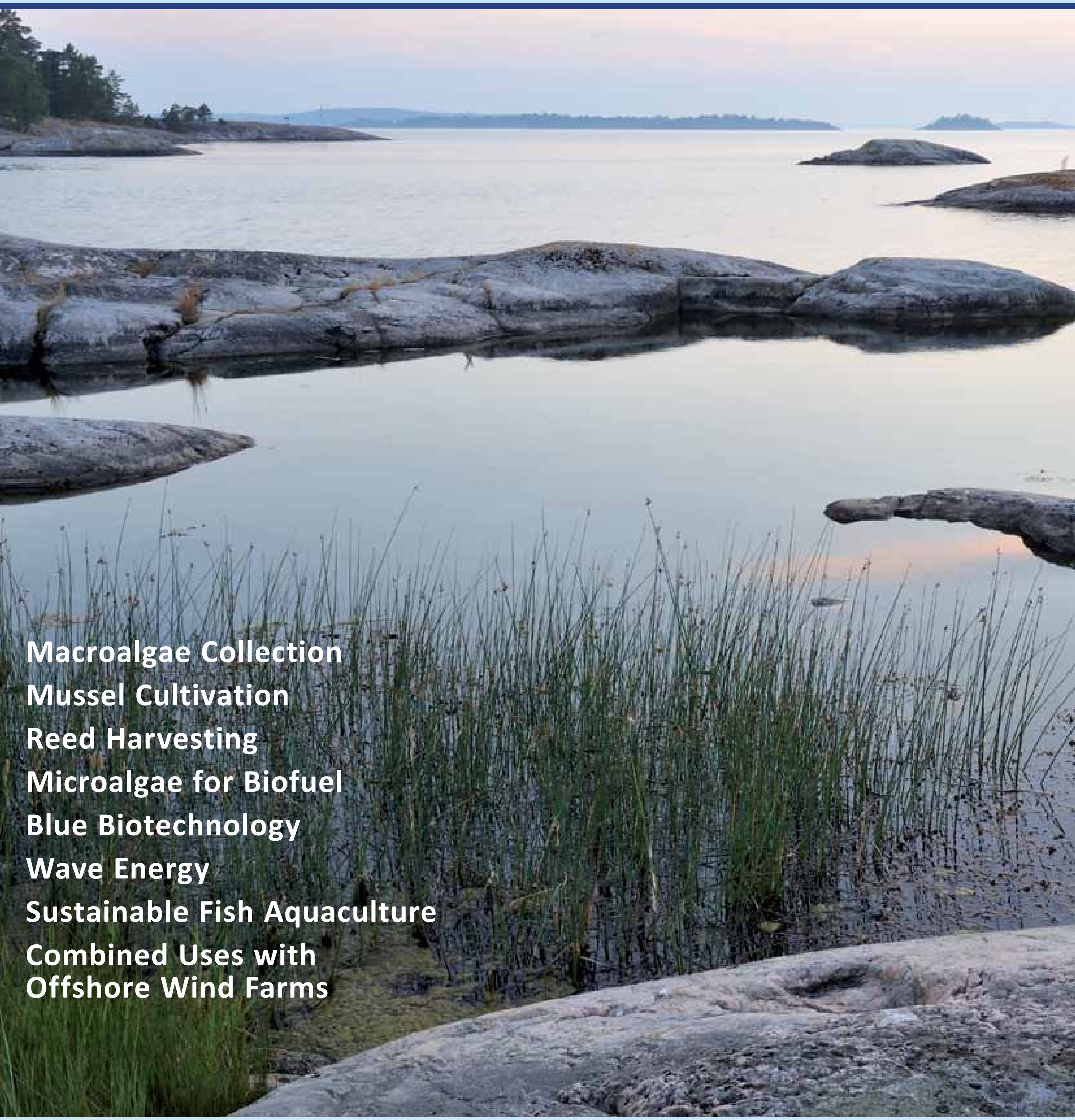
SUBMARINER

Sustainable Uses of
Baltic Marine Resources

Innovative Marine Uses at a Glimpse



Macroalgae Collection
Mussel Cultivation
Reed Harvesting
Microalgae for Biofuel
Blue Biotechnology
Wave Energy
Sustainable Fish Aquaculture
Combined Uses with Offshore Wind Farms

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(European Regional Development Fund)

Baltic Sea Region
Programme 2007–2013

www.submariner-project.eu

Dear Reader!

The SUBMARINER project partners are building the road for furthering environmentally friendly and economically appealing innovative uses within the Baltic Sea Region. This publication highlights how the Baltic Sea Region's environment, economies and societies can benefit from innovative uses of Baltic marine resources. Did you for example know that algae and mussels may reduce nutrient concentrations in the water while at the same time providing a source for bioenergy? Or have you ever thought about how many marine microorganisms provide the basis for new products for pharmaceutical, cosmetic and food industries?

This publication can only give you a short overview of the possible uses that we are currently analysing and discussing. SUBMARINER will also publish a detailed inventory of current and potential future marine uses and recommendations for the further promotion of beneficial uses in its SUBMARINER Compendium.

Stay tuned on our website www.submariner-projects.eu for further announcements.

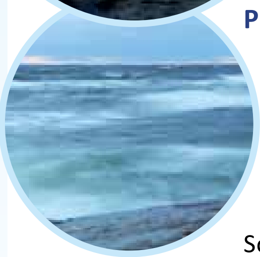
Joanna Przedrzymirska
The Maritime Institute in Gdańsk
SUBMARINER Lead Partner

Promoting innovative marine uses

The Baltic Sea Region faces enormous challenges including new installations, fishery declines, excessive nutrient input, the effects of climate change as well as demographic change. But novel technologies and growing knowledge also provide opportunities for new uses of marine ecosystems, which can be both commercially appealing and environmentally friendly. SUBMARINER provides the necessary basis for the region to take a proactive approach towards improving the future condition of its marine resources and the economies that depend on them.

The Baltic Sea – a vulnerable ecosystem

The Baltic Sea is the world's largest brackish sea, being comparatively shallow with an average depth of only 55 m. Large salinity variations characterize the Baltic Sea, with very low salinity levels in the Gulf of Bothnia and the Gulf of Finland. The Baltic Sea's ecosystem is fragile and particularly vulnerable to the effects of natural variability, introduction of alien species, the input of organic pollutants and large-scale human disturbance. Eutrophication and over-fishing have been the foremost cause of ecosystem deterioration.



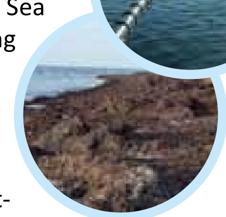
Political Strategies

European seas and oceans, including the Baltic Sea, are increasingly recognised as important pillars in order to meet environmental targets as well as to achieve sustainable economic growth.

