Interreg Baltic Sea Region

EUROPEAN UNION

EUROPEAN REGIONAL DEVELOPMENT FUND

Blue Platform

SUBMARINER Status Quo Report 2020

Five Years of Interventions for the Blue Bioeconomy in the Baltic Sea Region

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Author: Angela Schultz-Zehden et al.

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Introduction

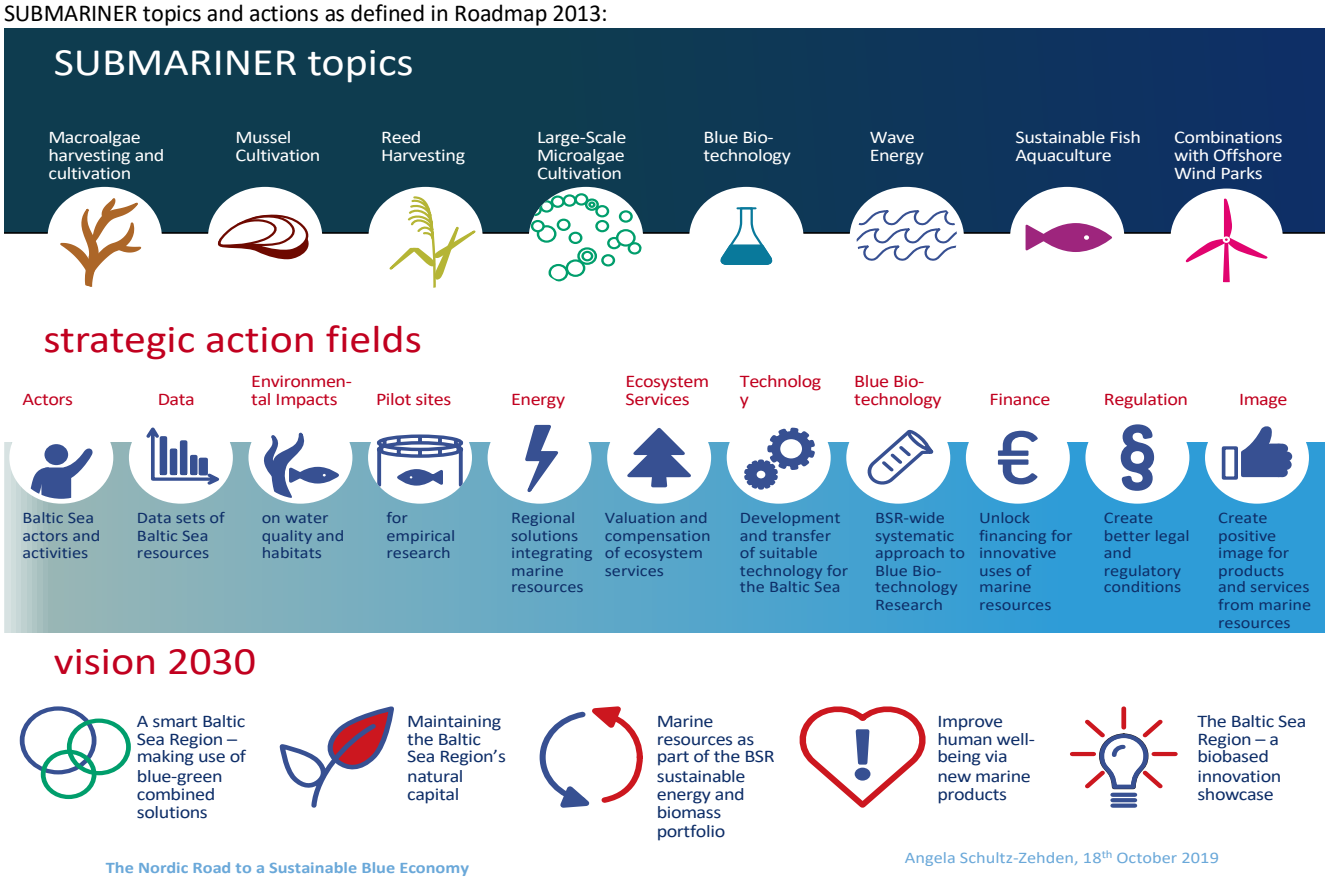
1 About the SUBMARINER Network

1.1 The evolution of SUBMARINER since 2015

The SUBMARINER Network for Blue Growth EEIG, a flagship umbrella project of the EU Strategy for the Baltic Sea Region, was established in 2013. Since then it has developed into the leading transnational hub in the Baltics for promoting sustainable and innovative uses of marine resources. The Network brings together authorities, research and innovation actors - both public and private - across the Baltic Sea Region, integrating perspectives from local to transnational scale and different scientific and economic spheres.

The work of the SUBMARINER Network for Blue Growth EEIG between 2015 and 2020 has been guided by the topics and actions described in the SUBMARINER Roadmap (dated 2013) as necessary to realise innovative and sustainable uses of marine resources throughout the Baltic Sea Region.

SUBMARINER topics and actions as defined in Roadmap 2013:

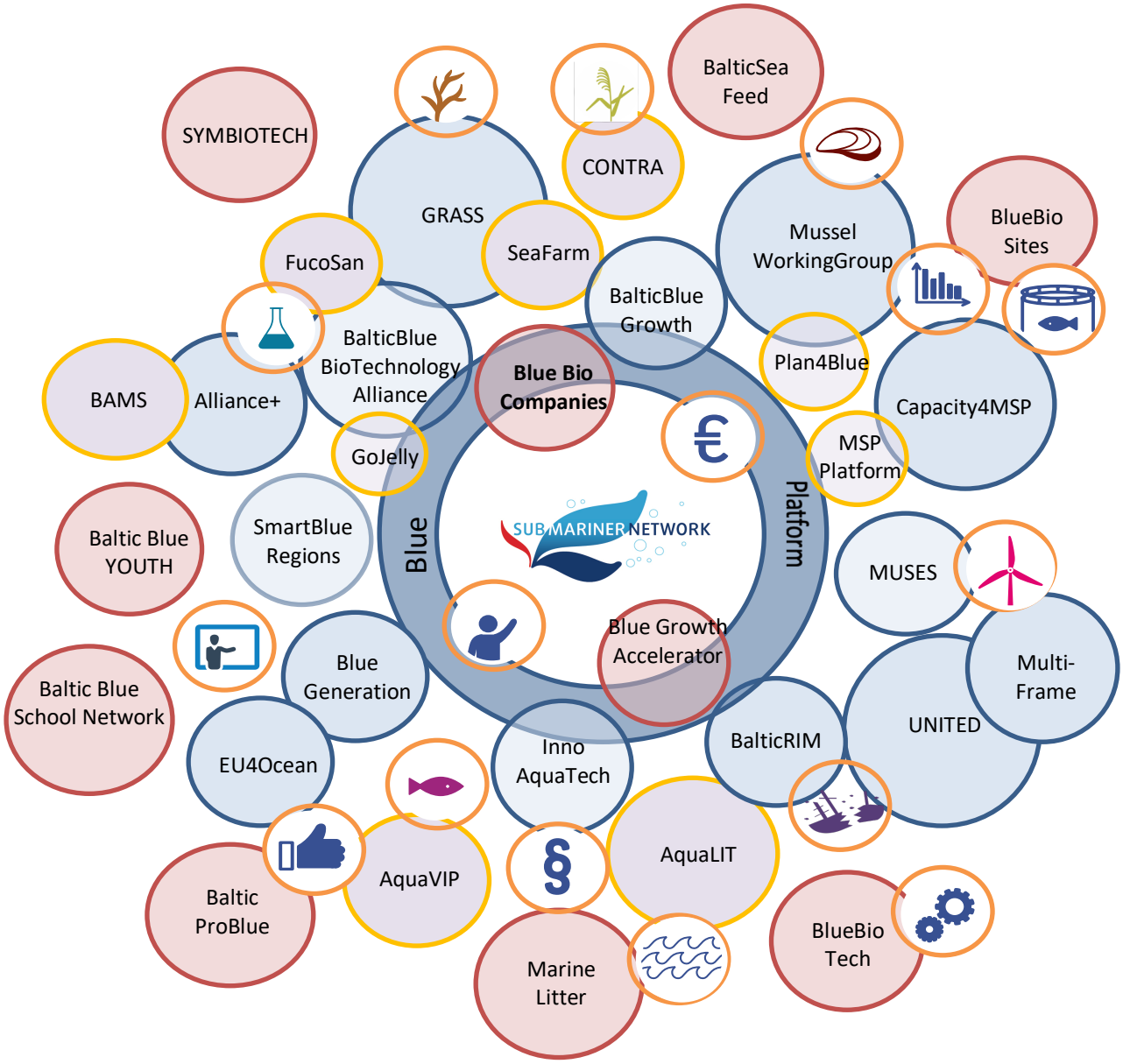


Starting off from an initial set of seven full members only, the SUBMARINER Network has by now attracted many new relevant institutions and individual experts to join currently counting for ten full members and 28 associate members. With no statutory support, the Network has over the course of the past years, succeeded in leveraging the membership funding by applying for project funding under the various Baltic Sea Region INTERREG schemes, Horizon 2020, EMFF projects, EEA Norway Grants as well as national programmes.

1.2 Overview on SUBMARINER Projects

Until 2020, the SUBMARINER secretariat has initiated 25 transnational projects, of which 20 received funding with a total volume of more than 41 million €, of which almost 30 million € are for activities in the Baltic Sea Region. The projects provided an extra funding of € 1,25 million to the SUBMARINER secretariat; while an additional total volume of more than 13 million € has been allocated to SUBMARINER members. This funding allowed members to implement the activities defined in the roadmap. Moreover – individual SUBMARINER members have also been able to attract additional projects – in line with the SUBMARINER mission and thus forming part of its Baltic Sea wide knowledge and Actors hub.

The projects have also been a way to reach out and involve many more actors involved within the Blue Bio-economy: apart from the 40+members, more than 150 other parties have participated in one or more of the SUBMARINER projects.



SUBMARINERS Project Cloud (2015-2021)

The original set of topics & actions from the Roadmap have over the course of the past years been slightly adapted as to cover new, important areas of work such as **marine litter** and **underwater cultural heritage.** Instead of dealing with reed harvesting only, projects have extended this topic to cover improved use of **beach-wrack** and installation of **artificial lagoons**. Also new policy instruments such as **Smart Specialisation** and **Maritime Spatial Planning** have been added. Moreover, **capacity building, training and skills development across all levels (i.e. from civil society to public authorities)** have been added as crucial action fields.

SUBMARINERs 1st Generation of Projects (concluded in 2019/2020)

- **Smart Blue Regions:** Smart Specialisation and Blue Growth in the BSR
- **Baltic Blue Growth:** Initiating full-scale mussel farming in the Baltic Sea
- **InnoAquaTech:** Cross-border transfer of innovative & sustainable aquaculture technologies
- **MUSES:** Exploring opportunities for Multi-Use in European Seas
- **Baltic Blue BioTech Alliance:** Advancing marine bio-based product development

- **Baltic RIM:** Integrated Maritime Cultural Heritage Management

SUBMARINERs 2nd Generation of Projects (numerous to be finalised in 2021)

- **GRASS:** Capacity building for public authorities on supporting macroalgae production & use
- **Blue Generation:** Inspire & engage young people to stake up Blue careers
- **Alliance+:** Advancing marine bio-based product development
- **UNITED:** Demonstrating Multi-Use in the North & Baltic Sea
- **Capacity4MSP:** Capacity Building for MSP
- **Blue Platform:** Advancing Blue Bioeconomy Capacities in the Baltic Sea

SUBMARINER Members Projects

Some projects, highly relevant to the overall mission of SUBMARINER, involve SUBMARINER members, but not its secretariat. These projects include among others:

- **AquaLIT:** Working with the aquaculture sector to prevent marine litter (s.Pro)
- **AquaVIP:** Aquaculture Virtual Career Development Platform (Uni Gdansk, KSTP, CORPI
- **CONTRA**: Conversion of a Nuisance to a Resource and Asset (SDU, Uni Tartu)
- **FUCOSAN**: Health from the Sea (GEOMAR, CRM)
- **SeaFarm**: Macroalgae for a biobased society**,** culture**,** biorefineries and energy (KTH, UGOT)
- **BAMS**: Bioeconomy for Blue Sites (CAU, CRM, Geomar)
- **SUSCULT**: Sustainable cultivation of seaweed (SYKE, KTH)
- **AquaVitae**: Low-Trophic Aquaculture in the Atlantic (IVL)
- **Multi-Frame**: Developing an Assessment Framework for Multi-Use

In addition, projects like Coastal BioGas and OPTIMUS are directly linked to SUBMARINER Roadmap actions, but are implemented by actors outside the SUBMARINER network current membership.

Unsuccessful topics streams

The following project applications submitted by SUBMARINER members were not successful:

- Efficient and relevant data & information sourcing to promote the blue bioeconomy
- Wave energy development in the Baltic Sea Region
- Developing sustainable feed systems for aquaculture
- Marketing & labelling of blue bioeconomy products & services
- Promoting blue economy investments & new funding mechanisms
- Promoting blue-green regional solutions
- Streamlining blue biotechnology product biodiscovery

This does not necessarily mean, that the topics in question should no longer be pursued by the SUBMARINER network. In some cases topics have, however, proven to be too far fetched as to offer real innovation boost; i.e. whereas 'microalgae cultivations' may play a crucial role in food and high value products and 'wave energy' may still be interesting as an additional source of energy in combination of other offshore installations; both are no longer seen as distinct topic fields. Whereas wave energy is now covered under the 'multi-use' topic; microalgae has been included in the topic of blue biotechnology.

1.3 The Role of the SUBMARINER Network Secretariat

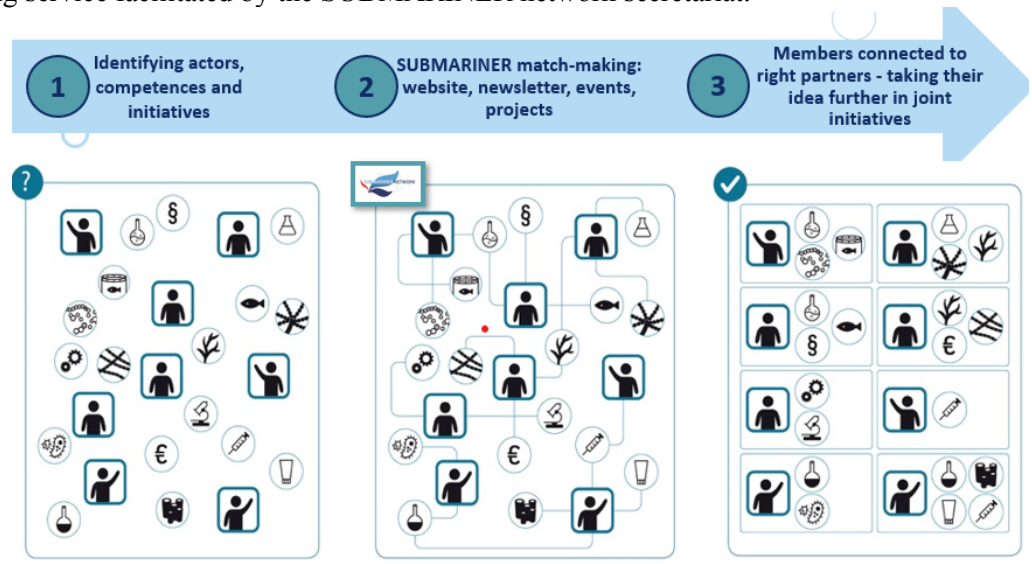
Right from the outset the SUBMARINER Network decided to install a permanent, central secretariat based in Berlin. The number of team members depend on project resources, but have over the past years included between 4-5 multi-lingual professionals with background in project coordination and communication.

All SUBMARINER members benefit from the following services provided by the secretariat:

- Promotion and representation of members' competences and interests in news and events via all SUBMARINER network channels; e.g. website, quarterly newsletter, social media
- Exclusive member access to all internal information; funding opportunities; pitching and matchmaking events; annual members' assembly and specific workshops, study visits and searchable database including more than 3,000 blue bio-economy actors

- Co-ordinated access and set-up of project development consortia, support, administration and facilitation of projects, thematic network working groups and set-up of project development consortia
- Joint formulation and dissemination of policy-oriented position papers
- Expert advice and coaching via the secretariat hub and/or direction to relevant network members

The continuous identification, communication, coordination and match-making between actors as well as ongoing identification of funding opportunities and project development has proven to be the most important overarching service facilitated by the SUBMARINER network secretariat.



1.4 The SUBMARINER Vision

All activities of the SUBMARINER Network are guided by the strong belief that innovative and sustainable use of marine resources can contribute significantly not only to Baltic Sea Region, but global, challenges – which have by now been framed within the UN Sustainable Development Goals.

Most notably, SUBMARINER actions aim to address

Reduce Climate Change	⇨ instruments and measures to reduce Greenhouse Gas Emissions ⇨ stimulating more local and regional sustainable production; including renewable energy as well as feed, food and materials
Reduce Pollution	⇨ new measures for nutrient uptake; including dealing with the internal nutrient load within the Baltic Sea ⇨ effective measures to reduce marine litter ⇨ sustainable ways of fishery and aquaculture
Increase Biodiversity	⇨ offering new ways for ecosystem restoration by 'building with nature' ⇨ increasing efficiency of use of marine space by promoting the concept of multi-use
Increase Protection	⇨ extending the concept to nature protection to noise and the seabed ⇨ extending the concept of nature protection towards cultural heritage
Address Demographic Change	⇨ opening up towards new feed, food and material resources derived from the sea; which can ⇨ be explored sustainably ⇨ address important health issues
Foster Competitiveness of the Baltic Sea Region	⇨ opening new economic activities not only in metropolitan areas, but also in rural, coastal regions offering additional income sources for societal groups, which lose jobs in traditional marine sectors

By 2013, SUBMARINER topics were far from being commercially viable or politically established, but had already been addressed by numerous studies and research projects. The SUBMARINER Compendium published in 2012 represented the very first systematic compilation of these possible sustainable uses of marine resource; all of which aimed for restoring the Baltic Seas' good environmental status as well as providing benefits to humans' well-being. The following SUBMARINER Roadmap provided a strategic and systematic approach towards rolling out the various actions needed, in order to promote them across the Baltic Sea Region. Seven years later, the following document provides for a first ex-post evaluation of what has been achieved in the meantime; which kind of new developments have to be considered by now and the resulting priorities of SUBMARINER actions for the coming future.

1.5 Benefits associated with SUBMARINER Topics

Concretely, the following uses of marine resources promoted by SUBMARINER entail the following benefits:

Use	Rationale	Benefits	
Mussel Farming and Use	Additional sea-based measure to deal with the already existing nutrient load. Mussels can be used as a regional protein source in feed as well as other commercial applications.	Climate Change: ZeroPollution: Biodiversity: Nature Protection: Demographic Change: Regional Development: EUs' Competitiveness:	+ +++ ++ ++ + + +
Macroalgae Harvesting, Cultivation & Use	Baltic macroalgae can provide an important food and feed source, but also a valuable resource for ingredients, materials and energy. Green, red and brown, algae species can grow inside the Baltic proper providing ecosystem services, e.g. nutrient load reduction, habitat provision and increased localised CO_2 fixation.	Climate Change: ZeroPollution: Biodiversity: Nature Protection: Demographic Change: Regional Development: EUs' Competitiveness:	++ +++ +++ + +++ ++ +++
Harvest of Floating Emergent Aquatic Plants	Various ecosystem services are supplied by emergent macrophytes and halophytes on floating structures: Nutrients and pollutants are absorbed from the water column and wave energy attenuated. The root network provides shelter to aquatic fauna and increases microbial biodiversity. The flowering plants can create colourful landmarks; enhance the aesthetic value of and benefit tourism. Coastal municipalities have shown much interest.	Climate Change: ZeroPollution: Biodiversity: Nature Protection: Demographic Change: Regional Development: EUs' Competitiveness:	+ +++ +++ ++ + +++ +
Collection and Use of Beach-wrack	Wrack along the Baltic Sea coast-line it mainly consists of torn off eelgrass, brown, red and green macro algae, seashells, and dead animals; which are washed ashore on the beach. The methodologies employed and the treatment of this nutrient rich resource do not exploit its full potential for water management and pollution reduction.	Climate Change: ZeroPollution: Biodiversity: Nature Protection: Demographic Change: Regional Development: EUs' Competitiveness:	++ ++ - - - +++ +
Sustainable Fish & Shrimp Aquaculture	The importance of aquaculture as a source of animal protein is continuously increasing as fish stocks are decreasing and agricultural systems cannot keep up with the increased demand for healthy food. Land-based systems such as Recirculating Aquaculture or Aquaponics and Marine systems such as Integrated Multi-Trophic Aquaculture or offshore installations create opportunities for more regional fish & shrimp production.	Climate Change: ZeroPollution: Biodiversity: Nature Protection: Demographic Change: Regional Development: EUs' Competitiveness:	- + ++ + +++ +++ +++
Blue Biotechnology	Baltic marine and freshwater ecosystems host a thriving biological diversity of organisms with many possibilities for further advancements across various value chains. Whereas aquaculture can supply blue biotechnology with primary and secondary resources; blue biotechnology is crucial in all steps from growing biological resources to recovering biomaterials from process side-streams.	Climate Change: ZeroPollution: Biodiversity: Nature Protection: Demographic Change: Regional Development: EUs' Competitiveness:	- + + + +++ +++ +++

Multi-Use of Marine Space	Ocean multi-use can contribute to a more sustainable and efficient use of ocean resources, by reducing the demand of 'un-used' sea space and potentially offering significant socio-economic and environmental benefits.	Climate Change: ++ ZeroPollution: + Biodiversity: +++ Nature Protection: +++ Demographic Change: + Regional Development: +++ EUs' Competitiveness: +++
Marine Litter	Marine Litter has not only devastating consequences for the marine environment; but also cause serious economic damage: losses for coastal communities, tourism, shipping and fishing. At the same time, valuable material that could be brought back into the economy is lost, once littered.	Climate Change: - ZeroPollution: +++ Biodiversity: +++ Nature Protection: ++ Demographic Change: + Regional Development: ++ EUs' Competitiveness: +
Cultural Heritage	The Baltic Sea Region underwater and maritime cultural heritage forms a rich and diverse assemblage that has cultural and societal values. New forms of dealing with UCH can provide jobs and revenues due to new tourism services; increase public appreciation of the value and significance of UCH sites; while at same time enabling better protection, maintenance and control of them.	Climate Change: - ZeroPollution: - Biodiversity: + Nature Protection: +++ Demographic Change: + Regional Development: ++ EUs' Competitiveness: +

1.6 Strategic Actions foreseen to reap these benefits

The following strategic actions had been identified in the SUBMARINER roadmap to achieve the ambitions set out in the SUBMARINER compendium. The following overview shows how the various projects were able to address these actions:

1.6.1 Actors Mapping / Match-Making

Objective: Continuous identification and matching of public and private actors involved in new marine uses as to achieve better and faster results with less resources

	Status	Projects
Collect information, establish and maintain a BSR-wide database on:		
• Research institutions, researchers and experts;	YES	ALL
• Companies;	YES	Blue Platform
• Past and ongoing activities and projects;	YES	Blue Platform
• Intermediaries and transfer organizations;	Partially	Alliance
• New research and project ideas;	Partially	ALL
• (Bio-)technical equipment;	Partially	Alliance
• Available education in various levels;	Partially	Alliance
Support actions for		
• information and contact exchange among new marine use stakeholders;	YES	ALL
• networking & coordination with other networks;	YES	ALL
• organisation of sectoral and cross-sectoral match-making events;	YES	SmartBlueRegion Alliance
• identify potential linkages between natural and socioeconomic research and introduce research results of both disciplines to each other;	YES	BBG, GRASS
• communication across EUSBSR stakeholders and related BSR projects;	Partially	Blue Platform
• facilitate good practice transfer from traditional maritime sectors as well as terrestrial bio-economy stakeholders to SUBMARINER cases	NO	
Include marine sectors into BSR region wide research and technology development projects, which integrate knowledge for whole the Baltic Sea catchment area, e.g. energy, waste treatment, CO2 capture and storage, socio-economic aspects.	Partially	

1.6.2 Data / Tools / Environmental Monitoring

Objective: A structured approach to fill the gaps identified in SUBMARINER Compendium 2012 on blue biomass resources and the environmental impacts associated with their increased use.		
• Establish and implement BSR-wide best practices for monitoring and systematic mapping of: o biomass resources (macroalgae, reed) o nutrient resources and CO2 sources for microalgae cultivation	Status YES No	Projects GRASS CONTRA
• Identify and recommend institutional structures for permanent monitoring, data-sharing and visualization	No	BlueBioSites
• Link the data sets with surveys and mapping of other local (terrestrial) resources and demand for biogas or any other biomass refinery process	No	
• Develop a system to support the use of existing monitoring data to identify best sites (environmental and cost-effectiveness) for mussel and macroalgae cultivation and fish aquaculture sites	Partially	BBG GRASS InnoAquaTech
• Conduct systematic research on the role of reed beds and harvesting, macroalgae and mussel harvesting and cultivation on local biodiversity and water quality	YES	BBG CONTRA GRASS
• Assess consequences for nutrient regeneration, biogeochemical cycling and benthic habitat deterioration arising from increased sedimentation and sediment oxygen uptake by mussel cultivations	YES	BBG Ecopelag Optimus
• Assess the relationship between offshore, attached, living macroalgae stocks and beach-wrack macroalgae in terms of biomass, density and annual production rates to support the derivation of sustainable quantities of beach-wrack and free-floating algal mats that can be removed	Partially	GRASS CONTRA
• Further investigate feed supply and efficiency for fish aquaculture sites	No	RASFeed

1.6.3 Access to Pilot Sites & Facilities

Objective: establish more such pilot sites around the Baltic Sea Region to enable empirical research.

