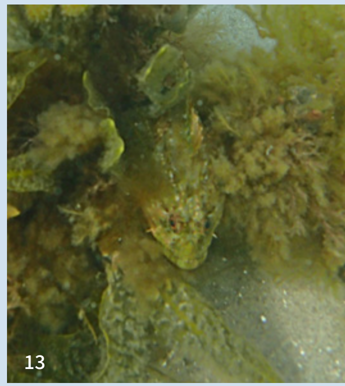
Most algae need solid substrates on which to settle; only a few species live freely floating in the water. In the Baltic Sea, so-called "stone fishing" was carried out from the 1930s until the 1970s, removing a 3.5 million tonnes of the important habitat for macroalgae (such as bladderwrack and serrated wrack). As part of ecological compensation measures, new **REEFS MADE OF NATURAL STONES** are now being placed under water at suitable sites to restore these species-rich habitats. In Germany, reefs (e.g. stones covered with macroalgae) are legally protected biotopes and are classified as habitats of European conservation importance (Fauna-Flora-Habitat Directive, habitat type 1170).

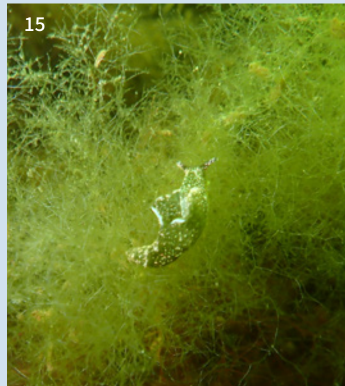
Macroalgae are **BIODIVERSITY HOTSPOTS:** they are habitat for other algal species and many other marine organisms. They provide hiding places and nurseries for crustaceans and fish, and are an important food source for fish, snails and plankton.

With their varied structures, algae offer much larger settlement surfaces than bare stone or sand. This benefits the spawning (egg-laying) of fish and snails. Algae form their own complex and **SPECIES-RICH MINI-ECOSYSTEM.** They are key building blocks of marine diversity – habitat, refuge and food source, all in one.

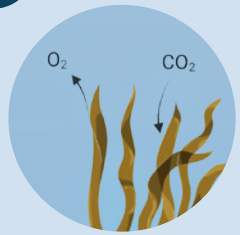
Foto 11: Photo 11: Swimming shrimps in front of a small stone reef overgrown with red algae
Photo 12: Rockpool prawn
Photo 13: Hidden fish (sea scorpion)
Photo 14: Young starfish
Photo 15: Green sea slug







ALGAE ARE GOOD FOR THE **CLIMATE!**

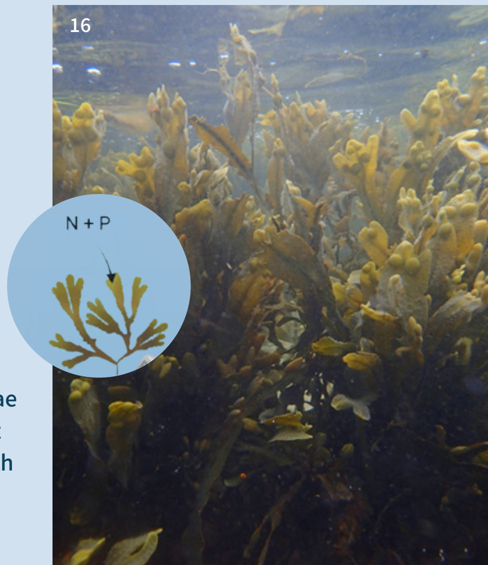


Algae absorb carbon dioxide (**CO_2**) and produce the vital oxygen (**O_2**) through photosynthesis. In the case of macro-algae this amounts to around **5 MILLION TONNES PER YEAR,** similar to the Amazon rainforest! Roughly every second oxygen molecule comes from algae in the sea.

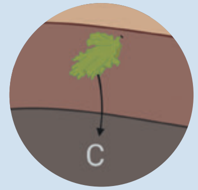
Algae regulate the **pH** of seawater and thus counteract ocean acidification. In this way they help calcifying shell-forming animals such as mussels, snails, corals and foraminifera to build their hard, calciferous shells, which also bind carbon from the water.