Some samples: the European Commission's **Renewable Energy Roadmap** calls for a mandatory target of a 20 % share of renewable energies in the EU's energy mix by 2020. As a result, the Baltic Sea Region countries are looking for ways to boost e.g. offshore wind energy, bioenergy or wave energy.

The sustainable use of marine resources can also substantially contribute to the nutrient reduction targets set by the **HELCOM Baltic Sea Action Plan**. The maximum allowable nutrient inputs to the sea were set up on the level of about 21,000 tons of phosphorus and 600,000 tons of nitrogen per year.

The EU's **Blue Growth Initiative** aims at fostering smart, sustainable and inclusive economic and employment growth from the maritime sector. A related background paper expects the importance of the Baltic Sea Region to increase for e.g. Blue Biotechnology.



Numerous countries throughout the Baltic Sea Region are currently developing or updating **Maritime Spatial Plans**. For this purpose, it is important to understand how much space needs to be set aside for future uses, possible combinations and cumulative impacts of them and their possible co-existence with protected areas (e.g. Natura 2000).

Scope

For decision-makers, it is currently difficult to judge which uses are most desirable and what actions are necessary to create a framework beneficial to their development while discouraging potentially damaging applications.

SUBMARINER is thus for the first time providing a comprehensive assessment covering not only natural science, but also economic, technological, institutional and legal aspects of marine uses.

The assessment encompasses those marine uses which seem promising with regards to environmental as well as economic aspects. For most of those uses, pilot sites are already in place, but no full-scale commercial applications:

Macroalgae Collection & Cultivation: Free floating or beach cast macroalgae can be collected to support water quality, nutrient recycling and biogas production. They can also be cultivated in nearshore installations.

Mussel Cultivation: Nearshore mussel farms may support water quality and nutrient recycling and offer valuable feed stuff.

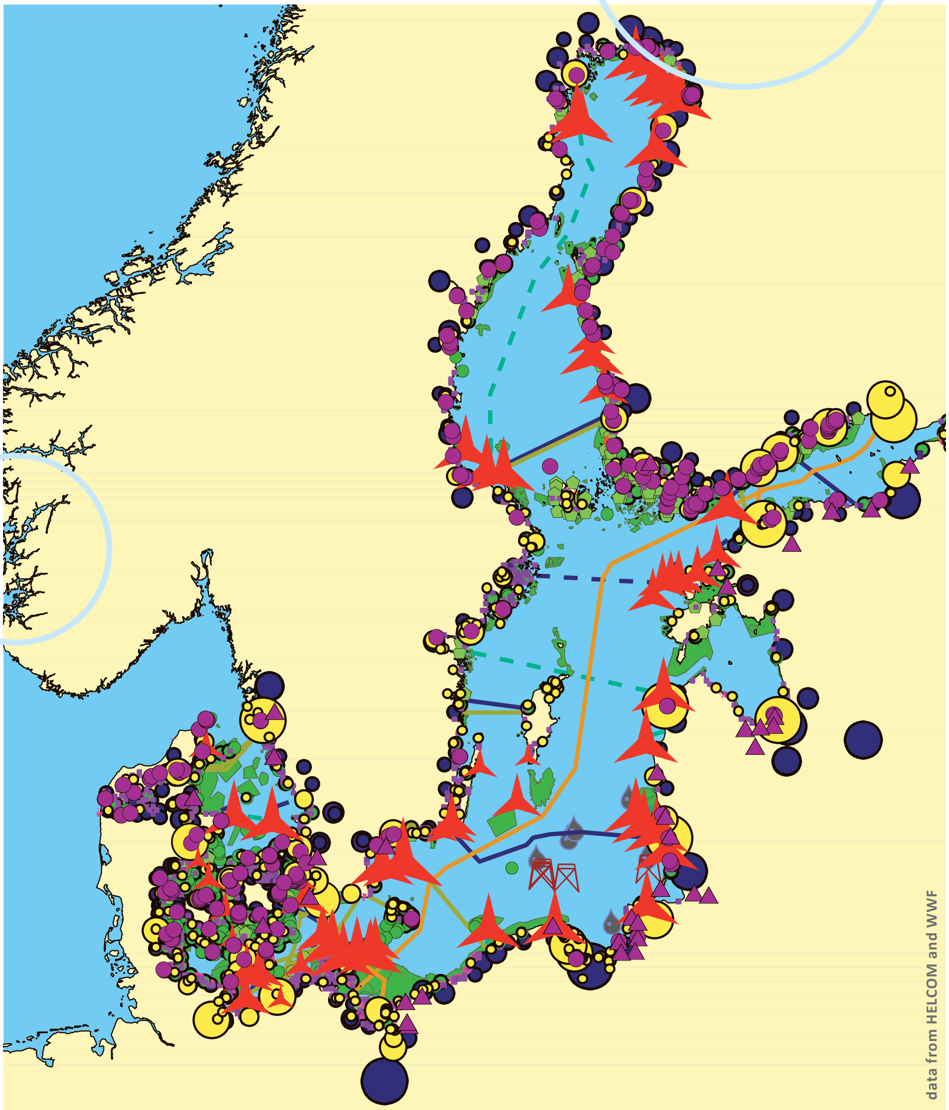
Reed Harvesting: Removing reed from nearshore reed beds can support nutrient removal and bioenergy production.

Microalgae for Biofuel: Cultivating microalgae can be carried out in land-based cultivation systems and coupled with CO_2 and nutrient-rich waste water streams.

Blue Biotechnology: By extracting valuable substances produced by marine micro and macro organisms, e.g. bioengineering, pharmaceutical, medical and cosmetic purposes can be supported in a sustainable manner.

Wave Energy: Developing novel wave energy devices may offer the Baltic Sea Region an additional alternative energy resource.

Sustainable Fish Aquaculture: Through innovative and environmentally sound technologies, fish aquaculture may be expanded also in the Baltic Sea in order to meet the rising demand for seafood for human consumption.



The Baltic Sea is already full of competing uses: fishing, energy cables and pipelines, tourism and recreation are some of them.

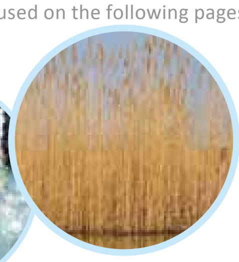
Potential Benefits of New Uses of Marine Resources

	Macroalgae Collection & Cultivation	Mussel Cultivation	Reed Harvesting	Microalgae for Biofuel	Blue Biotechnology	Wave Energy	Sustainable Fish Aquaculture	Combinded Uses with Wind Farms
Nutrient Recycling & Water Quality	●	●	●	●	●		○	●
Renewable Energy Resource	●	○	●	●		●		○
Biodiversity	○	○	○		○		●	
Societal: Health / Food	○	○			●		●	
Spatial efficiency				●			●	●

● = Main Benefit; ○ = By-product of main benefit

This colour scheme for the different benefits will also be used on the following pages.