IMTA: investigate site-specific solutions with varying combinations of fish, algae and mussel farming at one site in order to find optimal technical and economical solutions	Status Partially	Projects BBG / AquaVitae One case: Musholm / DK
RAS technologies in combination with specific sites around the Baltic Sea	YES	InnoAquaTech
Pilot sites for **agar production**	No	
Mussel cultivation pilot sites	YES	BBG / Ecopelag OPTIMUS /German Study
Macroalgae cultivation pilot sites	Partially	SeaFarm / GRASS (only sites at West Coast)
Pilot sites for **reed harvesting**	Partially	CONTRA (use of Beach-wrack)
Microalgae cultivation pilot site(s) for multidisciplinary research around uses for large-scale cultivation, including test sites for nutrient removal from waste streams;	Partially	No project but examples in SE / cases in *Alliance* accelerator
Biorefinery pilot sites	Partially	Macrocascade
Wave Generation	No	Wave Project rejected

1.6.4 Technology Development & Transfer

Objective: develop environmentally friendly and cost efficient technologies suitable for Baltic Sea conditions taking into account knowledge and technologies from terrestrial resources

Collect information about technologies and scientific expertise available at national level; • Match-making between technology providers and users; • Introduce technologies and know-how available in other BSR countries to national research organisations and companies; • Offer study visits, meetings, info websites	Status YES	Projects BBG InnoAquaTech Alliance SmartBlueRegion GRASS AquaLIT

Scout for pilot installations and technology providers; enhance information exchange between technology providers and users, foster technology developments:		
• Underwater mussel and macroalgae farming technologies crucial for Baltic Sea conditions (i.e. ice / open coasts);	YES	BBG / GRASS / SeaFarm
• Environment friendly reed and beach-wrack harvesting technologies;	YES	CONTRA
• Sustainable Fish Aquaculture solutions; such as multi-use with wind parks and new IMTA / RAS production methods	YES	InnoAquaTech / UNITED
• Water treatment technologies using blue biotechnology or algae cultivation	Partially	Alliance cases
• Microalgae cultivation technology suitable for seasonal fluctuations of temperature and light in the BSR;	No	
• Scale-up processes for getting raw materials, valuable ingredients or cells from marine organisms for Blue Biotechnology products;	Partially	Alliance
• Adapt and develop biosensors suitable for marine resources;	No	

1.6.5 Regional energy solutions with marine resources

Objective: 'encourage appropriate consideration of marine resources in energy planning in order to create markets for climate friendly energy production'.

	Status	Projects
Develop concepts for integration of marine resources in regional plans on renewable energy and climate protection; • Introduce concept of smart combinations of uses, where a systematic approach to biomass use beyond the energy sector complements the biorefinery concept; • Develop economic models for use of marine resources in renewable energy production and well as regional studies & models	Partially	COASTAL Biogas
Develop a placement strategy for biorefineries using marine resources around coastal regions; • Improve networking among biorefineries across BSR; • Use experience of forestry and agriculture in blue refinery concepts:		
• Encourage technology development and continue to refine the process of biogas from marine resources; • Optimize techniques and logistics for harvesting biomass, transport to biogas plants, and for refining products;		
• Promote use of small scale wave energy generators	No	Wave Project rejected

1.6.6 Introduce ecosystem service payments

Objective: 'develop an accepted approach to valuation of ecosystem services and propose compensation mechanisms for the provision of ecosystem services by new marine uses'.

	Status	Projects
Assess the applicability of new marine uses on ecosystem services for different sub-regions of the BSR	Partially	BBG / GRASS
Proactively liaise and inform EU, HELCOM and relevant Priority Areas of initiatives related to valuation and compensation of ecosystem services	YES	Mussel WG
Develop a practical BSR-wide methodology for valuation of ecosystem services, as the basis for ecosystem services compensation schemes	Partially	BBG
Develop recommendations and proposals for establishment of ecosystem service compensation schemes based on: • Analysis of existing and proposed (if any) compensation mechanisms; • Assess the role of private sector and NGOs and get them involved; • Consider and assess various possible schemes, i.e. via taxes, national and transnational models; possible voluntary initiatives (e.g. Baltic Sea friendly coastal municipality); market opportunities	YES	BBG ecosystem service payment study

Generate life cycle assessments and techno-economic models pertinent to local conditions in the BSR to critically examine the costs and benefits of new uses and technologies compared with existing solutions	YES	BBG ecosystem service payment study
Assess the role of Blue Biotechnology products with respect to benefits to ecosystem services	YES	ALLIANCE SDG analysis

1.6.7 Unlock financing for innovative uses of marine resources

Objective: 'Improve access to finance for collaborative projects with private and public stakeholders.'

Collaborate with investment funds, venture capital organizations:	Status	Projects
• Establish contacts with public and private financing organizations; • Identify offers, interests and needs by financing bodies and fields of cooperation; • Raise awareness among researchers, research institutes and other stakeholders on requirements of "bankable" projects; • Study and assess innovative forms of knowledge brokerage; • Initiate individual and multilateral meetings and consultations.	YES	ALLIANCE+ InnoAquaTech
Improve relationship between public research and private companies: • Raise awareness among industry on project opportunities and benefits to be gained from participation in public funded programmes and seek their active input a; • Study and assess challenges for private-public collaboration; • Identify, assess and disseminate good practices of private and public collaboration, develop "vademecuum / guidelines"; • Organize and attend workshops showing case studies on how companies and research can collaborate; • Encourage and assist networking and concrete development of Public-Private Partnerships at regional and local level.	YES	ALLIANCE+ InnoAquaTech
Develop applications to both public and private funding programmes: • Inform SUBMARINER Network partners on funding opportunities and their specific requirements and vice versa; • Develop strong triple-helix project partnerships based on partner institutions strengths.	YES	ALLIANCE+ UNITED All future projects

1.6.8 Create better legal and regulatory conditions

Objective: 'Reduce vagueness in legislation and regulations for innovative uses of marine resources'.

Assess the existing integration of innovative uses of marine resources in relevant EU Directives and establish a dialogue with national authorities and EU Directorates	Status YES	Projects BBG, GRASS
Foster a joint interpretation on targets set by relevant EU Directives (Natura 2000, WFD, MFSD) with regard to "harvesting" marine resources (e.g. macroalgae, reed);	Partially	BBG, GRASS
Consider how new uses of marine resources shall be considered in Maritime Spatial Planning (i.e. develop pilot plans in various regions, develop criteria for "suitable sites");	YES	BalticRIM, BBG
BSR-wide agreement on integrating reed and mariculture cultivations as an environmental remediation measure under the HELCOM BSAP	YES	BBG
Recommendations on incentives for combinations with offshore wind parks	YES	MUSES
Recommendations for a common approach to use fish aquaculture for restocking	NO	-
Assess tools for ensuring the exploitation rights for all actors involved in finding, development and commercialization of Blue Biotechnology products.	YES	ALLIANCE

1.6.9 Public Awareness

Objective: Create a market in which consumers are aware of the benefits of sustainable blue products and are motivated to contribute to solutions.

Carry out public awareness campaigns:	Status	Projects

• Create information material on potential of new and innovative sustainable marine resources	Partially	All projects
• Identify and create success stories (local, regional, national)	YES	Blue Platform
• Undertake campaigns on value of ecosystem services and nutrient recycling	Partially	BBG
• Produce and disseminate "SUBMARINER" newsletter and/or magazine;	YES	SUBMARINER
• Create cooperation with media to integrate them into public campaign	Partially	BBG
Conduct market surveys on products from marine resources	Partially	GRASS
Carry out information campaigns, workshops and involve companies on: • new and local fish species (regional level) • development of new fish, chicken & cow feed • organic fertilizers; • blue biotechnology applications; • reed / beach cast as ecological insulation material;	Partially	BBG Alliance Blue Platform Fucosan CONTRA
Support establishment of a Baltic Sea Brand and Distribution Network for: • Fish & Algae from BSR aquaculture; • Mussel meal products and organic fertilizers; • Cosmetics, health care and wellness products;	No	Sea to Fork

SUBMARINER Topics: Achievements & Future Needs

2 Mussel farming in the Baltic

2.1 Ambition

The original SUBMARINER compendium had highlighted the potential of Baltic Sea mussel farming to serve as an additional measure to mitigate eutrophication – and in fact the only known sea-based measure to deal with the already existing nutrient load, together with algae cultivation. Moreover, it had pointed towards the advantages of using mussels as a regional protein source in feed as well as other commercial applications.

2.2 Projects

Since the publication of the SUBMARINER roadmap (2013) a variety of projects have been funded, which relate to Mussel Cultivation at the Baltic Sea Region:

Baltic Blue Growth (Interreg BSR 2016-2019)

tried to kick start the development of commercially viable large-scale mussel farming in the Baltic proper by addressing technological, environmental, legal as well as economic challenges. It **operationalised 3 mussel farms** with a total harvest of more than 100 tonnes of blue mussels in the Baltic Proper in 2018. The project showed that mussels can be farmed successful in large parts of the Baltic Sea, if **farming methods are adapted to local conditions**. With close to zero negative effects reported from the 4 pilot farms, it demonstrated that the **environmental effects from farms are largely beneficial**. BBG highlighted how the ecosystem services provided by mussel farms (filtering the water and trapping excess nutrients), can be monetised and suggested possible payment schemes.
SUBMARINERs: Region Östergötland (SE), LIAE (LT), Ministry for Agriculture, Environment, Nature and Digitalization of Schleswig-Holstein (DE), GMU (PL), UTartu (EE)
Weblink: https://www.submariner-network.eu/balticbluegrowth

OPTIMUS (BONUS 2017-2020)

aimed to provide robust evidence-based documentation (ecological, social, and economic) on ecosystem goods and services as well as environmental impact of mussel farming to support its future expansion. It delivered **policy guidelines** for the implementation of mussel cultivation **as a mitigation measure for coastal eutrophication in the Western Baltic Sea**, as well as a Guideline to increase social acceptance of the mitigation concept. The consortium also produced a **Spatial Model for nutrient mitigation potential** of blue mussel farms in the Western Baltic Sea, which considers variability, uncertainty, food limitation and required hydrodynamics. OPTIMUS also delivered a report on product optimization, as well as a **new cost-efficient technique for processing mussel meal**. The project showed that mussel farming is a highly competitive mitigation measure in the Baltic Proper.
SUBMARINERs: University of Gothenburg (SE)
Baltic Partners: DTU Aqua, Technical University of Denmark, Aarhus University (all DK)
Weblink: https://www.bonus-optimus.eu/

Rich Waters (LIFE IP 2017-2024)

aims to boost the full implementation of the River Basin Management Plan 2016-2021 of the Northern Baltic Sea District and has a focus on Sweden. The project shall demonstrate and evaluate mussel farming as an in-situ measure for nutrient reduction of eutrophication of coastal waters in the Stockholm archipelago (thus Northern Baltic Sea Region) with focus on internal nutrient loading. The project so far has supported results from BBG that mussel cultivation with new technology adapted for Baltic Sea mussels can be successful.
SUBMARINERs: IVL Swedish Environmental Research Institute (SE)
Weblink: https://www.richwaters.se/category/en/

AquaVitae (Horizon 2019-2022)

aims to increase low-trophic aquaculture around the Atlantic Ocean. Mussel aquaculture in offshore areas and semi-intensive seed production techniques are included as a case study, with a specific focus on the Great Belt, Denmark. The case study shall show how blue mussels can be cultivated in offshore areas and document how mitigation from mussel cultivation can also increase offshore fish farm production. The project will quantify ecosystem services (i.e. eutrophication mitigation) and develop new hatchery production techniques to find a solution for the low settlement rates of mussels, which is a key industry barrier.
SUBMARINER Project Partners: IVL (SE)

Weblink: https://aquavitaeproject.eu

Combined Marine Aquaculture project Mecklenburg-Western Pomerania – Germany ('*Kombinierte marine Aquakultur'*, Regional funding 2019-2023)

implemented by EUCC-D (SUBMARINER Mussel WG) tests the combination of a blue mussel production process with fish farming (Baltic White Fish) for decentralized aquaculture in Mecklenburg-Vorpommern. The project focuses on technical and biological testing of mussel cultivation in connection with fish production in the Baltic Sea, to assess whether integrated farms (i.e. IMTA) are possible in a more decentralised way in Germany, specifically also with regard to smaller farmers. The aim is to increase aquaculture production in the region and ultimately to increase business opportunities for regional coastal fishing.

Weblink: https://www.landwirtschaft-mv.de/Fachinformationen/?id=1023&processor=processor.sa.lfaforenbeitrag

Marine bioeconomy for circular nitrogen and phosphorus flows in Sweden: Alternatives, hurdles and policy tools (SNOOP, 2018-2020, Formas)

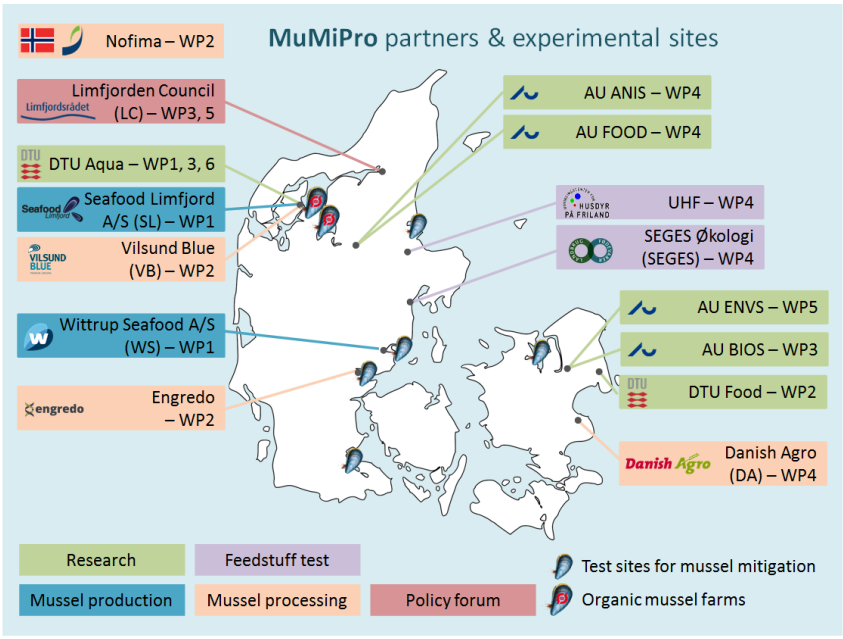
explored and compared current and future bioeconomy activities that can contribute to the recovery and reuse of nitrogen and phosphorus. The projects included mussels as a case study to look at the potential of (amongst other marine biomass alternatives) to capture N and P in the Baltic.

SUBMARINER Project Partners: KTH (SE).

Weblink: https://www.kth.se/en/seed/forskning/ali/pagaende-forskningsprojekt/marine-bioeconomy-1.922864#

MuMiPro (InnovationFund DK 2017-2020)

The objective of MuMiPro is to develop and optimize a new mussel production concept, i.e. producing mussels as an organic protein rich feedstuff for organic husbandry and as a tool to mitigate effects of excess loading of nutrients to coastal waters thus increasing sustainable production and job opportunities. MuMiPro involved 15 partners including mussel farmers, feed producers and research institutions within mussel production, husbandry, feed production, organic production and environmental management. MuMiPro is expected to result in more area efficient and cheaper production methods and relevant processing technologies making it more attractive for mussel farmers and processors to invest in this type of business. With an area efficient production method and a national estimate of mitigation potential, mitigation cultures can be included as a measure in the third generation water plans. Furthermore, payment schemes for ecosystem service provision can be translated into a business opportunity by effectively reducing the production costs. The project has also resulted in Blue Mussel Mitigation Farm Site selection tool for the Western Baltic Sea (Mytigate).



Danish Partners: DTU Aqua, Aarhus University, etc. (see visual)

Weblink: https://www.mumipro.dk

BalticSeaFeed (Swedish Institute SEED money, 2020-2021)

Feed from Baltic Marine Resources such as micro or macro-algae, mussels, non-quota fish or fish side streams, which is not only used in Baltic fish farms, but also for cows, chicken (incl. egg production) or pet food – make animal production in the Baltic Sea Region more sustainable. Not only are nutrients recycled and not brought to the Baltic Sea from outside. Research also shows that the amount of nutrients or methane released by the animals fed with Baltic Marine Resources is substantially lower compared to animals fed with traditional feed. The aim of the BalticSeaFeed SEED money project is to explore the current state of art in this field and to develop a large scale project to cover the respective knowledge gaps.

SUBMARINERs: KTH, Kalmarsund Commission (SE), NMFRI, GMU, Uni Gdansk (PL), UTartu (EE), LUKE (FI)

2.3 State of Play

By 2020, mussel farming in the Baltic Sea Proper is nevertheless still in infancy, with hardly any large commercial farm being operational yet in the region. At same time, there is an increasing number of pilot sites (e.g. in the Stockholm archipelago, Estonia), a growing community of mussel farmers (including some from the Western Baltic) and also an increasing willingness among environmental decision makers to accept mussel farming as a possible sea-based nutrient removal measure. Apart from some farms in Sweden, Denmark and Germany, there is also already one operational mussel farm in Estonia operated by the company Redstorm OU (which is a subsidiary of the large scale fish producing company PR Foods), which is situated in the Tagalaht Bay at the Western part of the Saaremaa island and has been installed as a compensation measure for the fish farm operated by the same company in that area.

Considering the average growth, you may get over 8.000 kg of mussels per 1 km^2 per 2 years also within the less favourable conditions in the Baltic Sea. These figures are manifold higher in the western-most parts of the Baltic Sea. A total harvest of some ten thousand tons of mussels annually from the Baltic Sea could be realistic in the future, requiring only a few km^2 of farms. Compared to the total surface area of the Baltic Sea, this is only a very small space requirement.

Area	Salinity	Meat dry matter %	% Soft tissue	Soft tissue fat %	N (% soft tissue dry weight)	P (% soft tissue dry weight)
Western Baltic	High	15.1 a	58 a	9.5 a	9.5 a	1.41 a
Central Baltic	Moderate	14.2 a	52 b	10.3 a	10.3 a	1.48 a
Eastern Baltic	Low	13.7 a	41 c	9.7 a	9.7 a	1.33 a

Table 1. In this table, data from analyses of mussel flesh from the Western Baltic (high salinity), the Swedish East Coast (medium salinity) and the Baltic coast and Åland (low salinity) is presented. Parameter values that are followed by the same letter show no statistically significant difference between regions.

Since 2019, the SUBMARINER Network secretariat has taken the role to coordinate and synthesize the results of the various projects dealing with mussel cultivation in the Baltic Sea Region and to continuously update and feed them with new information coming in from research as well as operational farms. The **Mussel Working Group** established and facilitated by the SUBMARINER Network secretariat – through regular online meetings – allows for a regular experience and data exchange among all relevant actors.

In September 2019 the Working Group has published a policy paper[1], which summarizes the data and results based on five years of simultaneous projects researching the possibilities of mussel farming in the Baltic proper for nutrient removal and feed production. The paper provides **evidence of the positive results achieved that encourage scaling up**. It makes two essential points:

- Mussel farms in the Baltic Sea can make a significant contribution to reduce eutrophication, in addition to being cost-effective, they are also the only proven measure to deal with the existing nutrient load.
- If available in a sufficiently large amount, mussels can also provide a new sustainable (regional protein) resource for the feed industry or serve as a biological alternative to chemical fertilizers – creating a better balance between exports and imports of nutrients.

The paper shows the following positive advancements made during the past years:

a. **There is no difference in the total amount of mussel meat (dry matter) between mussels cultivated in high or low salinity areas**. The use of new technology – adapted towards the smaller, slower growing Baltic Sea mussels – led to 4 times higher production rates than previous initiatives.
b. There is much less difference than previously expected between the nutrient content of mussels cultivated in lower or higher salinity levels. Moreover, the data suggests that there is a variation in nutrient content

[1] Schultz-Zehden, A et al.; SUBMARINER Network Mussels Working Group, 2019. Mussel farming in the Baltic Sea as an environmental measure. Berlin, Germany.

seasonally. This means that there may be potential to increase the nutrient uptake even further by selecting the right harvest period.

Mussel farms, situated in areas where nutrient removal is most important, are therefore much more effective than previously expected, when considering content and production efficiency. Also, the new data allows a much better prediction of nutrient removal by farms in different areas and seasons.

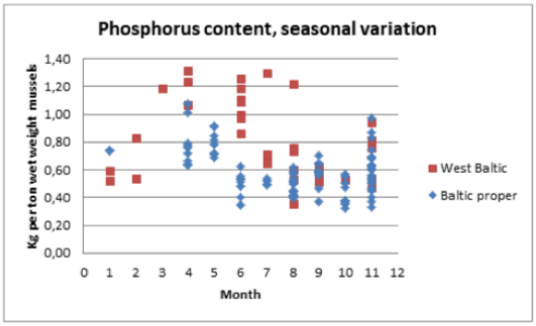


Figure 2. Phosphorus content, seasonal variation.

c. **The sedimentation from the studied mussel farms was highly local and less than expected, and no oxygen depletion was noted in the near-bottom waters**. The content of nutrients and carbon in the sea bottoms were the same at the mussel farms as in reference areas with no mussel farms. The benthic communities showed higher biodiversity in and around the mussel farms probably caused by the sedimenting shells and mussel faeces. Finally, an underwater video recording showed a clearer water due to the filter feeding mussels. This in turn can promote growth of macro-algae and eelgrass, which improves the breeding grounds for fish.

Negative impacts of mussel farms are likely to be minimal when placed in suitable locations. It is, however, important to continue the environmental monitoring at the mussel farms with the focus on bottom conditions, e.g. oxygen levels and benthic fauna.

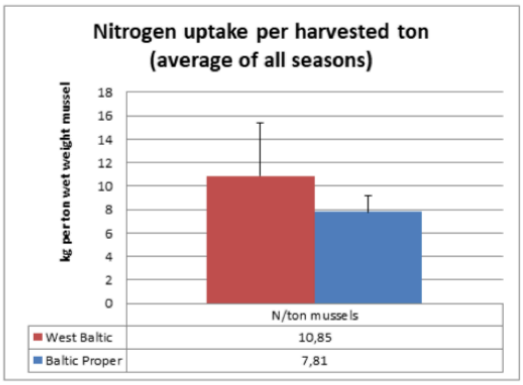


Figure 4. Nitrogen uptake per harvested ton.

d. The number of mussels produced by farms in the Baltic proper as well as possible negative impacts are heavily **influenced by a number of environmental conditions**, including availability of nutrients, temperature and movement of the water, as well as the occurrence of predators.
e. Sites should be carefully selected in view of a) investment and production costs, b) pricing and market stability, c) infrastructure to connect to shore, as well as d) lowering the risk of mussels dislodging from the substrate. **Until these potential barriers are addressed and better offshore technology is developed, it is recommended to focus on locations in near-shore or sheltered areas**.
f. The current projects show that there is **further potential for cost reductions** through adopting work-saving technologies as well as joint purchase / use of harvesting, processing and farm operational management equipment. Production costs are expected to drop substantially when more farms are installed.
g. Studies conducted within the BBG project, showed that **mussel meal is a good raw material and feed ingredient** with no deviance from reference feed (containing soy protein) with regard to growth and health for chickens. Neither the mussels, the mussel meal or chicken tissues tested exceeded EU food or feed regulations in view of hazardous substances.

Even under current non-favourable cost condition, mussel cultivation in the Baltic proper (thus the area where nutrients levels have to be reduced) can be much more cost-effective in certain areas than land-based nutrient removal measures, which already receive support via rural development programmes. What is currently still lacking – and was impossible to be achieved by the projects themselves – was an appropriate support scheme (e.g. payment for ecosystem services) to cover for the ecosystem services provided by a mussel farm.

2.4 Conclusions and Recommendations

In order to turn mussel farming into an economically feasible and environmental safe business in the Baltic, it is necessary to:

- allow and fund more and larger demonstration sites to be installed in the coming years;

- further advance cultivation and harvesting technologies as well as better techniques to process raw small mussels into feed and food
- gain better data through systematic monitoring;
- optimize the way of how to channel mussels (and thus the nutrients) back into the food system by using them as a resource for feed products and thus;
- demonstrate to the feed industry that mussels can be produced and delivered as bulk flow.