Algae absorb **NUTRIENTS**, especially **NITROGEN (N)** and **PHOSPHORUS (P).** Without this natural filtration mechanism, nutrients accumulate and lead to over-fertilisation of the water – so-called **EUTROPHICATION**. This has far-reaching consequences and is unfortunately already evident in many coastal regions, particularly the Baltic Sea: oxygen depletion, the die-off of entire communities of organisms, the spread of overgrowing filamentous algae and toxic microalgal blooms. Macroalgae help counteract this process and thus contribute to the stability and health of marine ecosystems.

Photo 16: Algae (here: bladder-wrack) absorb nutrients and help keep the water clear.



Algae are a **CO_2 SINK AND CO_2 STORE**: around **100,000 TONNES OF CARBON (C)** are bound in algal biomass through photosynthesis or stored in algal remains on the seabed. Macroalgae are estimated to bind **1–2 GIGA-TONNES OF CO_2** per year. About 10% of this sinks to the seafloor. According to current knowledge, it takes **600 TO 1,000 YEARS** before the CO_2 contained in this biomass is released back into the atmosphere.



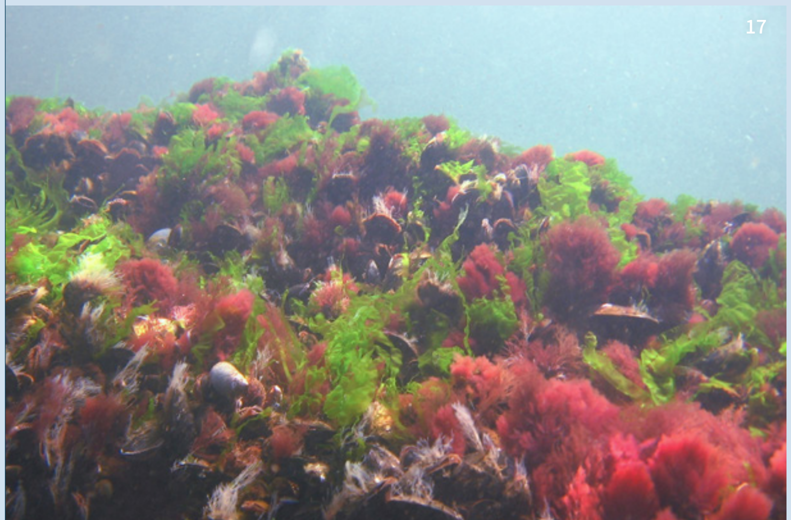
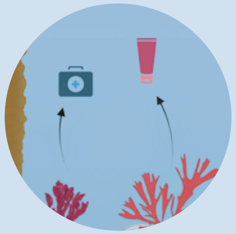


Photo 17: Mussel bank biotope with sea lettuce and red algae

Algal forests – especially large brown algae – make an important contribution to **COASTAL AND FLOOD PROTECTION**. Like living breakwaters, they dampen the force of incoming waves before these reach the coast. This slows the current, which not only reduces the energy of the waves but also lessens erosion of sand and rock. In this way, algal forests naturally counteract coastal erosion and stabilise coastal ecosystems. In times of increasing storms and rising sea levels, they are valuable allies to help us adapt to a changing climate.

Photo 18: Coastal protection by bladderwrack stands in shallow water

ALGAE ARE GOOD **FOR US!**



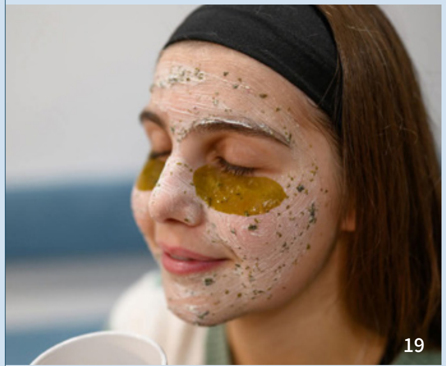
Algae are used in many ways for both internal and external applications:

- **FOOD:** They provide dietary fibre, unsaturated fatty acids and many important minerals and vitamins – with most kelps especially high in iodine!
- **DIETARY SUPPLEMENTS:** Algae contain special sugars that do not occur in land plants, as well as antioxidants and trace elements.
- **SKIN CARE:** Algal sugars act as moisturisers and free radical scavengers.
- **MEDICAL RESEARCH:** Extracts from brown algae have shown promising effects against cancer cells in initial laboratory studies. The active components – antioxidants and fucoidans – are being studied in more detail.