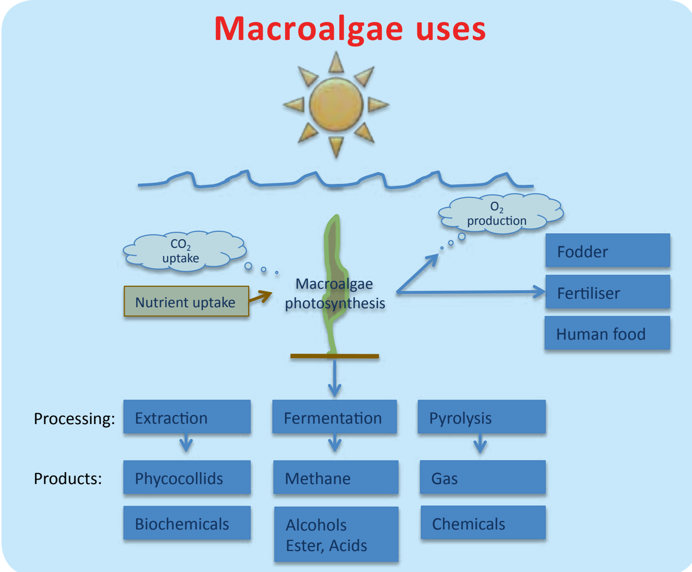
Combined Uses with Offshore Wind Farms: The possibility of combining offshore wind farms with cultivation of e.g. macroalgae, mussels and fish is explored in order to use the space between the individual wind mills efficiently.



Macroalgae collection: no longer a vision in the Baltic Sea Region

Macroalgae or seaweeds are plant-like organisms that live in the aquatic environment. They are classified as brown, red and green algae and – in contrast to microalgae – can be seen by eye. Macroalgae are of great ecological importance since they act as one of the primary producers in the marine food chain and assist in supplying oxygen to the sea.

Macroalgae can be used as substrate to produce renewable energy in form of e.g. bioethanol, biogas and biodiesel. At the same time, they function as biofilters that take up nutrients from the surrounding as they use nutrients like nitrogen and phosphorous for growth. As a side effect, fish stocks may increase when collecting dense macroalgae mats.



Collection of beach cast and free-floating algae

It is not likely that commercial harvesting of attached perennial macroalgae will be allowed in the Baltic Sea. The main reason is the very important ecological role of these macroalgae and the slow growth of species with marine origin in brackish conditions.

The collection of beach cast and free-floating macroalgae assemblages close to the shoreline, however, is already happening at different places around the Baltic Sea. Macroalgae beach cast is a problem for coastal tourism as it stops people from swimming and creates a bad smell. Cleaning beaches from beach cast improves the quality of life in coastal communities with positive impacts on tourism and increasing house values. At the same time, beach cast is a natural resource which is presently available without any costs, e.g. as a resource for biomass.

Other marine resources might be more efficient either from a nutrient removal or energy balance perspective. However, it is the combination of positive effects that makes the collection of beach cast attractive. Trelleborg in Southern Sweden and Solrød on Eastern Zealand (Denmark) are examples of municipalities that have already recognized this potential. Solrød is planning the construction of a biogas plant which shall – among other organic resources – use locally collected macroalgae as biomass.

Costs and benefits (€ per t and year) from the collection of free-floating macroalgae and beach cast in the case of Trelleborg municipality, Southern Sweden

	Costs ($€\ t^{-1}\ y^{-1}$)	Benefits ($€\ t^{-1}\ y^{-1}$)	Comments
Increased tourism	–	750–1,070	Based on case study from Öland
Increased fish stocks	–	–	Could not be calculated, but may have substantial value
Nutrient uptake			Societal benefit calculated on basis of marginal costs for nutrient removal
Nitrogen (109–150 t)	–	580	
Phosphorous (9 t)	–	980	
Beach cast collection	140		Labour & machinery costs
Production, transport & sale			Investment costs for biogas plant not calculated, distance to biogas plant decisive factor
… of raw biogas	20–40	90–170	
… of upgraded biomethane	50–80	320	
CO_2 emission savings	–	1.5	Equivalent to voluntary payment schemes for CO_2 emissions
Fertiliser	–	0	Not feasible in Trelleborg, but possibly elsewhere
House prices	–	–	Cannot be valued at present
TOTAL			
… for raw biogas	160–180	2,400–2,800	
… for upgraded biomethane	190–220	2,630–2,950	

Challenges and outlook

Commercial full-scale establishments within the Baltic Sea Region are hampered by scepticism of energy producers towards new substrates, the seasonal variations in the quality of algae biomass as well as legal barriers to harvest macroalgae. What is more, further research is needed on the ecosystem dynamics of macroalgae collection.

Lead authors: Eva Blidberg & Fredrik Gröndahl, Royal Institute of Technology (KTH)

Cultivating macroalgae

Only one macroalgae farm of commercial value is existing in the Baltic Sea. However, several pilot cases for macroalgal cultivation are performed within the Baltic Sea Region.
The growing demand for high-valued macroalgae products can be a driving force for furthering macroalgae cultivation, as the macroalgae quality required for many high-valued products cannot be obtained from beach cast. The lack of experience and the low growth rates of marine species in the Baltic Sea might, however, be constraints against macroalgae cultivation in the Baltic Sea.

Mussel cultivation as a contribution towards counteracting eutrophication

Mussels are, like many other marine organisms, filtrating animals. They live by pumping in the surrounding water and filtrate off particles, mainly phytoplankton. Around the Baltic Sea, mussels like blue mussels (*Mytilus edulis*), which live in marine and brackish waters, and zebra mussels (*Dreissena polymorpha*), which are present in coastal lagoons, are identified as promising biofilters.

Mussels as nutrient harvesters

Mussel farming may have a large potential within the Baltic Sea as one of the few available operational, simple, flexible and cost-effective methods to counteract the negative effects of eutrophication caused through diffuse nutrient leakage from agriculture operations, sewage discharges and other human activities.

Mussels improve coastal water quality as they "harvest" nutrients through their food intake of phytoplankton. Numerous pilot studies have proven that the establishment of mussel farms has dramatic effects on water clarity.

1kg of fresh mussels contains	
Nitrogen (N):	8.5–12 g
Phosphorous (P):	0.6–0.8 g
Carbon (C):	40–50 g

! It seems realistic that 700 ha of mussel farming can be created in Sweden – taking up around 5 % of the country's nitrogen reduction target from the Baltic Sea Action Plan (21,000 t/year).