The SUBMARINER Network therefore makes the following **recommendations:**

1. **Complement land-based nutrient reduction measures with appropriate marine actions for nutrient removal in order to achieve the Baltic Sea environmental goals**
    a. accept mussel farming as a nutrient mitigation measure
    b. acknowledge the additional positive protein recycling effects – if mussels are used in food/feed production
    c. develop and agree on a certification scheme using indicators based on standardized monitoring data and potentially based on the Aquaculture Stewardship Council standards and certification schemes
    d. develop an appropriate systematic (financial) support scheme
2. **Consider restorative aquaculture**, whereby mussels are used for the restoration of declining wild mussel populations and in the long-term supporting the declining Eider duck population, should be considered in potential support schemes
3. **Identify and pick most optimal location**
    a. based on transport, salinity, exposure, biological conditions and
    b. differences between deep and shallow waters
4. **Invest in more and larger demonstration farms at these strategically selected sites**
    a. to increase knowledge of the environmental effects – on more and larger crops according to standardized methods – esp. also in view of sedimentation issues
    b. to identify and optimize appropriate technology development
    c. to lower production costs
5. **Develop the mussel market within the feed industry**
    a. by creating the connection between these two dispersed industries
    b. by securing a sufficient and stable supply of mussels
    c. lowering production, harvesting and logistical costs
    d. created through larger demonstration sites and
    e. a systematic and cooperative approach between the farms as well as
    f. widening the scope beyond the Baltic Sea only (e.g. through the BioMarine global 'Blue Coop' initiative supported by SUBMARINER) – e.g. marketing Baltic Sea mussels as an alternative to the green lip mussels from New Zealand that are currently often used for dog feed
6. **Allow for the expansion of an environmentally friendly, sustainable marine fish aquaculture industry at selected sites within the Baltic Sea Region**
    a. by accepting mussel farming as a compensation measure
7. **Look into further commercialization options**
    a. by also taking into account options of making use of mussel shells (e.g. within the SUBMARINER Accelerator)
8. Provide further support to first runner mussel farms through
    a. joint business planning
    b. certification, labelling and Baltic-wide marketing campaigns.

2.5 Activities suggested for the SUBMARINER Mussel Working Group

1. Continue to collect data and information on the currently operational farms and share this through the Operational Decision Support System (ODSS)
2. Investigate a **coherent Baltic Sea wide business plan** – showcasing of how many mussel farms / mussel harvest and which locations are necessary to provide the feed industry with a cost-effective alternative protein source
3. Take a collective and coordinated approach towards lobbying for changes in legislation and funding programmes and cooperation with certification bodies

4. Organise dedicated meetings / initiatives to connect the mussel farm community with relevant players in policy and the feed industry
5. **Widen the scope of the SUBMARINER WG on mussels, so that it is more in line with currently popular wider concepts** such as “circular economy’’ / “IMTA (including not only low-trophic but also fish)” / “climate change mitigation” / “environmental protection & restoration services” / “blue-green infrastructure” or “multi-use”.
6. This would allow for the easier linking and promoting exchange among different interests within the Network as well as other related projects; i.e. the ongoing LIFE project on “artificial /floating lagoons”.
7. The mussel topic should be framed as to provide better help directly to municipalities.

3 Macroalgae Cultivation and Wild-harvesting

3.1 Ambition

Production of Baltic macroalgae can provide an important food and feed source, but also a valuable resource for ingredients, materials and energy. Green, red and brown, algae species can grow inside the proper providing ecosystem services, e.g. nutrient load reduction, habitat provision and increased localised CO_2 fixation.

Macroalgae are a much-promising family of aquatic plant-like multi-cellular organisms with versatile and multi-functional properties beneficial to human health and the natural environment. Macroalgae can have nutritional value for food suitable for human consumption. They also perform very well as biofertilizers; feed additives in pigs, fish and cows; in cosmetics and therapeutic applications and are even suitable for energy production.

Environmental assessments of seaweed farms have shown that they absorb nutrients from the water column, provide shelter to small fish and increase biodiversity. The magnitude of impacts depends on the method of cultivation, the surface area of the farm and the site where the farm is located. Potential risks are largely associated with large scale seaweed farming and harvesting including aesthetic impacts and changes to primary and secondary productivity levels.[2] In addition, life-cycle assessment (LCA) studies have demonstrated that kelp production (including hatcheries, cultivation, harvesting and preservation) can deliver products that are both low-carbon and locally mitigating eutrophication, even taking a full life-cycle perspective[3]. These studies also highlight that the carbon that is fixed during photosynthesis may be end up stored long-term in soil, if it is utilised e.g. as a fertiliser. However it can also end up back in the atmosphere relatively quickly depending on how the seaweed is consumed, thus potentially cancelling out any climate impact mitigation of the original carbon fixation.

At the time, when the original SUBMARINER Compendium (2012) and Roadmap (2013) were published, some harvesting activities of wild macroalgae were already taking place within the Baltic Sea Region; however, not one single macroalgae farm existed yet. The ambition was therefore to establish macroalgae cultivation first at pilot and then demonstration level, in order to drive the establishment of commercial macroalgae cultivations throughout the Baltic Sea Region, including also the Baltic proper.

3.2 Projects

Baltic GRASS (Interreg BSR 2019-2021)

seeks to unlock the potential of macroalgae in the participating countries and regions in the Baltic Sea Region. More specifically GRASS 1) looks into the environmental, regulatory and socio-economic aspects of macroalgae cultivation, harvesting and use across the Baltic Sea Region, 2) identifies suitable areas and technologies for cultivation in the Baltic Sea Proper, 3) develops evidence and communication material to raise awareness on the benefits, risks and opportunities of macroalgae both as climate-smart catch crops and as a versatile biomass resource for food and in a circular economy context, 4) builds capacity on how to deal with current legislation barriers and gaps, and 5) improve capacities among public authorities to support the macroalgae sector in the BSR.

SUBMARINERs: KTH (SE), SYKE (FI), UTartu (EE), NMFRI (PL), SUBMARINER Secretariat

Weblink: https://www.submariner-network.eu/grass

Fucosan (Interreg DE-DK 2016-2020)

researched and compared Fucoidans of different brown algae species. The activities covered various aspects from cultivation and collection, processing, and extraction of the fucoidans to their properties and applications.

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[2] GRASS A1.3: A manual on environmental impact assessment for macroalgae cultivation and harvesting in the Baltic Sea (in Press)

[3] THOMAS, J.-B. E., RIBEIRO, M. S., POTTING, J., CERVIN, G., VISCH, W., NYLUND, G. M., OLSSON, J., ALBERS, E., UNDELAND, I., PAVIA, H. & GRÖNDAHL, F. 2020. A comparative environmental life cycle assessment of hatchery, cultivation and preservation of the kelp Saccharina latissima. *ICES Journal of Marine Science*.

The results were stored in a new database and published in many journal articles. To take it to the next stage of innovation, the suitability of selected fucoidans was tested in the fields of cosmetics, ophthalmology, regenerative medicine (tissue replacement methods for bone healing). In addition, the project partners developed a new network with actors from applied research and companies in the German-Danish border region in order to consider the economic potential and conditions for commercial use of the fucoidans, which will be funded again by Interreg DE-DK.
Funding: 2,2 million €
SUBMARINERs: SDU (DK), Ocean Basis, CAU, GEOMAR (all DE)
Weblink: https://www.fucosan.eu/en/

Seafarm (FORMAS, 2015-2020)

aimed to lay the foundations for a future Swedish seaweed industry by nurturing the development of a pilot kelp supply chain including a hatchery, cultivation site, harvesting methods, preservation of biomass, biorefinery processing and energy/fertiliser recovery – all of them trying to optimise their sustainability performance through a series of assessments. The project also led to a series of follow-up sister projects, to expand cultivation scale (Aqua-agri) and assess other native Swedish seaweeds potentials (Sweweeds). Several start-ups have merged over the past few years, benefiting from knowledge generated in these projects. Most notably Nordic Seafarm, previously known as KosteeerAlg, is now the largest commercial seaweed (sugar kelp) farm not only in Sweden, but throughout Baltic aiming for food applications.
SUBMARINERs: KTH (SE), UGot (SE)
Weblink: www.seafarm.se

Blue Food - Blå Mat (FORMAS, Sweden, 2021-2024/8)

"Blue Food - Center for the Seafood of the Future" brings together a number of universities, companies and organizations. The goal is for Sweden, with the help of research, innovations, collaborations and campaigns, to become a EU leader in sustainable seafood. Formas finances the project with SEK 48 million for the first four years, and if it goes well with SEK 48 million for another four years. Some of the parties in Blue Food are KTH, University of Gothenburg, Chalmers, SLU, Uppsala University, RISE, Innovatum, IVL, Region Stockholm and Region Västra Götaland. About seventy companies also participate, including food producers and companies from the grocery trade and the restaurant industry.
Swedish SUBMARINERs: KTH, UGOT , Uppsala University, IVL and Innovatum.
Weblink: https://www.kth.se/en/aktuellt/nyheter/havet-ar-nyckeln-till-en-hallbar-framtid-1.1029849

TANG.NU (VILLUM/VELUX FOUNDATION, 2017- 2020)

investigated sustainable cultivation and harvesting of *Saccharina latissima*, *Ulva*, *Palmaria palmata*, and *Fucus* species in the Kattegat and the Limfjord and assessed the associated environmental benefits and risks. The project also examines the perspectives of using harvesting and collecting seaweed as a so-called engineered ecosystem services to extract nutrients, reduce eutrophication, create a cleaner marine environment, and subsequently using the seaweed biomass for food and feed. TANG.NU focuses on using the harvested seaweed in feed for cattle, pigs and fish and to develop pathways for certification of seaweed for food purposes.
Danish Project Partners (no SUBMARINER): Aarhus University, DTU, Roskilde University, DTI, more
SUBMARINER associate project partners: Guldborgsund Municipality,
Weblink: https://tangnu.dk/

Macrofuels (Horizon2020, 2016-2019)

aimed to produce advanced biofuels (ethanol, butanol, furanics and biogas) from macro-algae. By the end of the project, Macrofuels had harvested 10 t of seaweeds in Scotland and 200 kg in Denmark and produced 20 liters of seaweed-derived car fuel as a proof of concept.
Baltic Project Partners (no SUBMARINER): DTI, Fermentation Experts and Aarhus University (all DK)
Weblink: https://www.macrofuels.eu/

Macrocascade (BBI-JU, 2017-2020)

aimed to proof the concept of a cascading marine macroalgal biorefinery; developing a production platform covering the whole technological chain for processing sustainable cultivated macroalgae biomass, mainly *Sacharina latissima*, up to highly value processed products. MACRO CASCADE mixed seaweed with rapeseed meal and used a 2-step lacto-fermentation ensilaging method to increase digestibility higher than 25%. The developed process considerably increased content of glucose, lactic acid, free amino acids and

vitamins.[4] The project also enhanced the previous process for production of algae-enriched rapeseed based feed for pigs[5] and developed a new process of fermenting rapeseed and seaweed food grade and investigated the potential of using such a fermented food product to reduce the inflammation response in human cells with promising results.[6] Finally, MACRO CASCADE suggested processes for alginate extraction, and combined isolation of vulnerable (bioactive) compounds like laminarin, mannitol and fucoidan.[7]

Baltic Project Partners (no SUBMARINER): DTI, DTU, Novozymes, Fermentation Experts (all DK), Lunds (SE), Ocean Rainforest (Faroe)

Weblink: https://www.macrocascade.eu/

SeaSus-protein (GUDP Denmark, 2020-2023)

Aims at producing functional foods from four Nordic seaweed species. The project will use biorefining to make the seaweed proteins digestible for human stomachs and investigate how the refining affects the quality of the protein. The project will explore the potential of using free-floating seaweeds for production of food.

Weblink: https://mst.dk/erhverv/groen-virksomhed/groent-udviklings-og-demonstrationsprogram-gudp/gudp-projekter/2019-projekter/2-seasus-bioraffinering-af-tang/

Danish Partners: Aarhus University; Nordisk Tang; Danish Marine Protein; HedeDanmark; Orbicon.

Development of cultivation technology for *Ceramium tenuicorne* to obtain biomass suitable for extraction of red pigment phycoerythrin of analytical grade purity (EMFF Estonia, 2020-2022)

The widely distributed red macroalgal species in the Baltic Sea, *Ceramium tenuicorne* has great potential as raw material for highly valued bioactive compounds, first of all for extraction of the red pigment phycoerythrin. *C. tenuicorne* is the only red algal species in Estonian coastal waters from which the pigment could be extracted with analytical grade of purity. The aim of this project is the development of cultivation technology for *C. tenuicorne* to obtain biomass, which quality is suitable (high content of phycoerythrin) for the extraction of the pigment and high growth rate of the species.

SUBMARINERs: UTartu / Estonian Marine Institute

Land-based cultivation technology of green algae *Ulva intestinalis* in the fresh- and brackish waters (EMFF Estonia, 2020-2022)

The aim of the project is to test land-based cultivation technology of green algae Ulva intestinalis in the fresh- and brackish waters, to determine under which environmental conditions *U. intestinalis* has the highest growth rate values, while maintaining the valuable quality of the raw material.

Weblink: https://www.etis.ee/Portal/Projects/Display/3247ecd0-e4c2-4df1-8d05-a1bf226c42b5?lang=ENG

SUBMARINERs: UTartu / Estonian Marine Institute

SNAP (ERA-BlueBio Co-fund, 2020-2023)

aims to develop novel products by upgrading and modifying five different polysaccharides from selected brown and red algae (Laminaria hyperborea, Saccharina latissima, Alaria esculenta and Chondrus crispus).

SUBMARINERs: KTH (SE)

Weblink: https://bluebioeconomy.eu/seaweeds-for-novel-applications-and-products/

Alget2 ALGae EnTrepreneurs (NorgesVel 2019-2021)

Aims to strengthen competence in sustainable and quality harvesting, processing and product development of macroalgae in the North Atlantic region and to also increase knowledge about market demands within the food- and cosmetics/skin care industries, based on macroalgae as product or ingredient in products.

Weblink: https://www.norgesvel.no/alget2

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[4] MACRO CASCADE D3.1 Process of conversion of algae into nutritious feed additives with increased (25%) digestibility: https://www.macrocascade.eu/wp-content/uploads/2020/04/MacroCascade-D3.1-Summary-1.pdf

[5] D3.2 Process for production of algae enriched rapeseed-based feed for pigs (Danish Technological Institute; M24) https://www.macrocascade.eu/wp-content/uploads/2020/04/MacroCascade-D3.2-Summary.pdf

[6] D3.4 Report on process development for algal based food product https://www.macrocascade.eu/wp-content/uploads/2020/04/MacroCascade-D3.4-Summary.pdf

[7] D4.1 Report on biorefinery approach based on sample composition: https://www.macrocascade.eu/wp-content/uploads/2020/04/MacroCascade-D4.1-Summary-1.pdf

MAB4 (Danish Innovation Fund, 2016-2019)

aimed to develop improved cultivation methods for macroalgae (*S. latissima*) in Danish and Faroese waters with special attention to the seasonal development of the algae's bioactive substances and their preservation during harvest and storage. The project also developed and optimized sustainable enzymatic and green-solvent extraction methods for the production of high value products, including antioxidants, fucoidan, laminarin, alginate and minerals, for feed and food ingredients as well as skin creams. The entire product chain from cultivation of the macroalgae up to the refined end product was evaluated economically and sustainably (LCA).

Danish Project Partners (no SUBMARINER): DTI, Aarhus University, DTU, University of Copenhagen, Ocean Rainforest, FermentationExperts.
Weblink: https://www.teknologisk.dk/projekter/projekt-makroalge-bioraffinering-til-hoejvaerdiprodukter-mab4/36882

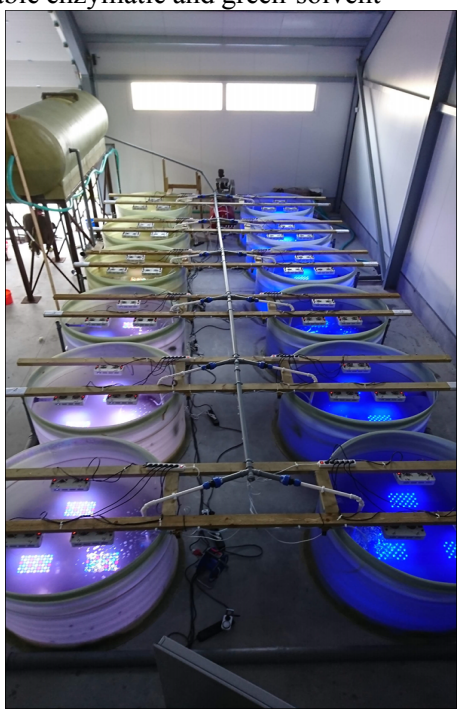


Figure 1 Furcellaria cultivation on land at University of Tartu, Photo credits: Tiina Paalme, University of Tartu.

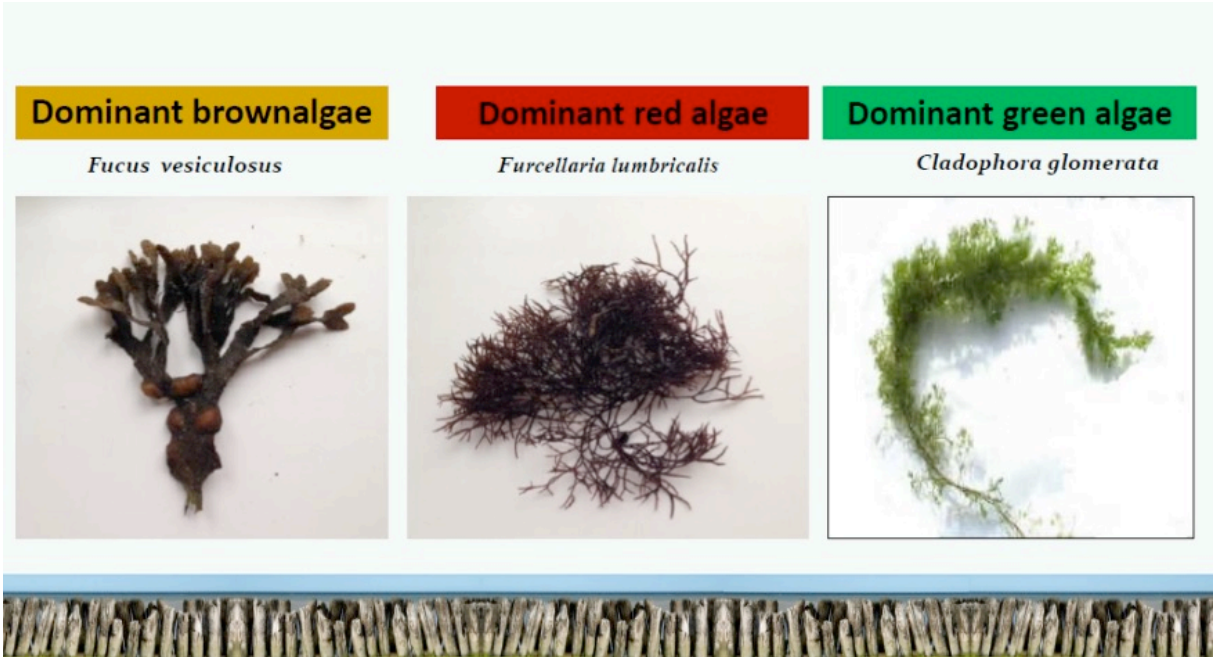
Development, testing and evaluation of intensive cultivation technology for production of unattached form of Furcellaria lumbricalis (EMFF Estonia, 2017-2019))

Aimed to develop intensive cultivation technology suitable for unattached form of *Furcellaria lumbricalis*, that is characterized by relatively slow growth in its natural habitat in West Estonian Archipelago Sea area. Cultivation of *F. lumbricalis* was tested in land-based system with artificial, controlled light environment and natural seawater. Experiments tested *F. lumbricalis* cultivation with different light conditions (irradiance, spectral composition, day length) to find optimal growth conditions and enhance the growth rate of the alga as well the protein content (e.g phycobiliproteins).

Weblink: https://www.etis.ee/Portal/Projects/Display/f17024b4-8f0f-4752-b1e2-b505432a6dcd?lang=ENG
SUBMARINERs: University of Tartu, Estonian Marine Institute

Seaweed assessment and management plan along Latvia's seacoast (Latvian FLAG, 2018)

The project aimed to help institutions, municipalities and entrepreneurs seize opportunities presented by the presence of algae, and to provide through scientific information for guidelines for sustainable harvesting of the resource. The project included: data gathering; analysis and laboratory testing; the development of tools, maps and guidance for end users. It has led to the development of a national data collection, including the different types of seaweed present in Latvia; their location; potential uses; guidance for business development and environmental advice and monitoring, including the identification of the nesting and feeding places of coastal birds.



Havhøst (Denmark)

Havhøst, or "Ocean Harvest" in Danish, is a national network on regenerative (low trophic) aquaculture that aims to raise awareness of mussels and seaweed cultivation, and enables local communities use blue areas to farm own seaweed and mussels for food purposes. Through events and activities, the organisation encourages locals all around the country and of all ages to try their hand at local, sustainable food production.
Weblink: https://www.xn--havhst-eya.dk/

Seaweed for Europe

Seaweed for Europe is a bottom-up European initiative that brings together a range of players from the seaweed value chain, the investment world and thought leaders. Funded by philanthropic means, the Coalition Secretariat is managed by SYSTEMIQ, a system change organisation which partners with business, finance, policy makers and civil society to make economic systems truly sustainable. Seaweed for Europe has published in October 2020 a report that quantifies the potential economic, social and environmental benefits of a sustainable seaweed industry in 2030.
SUBMARINER Network is an active member of Seaweed for Europe
Weblink: https://www.seaweedeurope.com/

3.3 State of Play

With some exceptions there is no tradition for using macroalgae in the Baltic (even if sourced from other parts). However, there is a recognized growing demand for macroalgae products. According to an international consumer study done by the GRASS project in 2019 out of 2,000 received responses, **30% of Baltic respondents regard seaweed as very healthy food**, and 25% believe in special benefits of seaweed cosmetics use. Consumption patterns showed that **26% of respondents ate seaweed as an ingredient of sushi**, **while nearly every fourth consumer has tried seaweed already in other forms** (e.g. salads, soups, snacks).

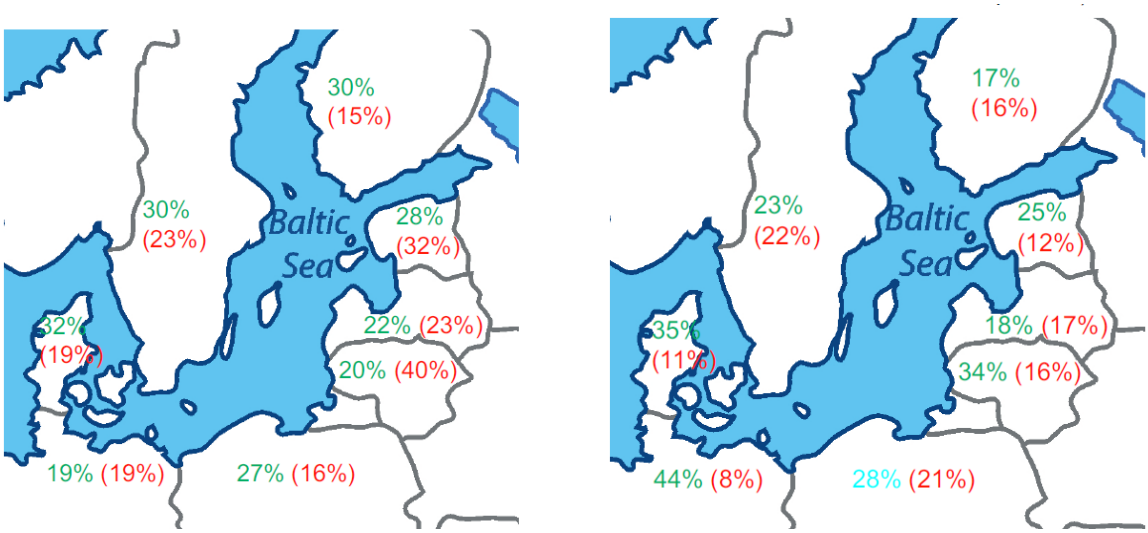


Figure 2. Left – Percentage of people declaring consumption of seaweed in individual countries: only in the form of sushi (in green) or in various forms (in red). Right – Percentage of people in individual countries recognising seafood (including seaweed) from the Baltic Sea as good quality local food (in green) ver. Consumers recognising Baltic food products as polluted / unhealthy (in red). Source: NMFRI GRASS project WP4.1 report 2021.

3.3.1 Production of macroalgae

Production of macroalgae and seaweed is at a nascent phase in the Baltic and almost 100% macroalgae raw material supply come from import from EU countries and third countries, like in Norway, Russia, China, and Japan. Due to the reduced salinity levels and other particularities of the Baltic proper, fewer species with a commercial value can grow in the proper. The most promising seaweed species for cultivating in the Baltic Proper are *Fucus vesiculosus and Ulva intestinalis*. In addition, in the Western part of Baltic, e.g. Danish Straits, Western Sweden and Kiel area in Germany, where salinity is higher, *Saccharina latissima, Laminaria*

digitata, and *Palmaria palmata* can also be cultivated, all of which are very popular cultivars in Europe.[8] In search of sites for cultivation, the salinity has to be carefully considered to match the choice of species. The GRASS project has developed models and maps that provides stakeholders with the basis to identify suitable areas for macroalgae cultivation and harvest, by incorporating also salinity and other environmental factors among others (http://www.sea.ee/bbg-odss/Map/MapMain).

Commercial macroalgae production activities in the Baltic are mostly limited to wild harvesting at local radius, with Denmark being the largest seaweed producer (100 tonnes in 2018). Only a handful of marine seaweed farms exist so far in the Baltic Sea Region; all of them being located in the Western Baltic and apart from one growing Ulva, all others grow *Saccharina latissima*: one farm in Germany, three farms at the Western coast of Sweden and 4 farms in Denmark. There are also a few experimental farms in Western Baltic and one in Estonia.