Healthy all-round!

Algae contain valuable substances that can act, among other things, as:

-> antiviral
-> antitumour
-> antibacterial
-> antioxidant (free radical scavengers)
-> anti-inflammatory
-> moisturising (for the skin)
-> regulators of the gut microbiome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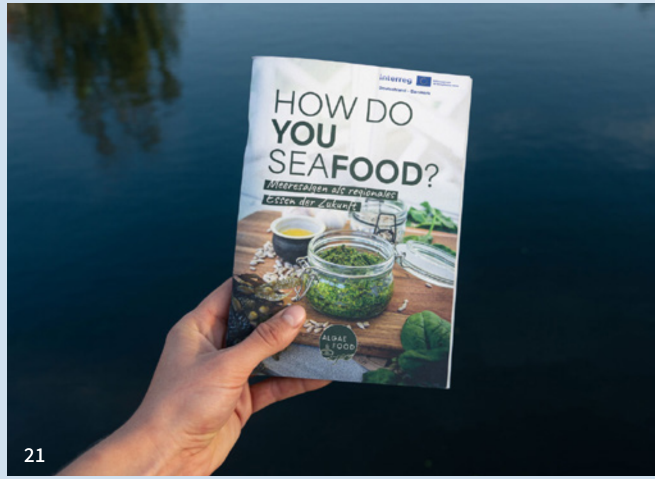

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Photos 19+20: Cosmetic uses of algae
Photo 21: AlgaeFood brochure with many recipe ideas for the kitchen
Photo 22: Lasagne with oarweed

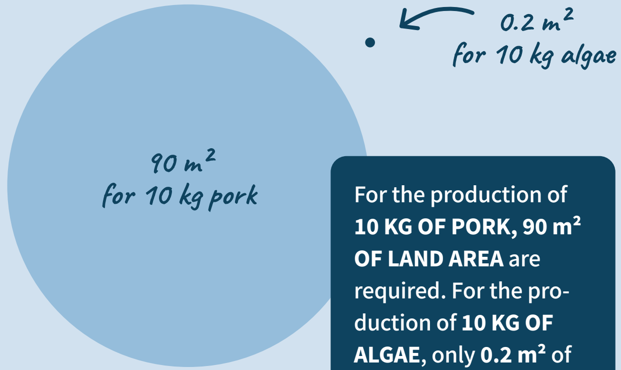
Recipe ideas

Algae are tasty and extremely versatile, even in home cooking! You can find more information and recipe ideas in the “How do you seafood?” brochure, also produced in the AlgaeFood project.

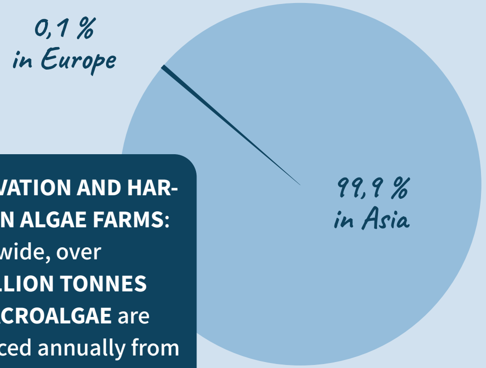
HOW CAN WE USE ALGAE **SUSTAINABLY?**

Gentle **WILD HARVEST** along the coasts: Worldwide, **1 MILLION TONNES OF ALGAE PER YEAR** are harvested from wild stocks, almost a third of this in Europe (280,000 t).