Estimation of Blue Mussel farm potential			
Coastal Area	**Estimated harvest per ha farm area** (1,5–2,5 years)	**Estimated amount N per ha & year**	**Estimated amount P per ha & year**
South Baltic	150 t	1.8 t	0.12 t
North Baltic	100 t	1.2 t	0.08 t

Fertilizer and feed stuff

The phytoplankton biomass, i.e. the mussel meat, can be used as high protein animal feed-stuff, as a fertilizer in agriculture operations and/or energy resource for biogas plants. With the production of nitrogen as a fertilizer being an energy demanding and climate negative process and phosphate being a limited resource on a global scale, recycling of nutrients is necessary both from an environmental as well as a socio-economic point of view.

Moreover, since mussels are at the second step of the marine food-chain, the use of mussels instead of fish for feed production is also an important contribution against overexploitation of fish stocks.

On a global scale, mussel farming is normally pursued in order to produce food for human consumption. Due to low salinity levels, Baltic Sea mussels are, however, too small to be harvested for traditional seafood purposes, especially in the north and east. Thus, this application plays only a minor role within the Baltic Sea Region.

Main benefits & uses:

Choosing the right site

Only a limited number of sites seems to be suitable for mussel farming because many criteria have to be fulfilled. Here are some of them:

- Sites should be protected from heavy waves and ice drift in the winter
- The water depth should be between 10 and 30 m
- The site area should be between 1 and 10 ha
- Salinity should not go below 4 PSU
- Bottom water exchange is needed in order to avoid low oxygen benthic conditions below a farm

Challenges for mussel cultivation in the Baltic Sea Region

Mussel farming for nutrient recycling has not gone beyond pilot stage yet. The main obstacle so far is the lack of economic incentive provided as no income can be generated from nutrient harvesting. Another limiting factor is the lack of suitable sites (see box). The combination with offshore wind parks could, however, offer new chances (see p. 11).

Lead author: Odd Lindahl, The Royal Swedish Academy of Sciences

Mussel cultivation on the Åland islands

Reed: a "forgotten" resource being rediscovered

The common reed (*Phragmites australis*) is a perennial grass, which grows best in areas with slow or stagnant and shallow fresh or brackish water. It is often the key-species in wetland ecosystems and usually forms dense stands – reed beds.

Large coastal areas along the Baltic Sea are covered by reed beds with its shallow bays and lagoons offering ideal conditions for its growth. The overall area of reed beds throughout the Baltic Sea Region has increased rapidly during the least 150 years. The factors contributing to this expansion have been the increased input of nutrients to the water bodies, which favours reed growth, as well as the designation of many wetlands as nature reserves. Due to lack of monitoring, it is currently not possible to make a precise assessment of the overall size of reed areas in the Baltic Sea Region. A rough inventory is nevertheless shown in the below table.

Area of reed beds in shallow bays and coastal lagoons of the Baltic Sea

Country	Region	Reed area, ha
Russia	Kaliningrad Oblast	200–300
Lithuania		5,000
Latvia	Pape, Liepāja, Tosmare	2,800
Estonia		20,100
Finland	South / South-West	< 30,000
Sweden	South	> 230,000
Denmark	*	–
Germany	Mecklenburg-Vorpommern**	1,500
Poland	Puck Bay, Vistula Lagoon, Odra Estuary	1,700
TOTAL		**> 300,000**

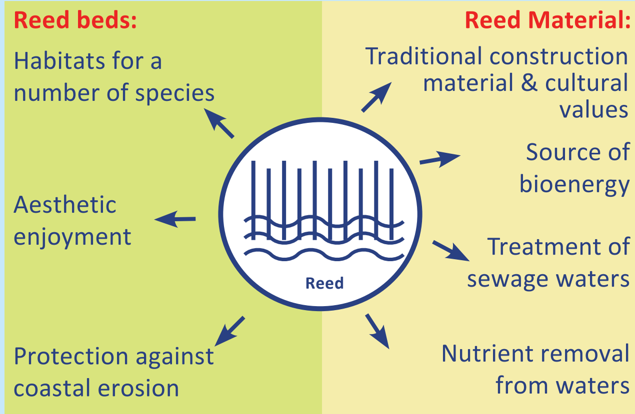
* no data available for Denmark ** area that can be harvested annually

Traditional and new uses of reed

Common reed has been used for different purposes since ancient times, e.g. to make reed whistles and pipes, to use it as fodder for cattle or for fuel and cooking in coastal areas and most importantly of course as construction material for roofs as well as for building fish barriers or catches.

More recently, however, reed has been rediscovered as a useful resource to address growing needs related to environmental and climate change concerns. Such new uses include reed as a resource for biogas and bioethanol production as well as nutrient removal from water systems (including post treatment of wastewater). Whereas the latter is already commercially feasible, the use of reed as a bioenergy resource is still in an experimental stage.

Possible uses of reed



A matter of seasonality

The maintenance of reed beds has a high environmental as well as cultural value since they provide important habitats for a number of species, act as a protection against coastal erosion and offer aesthetic enjoyment.

Thus it is understood that any kind of harvesting has to take these factors into account. In most countries, regulations are already in place which restrict reed harvesting to a specific season.

At the same time, studies have shown that mowing and the subsequent removal of biomass can have positive impacts on biodiversity. The key to a sustainable approach towards reed harvesting will be to find the optimal balance between the natural ecosystem services reed beds provide and developing the potential they may have on further ecosystem services.

A regional solution for energy and nutrient uptake

Assuming that roughly 20 % or 50,000 ha of Sweden's total reed area (230,000 ha) could be harvested annually, a theoretical energy value of roughly 1 TWh could be produced in total, representing an uptake of 250–500 t of phosphorous and 2,500–5,000 t of nitrogen.
To put it into perspective: The renewable energy effect would be marginal as the total energy generated from biomass in Sweden is 115 TWh. Nevertheless, it would contribute to quite a large extent to Sweden's nitrogen reduction target from the Baltic Sea Action Plan (21,000 t/year).

Lead author: Arvo Iital, Tallinn University of Technology

Microalgae for biofuel: A promising alternative to land plants

Microalgae are microscopic organisms: the size of their cells varies from approximately 1 to 100 micrometers (µm). They are ubiquitous and fast-growing organisms living either as floating in the water (phytoplankton) or as attached to surfaces. In the Baltic Sea, around 1,000–2,000 microalgae species have been identified, but the actual number might be much higher.