Table 1 Seaweed farms at the Baltic Sea Region

Name	*Stage*	*Type*	*Species*	*Country*
Coastal Research & Management	Commercial	Marine	*Saccharina*	Germany
	Research	On land	*Saccharina*	Germany
Kiel University/ Fucosan	Research	Marine	*Fucus*	Germany
Nordic Seafarm	Commercial	Marine	*Saccharina*	Sweden
Bohus Seaculture	Commercial	Marine	*Saccharina*	Sweden
Kristineberg Research Centre	Research	Marine	*Saccharina*	Sweden
Hjarnø Havbrug	Commercial	Marine	*Saccharina*	Denmark
Dansk Tang	Commercial	Marine	*Saccharina*	Denmark
Sømad	Commercial	Marine	*Saccharina*	Denmark
Pure Algae	Commercial	On land	*Ulva*	Denmark
Algae Centre	Research	Marine	*Saccharina*	Denmark
Estonia	Research	On land	*Furcellaria*	Estonia

3.3.2 Baltic Macroalgae Species

Neither Fucus nor Ulva species have yet been commercially farmed at sea.

There have been attempts to cultivate the ***Fucus vesiculosis*** in small-scale projects within the region for example in Sweden, Denmark. In the Fucosan project cultivation *of* ***Fucus vesiculosis*** and ***Fucus serratus*** was tested for commercial purposes in beds in Kiel Bay in Germany, by using asexual subjects with promising results that are worth developing further (see figure below)[9]. In this endeavour, biological fouling was identified a major obstacle that reduces the quality of product and strategies to tackle biofouling were tested[10]. **This experimental study could be seen as a**

[8] GoA 2.1. Assessing the PanBaltic potential of macroalgae cultivation and of harvesting wild stocks Jonne Kotta, Holger Jänes, Tiina Paalme, Anneliis Peterson, Ilmar Kotta, Robert Aps, Robert Szava-Kovats, Ants Kaasik, Mihhail Fetissov. Estonian Marine Institute, University of Tartu: https://submariner-network.eu/images/grass/GRASS_OA2.1_pan-Baltic_map_depicting_potential_of_macroalgal_cultivation_and_harvesting.pdf

[9] Meichssner, R., Stegmann, N., Cosin, A.-S., Sachs, D., Bressan, M., Marx, H., . . . Schulz, R. (2020). Control of fouling in the aquaculture of Fucus vesiculosus and Fucus serratus by regular desiccation. Journal of Applied Phycology. doi:10.1007/s10811-020-02274-2

[10] Fucosan project. 2020. Result Report: Algae sources, cultivation and collection. CRM. Interreg DE-DK: https://www.fucosan.eu/app/download/6216446466/Fucosan%20Result%20Report%20WP3%20web.pdf?t=1599217068

promising step for initiating similar pilot cultivation systems at other locations around the Baltic Sea area.

Figure 3 *Cultivation baskets were deployed in the sea and kept floating by plastic pipes (a) or JETFLOAT® elements (d).*

Ulva* species** are the dominant species in so called green tides, macroalgae blooms often devastating to populated coastal areas worldwide. *Ulva* are used for human consumption, bioenergy or in bioremediation projects to reduce nutrients in eutrophicated waters. There have been some attempts to cultivate both ***Ulva lactuca and ***Ulva intestinalis*** within the Baltic Sea region in pilot or experimental project[11]. Also, **Ulva** production on land is currently piloted for commercial production by two companies; Pure Algae in Denmark and Nordic Seafarm in Sweden. Indoor cultivation tests are carried out for ***Ulva gracilaria*** at Hamburg University and for ***Ulva intestinalis*** at the University of Tartu. The genus is not taxonomically well supported and latest studies with molecular data suggest that previous species identification based on morphology may not be correct; species morphology is often overlapping, and also show large variations within species depending on environmental setting and geographical location.

Palmaria palmata (Dulse) is another red algae species abundant in the BSR and already in high demand in world markets as food, feed, biofuel or for bioactive compounds (Grote, 2019). There is a clear possibility to develop large-scale open sea cultivations of Dulse in Europe but to get there, more knowledge is needed to develop cultivation techniques, disease control and strain selection before a commercialization of the production system could be developed. In the TANG.NU project in Denmark, studies of *Palmaria palmata* cultivations have shown how to improve the hatchery phase (Schmedes & Nielsen, 2020a) and how to avoid biofouling by changing salinity levels (Schmedes & Nielsen, 2020b).

3.3.3 Wild harvesting of macroalgae

Prominent inside the Baltic proper, are the harvesting activities take place in Estonia, where the two companies (Est Agar, Vetik) are allowed to harvest 2.000 tonnes of ***Furcellaria lumbricalis annually*** and also two harvesting companies operate in Latvia[12]. An additional 4,000 tonnes is being collected from *Furcellaria* wrecked on beaches (for more information on beach-wrack see chapter 8).

[11] GRASS A2.2: Manual on the efficient production methods of macroalgae farming in the Baltic Sea region (in press)
[12] GRASS A2.2: Manual on the efficient production methods of macroalgae farming in the Baltic Sea region (in press)

Furcellaria lumbricalis is the most common species in Estonian coastal waters where about 100,000-150,000 tonnes of wet weight of the species is produced every year in this area. There are two forms of *Furcellaria lumbricalis,* one attached and one unattached (free-flowing), where the latter is more interesting for harvesting. The population size of unattached Furcellaria is followed closely by Estonian researchers and harvest level needs to be kept at a low level to sustain a viable population in the area. Other environmental pressures such as eutrophication and ocean acidification might decrease the population of *F. lumbricalis*, which imply that harvest of wild stocks might need further restrictions in the future from a conservation point of view.

Also, in Denmark, companies have established commercial **seaweed wild-harvesting** activities (e.g. Nordisk Tang, Dansk Tang and Organic Seaweed) that they have organised themselves within a national Danish Seaweed Organisation (http://www.danish-seaweed.org/).

3.3.4 Macroalgae Market outlook

The market potential of seaweed in Europe is estimated as high as 9,3 bn € by 2030 with high potential for feed, food, pharmaceuticals, cosmetics, biofertilisers, biofuels, and bioremediation and ecosystem services. About 30% of this market could be met by European supply by 2030 by producing as much as 8,3 million tonnes fresh weight seaweed, thus increasing the EU production of 2015[13] 27-fold (see Figure 6).

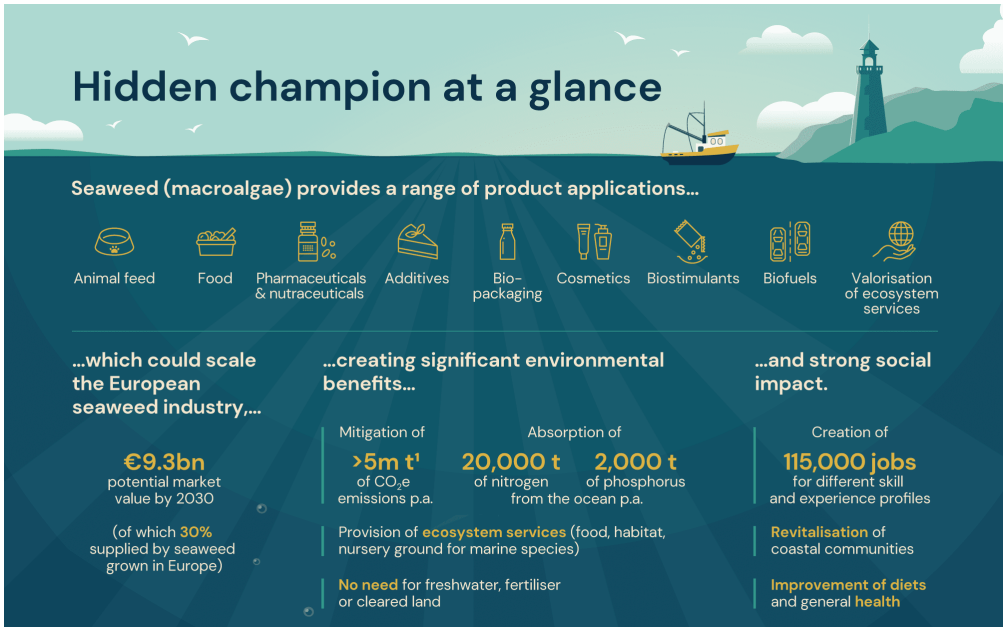


Figure 4 Seaweed for Europe "Hidden Champion" infographic 2020 [1]

Also in the Baltic, it is expected that seaweed cultivation activities will grow exponentially in Denmark, Germany and Sweden in the next 3-5 years. With only a handful of farms existing in the Baltic Sea region, almost all consumed seaweed is sourced from outside the Baltic region. **To harvest the socio-economic and environmental benefits of macroalgae, more seaweed needs to be produced locally.**

Developing an aquaculture system for Furcellaria is of high priority. Reproduction and cultivation is possible, but not well-understood yet[1].

In addition to the above primary producers, around 60 commercial companies are active in producing seaweed products marketed in the Baltics; of which some samples are shown here:

Food products	• Nordisk Tang, Dansk Tang, Seaman, and Gourmet Tang from Denmark • Numami in Estonia • Nordic OceanFruit and Algenladen in Germany
Cosmetics	• Melissa and Organic Seaweed in Denmark • Furcella and Vetik in Estonia

[13] Vincent, A., Stanley, A. and Ring, J., "Hidden champion of the ocean: Seaweed as a growth engine for a sustainable European future", Seaweed for Europe, 2020: https://www.seaweedeurope.com/hidden-champion/

	• Ocean Basis in Germany.
Seaweed enriched Feed	• Fermentation Experts in Denmark • Volta Greentech in Sweden
Technology providers	• Metal production/Rocket Cluster is a Lithuanian-Norwegian company offering non-standard design of hardware installations for aquaculture • SFTec in Finland is a SME that developed a modular drying solution for macroalgae; • Origin by Ocean is a Finnish start-up producing biorefining technologies for macroalgae as well beach-wrack (eelgrass) bioresources • EHP Environment in Finland is developing sensors for collecting marine and oceanographic data. • Pure Algae DK produces technologies for growing green seaweed in tanks on land • AquaGreen is a Danish company that has developed an integrated steam drying and pyrolysis solutions, suitable for wet biomass.

Other noteworthy initiatives include the 'Department of Seaweed', a German-Finnish art collective that uses seaweed in the interface of industrial design and architecture.

One third of the start-ups engaged in the SUBMARINER accelerator were engaged in seaweed production or use.

3.3.5 Legal innovation barriers

The macroalgae species put on the EU market are regulated by the Novel Food legislation which limits the entry of novel species on the EU market area. **The EU Novel regulation can potentially pose a barrier for new algae food products entering the EU market.** Even though many of the species mentioned earlier are accepted as non-novel food; *Furcellaria lumbricalis*, is for instance not included, even though it has been used to produce gelling agents for decades. Thus the catalogue should be extended to many more macroalgae species that can be produced and consumed safely in the EU.

Among the few countries with specific regulations on seaweed harvesting and cultivation (Norway, Iceland, Denmark, UK, France, Ireland) **the only Baltic Sea country is Denmark**. Estonia and Germany have at least some rules on seaweed harvesting. **For seaweed cultivation, however, there are no guides for future investors.** Thus, the general aquaculture permit procedures apply instead, as well as the water environment and water law. Permit paths are different in each country and are generally very lengthy and complicated. [14] **Sweden and Germany have both formed national roundtables with industry, R&D and regulators on macroalgae.**

3.3.6 Natural conditions in the Baltic Proper

The natural water environment and climate creates a barrier in what species can grow in the Baltic Proper. The GRASS project focused their environmental data analysis and resulting prediction models on Baltic species only, such as **Fucus and Ulva**, to reveal potential opportunities**:**

Fucus growth rates were highest in Danish Straits. Notably high production values were also observed throughout the southern Baltic and along Polish, Lithuanian and Estonian coasts (see Figure 9 below).
Ulva has a higher production potential (daily growth rate in %) compared to Fucus and also a wider spatial distribution of production hotspots; encompassing all Danish Straits, coasts of southern Sweden, Germany, Poland, Lithuania, Latvia and Estonia.

The modelling products were made public through an online Operational Decision Support System (ODSS) that provides stakeholders with the basis to identify suitable areas for macroalgae cultivation and harvest.

[14] GRASS A3.2: A manual on the regulative opportunities and barriers concerning macroalgae production in the Baltic Sea (in press)

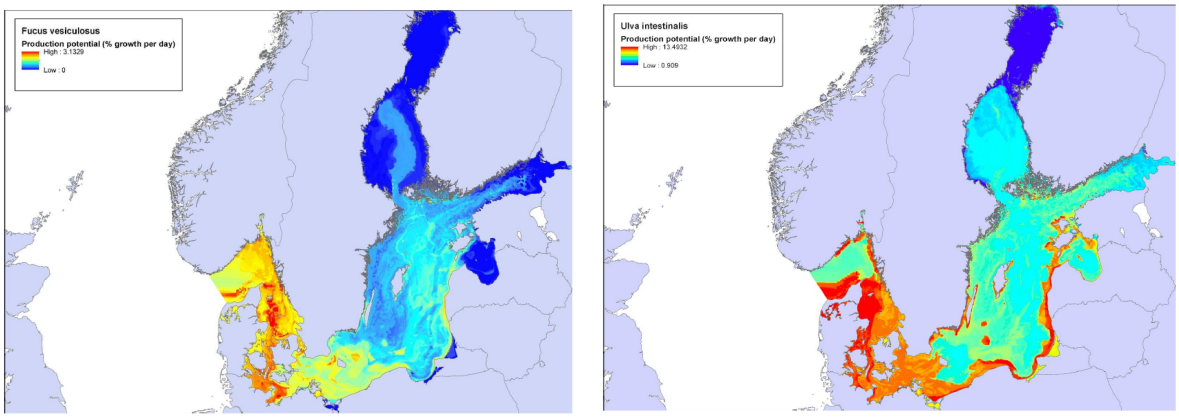


Figure 5 Left: *Fucus vesiculosus* production potential across the Baltic Sea; Right: *Ulva intestinalis* production potential across the Baltic Sea.[15]

3.3.7 Potential macroalgae cultivation sites

By combining results from the environmental model with the spatial dimension of other maritime uses, the ODSS tool analysed conflicts, synergies and opportunities for co-existence of macroalgae cultivations with other marine uses (human uses) in the best hotspots**. Low-trophic mariculture is a permitted activity, however, often not a priority in plans** (e.g. Poland & Latvia). Co-location with off-shore wind farms (OWF) is considered widely, in some cases as a synergy (in Finland and Estonia), in other as a question of the interest of wind farm operators or permitting (Latvia & Poland). For more information on multi-use consult Chapter 7. Synergetic co-existence of seaweed farming and fish aquaculture, local tourism, cultural heritage, and fisheries is highlighted as a means to increase local economic prosperity by providing more jobs. However, institutional and knowledge related conflicts occur as regulatory authorities take the precautionary approach and face difficulties issuing permits or even impose restrictions for macroalgae projects due to lack of evidence and experience.[16]

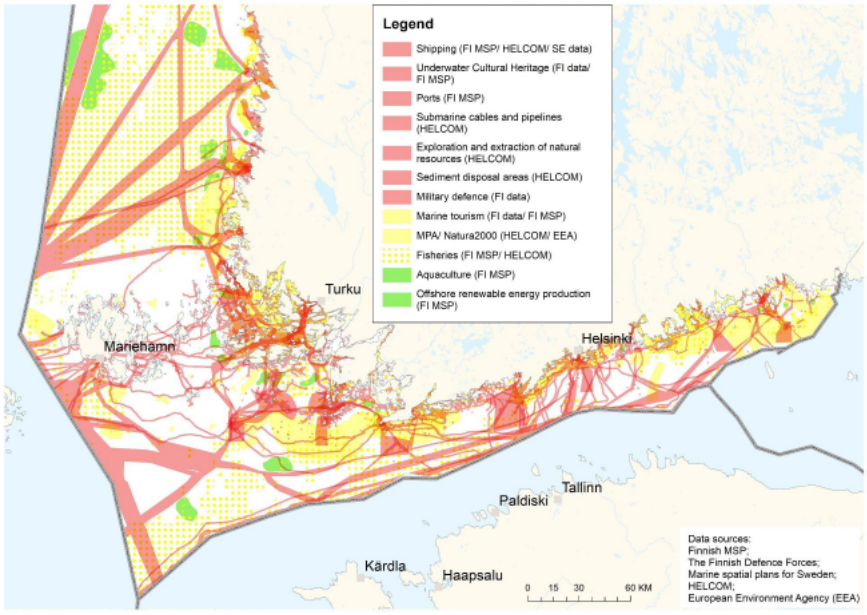


Figure 6 Use conflicts analysed in MSP maps of Turku, Finland; in green we see aquaculture and co-location OWF sites

The Seafarm and Macrofuels projects validated the substantial environmental benefits for industrial scale cultivation of *Saccharina latissima*:

1. Bioremediation through nutrient uptake, especially when combining with other forms of aquaculture e.g. salmon farms, or in nutrient-rich environments (Baltic Sea),
2. Climate resilience effects by reducing acidification, increasing oxygenation of sea and producing a low-carbon biomass (and products) for society. Cultivation and harvesting of brown seaweed extracted for

[15] GoA 2.1. Assessing the PanBaltic potential of macroalgae cultivation and of harvesting wild stocks Jonne Kotta et all. Estonian Marine Institute, University of Tartu: https://submariner-network.eu/images/grass/GRASS_OA2.1_pan-Baltic_map_depicting_potential_of_macroalgal_cultivation_and_harvesting.pdf

[16] GRASS A3.1: Maps illustrating best available sites for macroalgae cultivation and harvesting in the Baltic Sea based on a MSP approach (in press)

instance 1.3 ton CO2 and 5-60 ton N per ton dry seaweed 17. Downstream emissions, as seaweed products are consumed, may however negate net climate benefits.

Environmental risks associated with large scale seaweed (*Saccharina latissima*) production relate to emissions of other GHG emissions, e.g. N2O, risk of spreading non-native/harmful species, and loss of synthetic materials at sea, e.g. substrates.

Other challenges related to sustainable industrial seaweed cultivation are the need to:

1. improve mechanisation/automation of production (similar to mussel farming)
2. increase sustainability/recyclability of substrates e.g. ropes
3. demonstrate multi-use space frameworks with other aquaculture activities
4. reduce production costs by a factor of 5-10 for Saccharina cultivation
5. develop new product applications.

Finally, knowledge gaps with environmental impacts are associated with:

- environmental changes in relation to space and scale, incl. coasts,
- validated MSFD indicators, incl. biodiversity at levels of ecosystem, species and genes,
- local to global changes in relation to environmental chemistry and seaweed GHG emissions, and
- biosecurity strategies, incl. strategies against spreading pests and diseases, diagnostic tools, and quarantine procedures.

3.4 Conclusions and Recommendations

In 2020, macroalgae production is still in its infancy in the Baltic Sea Proper, with only a few commercial entities being involved in farming or wild harvesting seaweed. While there are more companies active in processing and product development using seaweed, most of seaweed is imported from other regions or countries. Compared to mussels, there are already by now more commercial seaweed farms in the Baltic, and also the sector enjoys a strong political and consumers support, given the environmental and socio-economic net benefits.

The report of the Seaweed for Europe Coalition published last October, authored by a wide panel of European seaweed experts, drafted a Roadmap of actions to bring disruptive growth to the seaweed industry till 2030. **The paper anticipated that a 27-fold growth of European seaweed production in 10 years' time is viable, and to attain this goal, a number of actions were recommended**. These translate into the following actions for the Baltic, taking into account our needs and particularities:

To take macroalgae to the next level, it is advised to:

- Allow new farms to be established at sea
- Validate and control the environmental and biodiversity risks of large-scale production against MSFD and the new Biodiversity Strategy
- Pilot and demonstrate macroalgae cultivation in the Baltic Proper.
- Expand and upscale cultivation of *Saccharina latissima* in Kattegat region and North Germany.
- Develop a market for local products and short value chains, primarily within the food, feed and cosmetics sectors.

For the Baltic, the SUBMARINER Network is making the following recommendations:

[17] MacroFuels project (2020): The Environmental Impacts of Large-Scale Seaweed Cultivation Findings and recommendations from the MacroFuels Horizon 2020 research and innovation project: https://www.macrofuels.eu/fact-sheets

Make marine space available for seaweed production

- Streamline and harmonise the licensing process for releasing new sites for macroalgae mariculture across the Baltic sea Region
- Make regulations and simpler licensing processes to accelerate process
- Alleviate institutional conflicts and knowledge related conflicts by disseminating toolkits and manuals developed, e.g. by the Baltic GRASS project18, specifically for pubic authorities and also promote development of national roundtables like those in Sweden and Germany19.

Develop safety standards for the marine environment, product and workers' occupation health

- Measure and validate environmental risks to alleviate the environmental and biodiversity-related risks with macroalgae production at sea
- Develop strategies for disease control and strain selection
- Address the lack of global food safety standards
- Ensure safe working conditions

Collaborate with EU Novel Food Regulation authorities to remove species consumed in the Baltic from EU novel food list

- Develop a funding guides for actors working at various TRLs.

Develop the Baltic seaweed market

- Develop resilient short local value chains securing local supply
- Increase local marketing for seaweed to improve Baltic seaweed image

Raise awareness on the benefits and potential of seaweed

- Monitor and document environmental benefits of seaweed production (LCAs)
- Demonstrate benefits of integrated multitrophic aquaculture systems (combination with fish / mussels)
- Increase capacities of Public Authorities in environmental and socio-economic impact on seaweed farming
- Educate and train future seaweed entrepreneurs and aquaculture practitioners, incl. retraining fishermen, by developing apprenticeship programmes, marine biology and bioentrepreneur programmes.
- Create seaweed campaigns with cookbooks and chefs, films, schools etc.

Test cultivation of Furcellaria and pilot / demonstrate cultivation of Fucus and Ulva in the Baltic Proper and also cultivation of Palmaria in Western Baltic

- Continue taxonomic studies on seaweed e.g. Ulva to clarify variations and overlaps
- Develop knowledge on farming Fucus, Ulva, Furcellaria and Palmaria in the Baltic environment
- Increase the understanding of reproduction and settlement biology of Furcellaria on various substrates
- Develop seeding, cultivation and harvesting technologies, incl. environmentally friendly substrates, and also pumps for land cultivation
- Transfer knowledge and technologies from other regions/countries more advanced at scale

Improve economy and reduce investment risk of seaweed farming

- Reduce production costs of *Saccharina latissima* by at least 5 times
- Develop new automated/mechanized and submerged technologies for seedling, cultivating, harvesting and handling Fucus, Ulva, and Palmaria, suitable for the Baltic environment.
- Develop smart technologies, drones, sensors, and data collection and exchange systems that reduce production costs, improve product yields and secure environmental benefits
- Transfer knowledge and technologies from other European regions more advanced at scale e.g. *Saccharina latissima* (e.g. Norway, Faroe)

[18] https://submariner-network.eu/grass
[19] https://www.submariner-network.eu/submariner-network-at-kieler-algen-stammtisch

Incentivize investments that support environmental sustainability and ecosystem services

- Introduce a regulatory framework that provide support to ecosystem service payments for pollution mitigation, carbon trading and nutrient uptake (IMTA concepts) leading to a reduce eutrophication of Baltic Sea waters and CO2 uptake
- Promote sea multi-use and co-location of marine activities (e.g with OWF).

Strengthen education and training in blue biotechnology, aquaculture and entrepreneurship

- More high-profile educational programmes are needed to teach the relevant methods and techniques and encourage the young generation to engage in blue biotechnology. The inspiring success stories of the BBMBC or ACES programmes should have a beacon function and may lead to similar future initiatives in the BSR.
- **More bio-entrepreneurship education opportunities are recommended** for future managers and business developers. This is especially relevant for important biotechnology city-clusters, for example in Kiel, Tartu, or Helsinki, thus copying the success of Copenhagen Business School
- Finally, **there is a lack of a knowledgeable, skilled, non-research work force**, especially connected to the harvesting, purification, and extraction of biomass.

Take the use / applications of algae a step further

- Advance algae biorefineries
- Increase visibility and access to multi-use, open-access, pilot-scale facilities, incl. biorefineries
- Develop close nutrient system such as combining macroalgae with aquaponics and/or fish RAS technologies.

3.5 Activities suggested for the SUBMARINER Network

1. Establish a 'Baltic Seaweed' Working Group to continue knowledge exchange with the mandate to implement the Roadmap actions
2. Promote development of national roundtables with industry, R&D and regulators on macroalgae in other Baltic states (like those in Sweden and Germany S-H).
3. Identify pilot facilities that can be accessible to companies (test beds, processing)
4. Increase visibility and access of relevant communication materials promoting benefits and opportunities of macroalgae to public authorities and other actors such as e.g. promoting the macroalgae sector, its actors[20], available tools and reports[21], the Blue Platforms' best practices (Interreg BSR)[22]
5. Collect data from operational seaweed farms and model data to validate environmental benefits and alleviate risks of seaweed production.
6. Support start-ups and SMEs at low TRLs that are not "investment ready" and need pre-acceleration and incubation facilities through the Blue Growth Accelerator.
7. Support Baltic farms in knowledge exchange, and also with European counter-parts
8. Lobby to include seaweed mariculture in MSP of Baltic states
9. Promote innovative and sustainable Baltic blue bioeconomy products and services already available by companies. Showcase 'future blue bioeconomy business canvas' pathways
10. Develop hackathons with concrete challenges submitted by companies.
11. Investigate technologies available in other regions that could be transferred to the Baltic.
12. Forster cooperation between algae R&D capacities with the emerging SUBMARINER's Blue Growth Accelerator23, to stimulate technology transfer and product development.
13. Encourage and coordinate development of new structures of small farms sharing costs (equipment) and knowledge, and secure joint larger contracts – a well-known approach to agricultural cooperatives.