Photo 23: Gentle wild harvest of bladderwrack on the Danish Baltic coast



For the production of **10 KG OF PORK, 90 m² OF LAND AREA** are required. For the production of **10 KG OF ALGAE**, only **0.2 m²** of sea space are needed, with no freshwater or antibiotics!



CULTIVATION AND HARVEST IN ALGAE FARMS: Worldwide, over **36 MILLION TONNES OF MACROALGAE** are produced annually from commercial aquaculture. The vast majority (> 99 %) is produced in Asia; only **0. 1%** in Europe **(30,000 t)**.[1]

RESOURCE-SAVING FOOD AND RAW MATERIAL PRODUCTION WITH ALGAE FARMS AND SEA GARDENS: No use of land area or freshwater, no need for fertilisers or pesticides.

The first **ALGAE FARM IN GERMANY** in the Baltic Sea was established in 1999 by the company **CRM** in Kiel. The underwater farm was created by divers in the Kiel Fjord, cultivating sugar kelp – the largest native brown alga. In 2008, mussels were added, forming a nutrient cycle in an **INTEGRATED MULTI-TROPHIC SYSTEM.** There are plans to integrate a third trophic level in the form of sustainable fish farming.[2]

Photo 24: First algae farm in Kiel (from 1999)
Photo 25: Algae farm in Kerteminde (Denmark)

[1] Figures: Food and Agriculture Organization of the United Nations (FAO), 2022
[2] More information at: https://www.kieler-meeresfarm.de

REGIONAL **SEA GARDENS** IN THE BALTIC SEA

Regenerative, community-based cultivation of “sea vegetables” has been established in Denmark for 10 years. There is a large community of around **40 SEA GARDENS,** where oysters, blue mussels and edible algae are cultivated on ropes or floating platforms in coastal areas. The sea gardens are run by associations whose members tend the gardens and share the harvest – like an “underwater allotment garden”.

The Danish association **HAVHØST** was founded in 2015 and, in addition to organising the sea gardens, also provides an educational space for schools. This helps raise pupils’ awareness of marine conservation and the production of food from the sea.
More information: https://havhøst.dk/about-havhoest/

Fig. 3: Nutrient balance in aquaculture, e.g. community sea gardens with mussels and algae

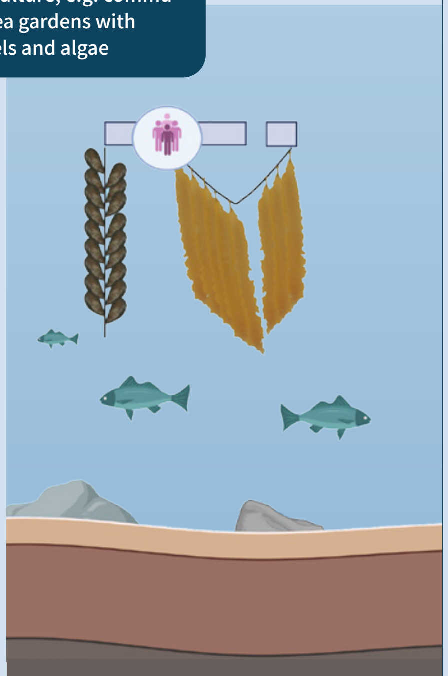


Photo 26: Community sea garden in Copenhagen (Denmark)
Photo 27: Sea garden in Flensburg

SHOULD THERE BE SEA GARDENS IN GERMANY TOO?

We think: yes!

In Flensburg, in partnership with German and Danish stakeholders, the first sea garden was established in 2024. Sugar kelp and blue mussels are already growing in the fjord and are maintained and harvested with the help of volunteers. Find out more at: https://www.flensburger-meeresgarten.de/

Further gardens for non-profit use are being planned. More information is available from the projects CoolBlue and CoolBlueBaltic (https://coolbluefuture.org/).

The advantages

- -> healthy and sustainable food for people
- -> greater biological diversity at the sea-garden sites
- -> improved balance of the marine ecosystem
- -> community use by enthusiastic people committed to protecting the sea
- -> educational space for children and young people on marine conservation and nutrition

WHAT **OTHER USES** DO MACROALGAE HAVE?