Potential of microalgae for biofuel

Throughout the world, microalgae are extensively studied as a potential and sustainable carbon neutral source for biofuels. As a sign of commercial potential, several oil companies have microalgae biofuels high in their research investment lists. Pilot scale cultivation systems have been built, but no commercial scale production unit exists yet.

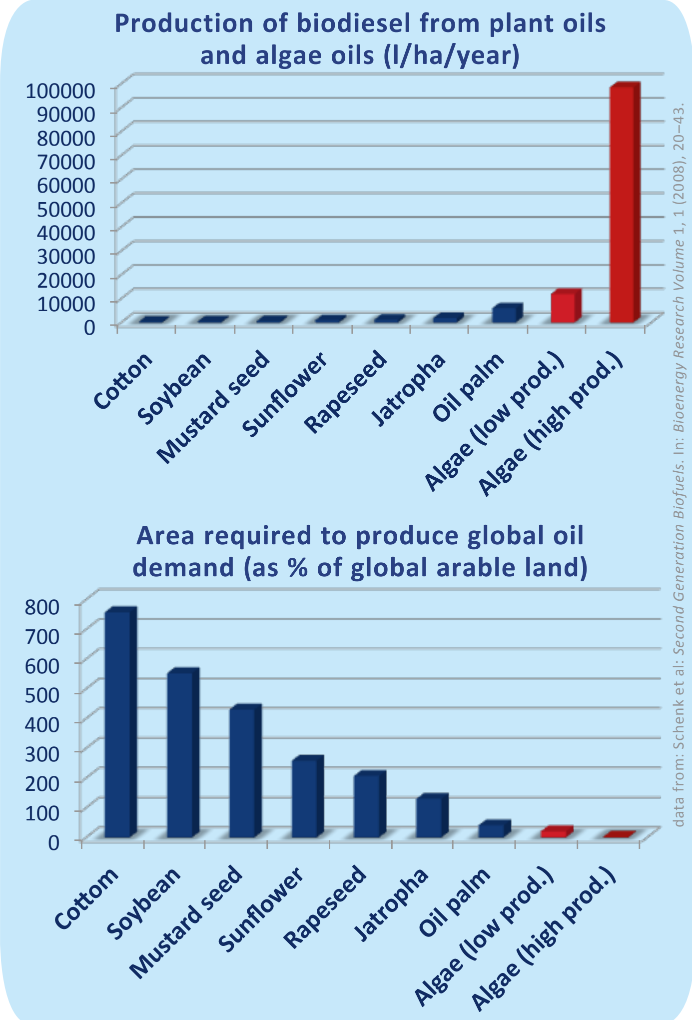
Several properties make microalgae an interesting alternative to land plants in biofuel production. While terrestrial crops used for biofuels have low yields, microalgae have high reproduction rates and high energy content. Also, while terrestrial crops are in conflict with food production, microalgae cultivation does not require fertile soil and can make use of saltwater and waste nutrients and thus decrease eutrophication of natural waters.

The Baltic Sea Region: A good place for cultivating microalgae?

Harvesting of natural microalgae biomass is challenging due to the very low density of these tiny organisms. Even during bloom conditions, the water contains less than 0.1 % of algae biomass (i.e. less than 1 g in 1 l of water).

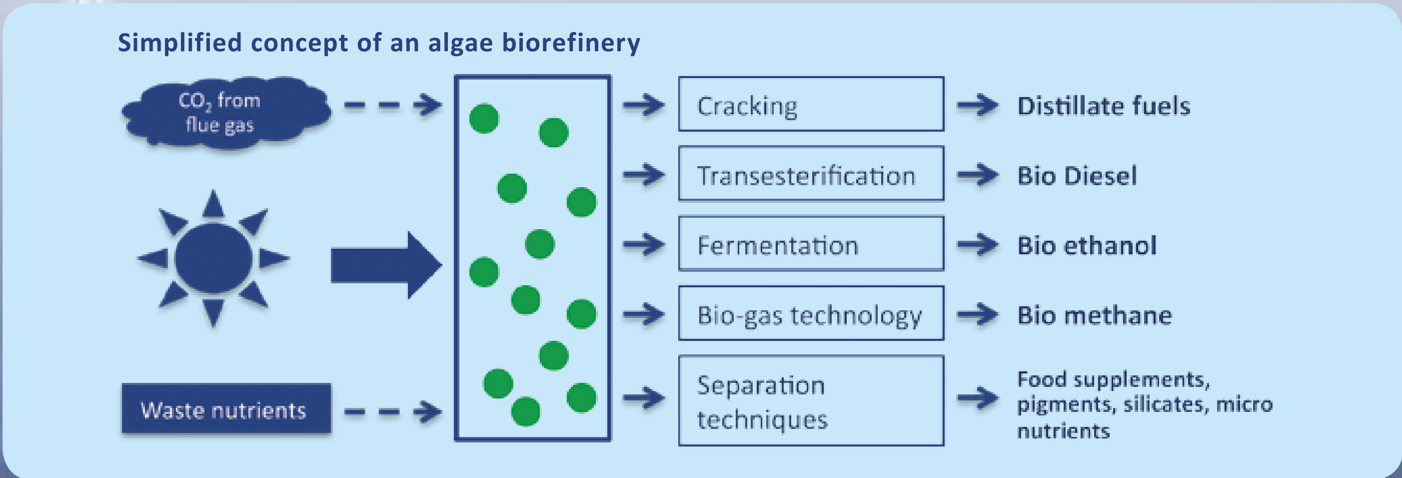
In cultivation systems, this density can be substantially increased, but it is still very low (>99 % water) for harvesting purposes. What is more, to obtain such densities, nutrients and CO_2 have to be added. Sites where the combination of microalgae cultivation with waste water treatment is possible, are very limited.

Also low temperatures and little sunlight during the winters might limit the growth of microalgae in the Baltic Sea Region and diminish possiblities for year round cultivation.



On the other hand, the Baltic Sea Region has many strengths which can help to foster the further development of microalgae cultivation in the region. There is not only a strong scientific background and a high level of multidisciplinary education in the field, but also strong governmental support for new solutions in bioenergy and many technology companies willing to invest in further research.