[20] https://blue-platform-map.web.app/
[21] https://www.submariner-network.eu/macro-algae-topic
[22] https://www.submariner-network.eu/good-practices-from-the-baltic-blue-bioeconomy
[23] https://submariner-network.eu/apply-for-alliance-accelerator

4 Harvest of Floating Emergent Aquatic Plants

4.1 Ambition

In 2013, when the original SUBMARINER Roadmap was published, the main focus was on Reed Harvesting in coastal areas to support nutrient removal and also provide a resource for bioenergy production as well as environmentally friendly construction material. In the meantime, however, another promising technology has emerged to improve Good Environmental Status and reduction of eutrophication in the Baltic; which considers the biological removal of phosphorus and nitrogen via the root system of emergent plants, which live completely or partially submerged aquatic plants (macrophytes and halophytes) on floating islands.

Comparable to macroalgae cultivation, various ecosystem services are supplied by emergent macrophytes and halophytes on floating structures. Nutrients and pollutants are absorbed from the water column and wave energy attenuated. The root network provides shelter to aquatic fauna and increases microbial biodiversity. The integration of flowering plants can create colourful landmarks and enhance the aesthetic value of floating wetlands and benefit likewise tourism. Furthermore, floating wetlands can develop into bird watching spots benefitting tourism. Coastal municipalities have shown much interest in these green technologies in blue environments.

In this updated roadmap, focus is therefore given not only to native reeds but also rushes and sedges as biomass resource for product development and ecosystem services provision offered through installations of floating islands.

4.2 Projects

LiveLagoons (Interreg South Baltic, 2017-2021)

aims at improving the water quality in eutrophicated lagoons in the South Baltic through innovative floating wetlands for nutrient removal. These 'living barriers' are floating islands planted with native emergent macrophytes such as *Phragmites australis* (common reed), *Carex acutiformis* (pond sedges) or *Juncus effesus* (common rush). Floating wetlands were successfully installed and harvested to remediate eutrophication in three different eutrophicated lagoons along the Southern Baltic Sea (Szczecin lagoon, Curonian lagoon, Darss-Zingst Bodden Chain).

Nutrient removal occurs on several levels: i) The most direct effect is the harvest of above-ground biomass (up to 0.50 g phosphorus per m² and up to 10.25 g nitrogen per m²) (Razinkovas-Baziukas et al. 2021). In addition ii) the root network impacts on the phosphorus burial in the sediment; iii) the microbial diversity promotes denitrification and iv) floating plant islands attenuate wave energy and water flow and are consequently able to enhance particle settling and nutrient burial (Pavlineri et a. 2017).

Furthermore, floating wetlands offer other ecosystem services such as the provision of habitats. In the LiveLagoons project, the floating wetlands served as a refuge for various aquatic species, inter alia the endangered eel, and as resting habitats for birds (Karstens et al. 2020).

SUBMARINERs: Klaipeda University (LT)

Weblink: www.balticlagoons.net/livelagoons/

HaFF: Halophytes and other macrophytes for the filtration of nutrient-contaminated waste and surface water in field culture (BMBF, BsMS, Germany, 2020-2022)

Aims to reduce nutrients in the wastewater from aquaculture farms as well as in eutrophicated coastal waters through production of local and biodegradable materials from vascular plants, using species of different salt tolerance corresponding to the different salinity concentrations along the German Baltic Sea coast or in the concerning marine aquaculture facilities. In addition to the construction of a plant-based sewage treatment system for marine wastewater on land, existing floating cultivation systems are enhanced to become more sustainable.

SUBMARINERs: CAU, CRM /Ocean Basis (DE)

Weblink: https://www.bams.uni-kiel.de/de/unsere-konsortien/haff-halophyten-und-andere-makrophyten-zur-filtration-von-naehrstoffbelastetem-ab-und-oberflaechenwasser-in-freilandkultur

4.3 State of Play

The very first floating wetlands in the Baltic Sea were installed in 2018 in three different lagoons (Darss-Zingst Bodden Chain, Curonian lagoon, Szczecin lagoon) and emergent macrophytes have been harvested since then on an annual basis. **Further installation sites in different environments will be necessary to broaden the experience, to improve the technique and to support the achievement of market-readiness.**

Currently already more than 10 commercial companies offer floating wetland technologies. However, most of them rely heavily on artificial polymers for buoyancy (Karstens et al 2020). The ambition is to develop floating wetlands constructed with local and bio-degradable materials that are still robust enough for harsh environments. Harvested emergent macrophytes can be utilized in various ways. While *Phragmites* or *Typha* have a long tradition as construction material inter alia for insulation, other macrophytes such as *Angelica archangelica* or *Acorus calamus* have a lot of potential as herbal medicinal. Halophytes, also known as salt plants, are still underestimated as high-quality products in the food, cosmetics and medical sectors. “Sea vegetables” like the European samphire (*Salicornia*) or sea kale (*Crambe*) – both occurring in the Baltic Sea - are real delicacies but still rarely known by the wider public.

The market potential for macrophytes and halophytes cultivated on floating islands in the Baltic Sea has not been researched yet. Cultivation and harvesting techniques for installation offshore are more challenging and more expensive than for example wet agriculture and forestry on peatlands (paludiculture).

4.4 Conclusions and Recommendations

- Awareness-raising of floating technologies for the cultivation of emergent macrophytes and halophytes as one option to remove nutrient from eutrophicated waters.
- Study the impact of floating wetlands not only on nutrient removal but also on other pollutants such as the bacterium Escherichia coli.
- Harvesting techniques offshore on floating structures are challenging and need technological advancements and innovative ideas.
- Utilization concepts of harvested biomass from these floating green technologies in blue environments are just emerging and need further research.
- Knowledge transfer on site selection, legal requirements, installation process, growth and harvest of the biomass as well as commercialization.

Currently (at time of writing) SUBMARINER member, University of Klaipeda (LT) has submitted an application within the EU COST programme to run the Network ARTFLOWET.

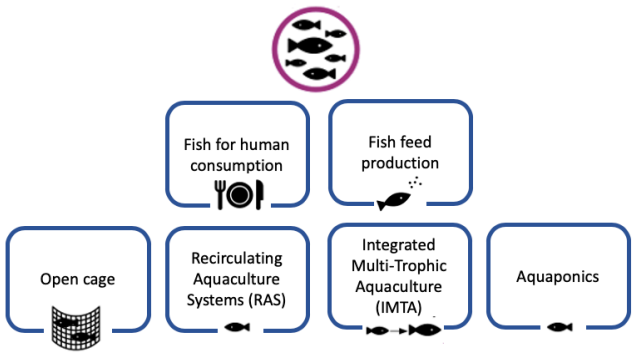
4.5 Activities suggested for the SUBMARINER Network

- Integrate the construction of floating structures with multi-use development (tourism and coastal/marine restoration)
- Consider floating structures in the overall action on technology development and transfer
- In addition to mussel and macroalgae cultivations as well as beach-wrack removal, promote the installation of floating structures as an additional nutrient removal measure

- Consider business ideas for the use of the harvested biomass within SUBMARINERs blue bio business and product development accelerator

5 Sustainable Trophic Aquaculture

5.1 Ambition



Already in 2012 the SUBMARINER Compendium showcased the potential of establishing a regional sustainable fish aquaculture business sector within the Baltic Sea Region, based on land-based systems as well as potentially further offshore installations.

The 2013 Roadmap therefore recommended to establish positive examples of such aquaculture forms in the Baltic Region; to promote the breeding of new species and to support further research in view of water treatment, feed supply and environmental impacts. Moreover it called for the creation of a unique Baltic brand for fish products; raising the public awareness for regional producers in order to develop a local market and producer groups.

Ever since, the importance of aquaculture as a source of animal protein has increased dramatically over the past years as fish stocks are continuously decreasing and agricultural systems are failing to keep up with the increased demand for healthy food. The EUs Blue Growth Agenda identifies aquaculture as a promising sector also for the Baltic Sea Region. However, while Denmark and Poland are among the main European producers in freshwater aquaculture, the further expansion of 'classical open pond' marine fish farms is hampered in the Baltic by restrictive environmental regulations since there are real and perceived problems with nutrient release, disease control as well as other operational issues such as logistics and predatory species[24]. On the other hand, there is also a lack of political will to support modern forms of aquaculture. In fact, the European sustainable aquaculture policy is characterised by a 'soft' approach, merely coordinating national efforts through national multi-annual plans, strategic guidelines and guidance on EU environmental law[25].

From a 2020 perspective, most of the above recommendations have been achieved to an extent, but the work should be ongoing. SUBMARINER's ambitions for innovative aquaculture are now more fine-tuned to focus on:

- RAS, aquaponics, IMTA as well as sea-ranching and offshore aquaculture
- Development and increased use of Baltic fish feed
- Interdisciplinary collaborations in harvesting, processing and biorefining technologies;
- Improved site selection off- and onshore (i.e. access to energy sources);
- New investments, projects and support for start-ups, pilots and demonstration sites;
- Improvements to legislation e.g. compensatory tools and nutrient output assessments

5.2 Forms of sustainable trophic aquaculture

The environmental challenges of marine aquaculture may be overcome by technology innovations, which allow farms to move away from sheltered coastal waters by either going more offshore or on land[26].

5.2.1 Recirculating Aquaculture Systems (RAS)

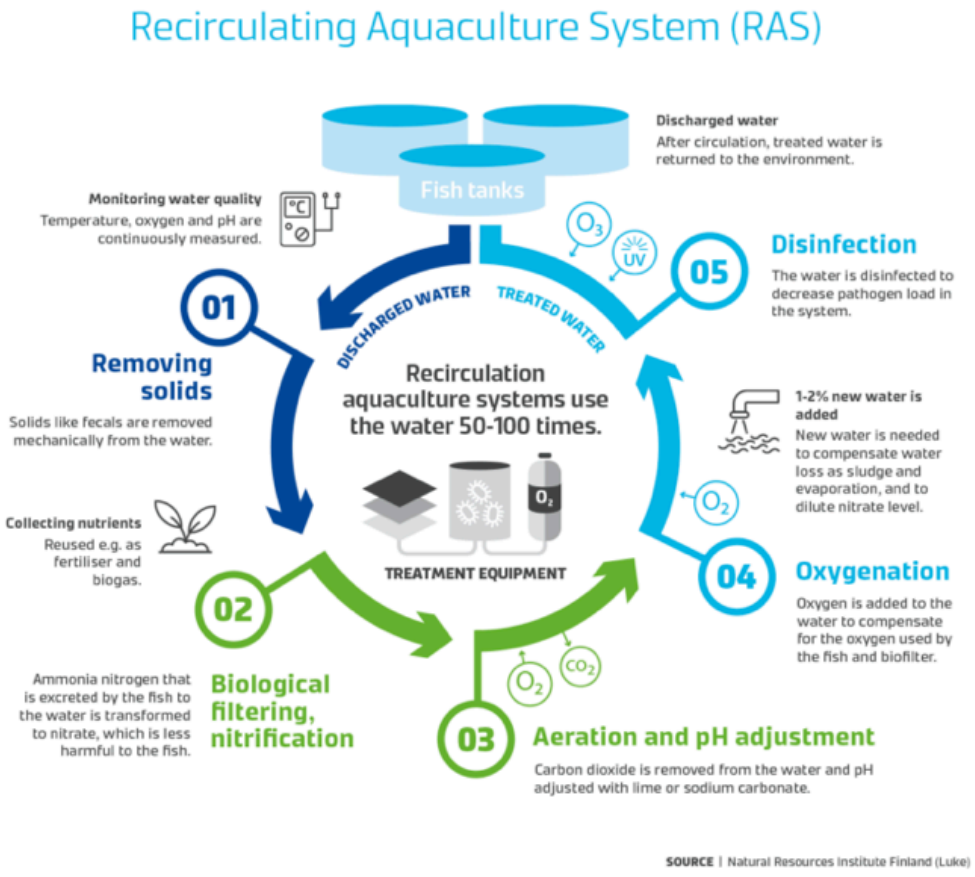
[24] East Regional Aquaculture Centre Vattenbrukscentrum Ost (2020). *'Fish Production Systems'*. Available at: http://www.vattenbrukscentrumost.se/en/aquaculture-systems/

[25] Dublin, D. (2015). *Recirculation in the EU aquaculture policy and organic rules.* Presentation at the International Seminar on Land Based Aquaculture Systems (2015). Available at: https://ccb.se/wp-content/uploads/2015/11/EC-MARE-Aquaculture-CCB-workshop-12-11-2015.pdf

[26] As already suggested in the SUBMARINER Compendium (2012) and subsequent SUBMARINER Roadmap (2013)

In view of the difficulties to open new marine aquaculture farms within the Baltic Sea Region, the SUBMARINER Network committed itself already by 2013 to the promotion of recirculating aquaculture systems (RAS) within the Baltic Sea, as one of the most promising forms of fish and crustacean aquaculture, especially within the South Baltic Region[27]. The ambition was to bring RAS systems to the level of full commercialisation; especially by developing and transferring suitable technologies, which would in turn increase the productivity and efficiency of these systems.

With a RAS system, the farmer has full control over parameters such as light, water conditions and feed and there is more control regarding infectious diseases and potential escapes. In addition, the nutrients released can be collected and used in feed materials, fertiliser or even bioenergy[28]. A RAS generally consists of a unit for the culture of organisms and a unit for water treatment, which are connected by water flow (pump). The integrated water treatment continuously adapts the water quality to the requirements of the culture organisms, meaning that the water can be re-used[29].



Issues with high nutrient loads and the use of antibiotics are addressed by RAS as they minimise water exchange and nutrient input into the natural environment and improve feed quality by including the use of pro- and prebiotic additives, with the support of innovations in blue biotechnology[30]. A RAS can be installed in nearly all locations where there is access to water and – in view of lowering operational costs - access to low cost energy.

[27] Krupska, J. et al. (2019). *Guidelines for applying innovative finance mechanisms.* Deliverable under the InnoAquaTech project. Available at: https://submariner-network.eu/images/Guidelines_for_applying_innovative_financing_mechanisms.pdf

[28] East Regional Aquaculture Centre Vattenbrukscentrum Ost Web Article 'Fish Production Systems' (2020). Available at: http://www.vattenbrukscentrumost.se/en/aquaculture-systems/

[29] http://aquaculture.teknologisk.dk/Home/TechOverview InnoAquaTech project ‚Decision Support Tool'

[30] **Baltic Blue Biotechnology Alliance project (2016–2019)** Findings from the Alliance mentoring and accelerator programme.

5.2.2 Aquaponics

Aquaponics technology is defined as the combination of aquaculture and hydroponics, producing fish and terrestrial plants for human consumption within one system. Conventional RAS systems have the challenge of exchanging water filled with metabolic fish products, which is often expensive. In aquaponics this nutrient-enriched aquaculture process water is directed to hydroponic systems, where a biofilter (i.e. a substrate of nitrifying bacteria) cleans the water through the process of nitrification – converting ammonium and ammonia into nitrates – which can then be absorbed by plants for growth.

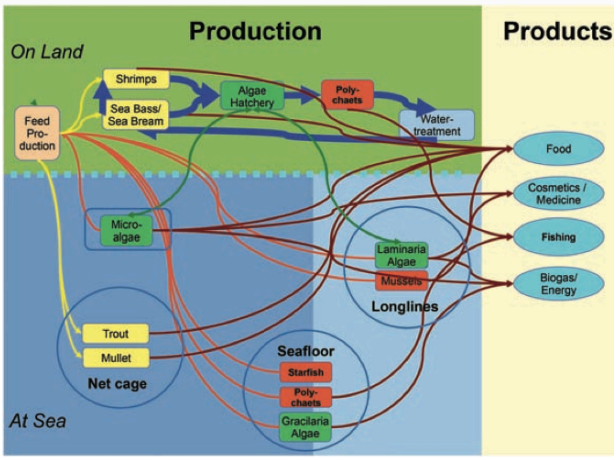
A survey[31] conducted online in 2017 among 60 early adopters of commercial aquaponic farms in Europe showed that environmental considerations are the main reason for starting aquaponic farms as well as a perceived higher quality of product. The results of the survey also indicated that economic motivations were not the main driver for starting an aquaponics farm. In Europe, existing aquaponic farms are very small, as there are high investment costs and the technologies used are not mainstream. One example of a commercially viable aquaponic farm is ECF Farm Systems GmbH in Berlin, which grows tilapia in combination with basil for local supermarkets, and increasingly exports their aquaponic systems across European cities (e.g. Brussels).

5.2.3 Integrated Multi-Trophic Aquaculture (IMTA)

Integrated multi-trophic aquaculture (IMTA) systems combine fish farming with oysters, mussels and/or seaweed, in an effort to realize zero nutrient emissions. To that end the Danish fish farm Havnø Havbrug (http://www.havbrug.dk/) has maintained both kelp and mussel farms in the vicinity of their open water fish farms for several years already. Also the Kieler Meeresfarm have taken up the gauntlet, with trials still ongoing. The marine fish farm 'MUSHOLM' had received a trial license to open a mussel cultivation as a compensation for their fish farm. This trial was, however, not successful within the 1st year and the license was taken back again.

This shows that – even though some IMTA systems are currently under development in Baltic countries - there are still numerous gaps about how to best realize such system combinations, especially in terms of licensing, permits and regulation.

While future IMTA systems could include invertebrates and microalgae for further valorization of waste products, there is still a marked imbalance in achieving a closed nutrient loop, since the proportion of non-fed (i.e. seaweed or molluscs) species has to be considerably greater than that of fish'[32]. In the Baltic Sea Region (and generally across Europe), aquaculture follows a 'single-species' approach, and the implementation of IMTA does not exist at commercial scale.[33]



A truly "multitrophic" aquaculture. Fish feed are based upon local marine primary producers. Warm water species cultivation uses process heat from local industries, © Peter Krost

[31] Turnsek, M. et al. (2020). *Challenges of Commercial Aquaponics in Europe: Beyond the Hype*. Water 2020, 12, 306. Available at: https://www.mdpi.com/2073-4441/12/1/306/htm
** Survey available at: https://www.mdpi.com/2073-4441/8/10/468/htm*
[32] Krost, P. (2014). Perspectives to bolster European marine aquaculture. EUCC Magazine Coastal & Marine, 2014-2
[33] Setälä, J., Virtanen, J., Nielsen, R., Hoff, A., Waldo, S., & Hammarlund, C. (2019). Determining the economic value

5.3 Projects

AquaBest (Interreg BSR, 2011-2013)

delivered recommendations[34] on regulatory improvements, local fish feed production and the implementation of RAS. The project also published an 'Economic feasibility tool for fish farming – a case study on the Danish model fish farm in Finnish production environment'[35]. In addition, AquaBest developed spatial planning guidelines[36] based on a spatial planning process for fish and mussel farming in two Swedish regions, to test a common roadmap for localising sustainable aquaculture farms in the Baltic Sea Region.
SUBMARINERs: UniTartu (EE), LUKE (FI)
Weblink: http://eu.baltic.net/Project_Database.5308.html?contentid=72&contentaction=single

InnoAquaTech (INTERREG South-Baltic, 2016-2019)

aimed to foster cross-border development and transfer of innovative and sustainable aquaculture technologies in the South Baltic area and thus increase the innovation capacity of SMEs and their support organisations as well as enabling them to develop and implement cross-border value chains for sustainable seafood.
SUBMARINERs: BioCon Valley, University of Gdansk, Maritime Institute, CORPI, KSTP, DTI

AquaLIT (EMFF, 2019-2021)

focused on measures to reduce marine litter derived from the aquaculture sector; which have been collated into the AquaLIT 'toolbox' and have been disseminated through 'Learning Labs' with aquaculture farmers in each sea basin (incl. the Baltic Sea). The resulting 'Marine Litter Inventory' can be searched by type of litter or by sea basin (see 'Baltic Sea Map on Aquaculture Litter' below). *AquaLit showed that there is a lack of data from aquaculture facilities dealing with finfish, shellfish and seaweed from numerous Baltic countries. Moreover, different classification methods make it difficult to assess the quantity of aquaculture related litter in the Baltic.*
SUBMARINERs: s.Pro (DE)
Weblink: https://aqua-lit.eu

AquaVIP (Interreg South Baltic, 2020-2023)

aims to increase entrepreneurial capacity in aquaculture and create a prepared labour force throughout the South Baltic Region. AquaVip focuses on modern technologies such as aquaponics, microalgae cultivation and RAS. The ultimate deliverable will be a 'Virtual Career and Mobility Centre for an Innovative Aquaculture Sector'.
SUBMARINERs: KSTP, Klaipeda University (LT) University of Gdansk (PL)
Weblink: http://aquavip.edu.pl

Research Projects

In addition to these more applied projects, the following number of (probably not comprehensive) research projects also include Baltic Sea aquaculture aspects:

AquaCross (H2020 2015-2018)

developed an 'Ecosystem-based Management Cookbook for Practitioners37': a guide for policymakers and practitioners, with practical examples from 8 case studies including one in Lake Ringsjön in Sweden38 on how to restore good water quality. The project's analysis showed that management actions can lead to considerable

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[34] Finnish Game and Fisheries Research Institute (2014). *Aquabest Recommendations: Developing responsible aquaculture in the Baltic Sea Region.* Available at: https://portal.helcom.fi/workspaces/CG%20Aquaculture-138/Shared%20Documents/Available%20material%20on%20BAT%20and%20BEP/AQUAB_Recommendations_Printed_FINAL.pdf

[35] Kankainen, M., Nielsen, P. And Vielma, J. (2014). *Economic feasibility tool for fish farming case study on the Danish model fish farm in Finnish production environment.* Deliverable under the AquaBest project. Available at: https://docplayer.net/21640601-Economic-feasibility-tool-for-fish-farming-case-study-on-the-danish-model-fish-farm-in-finnish-production-environment.html

[36] AquaBest (2014). *Spatial planning guidelines for Baltic Sea Region aquaculture.*Available at: https://www.msp-platform.eu/practices/spatial-planning-guidelines-baltic-sea-region-aquaculture

[37] https://aquacross.eu/results

[38] AquaCross (2018). Case Study 6: Understanding eutrophication processes and restoring good water quality in Lake Ringsjön - Rönne å Catchment in Kattegat, Sweden. Deliverable under the AquaCross project. Available at: https://aquacross.eu/sites/default/files/D9.2_CS6_Annex_28092018_FINAL.pdf

ecosystem improvements if a certain time lag is taken into account. The projects 'Information Platform'39 and 'AquaLinks' Tool40 provide open access aquatic ecosystems, biodiversity resources and the causal links between activities, pressures, biodiversity, and aquatic ecosystem functions and services.
Weblink: https://aquacross.eu

FLAVOPHAGE (BONUS, 2017-2020)

focused on the development of environmentally sustainable technologies across the aquaculture rearing cycle. The project's novel disease management uses natural microbial 'warfare' (bacteriophages) that is both sustainable and environmentally friendly.

CLEANAQ (BONUS, 2017-2020)

targeted end-users such as engineers and constructers within RAS and commercial fish farms. It developed new procedures for end-of-pipe nutrient removal, to improve cost-efficiency and further reduce the environmental impacts of RAS fish farming. The project investigated three methods for the treatment of effluents: 1) single-sludge denitrification, 2) carbon-free woodchip denitrification, and 3) non-microbial nutrient removal.
SUBMARINERs: KTH (SE) - Weblink: https://www.bonus-cleanaq.eu

Waseabi (BBI JU, 2019-2023)

aims to optimize the utilization of seafood side-streams, by-products and waste through the design of new holistic process lines. More concretely, the project will deliver solutions for storage and sorting; deliver 3 high quality side streams as well as 6 marketable food ingredients, create 7 new bio-based value chains and validate 7 new and improved processing technologies in lab and pilot scale.
Weblink: https://www.waseabi.eu

AquaHealth (Blue Bio Fund, 2019-2021)

will assemble and apply an advanced meta'omics toolbox on the natural synergy of microalgae and microbial consortia associated with fish to discover and validate novel bioactive and prebiotic candidates for sustainable use in preventing and treating disease in land-based aquaculture systems.

Baltic Sea Project Partners: Hamburg University of Technology, Sea&Sun Technology GmbH (DE), AAU (DK)

DIGIRAS (Blue Bio Fund, 2019-2021)

aims to develop innovative and data-driven solutions for digitalization of future RAS technology in order to increase environmental compatibility, fish health and productivity. The project intends to reach this goal by systematic acquisition of relevant water quality data, parameterization of fish behaviour, developing new biological and chemical sensors and efficient water treatment technology.
Baltic Sea Project Partners: FRESH Völklingen GmbH (DE), Lappeenranta University of Technology (FI)

InEVal, Increasing Echinoderm Value Chains (Blue Bio Fund, 2019-2021)

deals with sea stars, sea urchins and sea cucumbers, all of which are abundant marine biomass resources that are under developed, wastefully exploited, disregarded and discarded. InEVal looks for new solutions to current challenges for human food, aqua feeds and ecosystem services by:

1. Up-valuing bycatch sea stars from Irish and German inshore shellfish fisheries to highly processed supplements for Salmon, shrimp and Seabass diets using milling, washing and enzymatic fermentation.
2. Improving low-value sea urchins from heavily impacted sea urchin barrens to high quality food for humans for high value niche markets in novel land-based enhancement systems under optimal holding conditions.
3. Seeding and harvesting sea cucumber for site remediation at aquaculture sites that are enriched with nutrients. Sea cucumbers perform a valuable and sustainable site remediation service followed by their utilisation as a high value human food resource.