Numerous **RESEARCH PROJECTS ON ALGAE** are exploring further properties and fields of application. Here are some current examples.

Photo 28: Extracts from bladderwrack (Fucus vesiculosus)
Photo 29: Sustainable algae collection
Photo 30: Research on brown algae in Kiel

AlgaCalma

The *AlgaCalma* project aims to develop a special textile coated with substances from algae to help people with the skin disease atopic dermatitis (AD). This disease causes chronic skin irritation, inflammation and severe itching. The project focuses on the anti-inflammatory effect of native large algae, whose extracts can strengthen the skin barrier. These extracts are to be optimally applied to textiles worn by patients, helping to alleviate AD symptoms.

AlgaeProBANOS

The *AlgaeProBANOS* project, with a total of 26 European partners from science and industry, aims to demonstrate the feasibility and market accessibility of sustainable, innovative algae-based products and solutions in the Baltic and North Sea regions. In cooperation with University Hospital of Schleswig-Holstein in Kiel (UKSH), the project will first investigate the effects of **FUCOIDANS** (sugar compounds from brown algae) on age-related macular degeneration – an eye disease that leads to loss of vision in the area of sharpest sight.

BlueBioPol

This project is exploring new treatment options for chronic diseases such as cardiovascular disease and joint degeneration. Special carrier materials are to be developed that can transport active substances, genes or cells precisely to where they are needed. Natural substances from the sea – so-called marine biopolymers – play a key role here. One example is alginate, obtained from native algae. This alginate is processed in such a way that it serves as a building block for gels or tiny particles. These can store active substances and then release them in a targeted way inside the body.

Greengold

The *Greengold* project aims to develop sustainable land-based cultivation systems for the green algal species Ulva and Chaetomorpha spp., in order to use them as novel sources of phycocolloids (gelling polysaccharides) for the cosmetics industry. Further goals include strengthening the German macroalgae industry by diversifying the cultivated species and utilising previously underused algal resources, as well as promoting sustainable business models for integrated aquaculture.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PolySpon


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This project is developing an aquaculture system for the production of the collagen-rich sponge species Chondrosia reniformis, based on the concept of integrated multi-trophic aquaculture (IMTA). The sponges are kept together with the macroalga sea lettuce (Ulva lactuca) and European seabass (Dicentrarchus labrax). The excretions of the sea-bass serve as nutrients for the sea lettuce and as food for the sponges, whose ability to absorb nutrients and purify water is harnessed in the system.

Applied practice: habitat networks

Habitat networks on land and under water help secure and interconnect habitats. On behalf of the Environment Office of the City of Kiel, CRM has developed a habitat network concept that is being successfully implemented in the Kiel Fjord as part of ecological compensation measures. Underwater biodiversity is promoted and the genetic as well as trophic connection between isolated biotopes is ensured. Large algae such as sugar kelp and bladderwrack in particular find new settlement opportunities on the natural stones placed in the Baltic Sea.

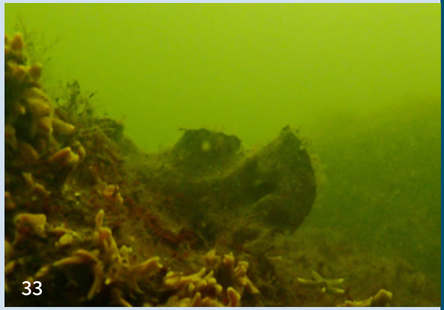
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Photo 31: Ulvan extraction in the laboratory
Photo 32: Native green algae for aquaculture
Photo 33: Underwater reef with sugar kelp and sponges

ALGAE FOOD

Plumb the hidden depths of macroalgae!

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ALGAE FOOD

Ecosystem services and the potential of macroalgae

1. Valuable biotopes in the sea
2. Climate and environmental protectors
3. Food, skin care and medicine of the future

Discover fascinating facts about algae in general and in detail: why they are good for people and marine life, and what hidden properties are yet to be discovered. In this brochure, find out more about innovative projects in the Baltic Sea region!

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