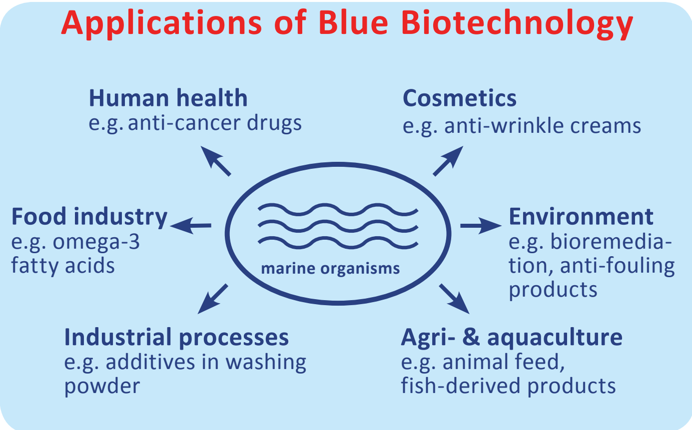
Lead author: Jukka Seppälä, Finnish Environment Institute – SYKE



Meeting global challenges with the help of Blue Biotechnology

According to the OECD definition, Blue Biotechnology involves the use of valuable substances produced by living marine organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.

Marine organisms used for Blue Biotechnology are microorganisms – such as bacteria, fungi, and microalgae – or organisms such as macroalgae and mussels. Their valuable ingredients may be biological active compounds, pigments, antioxidents, vitamins, polysaturated fatty acids, enzymes, polymers and biomaterials.



Wide range of applications

High value marine products can have a wide range of applications. Potentially, they can offer some answers to global challenges related to health, food demands and environmental concerns. Human health and genetic engineering are the fields that are proposed most often in the description of patents associated with genes from marine organisms.

By comparison with terrestrial resources, marine resources are largely untapped. Thus it is hoped they will provide a new important resource for the identification of high value ingredients. However, screening processes have to become more efficient and coordination between research institutes and the industry has to be improved.

Huge growth predicted

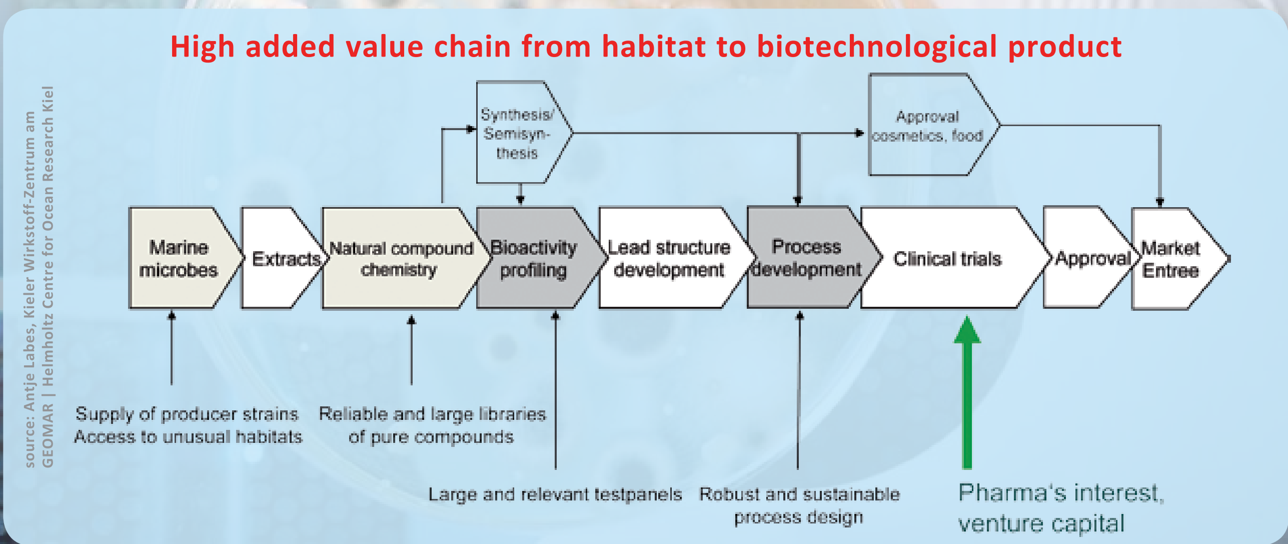
Even if Blue Biotechnology is still very much research & development focused and shows a limited economic performance today, numerous studies project major growth, huge demand and corresponding large markets in the field. Already for 2012, the Marine Board of the European Science Foundation (ESF) rates the market in this segment to be € 2.8 billion, with annual growth rates of 12 %.

Blue Biotechnology in the Baltic Sea Region

In the Baltic Sea Region, Blue Biotechnology has so far not played a major role. The main challenges the region has to overcome in order to benefit from the projected growth of the Blue Biotechnology sector are:

- Low awareness about the economic and scientific potential of Blue Biotechnology in many Baltic Sea Region countries,
- Skills shortage and low level of interdisciplinary cooperation,
- Limited number of financially strong companies active in the field of Blue Biotechnology.

Nevertheless, many case studies have demonstrated the successful scientific investigation and economic use of products from the Baltic Sea, which offers a unique habitat for many micro- and macroorganisms.



Lead author: Jutta Wiese, Kieler Wirkstoff-Zentrum am GEOMAR | Helmholtz Centre for Ocean Research Kiel

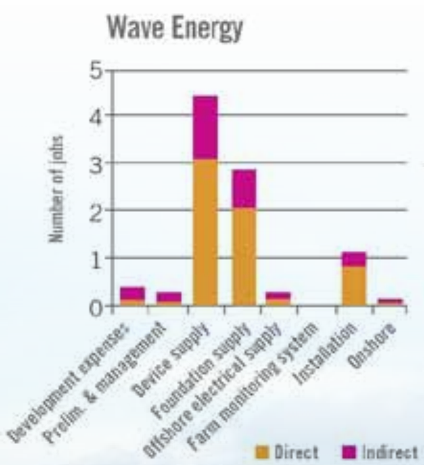
Waves: An energy resource for the Baltic Sea Region?

Ocean waves represent a vast potential, but are still an untapped natural renewable energy resource. Globally, the energy contained within waves has the potential to produce up to 80,000 TWh of electricity per year – sufficient to meet our global energy demand five times over. Compared to e.g. wind or solar energy, wave energy is by its origin steadier and more predictable, as it can be available around the clock, day to day and season to season.

Within the Baltic Sea Region, wave energy has not yet been tested intensively. The main reason behind this is that the Baltic Sea's wave energy potential is usually regarded to be relatively low. Waves are also most often considered together with other related hydropower energy sources such as tides and currents. The Baltic Sea, however, is an almost tide free basin. But even in a shallow and relatively sheltered sea as the Baltic Sea, the annual gross wave energy may be extensive. With proper technological developments and in combination with other uses and other favourable factors – such as newly developed grid connections – wave energy may become an additional energy option in the Baltic Sea, especially for small islands or offshore installations, such as oil platforms, hydrographical buoys, marinas, navigation signs etc.