Baltic Sea Project Partners: AWI, CRM (DE)

[39] http://dataportal.aquacross.eu
[40] AquaLinks Tool. Availabe at: https://zenodo.org/record/1101159#.X1Zhgi2w1QI

5.4 State of Play

5.4.1 Aquaculture Production in the Baltic Sea Region

Currently, fish aquaculture is driven by increasing global demand of fish, declining natural fisheries, food security and blue growth policies. At the same time, environmental policies such as the EU Water Framework Directive and the Marine Strategy Framework Directive set tightening legal-ecological requirements for the industry's nutrient emissions. Against this background, the success of blue growth policies related to aquaculture – and the hope of reconciling competing interests at sea – boil down to measures available for dealing with excess nutrients[41]

European aquaculture accounts for around 20% of seafood production, and is mainly concentrated in Spain, France, Italy, the United Kingdom, and Greece[42]. Yet the EU imported over €8 billion more seafood from developing countries than it exported in 2019 (cbi.eu), indicating potential for significant growth to meet this demand. As things stand, the Baltic Sea states (excluding Russia) account for around 5% of total EU production and 3.7% of total EU value (FAO 2018). In a global context, this translates to 0.2% of production and 0.25% of value (approx. €428m). With environmental regulation limiting offshore aquaculture in the Baltic Proper, Baltic production figures predominantly refer to extensive freshwater aquaculture of species such as carp in ponds or trout reared in tanks, raceways or brackish water cages.

The following table shows the state of play as described in the EuroFish report from 2015[43] as well as information provided by the Russian Blue Platform partner.

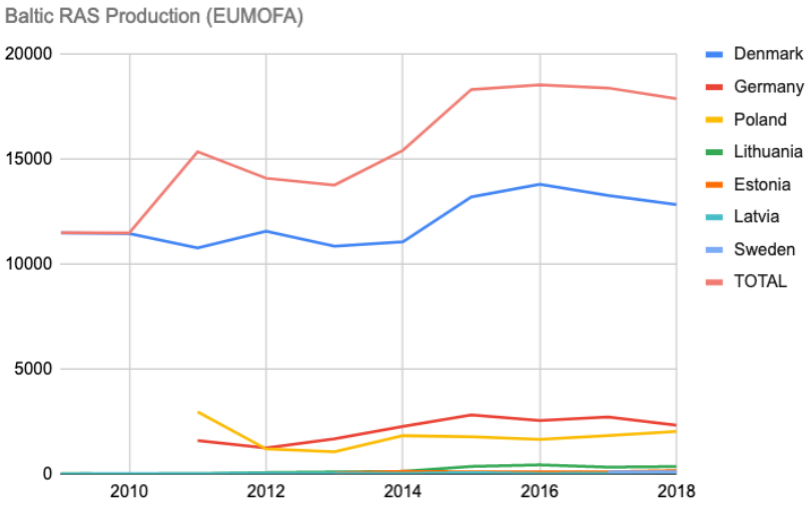
Country	Size of Sector	Main species
Denmark	Freshwater aquaculture has increased 7 times since 2008 despite the strong environmental legislation concerning aquaculture in DK.	Rainbow trout (90%), European eel, Blue Mussels
Poland	Main freshwater aquaculture producer in EU (carp & trout)	Common carp, rainbow trout Polish RAS farms also produce sturgeon, tilapia, and barramundi
Sweden	Rapid growth of inland aquaculture between 1995-2015	Rainbow Trout, Arctic char, Blue Mussels
Finland	Leaders in Baltic Sea offshore cage aquaculture	Rainbow Trout, European Whitefish, Sturgeon, Pike perch, Nelma
Germany	Inland aquaculture farms mainly in South	Rainbow trout, Common carp, Blue Mussels
Estonia	Environmental conditions limit Estonian aquaculture to 700 tonnes annually.	Rainbow trout (90%), Common Carp, Sturgeon, European eel
Latvia	Small aquaculture sector	Common Carp, some sturgeon, trout, pike, crayfish
Lithuania	Increase of 45% between 1995 and 2015	Common Carp, some rainbow trout, sturgeon, African catfish, and European eel

[41] Soininen *et al.*, Marine Policy 110, 2019
[42] *EU Blue Economy Report 2020*
[43] Eurofish (2015). Fisheries and Aquaculture around the Baltic Sea. Available at: https://issuu.com/eurofish/docs/baltic_brochure-final

Russia	The aquaculture sector contributes 4% to Russia's overall fish production with 3000 operational farms (72% pond and pasture, 25% industrial, 5% mariculture, 1% RAS).	Main cultivated species: carp, trout, salmon and sturgeon

5.4.2 Growth of RAS in the Baltic Sea Region

In general, Denmark is by far the leading Baltic country in RAS, focused mainly on trout farming, feed production and technology services. A handful of fully recirculated commercial plants are in operation farming pike, perch, yellowtail, salmon with one sturgeon/caviar farm[21].



Outside of Denmark, there has been considerable investment in new RAS facilities in Poland such as Jurassic Salmon and Pure Salmon, or Premium Svensk Lax in Sweden, with the former two having already achieved ASC certification.

In Finland, industry actors are aiming to make rainbow trout a competitor to Norwegian salmon. Recirculating fish farms are considered a good means of increasing Finnish food fish production, because the environmental impact of a recirculating fish farm is lower than that of a traditional fish farm. Last year, fish farms that use recirculated water produced approximately one million kilograms of food fish, mainly rainbow trout (LUKE).

Shrimps have been identified as high-value and environmentally sustainable species for cultivation in recirculating systems within Europe. Crustaceans currently comprise 24% of Europe's total seafood imports from developing countries, mostly as a variety of frozen products, the most important of which are warm water shrimp (95%)[20]. Several commercial RAS shrimp farms have become operational in the Baltic Sea region in recent years, with a large number in Germany (e.g. CrustaNova, FördeGarnele, CaraRoyale). Local Ocean in Lithuania is another European success story of an inland, sustainable and commercially viable shrimp farm in a recirculating system.

Table 4: Top 10 species groups by value in world aquaculture, 2017

Top 10 species groups		World aquaculture (2017 value)			
Species group	ISSCAAP division	Number of ASFIS species items in the group farmed in global aquaculture	Number of countries farming the species group	World production value of the species group (farmgate; USD 1 000)	Share of world production value of all species (%)
1. Carps, barbels and other cyprinids[1]	Freshwater fishes	38	92	61 437 284	24.62
2. Marine shrimps and prawns[2]	Crustaceans	14	60	34 220 879	13.71
3. Salmons, trouts, smelts[1]	Diadromous fishes	20	83	22 310 102	8.94
4. Tilapias and other cichlids[1]	Freshwater fishes	18	127	11 031 140	4.42
5. Catfishes[3]	Freshwater fishes	27	86	10 569 972	4.24
6. Crayfishes[4]	Crustaceans	7	15	10 008 865	4.01
7. Clams, cockles, arkshells[1]	Molluscs	29	21	9 779 660	3.92
8. Freshwater crabs[5]	Crustaceans	1	3	9 540 416	3.82
9. Freshwater perch-like fishes[6]	Freshwater fishes	9	30	7 110 761	2.85
10. Oysters[1]	Molluscs	12	44	6 788 868	2.72
Other species		n.a.	n.a.	66 781 214	26.76
All species		**424**	**196**	**249 579 163**	**100.00**

Data source: FAO Global Fishery and Aquaculture Production Statistics 1950–2017 (v2019.1.0), published through FishStatJ (March 2019). Available at www.fao.org/fishery/statistics/software/fishstatj/en.

Various RAS projects are also testing other non-endemic species for their market potential, such as Giant Grouper together with edible halophytic plants in a multi-trophic (IMTA or IMRAS) approach under the OptiRAS project, and as part of the HaFF project, providing a test bed for growth of halophytic plants using shrimp wastewater from FördeGarnele.

Demonstration Sites in the Baltic Sea Region

The InnoAquaTech project tested the farming of new species and innovative combinations of RAS with plant production and/or renewable energy at **4 pilot demonstration sites**:

1. **Denmark: Fish and macro-algae production under controlled conditions**

The Danish Technological Institute (Danish Technological Institute) calculated the viability and potential productivity of combining fish farming in RAS with the cultivation of microalgae. The pilot facility focused on African catfish (*Clarias gariepinus*) combined with outdoor microalgae basin cultivation. The pilot facility was open to the public at the Guldborgsund Zoo and was seen by more than 26.000 visitors. *The experiments proved that microalgae can grow in effluent water from aquaculture and therefore be an effective way to remediate nutrients. 100% of the African catfish survived. In addition, a new re-use of the RAS sediment was applied in the form of vermifiltration, demonstrating proof of concept and significant reduction of Biological Oxygen Demand.*

2. **Germany: The 'FishGlasHaus': innovative aquaponics in Mecklenburg-Vorpommern**

The University of Rostock modular aquaponics research facility researched a combined production of warm water fish species and plants for human consumption. The pilot carried out advanced experiments focusing on analyses and evaluation of nutrient fluxes and possible reuse strategies for tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). *The aquaponics research, using plants to clean the process water of nutrients, showed that selective addition of fertilizer is required for most crops in order to avoid nutrient deficiency. Based on the lessons learnt from the Danish and German pilots, a Feasibility Report on innovative aquaponics systems production was developed.*

3. **Lithuania: Zero emission RAS system combined with geothermal energy**

The Klaipeda Science and Technology Park developed a RAS for shrimp production with heating coming from geothermal energy. The first experimental whiteleg shrimp production took place in 2019 from shrimp larvae imported from Scotland, producing a yield of 200 kg. *The testing of the new technologies supported new business activities and increased the competitiveness of the Lithuanian aquaculture industry.*

4. **Poland: Farming shrimp in Poland: increasing the potential of RAS**

The University of Gdánsk organised a laboratory study to demonstrate and raise awareness of the economic and environmental benefits of RAS shrimp production in Pomerania, Poland. Two breeding experiments were carried out, where shrimps (*Litope naeus vannamei*) were grown at 25°C and with a salinity of 28 PSU. *The pilot facility raised consumer awareness about how cultured crustaceans have a similar nutritional value to imported crustaceans and actually contain higher levels of polyunsaturated fatty acids.*

5.4.3 Aquaculture-Based Fisheries Management ("Sea Ranching")

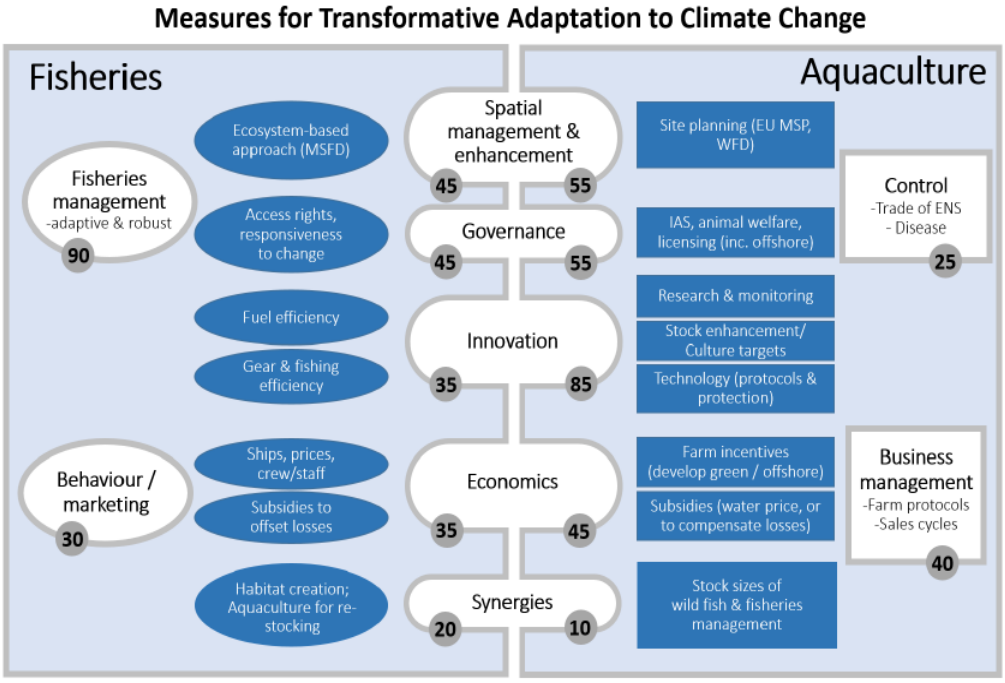
As identified in the Roadmap in 2013, aquaculture in the Baltic region plays an important role in supporting wild fish populations. A percentage of fingerlings and smolts bred in hatcheries from wild broodstock around the Baltic Sea Region are used for restocking and "sea ranching" purposes. In the latter case, juveniles are released in targeted locations with the goal of improving natural fish stocks and consequently improving the return from capture fisheries.

In Denmark in 2017, around 289,000 juvenile Atlantic salmon (*Salmo salar*) were released into three western Jutland rivers, with stocking even being discontinued in the River Storå due to the success of an integrated river basin management plan to achieve 'Good Ecological Status' (Aarestrup et al 2019). Other commonly released species released include trout, European eel *(Anguilla anguilla*) and also flatfish such as plaice or turbot (FAO).

A total of 4.7 million Baltic salmon smolts were released into the Baltic Sea in 2019, led by Sweden (1.5 million), followed by Finland (1.4 million). In the same year, a total of 2.7 million sea trout smolts were released, mainly in Poland at just under 1 million, with Finland and Sweden both releasing over half a million smolts. The total includes a further estimated 245,000 from the release of eggs, alevins, fry and parr (ICES WGBAST 2020).

In Finland, the Natural Resources Institute (LUKE) monitors the results of stocking. A key research innovation in recent years lies in the introduction of a method known as "enriched rearing" which helps stocked juveniles to survive in wild waters. Fry are raised in Finland in recirculating systems alongside food fish to be released into natural water bodies. Most of the fry raised to be released are whitefish (some 17 million fry in 2019) and the second most common species is pike-perch (some six million fry), with over a million brown trout fry. A total of around 50 million specimens of fry – excluding newly hatched individuals – were produced for the purposes of restocking or ongrowing in Finland alone (LUKE).

However, the number of stocked species has been reduced in recent years. This is due to the recovery of natural reproduction capability among certain fish populations from advances in stocking methods, management of recreational fishing and a focus on habitat restoration. Stocking is increasingly switching to areas where it supports the natural reproductive cycle of fish, thereby reducing the need for stocking in the long run (LUKE).



CERES project synthesis report 'Climate change and European Fisheries and Aquaculture' (Peck et al. 2020)
Numbers indicate percentage priority

In Russia, stocking of 150,000 whitefish fingerlings is also underway at the Curonian Lagoon hatchery, run by Kalinigrad State Technical University together with the Main Basin Department for Fisheries and Conservation of Aquatic Biological Resources, Glavrybvod (Prof. Sergey Shibaev 2020).

The AQUAFIMA (2011-2014) project and the more recent CERES project synthesis report '*Climate Change and European Fisheries and Aquaculture*' (Peck et al. 2020) both recommend habitat creation and innovative aquaculture-based stock enhancement of native, endangered or commercially valuable species groups such as salmonids or whitefish as strategies to rebuild Baltic fish stocks in the face of climate change.

5.4.4 Offshore Cage Aquaculture

Throughout the Baltic, areas available for food production both on land and in sheltered sea and water areas are decreasing. As part of an EMFF-funded aquaculture innovation programme, Finland has prepared a national spatial plan for aquaculture, according to which fish production areas are mainly located offshore in the Baltic Sea (LUKE).

Specific challenges are presented by winter and ice – production equipment must be returned from offshore to the archipelago in the autumn to protect it from the moving pack ice in the winter. In the Baltic Sea, waves are denser than the ocean swell, which subjects farming equipment to different hydrodynamic stresses. Finland aims to develop fish farming solutions that are both durable, rapidly movable or submersible. As supply distances increase for farming units, so too do logistical costs, requiring remote monitoring and automated feeding technologies (LUKE). Nonetheless, while the nutrient loading of offshore cages may be more dispersed, the environmental impact of open cage farming is still subject to controversy.

https://www.luke.fi/en/fish-farmers-set-their-sights-offshore-areas/

An effective remediation and offsetting regime could potentially ensure the ecological quality of waters and still allow an increase in aquaculture production. The problem with this approach, however, is that the current Environmental Protection Act of Finland only pays attention to the local impacts of aquaculture and does not take a holistic perspective looking at cross-sectoral benefits, or benefits to the Baltic Sea as a whole (Soininen *et al.*, Marine Policy 110, 2019). An alternative solution may come in the form of so-called "closed containment systems" (The Fish Site). These high-tech, semi-closed or closed units aim to minimise escapes, parasites, predation and effluent discharge whilst improving data acquisition and fish welfare. However, the technology is still in its infancy and will need further adaptation for the particular conditions of the Baltic Sea.

Alongside lobbying and adaptation of the existing regulatory frameworks, closed-loop technologies, efficient use of feed, effective waste-water management, flexible farming strategies as well as remediation and offsetting measures have been identified as strategies to facilitate future growth of the sector. However, these are only likely to be economically viable either at large scale or as part of offshore or industrial symbioses, for example combining fish with energy production or waste-water treatment (Soininen *et al.*)

5.4.5 Aquaculture Legislation and Compensation

There are several challenges in terms of reconciling sustainable aquaculture with environmental objectives, most notably the eutrophication status of the Baltic Sea, the need for cumulative impact assessments and a general lack of nutrient offset/compensation schemes for the sector.

The question is whether the EU legal framework has enough adaptive capacity to reconcile growth of the sustainable aquaculture sector with good ecological status of coastal and marine waters. According to the Weser ruling of the Court of Justice of the EU in 2015, Good Ecological Status and non-deterioration of the marine environment are legally binding goals of the Water Framework Directive, meaning that Member States must refuse authorisation of projects that a) may cause deterioration of the status of a water body or b) jeopardise the attainment of the status objectives of the WFD. Often compensation measures are not included in legislative systems and requirements for licenses and permits are changed during the lifetime of farms, meaning that it becomes a regulatory challenge to balance old and new systems.

The portrayal of Baltic aquaculture is mainly negative, with a major focus on nutrient emissions and a perceived negative influence on the seabed and fish stocks. A recently published report from the Department of Food and Resource Economics of the University of Copenhagen formulates this as follows: '*...this negative image is also reflected in the way that the two sectors are regulated, including restrictions on catches, closed areas for fisheries and practically a moratorium for new aquaculture production sites in the Baltic Sea. However, in some cases, there is an inconsistency between the actual environmental effects and the way that the sectors are regulated. In cases where the production has a positive externality these are not taken into*

account by regulators, meaning that the sectors are restricted to produce less than what is optimal for the society as a whole[44]*.'*

The SUBMARINER position paper[45] on aquaculture legislation highlights how in countries without a unified law on aquaculture, separate orders can be contradictory and licensing processes being unclear (e.g. in Denmark and Sweden), whereas in other countries, definitions, regulations and guidelines for the sector are missing or incomplete. **A positive exception is Finland**, as shown in the following:

In Finland, a spatial plan for aquaculture was approved in 2014 after 6 years of development, allowing aquaculture farms in areas with good or satisfactory water quality, to be placed at least at 500m from summer cottages, and allowing larger fish farms further offshore in order to improve profitability. The idea is to put the offshore farms out in summer and to take them back or to submerge them during the winter period. The spatial plan was well received with many people applying for new licenses and farms; resulting in already some new aquaculture farms with almost 2.000 t higher production. The plan also allows certain nutrient levels in the target areas. In Finland, various administrative acts and policy planning documents (incl. the Marine Strategy Framework Directive) have formed the goal to have fish farming in the Baltic Sea use the fish feed produced from Baltic Sea fish. The new Finnish government programme foresees to provide incentives to aquaculture farms, which reduce nutrient loading and apply circular economy principles, like RAS and Baltic Sea Fish Feed. The implementation of the governmental programme has led to the drafting of the Finnish Green Deal by the Ministry of Agriculture and Forestry, including the voluntary use of Baltic Sea Fish Feed.

What is needed is a harmonized definition of aquaculture throughout the legislative system, as well as improvements of legislation of licensing by including compensatory tools and a fair assessment of nutrient output calculations (separate from land-based nutrient sources).

5.5 Conclusions and Recommendations

Increasing the environmental sustainability of aquaculture, together with a wish to grow the sector, has been on the agenda of Baltic and Nordic countries for many years. However, issued licenses are not corresponding to novel aquaculture production methods; despite the fact that these have increasingly achieved 'proof of concept'. Consequently investors or industrial producers are not encouraged to invest in the sector.

Nevertheless as shown, there are by now not only pilots, but also more and more commercial RAS plants in operation throughout the Baltic Sea Region (e.g. at least 7 RAS in Germany; 9 RAS in Finland; 2 in Poland; numerous in Denmark). The main challenge of these RAS operations remains their commercial viability; which has to be closely aligned with the development of a local high value market. Also Aquaponics are no longer a totally artificial endeavour: the scientific idea has entered the mainstream, albeit sometimes seemingly more of a marketing play rather than a commercially viable idea on its own.

On practical level, also more IMTA systems start to become operational: SUBMARINER network member, CRM in Kiel, Germany, has established the first organic mussel and macroalgae farm in the Baltic Sea, 'following the principles of IMTA' with the ambition to start fish aquaculture in the coming years. In Denmark, Hjernø Havbrug was the first to establish fish, mussels and algae production farms operating under IMTA principles. So far, however, algae and mussels are not accepted as compensation for the nutrient outflow from the fish aquaculture production measures neither in Denmark nor in other Baltic Sea Region countries. The exception is Finland; where compensation measures through IMTA systems. are now possible.

[44] Setälä, J., Virtanen, J., Nielsen, R., Hoff, A., Waldo, S., & Hammarlund, C. (2019). Determining the economic value of nitrogen and phosphorus removal from the Baltic Sea: derived as a positive externality from fisheries and aquaculture activities. Department of Food and Resource Economics, University of Copenhagen. IFROReport, No. 287 Available at: https://static-curis.ku.dk/portal/files/225000379/IFRO_Report_287.pdf

[45] https://submariner-network.eu/images/20200525_SUBM_Position_Paper_Baltic_Aquaculture_Legislation_draft.pdf

This leads to the following recommendations:

- Foster new investments, projects and support for entrepreneurs to install new pilots and demonstration sites to showcase the feasibility of innovative sustainable aquaculture systems such as RAS, IMTA and other combined uses across the Baltic Sea Region
- Search systematically for the right locations for these innovative fish farms; not only in open waters, but also on land (e.g. RAS/aquaponics); in order to be economically viable (e.g. close to energy plants; proximity to local markets).
- Promote interdisciplinary collaborations to scale up the aquaculture sector in the Baltic, with a specific focus on the harvesting, processing and biorefining technologies.
- Promote the uptake of sustainable fish feed; especially using Baltic Sea Region resources
- Continue to lobby for more suitable legislation, in line with new and more sustainable technologies
- Increase collaborative efforts among fish & shrimp producers; food processers; certification bodies; retail and public procurement as well as chefs to increase consumer acceptance and develop the Baltic market

5.6 Activities suggested for the SUBMARINER Network

5.6.1 Launch of the SUBMARINER Fish & Shrimp Aquaculture Group

The SUBMARINER Network has taken the first steps in establishing a Baltic Sea Region Fish and Shrimp Aquaculture Group. The objective is to turn the Group into the regular meeting point of SUBMARINER members interested in developing new actions under the umbrella of sustainable fish aquaculture; facilitate closer cooperation and knowledge-exchange between different stakeholders in the Baltic Sea Region; sustain the SME service offer developed under the InnoAquaTech project such as organising international business study trips; ensure that findings and tools developed under past and on-going relevant projects and initiatives are taken on board by future initiatives to come and act as 'one voice' of innovative and sustainable Baltic Aquaculture especially in lobbying for 'aquaculture versus agriculture' in terms of nutrient allowances and compensation schemes.

5.6.2 Promote uptake of sustainable feed

The development of new feed products for Baltic Fish farms is another important aspect in improving the sustainability of the sector. Using fish feed based on small pelagic Baltic Sea fish (e.g. *Baltic Blend*[46]) is one avenue to close the aquaculture nutrient loop. The Baltic Blend concept has been approved by the Finnish government as a compensation measure and is therefore expected to be taken up extensively in the coming years.

The SUBMARINER Network has already considered 'sustainable feed' in two projects:

RASFeed (Horizon2020 proposal submitted in Jan 2019 / not selected for funding)

idea aimed to optimize the existing production conditions of three selected freshwater fish species (rainbow trout, African catfish and pikeperch) in RAS systems; to valorise production side-streams in new bio-products; and to address potential regulatory and market barriers, public opinion, educational gaps concerning RAS production. It is suggested to revisit the idea for future proposals.

The BalticSeaFeed SEED project (Swedish Institute; 2021)

aims to provide an overview of the current state of play on the use of Baltic marine resources for feed (fish, cows, pigs, chickens, pets) – i.e. market trends, innovation potential and barriers - in order to develop a full-fledged proposal for a European funding programme. The project does not only consider fish feed from Baltic marine resources, but also its use for 'land' based animals. It has been shown that such feed has positive climate effects as it leads to reduced GHG emissions; while also improving the nutritional value of the products.
SUBMARINER Project Partners: KTH, Kalmarsund Commission, NMFRI, University of Tartu, Klaipeda Science and Technology Park, LUKE, GEOMAR

[46] https://www.raisioaqua.com/en/web/raisioaqua/environment

5.6.3 Sustainable and innovative product development and consumer uptake of Baltic aquatic food

Even though overall consumer awareness and demand for regional, environmentally friendly products is growing; the aquaculture sector has to overcome negative perceptions. As it is well known that the Baltic Sea is polluted, consumers often assume that fish and fish products produced in the region are not at all sustainable – but rather contaminated and dangerous to consume.