Technological forerunners in the Baltic Sea Region

Actually, a Danish pilot was among the first wave energy pilots in the whole world and also Sweden and Finland have made attempts to test and install wave energy prototypes. As there are direct relations between wind and wave energy developers, the main technological research experience and knowledge is concentrated in Denmark, Germany and Sweden. Germany, having a strong wind energy manufacturing sector, is also potentially well prepared for wave energy installations development, maintenance and supply. But up to now, knowledge from the Baltic Sea Region is exported to markets outside the region and full scale testing is still missing in the Baltic Sea. This can be changed – by providing new technical concepts, both small and large scale, in order to promote Baltic Sea waves as a realistic energy resource and to foster the regional industries connected to wave energy technologies.



Job creation per MW of wave energy installed capacity

source: European Ocean Energy Road map 2010-2050

Innovative wave generator developed within the SUBMARINER project

Within the SUBMARINER project, a prototype for generating energy from waves is being developed. The linear generator – an essential part of the prototype – has been tested and awarded the first prize in the "engines" category in an innovation contest at the 2012 BALTTECHNIKA exhibition in Vilnius.

The wave energy device prototype has been designed to meet the specific conditions of the Baltic Sea – occasional harsh storms and relatively low energy in a yearly run. The development is concentrated on minimising the investment costs and maximising the generator's efficiency.

High investment costs & job creation potential

Worldwide experience shows that investment costs for wave energy are still very high because of the harsh marine environment and the currently early level of industrial development, but they are expected to decrease substantially during the next twenty years. It has been estimated that costs to get from idea to a full-scale prototype amount to 30–35 million EUR. While the EU has significantly increased its research funding for wave energy during the last years, there is no specific programme to foster wave energy on the Baltic Sea Region level yet, while e.g. the UK has a comprehensive marine energy support regime in place. Several estimations have shown that wave energy might have a great employment potential. It is anticipated that approximately 6 to 7 direct and indirect jobs would be created for each MW installed.

Even more attractive when combined?

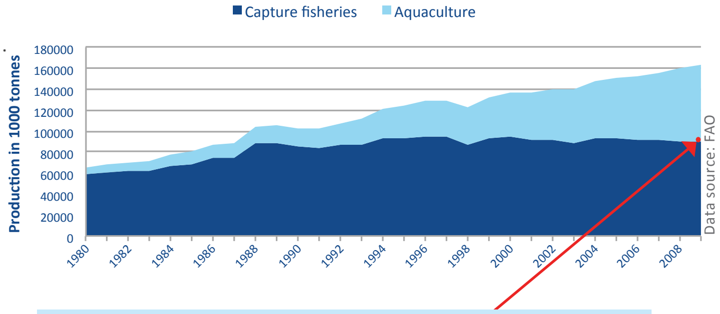
The development and testing of the new concept of a linear generator within the project has proven that generation of electricity from waves is feasible at any scale and space within the Baltic Sea. It is even more attractive if combined with already existing facilities at the sea. At a large scale, waves can be a vast energy source for offshore wind parks – using the same grid and energy accumulation facilities. At a small scale, waves can be a supplementary energy source near the end user for navigation buoys, oil platforms etc.

Lead author: Nerijus Blazauskas, Klaipeda University Coastal Research and Planning Institute

Towards sustainable fish aquaculture in the Baltic Sea Region: new opportunities and technologies

A stagnating fisheries production caused by globally overexploited fish stocks and a rise in demand for seafood have resulted in a spectacular growth in production in the aquaculture sector with an average worldwide growth rate of 6.6 % a year. Thus sustainable aquaculture proves huge opportunities.

Global production of aquatic species



! In 2009, marine aquaculture in the Baltic Sea Region only had a share of under 0.1 % of the global production.

Potential for the Baltic Sea Region

In view of low salinity levels and overall lack of sites with suitable hydrological conditions, marine aquaculture in the Baltic Sea Region has so far only played a very minor role on a global scale. There is, however, potential to develop the region's aquaculture sector. The search for methods to decrease its reliance on imports and ways to achieve fish restocking are important motivators for the further development of the aquaculture sector.

A dynamic research and technology sector, advanced equipment, trained and qualified entrepreneurs, a solid environmental and health protection legal framework and changing consumer demands towards more eco-friendly products are the strengths which can foster the further development of the Baltic Sea Region's aquaculture industry.

Innovative technologies for fish aquaculture

Challenges regarding environmental concerns as well as competition for space foster the development of innovations and technological breakthroughs.

- Countries with a longer background in marine fish farming (especially Sweden, Finland and Denmark) might choose to strengthen their industry by introducing innovative technology such as Integrated Multi-Trophic Systems (IMTA) to already existing farms, while at the same time establishing new emerging systems.

- Countries where marine aquaculture is not yet established due to lack of suitable sites, might seek to introduce aquaculture systems that are land-based and therefore independent from the hydrological water conditions of the sea, e.g. salt water Recirculating Aquaculture Systems (RAS).

- The development of offshore wind parks (see right page) and possibilities of combining aquaculture uses in them might offer new space for such kind of systems.

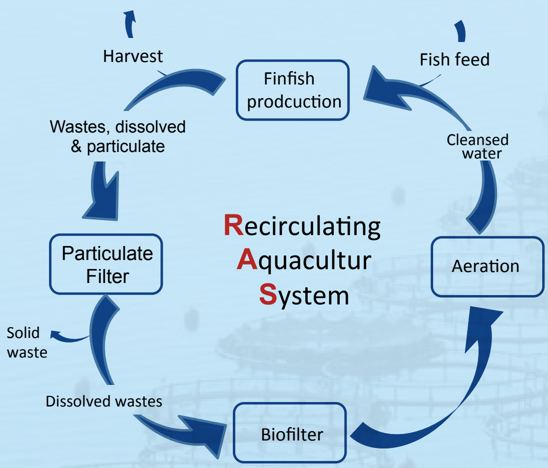
Why Baltic Sea fish aquaculture?

- High quality local seafood
- Important contribution to restocking measures
- Local employment creation

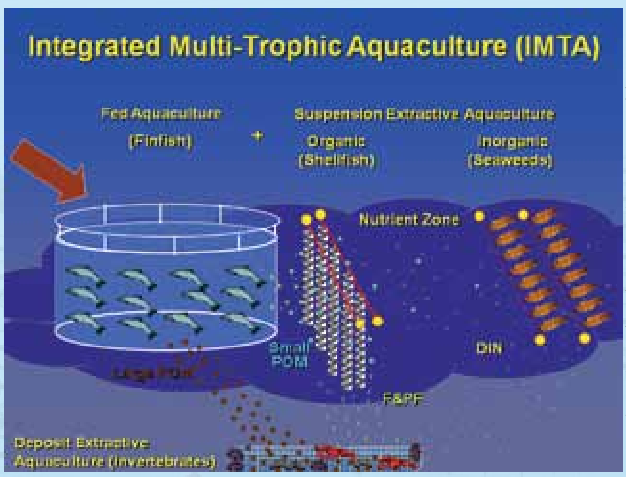
Emerging technology could also allow the introduction of new fish species, native and non-native, to reduce imports and increase freshness of the product for consumers. Furthermore, so-called hatcheries, where high water quality standards necessary for fingerlings and frey fish production can be assured, might make an important contribution towards restocking of fish within the Baltic Sea.

Lead author: Frank Neudörfer, BioCon Valley Mecklenburg-Vorpommern

RAS – new opportunity for land-based aquaculture



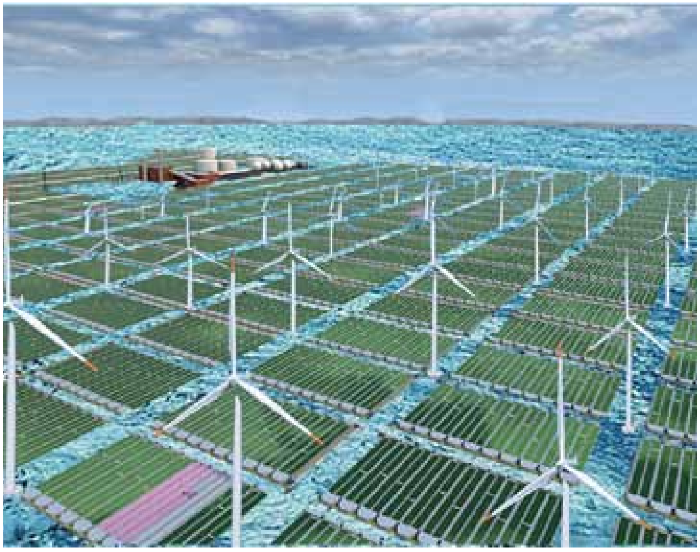
IMTA – Sustainable use in established sites



Picture from Chopin (2011) in: *Aquaculture Europe* 36 (4) , pp. 5–12.

Offshore wind parks: new sites for mariculture installations

The number of offshore wind parks in the Baltic Sea is constantly growing. It is predicted that by 2030, 65–70 offshore wind parks will be placed in the Baltic Sea, producing around 25,000 MW of electricity. Not only the number of wind parks, but also the size of the individual wind mills and thus the distances between them are growing dramatically. This results in an ever larger area occupied by offshore wind parks. Assuming that most wind parks will consist of wind mills with rotor diameters of 130 m and more, it can be expected that offshore wind parks will occupy between 3,000 and 3,500 km^2 of Baltic Sea space in 2030.



Vizualization of a wind mill park with photobioreactors

Promoting multiple spatial uses

As the Baltic Sea is a valuable common resource, its space should be used sparingly. With regards to an increasing competition for space between various uses, multiple spatial uses should be promoted. The space between the wind mills of the Baltic Sea's offshore wind parks offers a large potential in this respect.

Some investigations suggest that at least 25 % of the space between the individual wind mills in the parks – or 750 km^2 – may be suitable for other purposes and activities such as mariculture installations. Mussels and macroalgae cultivation, fish aquaculture and combinations of them are among the uses that could be combined with offshore wind parks.

! Annual harvesting of 140 km^2 of mussel farms would be sufficient to meet Sweden's nitrogen reduction target from the Baltic Sea Action Plan (21,000 t/year)

Challenges

There is a strong need for experimental pilot sites in the new wind parks in order to test the technical feasibility of such combined installations. What is more, the specific conditions of the Baltic Sea, e.g. shallow waters, low salinity levels and sea ice, need to be tested.

To some extent, there are opposing stakeholder interests and a lack of tradition in the aquaculture and (wind) energy sectors to cooperate with each other with regards to spatial, operation and management questions. Also legal and planning incentives are needed to promote the combination of offshore wind parks with other uses in the Baltic Sea Region.

Lead author: Pia Bro Christensen, Green Center

Why combine other uses with offshore wind parks?

- Offshore wind parks in the Baltic Sea "a given"
- Spatial efficiency: use synergies
- Spatial availability: growing competition
- Economies of scale and cooperation

The SUBMARINER project in a nutshell

The Baltic Sea Region faces enormous challenges including new installations, fishery declines, excessive nutrient input, the effects of climate change as well as demographic change. But novel technologies and growing knowledge also provide opportunities for new uses of marine ecosystems, which can be both commercially appealing and environmentally friendly. Through increased understanding and promotion of innovative and sustainable new uses of the Baltic Sea, SUBMARINER provides the necessary basis for the region to take a proactive approach towards improving the future condition of its marine resources and the economies that depend on them. It does so by focusing its efforts along four lines of activity:

- **Production of a compendium:** describing current and potential future marine uses by developing a comprehensive inventory of innovative sustainable uses, assessing their environmental and socioeconomic impacts, estimating the market opportunities and the availability of necessary technologies, and describing the gaps and obstacles in the legal framework.

- **Development of a roadmap:** recommending necessary policy steps to promote beneficial uses and mitigate against negative impacts, including suggested legal changes (e.g. spatial plans), environmental regulations and/or economic incentives.

- **Implementation of regional development activities:** testing new uses in real conditions, conducting feasibility studies for new uses in specific areas, assessing technological and financial needs, estimating impacts on environmental and socieconomic conditions, and evaluating specific legal constraints.

- **Building a network:** creating a selfstanding, independent network for sustainable innovative marine uses and stimulating cooperation among relevant players through virtual and real networking, information exchange and cooperation events.

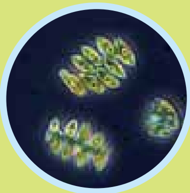
SUBMARINER Partners

Poland:
- **Lead Partner:** The Maritime Institute in Gdańsk
- Gdańsk Science and Technology Park

Germany:
- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
- Norgenta North German Life Science Agency
- Kieler Wirkstoff-Zentrum am GEOMAR | Helmholtz Centre for Ocean Research Kiel
- University of Rostock
- BioCon Valley Mecklenburg-Vorpommern e.V.

Denmark:
- ScanBalt
- Lolland Energy Holding

Sweden:
- Royal Institute of Technology (KTH)
- The Royal Swedish Academy of Sciences
- Trelleborg Municipality



Estonia:
- Tallinn University of Technology
- Entrepreneurship Development Centre for Biotechnology & Medicine

Lithuania:
- Klaipeda University Coastal Research and Planning Institute
- Klaipeda Science and Technology Park

Latvia:
- Ministry of Environmental Protection and Regional Development of the Republic of Latvia
- Environmental Development Association

Finland:
- Finnish Environment Institute – SYKE

Imprint

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