SUBMARINER under the lead of KTH, has developed an EU wide Sea2Fork proposal submitted in January 2021 under the H2020 Farm-to-Fork call. The project aims to mainstream the uptake of healthy and sustainable Blue Food by EU citizens by increasing the knowledge, availability, and acceptance of untapped, low-trophic aquatic resources (i.e. seaweeds, bivalves, small pelagic fish, freshwater species and side streams). By assessing, improving and developing attractive and affordable food products, Sea2Fork will stimulate demand from European consumers. The system innovation process will be catalyzed by a series of boot camps and food labs, bringing together scientists, chefs and companies across Europe to foster widespread uptake of Blue Food innovations, co-creating solutions to meet current consumers' needs. In parallel, an open data system will build on and improve tools/apps already successfully on the market, providing customized information (health, sustainability, nutrition) for professionals and end-consumers. Blue Food will be promoted by hundreds of online and physical interactions (i.e. cooking classes, living labs, school programs, tastings) and an annual Blue Food Week campaign to inspire consumers to expand their daily diet.
Funding: 12 million € // decision expected by July 2021
SUBMARINER Project Partners: KTH, UGOT, Innovatum, LUKE, SYKE, CAU, NMFRI

5.6.4 Work on Valorisation of waste

A large proportion of fisheries and aquaculture production is either lost or wasted - **35 percent of the global harvest.** This must be reduced to improve the efficiency and sustainability of the sector, through appropriate policies, regulatory frameworks, capacity building, services and infrastructure, as well as physical access to markets[47]. As the Sea2Fork proposal has only partially covered better use of fish waste and side streams – it is foreseen to develop a distinct pan-Baltic project on this topic.

[47] FAO. 2020. *The State of World Fisheries and Aquaculture 2020. Sustainability in action.* Rome. https://doi.org/10.4060/ca9229en

6 Blue biotechnology

6.1 Ambition

Blue Biotechnology is a **key enabling technology** for sustainable blue growth. Although considerable advances have been made in the sector in recent years, development of market-ready blue biotechnology products and services still need viable transnational and transdisciplinary cooperation along the entire value chain, from R&D to marketing.

As already shown in the SUBMARINER Compendium (2012) and resulting Roadmap (2013), the Baltic Sea region is well placed in using blue biotechnology as a driver for its blue economy development:

1. **Blue biotechnology is part of high-level strategies and policies**, such as the UN SDGs, the EU Blue Growth Strategy, the Marine Biotechnology Strategic Research and Innovation Roadmap, the EU Bioeconomy Strategy and the EU Blue Bioeconomy Roadmap. The Nordic Bioeconomy Roadmap and many national strategies throughout the Baltic Sea Region build on these strategies.
2. The **marine biodiversity of the Baltic Sea** – with its considerable salinity gradient, shallow waters and ice-cold winters – provides **untapped potential for exploration**.
3. Local and global **markets already display a demand for products based on aquatic resources** in various areas such as food, cosmetics or pharmaceutical products. Sustainable, climate-smart, fact-based innovation is becoming the new norm for blue biotechnology start-ups and SMEs.
4. The **BSR has strong R&D expertise** in blue & industrial biotechnology, marine biology, chemistry, and chemical engineering and is pioneering in basic and applied science as well as technological development. BSR research institutes have been partners in at least 17 transnational EU research and innovation projects (Horizon2020, EASME, ERA-Net, BONUS or Interreg).
5. To meet the educational demands of a changing economy, there is **increased interest in BSR institutions to develop and offer advanced education programmes** for future scientists and bioentrepreneurs.

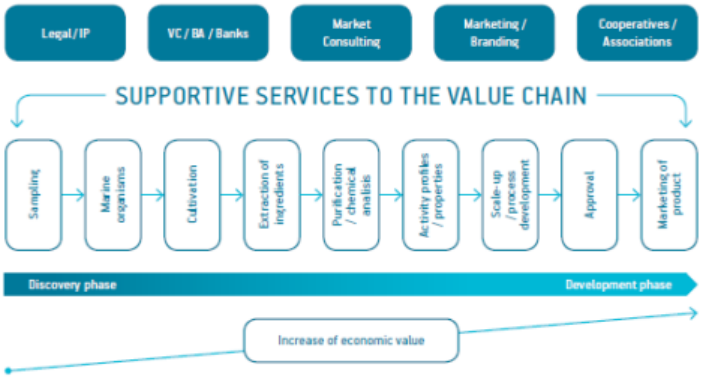


Figure I Blue biotechnology value chain – SUBMARINER Network.

However, in the highly specialised and research-driven blue biotechnology sector, individual Baltic Sea Region countries still do not have all the capacities and resources required to form the complete value chains needed in turn to realise full-scale commercial product development (Figure I). This was first observed in the SUBMARINER Roadmap (2013). The BSR needed a networking platform to establish a systematic approach to Blue Biotechnology research and to create the critical mass of actors to converge and convert science outputs into marketable products. The ambition of the SUBMARINER Network was to use the existing Blue Biotechnology research capacities more efficiently and effectively.

More specifically the following set of actions were defined as to lead to this objective:

- systematic mapping of research capacities and fields and laboratory equipment across the BSR
- analysis of BSR priorities and needs for Blue Biotechnology applications
- development of a national (blue) biotechnology strategies and a pan-Baltic research agenda
- identification and testing of Baltic Sea organisms for various applications
- establish a (virtual) BSR centre for bioprospecting of Baltic Sea microorganisms and a central information base for marine biomaterial
- increase national, transnational and international awareness and visibility of the BSR activities, which are carried out in the research and the exploitation of marine microorganisms for biotechnological products;
- promote the scientific expertise and product development know-how of the partners in the BSR centre.

6.2 Projects

Baltic Blue BioTech Alliance and Alliance+ (INTERREG, 2016-2019-2021)

As a response to this need, the Baltic Blue Biotechnology *Alliance* project was set up under the auspices of the SUBMARINER network. Led by GEOMAR Helmholtz Centre for Ocean Research Kiel, the consortium originally consisted of 26 project partners. These included some of the major research institutes of the region; business and technology parks; an initial group of SMEs as well as the SUBMARINER Network secretariat as the main communication and coordination hub. Over the course of three years, these partners developed an **accelerator programme** that carries out the continuous search for start-ups; pitching and matchmaking events as well as a **mentoring programme with a flexible service offer**, which was piloted with a total of 26 case studies. The follow-up 18-months-long Alliance+ extension project provides the seed money to recruit and commit new actors to become active members of the Blue Biotechnology Alliance as part of the SUBMARINER network; continue to organise matchmaking events, while also ensuring that the Alliance set up can be maintained without further finance from the BSRINTERREG programme.
SUBMARINERs: GEOMAR, SUBNet Secretariat, SYKE, KTH, KSTP, Tartu BioTech.
Weblink: https://www.submariner-network.eu/alliance

The experience and recommendations for future steps of the Alliance as an accelerator programme for companies is described in more detail under the 'Strategic Action Chapter XXX'. This chapter concentrates on the additional work stream of the Alliance project, which aimed to provide recommendations for a future pan-Baltic research agenda based on a comprehensive analysis of the competences, resources and interests of the regions' major blue biotechnology R&D institutions; their projects R&D needs and foresights as well as the recorded innovation barriers experienced during the Alliance's work with real cases.

Other Blue BioTechnology projects

A number of other worthy projects have been funded over the course of the past seven years in the field of Blue Biotechnology with the involvement of Baltic Sea Region partners.

The project SUNALGAE (LIFE 2017-2024) run by the Swedish Algae Factory aims to demonstrate a new, innovative **algae material** for enhancing the efficiency of silicon based and thin film solar panels. Other projects have been mentioned earlier being cross-disciplinary between blue biotechnology and fish aquaculture (Waseabi) and between blue biotechnology and macroalgae (MacroCascade, Fucosan).

As shown in Figure 10, the Fucosan project, analysed eight market opportunities and business models applying fucoidan in food, cosmetics and ophthalmological therapeutics[48].

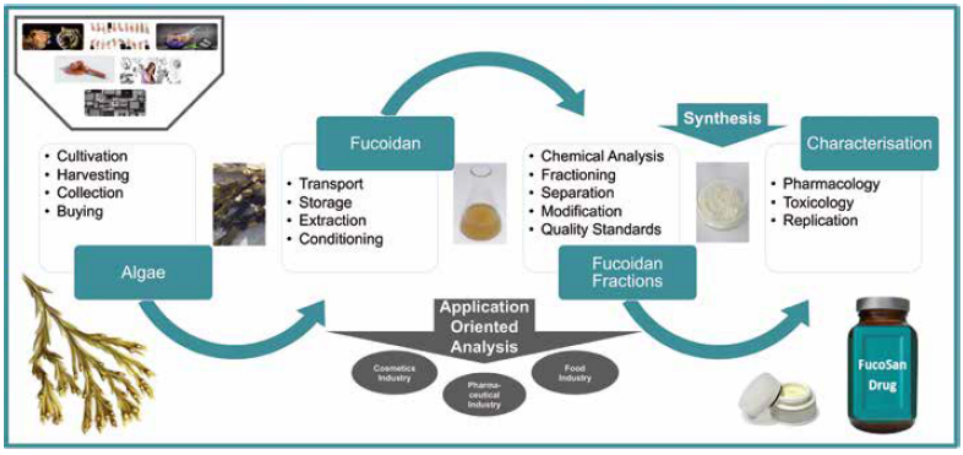


Figure 7 Fucosan project: The process of value creation.[1]

As shown in the following table, Baltic Partners are also increasingly active in the blue biotechnology research projects funded by the ERA-Net Blue Bioeconomy Fund.

[48] Fucosan project: Result Report Organisation and business models. 2020. CAU / SDU; www.fucosan.eu/app/download/6216447266/Fucosan%20Result%20Report%20WP6%20web.pdf?t=1599217068

Table 2 Blue Bio Co fund projects with Baltic partners

Title	Description	Partners	Weblink
BIOZOOSTAIN Sustainable utilization of zooplankton as by-products	The main objectives of BIOZOOSTAIN is to fully process valuable ingredients, such as astaxanthin, chitin, polyunsaturated omega-3 fatty acids, wax-esters and enzymes from marine zooplankton, such as Calanus finmarchicus, which are taken ashore and introduced as a side raw material or by-catch during pelagic fishing.	*DTU Aqua, FF Skagen Management (DK)*	https://bluebioeconomy.eu/sustainable-utilization-of-zooplankton-as-by-products/
AQUAHEAL3Dll -3D Printed Biomarine Wound Healing Accelerant	This project combines all renewable, marine sourced products to create a 3D printed wound healing medical device. We will incorporate Regenics' bioactive substances from unfertilized salmon roe, HTX, into a topical wound healing dressing (class III medical device) for chronic hardto-heal wounds.	*Citoxlab, RISE (SE)*	https://bluebioeconomy.eu/3d-printed-biomarine-wound-healing-accelerant-2/
BlueCC - Commercial exploitation of marine collagen and chitin from marine sources	The BlueCC project aim to take underutilised species such as invasive marine species, by-catch and cleaner fish from the aquaculture industry, to develop new marine ingredients and products, with significantly reduced impact on the environment. The specific focus will be on sustainable exploitation of collagen and chitin resources produced by jellyfish, starfish and cleaner fish, and invasive crabs respectively.	*Fraunhofer (DE)*	https://bluebioeconomy.eu/commercial-exploitation-of-marine-collagen-and-chitin-from-marine-sources/
ImprovAFish - Improving aquaculture sustainability by modulating the feedmicrobiome-host axis in fish	decipher the intimate functional coupling along the feed microbiome-host axis in an applied context, with the emphasis on a promising 'next generation' functional feed ingredient (beta- mannan) that is known to promote beneficial microbiota in production animals, including promising preliminary data in fish.	*Copenhagen University (DK), SLU (SE)*	https://bluebioeconomy.eu/improving-aquaculture-sustainability-by-modulating-the-feedmicrobiome-host-axis-in-fish/
MARIKAT - New catalytic enzymes and enzymatic processes from the marine microbiome for refining marine seaweed biomass	unlock the potential of microbiomes in providing tools for emerging biorefineries of Europe to establish an unique marine bioresource, seaweed polysaccharides as a feedstock. Enzymatic refining of macroalgal polysaccharides to added value products on industrial scale is near to non-existent today – robust enzymatic tools are lacking. MARIKAT entails retrieval, evaluation and industrial development of enzymes identified in novel marine microbial genomes and metagenomes.	*DTU, LLa Bioeconomy, Enza Biotech, Ocean Rainforest (DK), Lund University (SE)*	https://bluebioeconomy.eu/new-catalytic-enzymes-and-enzymatic-processes-from-the-marine-microbiome-for-refining-marine-seaweed-biomass/
MINERVA - Marine Innovation using Novel Enzymes for waste Reduction and Valorisation of Algal biomass	valorise underutilised seaweed biomass sustainably produced across Europe, to develop new high-value products and reduce waste in current processes. It will add value to brown algal biomass presently used at low efficiency, focused on bulk Ascophyllum (wild-harvest) and Saccharina (cultivated), in addition to other regionally important niche species of commercial potential, based on principles of waste reduction and 'food first' for new products within the blue bioeconomy.	*RISE (SE)*	https://bluebioeconomy.eu/marine-innovation-using-novel-enzymes-for-waste-reduction-and-valorisation-of-algal-biomass/
PlastiSea – Novel enhanced bioplastics from sustainable processing of seaweed	develop novel bioplastic materials based on cultivated and wild underutilized species of brown algae. The project will thus provide an innovative and sustainable bioplastic substrate with promising properties, and simultaneously add value to a growing seaweed industry in Europe. The seaweed biomass will be processed to obtain polysaccharide-rich fractions, employing various degrees of refinement toward single-use biodegradable materials for food industries as well as higher-value applications in the biomedical and cosmetic sector.	*AAU (DK), KTH (SE)*	https://bluebioeconomy.eu/novel-enhanced-bioplastics-from-sustainable-processing-of-seaweed/
RASbiome - Microbial management in	improving the sustainability of fish production in freshwater recirculating aquaculture systems (RAS) by introducing new and innovative approaches for	*DTU, Assentoft aqua Aps (DK)*	https://bluebioeconomy.eu/microbial-management-in-ras-

RAS for sustainable aquaculture production	microbiological water treatment. We will implement two fundamentally distinct biological water treatment strategies, new to RAS, to improve the management of nitrogen compounds. The first strategy involves anaerobic ammonia-oxidizing (anammox) bacteria, and results in almost complete removal of nitrogen from the water. The second strategy takes advantage of bioflocs formed by heterotrophic bacteria, assimilating nitrogen.		for-sustainable-aquaculture-production/
SIDESTREAM -	Secondary bio-production of low trophic organisms utilizing side streams from the Blue and Green sectors to produce novel feed ingredients for European aquaculture - production of high value compounds by utilization of low trophic marine invertebrates and bacteria, which will be reared on waste streams, following circular principles.	*Alfred Wegener Institute (DE)*	bluebioeconomy.eu/secondary-bio-production-of-low-trophic-organisms-utilizing-side-streams-from-the-blue-and-green-sectors-to-produce-novel-feed-ingredients-for-european-aquaculture
SNAP - Seaweeds for Novel Applications and Products	develops novel products and applications by upgrading and modification of five different polysaccharides from selected brown and red algae.	*KTH (SE), Tallinn University (EE)*	https://bluebioeconomy.eu/seaweeds-for-novel-applications-and-products/
SuReMetS - Microalgae Microbiomes –	A natural source for the prevention and treatment of diseases in aquaculture: develops novel marine ingredients from various resources such as underutilized material from fisheries and micro and macroalgae (seaweed) targeting the management of metabolic syndrome (MetS).	*University of Hamburg, BlueBioTech GmbH (DE)*	https://bluebioeconomy.eu/microalgae-microbiomes-a-natural-source-for-the-prevention-and-treatment-of-diseases-in-aqu-aculture/
AquaHealth - Microalgae Microbiomes	applies an advanced meta'omics toolbox on the natural synergy of microalgae and microbial consortia associated with fish to discover and validate novel bioactive and prebiotic candidates for sustainable use in preventing and treating disease in land-based aquaculture systems.	*Hamburg University of Technology, Sea & Sun Technology GmbH (DE), AAU (DK)*	https://bluebioeconomy.eu/microalgae-microbiomes-a-natural-source-for-the-prevention-and-treatment-of-diseases-in-aquaculture/
DIGIRAS - Optimizing land-based fish production in next generation digital recirculating	develops innovative and data-driven solutions for digitalization of future RAS technology in order to increase environmental compatibility, fish health and productivity. The project intends to reach this goal by systematic acquisition of relevant water quality data, parameterization of fish behaviour, developing new biological and chemical sensors and efficient water treatment technology.	*Bielefeld University, FRESH Völklingen GmbH (DE)Lappeenranta University (FI)*	https://bluebioeconomy.eu/optimizing-land-based-fish-production-in-next-generation-digital-recirculating/
InEVal - Increasing Echinoderm Value Chains	advances high quality Bioeconomic products and services from echinoderm biomass. InEVal addresses societal demand for new solutions to current challenges for human food, aqua feeds and ecosystem services.	*Alfred Wegener Institute, CRM GbR (DE)*	https://bluebioeconomy.eu/increasing-echinoderm-value-chains/
MedSpon -	Characterization of new antibiotic principles against WHO priority pathogens of sustainable produced marine sponges for nutraceutical applications: Addresses the discovery of new sources from sponge secondary metabolites especially of Chondrosia reniformis and Axinella polypoides in collaboration with the detection of convenient recirculating aquaculture system conditions for sponge fragments to build up a sustainable source for sponge biomass.	*Alfred Wegener Institute, KliniPharm GmbH (DE)*	bluebioeconomy.eu/characterization-of-new-antibiotic-principles-against-who-priority-pathogens-of-sustainable-produced-marine-sponges-for-nutraceutical-applications/

Other Blue BioTechnology Networks

Parallel to the SUBMARINER / Alliance Network, other networks have also evolved across Europe with slightly different scope. Rather than seeing them as competition, SUBMARINER has continuously sought close collaboration with them – as to increase the scope of actions.

Network / Scope	Type / Funding	Activities / Scope
BioMarine Global	Private	Yearly BioMarine Conventions (congress with exhibition, B2B, workshops) Sub-Activities: BioPlastics Consortium, Blue International Coop, Blue Fund
EMBRC-ERIC Europe with Norway No Baltic partners	Pan-European Research Infrastructure Cluster: EU funded	Cluster, which supports fundamental and applied research activities for sustainable solutions in the food, health, and environmental sectors Selected projects: • CORBEL: platform for harmonised user access to biological and medical technologies, biological samples and data services required by cutting-edge biomedical research • EMBRC BioBank: Organisms, cultures, strains, specific cell lines, tissues, tissue cultures and their DNA are available on-site or remotely • EMBRIC: accelerate the pace of scientific discovery and innovation from marine Bio-Resources. EMBRIC aims to promote new applications derived from marine organisms in fields such as drug discovery, novel foods and food ingredients, aquaculture selective breeding, bioremediation, cosmetics and bioenergy.
BlueBio Alliance Portugal	Non-profit Association: Sponsorship	Network covering the entire marine biotechnology value chain: raw material producers, R&D units, biotechnology SMEs, transforming centres and manufacturers, public sector entities, support companies, final product developers; organises once a year Blue Bio Value accelerator programme
European Algae Biomasss Association (EABA)	Non-profit Association	Promotes mutual interchange and cooperation in the field of algae biomass production and use, including biofuel uses. Defends members' interests at a European and international level. EABA organises the AlgaEurope Conference.
Pilots4U /Europe Baltic Partners: KTH (SE); VTT (FI)	Database BBI-JU project	Network (database) of open access pilot and multipurpose demo-infrastructures for the European bio-economy
Ocean4Biotech / Europe Baltic Partners: GEOMAR/CAU, DE RUC, DK Uni Tartu, EE Uni of Gdańsk, PL	COST Action	• brings together experts in marine biotechnology, • platform for sharing experience, knowledge and technologies, • designs a roadmap for a more efficient and rapid development of marine biotechnology research in Europe and beyond.
Microbial Resource Research Infrastructure (MIRRI) / European Baltic Partners: PL: University of Gdansk; IAFB Collection of Industrial Microorganisms; Polish Collection of Microorganisms (PCM), Hirszfeld Institute. Latvia: Microbial Strain Collection	European Research Infrastructure Consortium (ERIC)	Launched in 2012, the vision of MIRRI is to be a unique pan-European high-performance platform adding value to known and yet unknown microbial biodiversity and exploiting novel sources and knowledge to discover and disclose for the bioeconomy and bioscience. Provides overview on culture collections

6.3 State of Play

In addition to working with more than 30 cases, the ***Alliance*** surveyed 24 (out of a total of 62) participating R&D institutions (9 from within / 15 external to the ***Alliance***) in the Baltic Sea Region with a view to their competencies, activities and interests in the field of blue biotechnology. Even though non-exhaustive, the analysis provides a good snapshot of the existing technological expertise, know-how, and biological resources as well as R&D focus areas including applied science.

The study fields of the 24 R&D institutions shows a wide spectrum of competencies, resources and interests within blue biotechnology, namely within chemistry, biology, ecology, and engineering. Among the most popular fields of study were production of algae (both micro- and macroalgae) and bacteria (for example marine bacteria, cyanobacteria) for a number of applications from food and feed to highly specialised markets and bioremediation.

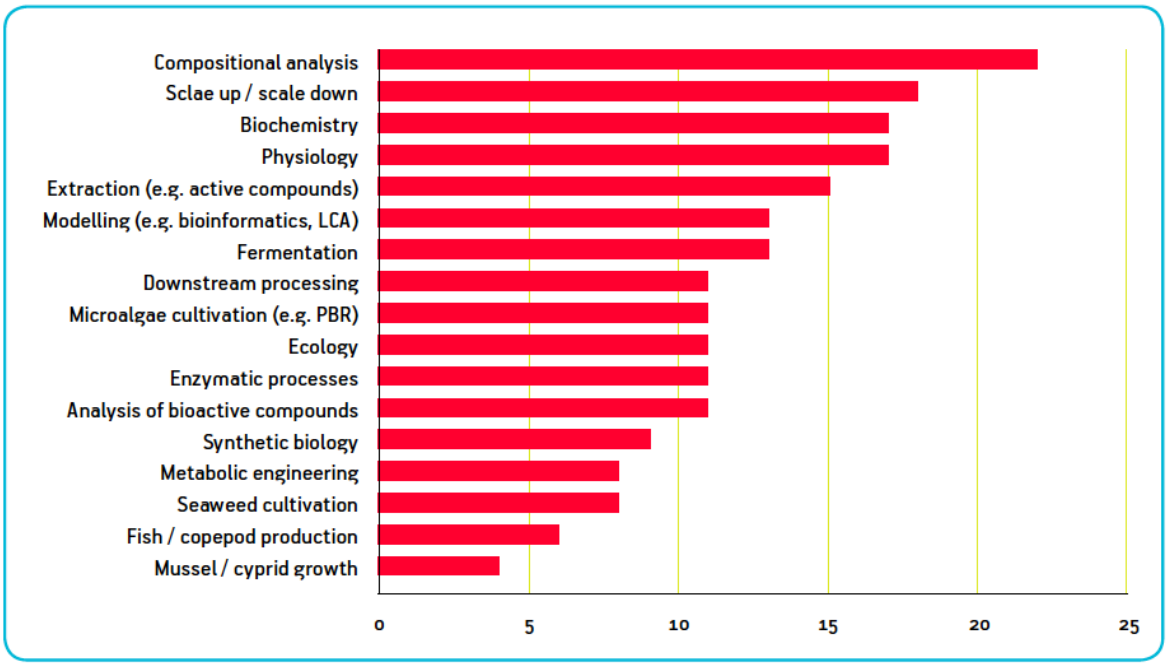


Figure 24 Expertise of R&D institutions in blue biotechnology.

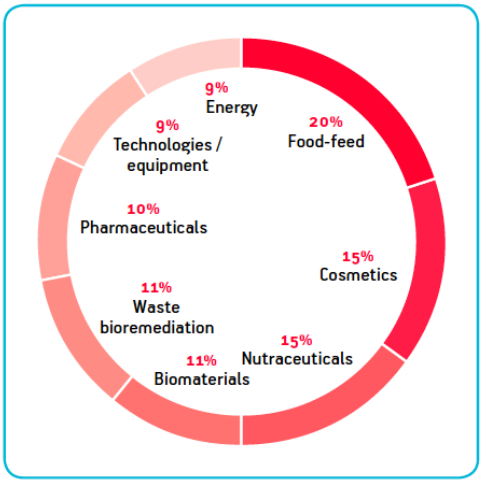


Figure 25 Blue bioeconomy market products in which R&D institutions have expertise and interest.

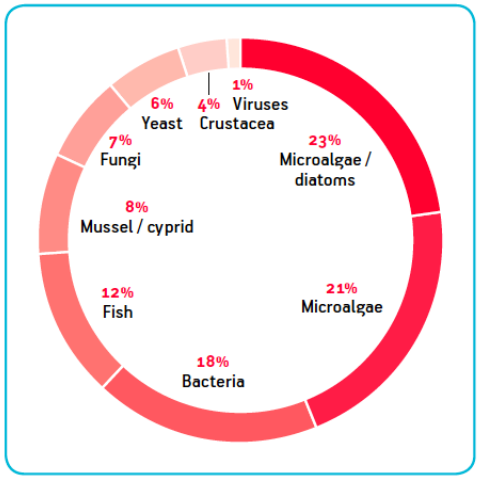


Figure 23 Type of marine biomaterials used for R&D

The survey showed, that dedicated **blue biotechnology study programmes are very rare in the BSR**. In many BSR countries, blue biotechnology teaching is realised by offering elective courses or specialised modules in the framework of other study programmes in (industrial) biotechnology or marine biology.

6.4 Conclusions

Finally, the *Alliance* assessed the current strengths and opportunities of the Baltic blue biotechnology research, development, and innovation ecosystem according to the **five thematic areas of the Marine Biotechnology Strategic Research and Innovation Roadmap**.

Access to aquatic biological resources

The survey showed that Baltic marine and freshwater ecosystems host a thriving biological diversity of organisms, including fungi, micro- and macroalgae, bacteria, sponges, and mussels. Ensuring access to these existing biological culture collections (e.g. microbial biobanks, microalgae collections), different types of biological resources in nature (e.g. macroalgae) or as yet undiscovered bioresources open great possibilities for further advancements across various value chains.

Sustainable integrated biomass production systems relevant for the Baltic Sea Region

Aquaculture and blue biotechnology are two distinct but highly intertwined sectors. Aquaculture can supply blue biotechnology with primary (e.g. macroalgae, fish, molluscs) and secondary resources (e.g. industrial processing biogenic residues and side-streams) – whereas blue biotechnology is crucial in all steps from growing biological resources (including fermentation, ecology engineering) to recovering biomaterials from process side-streams. It is therefore a key quality, that the SUBMARINER Network covers both sectors under one roof also in future activities.

Design new materials supporting the circular economy

On a global scale, we are facing a shortage or an increase in the cost of many raw materials. In addition, materials are produced that withstand degradation over long time scales and may harm the environment in general and the Baltic Sea environment in particular (see marine litter chapter). We should therefore focus on developing local and closed material circles.

Align blue biotechnology R&D with product market trends, challenges and opportunities

Linking R&D with innovation pathways and market applications at an early stage, for example at the bioprospecting stage, can accelerate product development. It also increases the cost efficiency of R&D by reducing costs and minimising risk of failure.

Even though the past years have seen the birth of numerous (blue) accelerator programmes (e.g. the most prominent programme being EUs' BlueInvest), almost all of them only accept/offer support to start-ups at high TRL levels. 'Blue incubators' taking lower TRLs have not come to our attention. Hence a crucial knowledge / financial gap remains.

Support structures like the *Alliance,* are able to bridge the gap between technological innovation and R&D on a transnational level. The *Alliance* also accepted/accepts companies that are at the pre-seed stage and still need to develop a minimum viable product (MVP). This stage already needs considerable financing for R&D, e.g. to develop a proof of concept and test a prototype.

Mapping capacities and resources to boost blue biotechnology R&D and innovation in the BSR:

The *Alliance* developed a database for cataloguing multi-purpose research infrastructure available to *Alliance* R&D institutes and companies. The analysis showed that the BSR lacks multi-use, open access, pilot-scale facilities relevant to (blue) biotechnology, which makes it difficult to test, validate and de-risk innovation at scale. Some large-scale facilities exist, such as the Kalundborg Forsyning photobioreactors and VTT facilities within the Baltic as well as the Bio Based Europe Pilot Plant and TNO in the Benelux, but they are often not accessible and others are not modular.

6.5 Recommendations

Link Baltic aquatic biological resource database to EU wide databases

The *Alliance* created a catalogue that lists the biological resources and culture collections of the *Alliance* partner R&D institutions in the BSR as well as the respective contacts at the partner institution.
Recommendation: In view of EU wide parallel processes aiming towards creating EU wide catalogues of culture collections it is highly recommended to refrain from further sea-basin specific activities, but rather **connect the *Alliance* catalogue with other EU blue biobanks** (e.g. EMBRC BioBank, MIRRI) in order to avoid generating parallel structures. Moreover, the Nagoya Protocol effectively results in a halt of an – even though efficient - sharing of bioresources across the EU. **Further training** and well-trained personnel are necessary to accomplish the implementation of the **Nagoya Protocol**, regulating transnational access and the benefit-sharing of biological resources.

Align Baltic blue biotechnology R&D with product market trends, challenges and opportunities:

A survey carried out with more than 100 participants of the Alliance conference 'Blue Biotechnology in the Baltic Sea Region' (Aug 2018, Greifswald) led to the following results:

What are the most important future research needs?	What are potentially highly profitable products?
• New food sources, food security, nutrition (71%) • Sustainable consumption and production (46%) • Sustainable use of oceans, seas, and marine resources (34%) • Sustainable and affordable energy sources (22%)	• Cosmetics and healthcare (64%) • Food and nutritional supplements (61%) • Antibiotics and pharmaceuticals (46%) • Special/valuable biobased compounds (e.g. enzymes, bioplastics, fine chemicals) (39%)

The SUBMARINER network is therefore currently pursuing efforts in promoting projects, especially within the food and feed sector.

Further R&D needs have been identified in sustaining and further developing knowledge in:

- **Develop technologies for converting aquatic biological resources (**e.g. algae, beach-wrack, bacteria) **into added-value products**, such as cosmetics, nutraceuticals and agrochemicals and pharmaceuticals, as well as develop biorefinery technologies to minimise waste.
- **Foster inter-disciplinary and inter-technological collaborations** both in applied science but also for developing auxiliary technologies for scaling up the aquaculture sector.
- Transfer and upscale symbiotic interactions of aquatic organisms in lab for production of new secondary metabolites with bioactive properties useful for various product applications.
- Test, optimise, integrate and upscale **Recirculating Aquaculture Systems (RAS) with microalgae cultures**, insect production, or aquaponics that, biologically clean wastewater to minimise water exchange and recycle nutrients in the house *(see also fish aquaculture chapter)*

Design new materials supporting the circular economy

Recycling and circular economy concepts need to be facilitated, and traditional industries should adapt to these challenges. When carefully planned and used, redirected side-streams can be a resource for biotechnological use. For example, nutrient-rich wastewater can be used to cultivate algae or shellfish for energy or other added-value products and simultaneously clean the water. The excess biomass could be used as a fertiliser in agriculture. Bioremediation technologies that can contribute to cleaning water or scavenge for nutrients and carbon should be studied in more detail.

Continue to map and integrate capacities, facilities and resources for blue biotechnology R&D and innovation in the BSR; strengthen collaboration with EU wide networks

The sector being still very small, it is important that clusters organise matchmaking events to bridge the gap between universities, research institutes, large industry, SMEs and start-ups. Even though hackathons and short-term matchmaking facilities serve their purpose in boosting innovation, these have to be embedded in **long-term continuous mechanisms** which follow a structured development pathway and provide a safety net that fosters ideation and risk-taking by start-ups and SMEs.

The Alliance accelerator programme, supported by the interdisciplinary mentors' forum, fills this gap with its fully customised mentoring programme for blue biotechnology start-ups and SMEs. Although this mechanism is ready and operational, funds are needed for the Alliance to continue provision of quality support and further enhancement of innovation capacities in the BSR (see strategic actions).

- The Alliance database of blue biotech experts, institutions and their infrastructures is a critical basis for connecting parties to create full product development chains. The **mapping of multi-use, open-access, pilot-scale facilities should be expanded**, and visibility of and accessibility to facilities be enhanced.
- Within the Baltic Sea Region, the ambition is for the **SUBMARINER network to be the single information and communication hub** for such facilities with the ambition to be as comprehensive as possible.
- Screening the results from scientific projects, which can be transferred into commercial applications, shall remain an ongoing exercise of the SUBMARINER Network secretariat.
- The **SUBMARINER network shall continuously collaborate openly with highly specialized (project based) networks** – as the one evolved from the DE-DK Fucosan project. The Alliance will send suitable cases from outside Germany/Denmark to the Fucosan network; vice versa Fucosan partners will transfer cases not relevant to their network to the SUBMARINER Alliance.
- The **SUBMARINER network will continue collaboration with other EU wide networks** (e.g. EMBRC; BioMarine; BlueBioAlliance; Biobased Industry Consortium) as to increase visibility of its own facilities and resources throughout Europe; while also benefitting from those outside the Baltic Sea Region.

The experience of the Alliance accelerator programme has shown that personal trust is an important good - which can e.g. overcome IPR issues. Personal contacts are easier to create across closer geographical vicinities (e.g. the Baltic Sea region, the Portuguese BlueBioAlliance). Anonymous databases alone will not solve the challenge on how to create a critical mass of action. SUBMARINER should remain focused on those, who are interested in a trustworthy network of actors, who interact at multiple times over a longer period of time.

Strengthen education and training in blue biotechnology and entrepreneurship

Currently, only few training possibilities exist for scientific fields within blue biotechnology. Most often the blue is offered in optional specialisation courses in biotechnology programmes.

- **More high-profile educational programmes are needed** to teach the relevant methods and techniques and encourage the young generation to engage in blue biotechnology. The inspiring success stories of the BBMBC or ACES programmes should have a beacon function and may lead to similar future initiatives in the BSR.
- **More bio-entrepreneurship education opportunities are recommended** for future managers and business developers. This is especially relevant for important biotechnology city-clusters, for example in Kiel, Tartu, or Helsinki, thus copying the success of Copenhagen Business School.
- Finally, **there is a lack of a knowledgable, skilled, non-research work force**, especially connected to the harvesting, purification, and extraction of biomass.

The SUBMARINER Network is continuously promoting the existing training and qualification programmes and courses on its own website and newsletter. However, a truly integrated 'internship' exchange facility has so far not been possible to be installed – mainly due to lack of outreach to the relevant 'exchange' offices within the universities / companies.

It is highly recommended to create an **education task force within the SUBMARINER network**; similar to the Ocean literacy initiative for schools and/or the SUBMARINER accelerator for start-up companies. The task force should evaluate: 1) the needs and feasibility of maintaining a transnational blue bioeconomy 'career' and 'exchange' service and 2) the need and feasibility to install a Baltic Sea wide collaboration on joint or aligned Master Programmes and 3) whether an application under ERASMUS+ and/or COST may be an option.

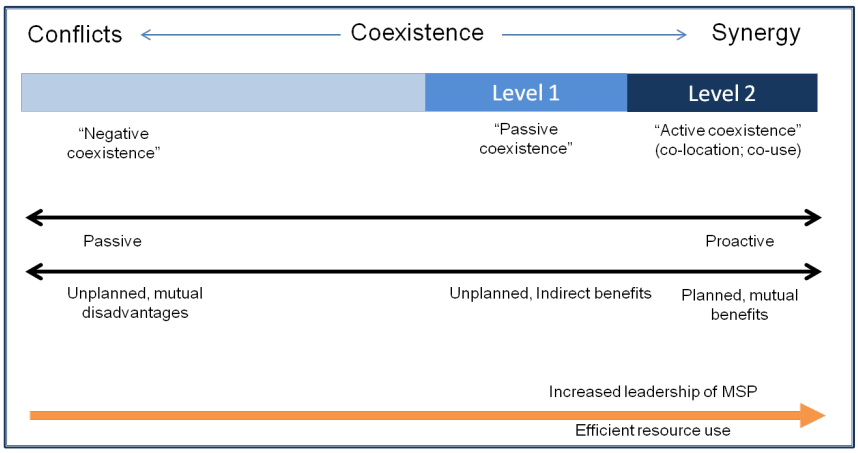
7 Promoting Multi-Use in the Baltic Sea

7.1 The Ambition

The concept of ocean multi-use – as already highlighted in the SUBMARINER Compendium in 2012 - has gained attention in the last years as an approach that can contribute to a more sustainable and efficient use of ocean resources, by **reducing the demand of 'un-used' sea space** and potentially offering significant **socio-economic and environmental benefits**.

What is ocean multi-use?

Multi-use stands for an intentional combination of different ocean uses both in close proximity, through joint operations (e.g. shared human resources), and/or the same platform (e.g. shared installations). Implementation of multi-use requires a radical change from the concept of exclusive resource rights to the inclusive sharing of ocean resources by two or more uses. Whereas the original concept often focused primarily on multi-use of offshore installations, research undertaken in past years has also pointed to numerous benefits of combining 'soft uses' with each other (e.g. small-scale fishery, tourism & environmental protection).



The discussion about multi-use in the Baltic Sea started off from the SUBMARINER project pilot where a **mussel cultivation was tested at the Danish Rødsand 2 wind farm**. The investigation suggested that approximately 25% of the space between the individual turbines could be used for combined uses such as aquaculture systems, or for collection of natural fouling agents (biomass) that can be used as a source of feed or energy. Apart from challenges related to the technologies applied, environmental (in-combination and cumulative) impacts resulting from combined uses, the project also highlighted that there is a lack of tradition for cooperation between the two sectors involved.

The SUBMARINER project concluded that **political support is necessary for the development and promotion of demonstration pilots**, which may provide convincing data with respect to positive environmental results, suitable technical solutions and economies of cooperation and scale – always to be taken within the local context where one such application is to be developed. Moreover, the **increasing need for initiatives combating climate change** were seen to serve as a driver for **opening up offshore wind farms to biomass collection as a CO2 sequestration mechanism.**

7.2 Projects

The Baltic Sea has hosted a multitude of multi-use related projects and studies to date, mainly driven by the large number of planned Off-shore Wind Farm (OWF) projects and existing Under-water Culture Heritage (UCH) sites. However, such initiatives have so far been mainly driven by the research community, supported by the EU research and innovation funds (e.g. FP7 and HORIZON programmes). **While the concept of multi-use has been frequently associated with combinations with the offshore wind, other multi-use combinations that do not require fixed installations, also have potential and are, to a certain extent, already present in the Baltic Sea.** These include combinations with underwater cultural heritage, and combinations with aquaculture. The following section provides more details about some of the projects and studies that have taken place in the Baltic Sea.

MUSES: Multi-Use in European Seas project (H2020, 2016-2018)

explored the opportunities and barriers for further development of multi-use solutions in the Baltic Sea such as combined production of offshore wind energy and aquaculture (mussels and seaweed), and offshore wind

energy and tourism, as well as the combinations between underwater cultural heritage, environmental protection and tourism. The **Ocean Multi-Use Action Plan developed by SUBMARINER** as part of the project has been widely used across the EU. The **two pilots developed by the SUBMARINER Members (KTH and DTI)** on offshore wind combined with aquaculture and/or tourism have provided valuable recommendations with regard to further development potential of the multi-use in Swedish and Danish part of the Baltic Sea. Both case studies have concluded that there are challenges related to stringed environmental regulation, unsupportive policy and lack of certainty for such investment (i.e. insurance policies, unclear ownership and synergies in the value chain).
SUBMARINERs: SUBMARINER Secretariat (DE), MIG (PL), KTH (SE), DTI (DK)

Projects focusing on "soft" multi-use combining Underwater Cultural Heritage and tourism

The Baltic Sea hosts around 100,000 shipwrecks on its seabed according to historical data. Due to natural water condition in the Baltic Sea these objects are preserved in exceptional conditions compared with other European sea basins (with the exception of the Black Sea).

- **Nordic Blue Parks** project combines Tourism, UCH and Environmental Protection by introducing sustainable blue trails to local UCH sites and formulating criteria and guidelines for further sites in Denmark, Finland and Sweden (Dalarö Blue Park). This is a joint initiative to protect local heritage and ensure public access to the wrecks. The project is led by the Finish Metsähallitus (a state company).
- **Vikingeskibsmuseet (Viking Ship Museum)** in Denmark has made authentic reconstructions of Viking ships discovered at Skuldelev (near Roskilde) and offers sailing trips to museum visitors.
- **Højklint underwater trail** in Denmark offers safe and easy dives in good visibility to a maximum depth of three meters.
- **Multitude of initiatives in Finland:** Finland is particularly advanced, with concrete cases in Kymenlaakso, Helsinki underwater park (UNESCO World Heritage site), Jussarö ship trap, Kvarken archipelago, Perämeri Underwater Nature Trail, and The Story of Vrouw Maria and St. Michael at the Maritime Museum of Finland in Kotka. The Kronprins Gustav Adolf underwater park, the first maritime historical underwater park in Finland and Baltic Sea region, hosts the Swedish ship of Kronprins Gustav Adolf. The sites allow access with no special permission needed for diving.
- **Trips to the ship wrecks from Polish ports:** In Poland, there is a special system established by maritime administration that opens some wrecks for diving, and the number of trips to the wrecks from Polish ports has been rising rapidly for several years.
- **The BalticRIM project (Interreg BSR)** explicitly analysed and led the way for new local opportunities in the blue economy sector in the Baltic Sea, including underwater cultural heritage. As part of the project, Germany and Denmark started a pilot management case project in Flensburg Fjord to find synergies between nature protection, tourism and the traditional maritime community, including maritime traditions such as the operation of historical ships and traditional usage of waterways.
- Additional examples of underwater cultural heritage and tourism include:
    - Kronprins Gustav Adolf (Finland)
    - BALTACAR Project sites in Sweden, Finland (Hanko, Hauensuoli) and Estonia
    - Dalarö underwater park (Sweden)

7.3 State of Play

As shown, since the publication of the SUBMARINER Compendium (2012), a series of theoretical studies have been conducted on multi-use on additional uses of offshore windparks; especially for tourism as well as ecosystem restoration. However, the operationalization of this multi-use combination differs across Baltic Sea countries due to different safety zone restrictions.

Actual multi-use developments in the Baltic Sea are still only few

In reality, there has not been a major uptake of the multi-use concept throughout the Baltic Sea within the past seven years. In fact, **much less offshore wind farms have been developed within the Baltic Sea than**

predicted by the SUBMARINER compendium in 2012[49]. Moreover, low trophic aquaculture as a potential secondary use to a wind farm is also still in its infancy.

Opportunities in countries with plans for new offshore wind farms

The studies have shown that it is much more difficult to integrate a new 'secondary' use within an existing offshore wind farm, for which a single use permit has already been awarded and insurance premiums agreed upon, than integrating a secondary use right from the onset, i.e. at the design and pre-planning stages, when insurance, permitting and ownership are clarified.

WindEurope (2019) expects that 9.000 MW of offshore wind could be developed in the Baltic Sea by 2030. In general, countries like Poland and Estonia, where the development of offshore wind is still at its inception (with no wind farm project actually having been realised yet), may benefit most from these existing early examples and studies by integrating the multi-use concept already in the **design and planning stage of future offshore wind farms**. Maritime spatial planning processes and/or offshore wind siting exercises offer an opportunity for planning authorities, together with stakeholders, to identify suitable areas and comprehensive policies **promoting multi-use, especially for new joint developments.**

Even with a concept of multi-use there may be competition among the 'secondary users': **fishery, aquaculture or marine protection areas may compete for taking the space within or around an offshore wind farm**. Thus, good stakeholder processes and political will are crucial.

Beyond offshore wind: local opportunities for combinations of 'soft uses'

The Baltic Sea has some of the best-preserved ship wrecks in the world, representing an important element of the underwater cultural heritage (UCH) of the region. Next to offshore wind park combinations, **multi-use of selected UCH sites with tourism and environmental protection** has not only been discussed; but pilot projects already exist especially in Finland. By making UCH sites accessible public appreciation of their value and significance is increased; while at the same time enabling better protection, maintenance and control of the UCH sites. Another driver for this multi-use combination is public demand for alternative tourism activities. It also shapes cultural identity of local communities and fosters interaction between the community and their history.

Combinations between tourism and small-scale fishery or shellfish / seaweed cultivations may also provide benefits to local communities around the Baltic Sea. These have however, not been sufficiently explored to date in the Baltic Sea, while the increased interest for sustainable forms of fishery and aquaculture may increase demand for such considerations in the future.

7.4 Ongoing Projects

UNITED (H2020; 2020-2024)

Building on MUSES project experience, **UNITED** will implement five demonstration pilots. The Baltic pilot focuses on the combination of the Middelgrunden **offshore wind farm and tourism just off Copenhagen (DK)**. UNITED addresses legal and insurance challenges as well as new opportunities stemming from expanding the tours by enhancing the boat service or offering scuba-diving and fishing around the site.
SUBMARINERs: SUBMARINER Secretariat, FuE-Zentrum Fachhochschule Kiel GmbH

MULTI-FRAME (Belmont; 2020-2023)

aims to increase the knowledge base and capacity of public and private actors for ocean multi-use systems by providing open source tools, assessment results and best practice examples. Results are expected to inform and encourage relevant actors to consider the concept in their marine planning practices and to streamline it in relevant ocean policies. As part of the project, multi-use scenarios will be developed in 5 case study areas (Sweden, United States, Mozambique, France and Norway). The Swedish case study is exploring two scenarios

[49] While the SUBMARINER Compendium predicted 10.843 MW energy production from offshore wind in the Baltic by 2020, there are currently only around 2.000 MW of offshore wind installed (Denmark 872 MW, Finland 68 MW, Germany 1074 MW and Sweden 192 MW).

in line with the MUSES project recommendations: **offshore wind and tourism** as a near future scenario, and **offshore wind and aquaculture** as a far future scenario. The case focuses on the Skagerrak area, which shows good opportunities for aquaculture, especially for mussels and seaweed. There are plans for offshore wind in the area, and there is great interest in combining this with aquaculture. The case study will explore **suitable layout and design of a farm** that may potentially double as an artificial reef and/or a no-take zone, as to allow for fish population recovery. It will also **investigate existing regulations** and their application; as well as selection of **optimal harvesting technologies** to minimize negative environmental impacts and maximize benefits.
SUBMARINERs: s.Pro (DE), KTH (SE)

7.5 Conclusions & Recommendations

Small-scale multi-use developments focused on tourism and closely monitoring environmental effects may hold significant benefits for certain regions, and may pave the way for potential future large scale rollout. Examples of such combinations include aquaculture and tourism which is already taking place in some parts of **Denmark in form of sea gardens**[50] (e.g. Ebeltoft harbour in Kattegat), as well as **offshore wind and tourism taking place in Middelgrunden** offshore wind farm off Copenhagen in Denmark. For existing offshore wind farms due to be decommissioned, the early consideration of concepts of re-use and re-purposing may allow for the operationalisation of circular economy concept in these economies.

Multi-use combinations with the underwater cultural heritage can provide new jobs due to new marine museums and information stands being developed on land and the increase of local revenues related to tourism services, as well as improved regulation and funding in place for UCH. Projects have mainly been small scale (local/national) while a wider exchange of management practices can contribute to a wider uptake of this concept.

The regulation differs across countries, and there is a need to **facilitate a better exchange of suitable regulation** that would allow multi-use, but still ensure appropriate level of protection of the UCH. Moreover, all projects implemented so far emphasize the lack of data on underwater cultural heritage, related tourism activity, marginality of the diving tourism, lack of awareness about and interest for the underwater cultural heritage, lack of investments and financing.

Given that this multi-use is of common interest in multiple Baltic Sea countries, **marketing the whole region as a cultural heritage tourism destination**, may be a good option to increase the visibility and attractiveness of such tourism offers. Such **smart specialization** and marketing approach may sustain coastal tourism even in cold months which especially relevant to remote and not so populated locations that strongly depend on seasonal coastal tourism for their livelihoods.

7.6 Activities suggested for the SUBMARINER Network

1. Advise national and local governments about the integration of the multi-use concept into planning, zonation and permitting of an offshore wind farm and **analysis of suitable institutional arrangements** to enable this (i.e. combined permitting procedure)

2. Assist the offshore wind companies in mediation processes with other uses and local governments and in **identifying benefits that certain multi-use combinations may bring** depending on the local conditions (i.e. local acceptance)

3. Form and facilitate the International **Ocean Multi-Use Community of Practice** to maximise collaboration opportunities on the topic between the industry and research community, communicate current multi-use opportunities and encourage the initiation of future projects.

[50] More information about sea gardens in Denmark available online: https://webgate.ec.europa.eu/fpfis/cms/farnet2/on-the-ground/good-practice/projects/community-sea-gardens_en

4. Conduct studies on the **identification of suitable environmental and socio-economic parmeters for siting of combined uses** and encourage mapping exercises that would clearly earmark the suitable multi-use zones where the combined use may bring more environmental and socio-economic benefits then the single use.

5. Advocate for the **identification of devoted offshore multi-use testing sites** (i.e. offshore innovation labs) and demonstration pilots that would showcase the impacts of multi-use and thus improve the confidence of governments and industry, facilitating further uptake of the multi-use concept.

6. Concrete studies for real site (at planning stage) on the potential of developing the aquaculture offshore, and its combination with future offshore wind farms. Explore multi-species mariculture among wind farms in the Baltic Sea to promote the sustainable development of fisheries in the light of the Common Fisheries Policy of the European Union.
7. Develop AI and sensor technologies for aquaculture farms to optimize farm operations that can improve economy and de-risk investments. This is relevant to aquaculture farms combined with OWF for instance, where optimized operations would reduce logistics, boat visits and potential accidents or disturbance.

8. Encourage the ocean literacy initiatives that would improve the visibility and interest in UCH sites and thus support their better management and protection. Communicate the need for more integrated cross-sectoral maritime skills, the application of systems and a circular approach in the development of the Baltic Sea Blue Economy (also advocated by the new Baltic Sea Region Programme – Orientation Paper, 2019).

9. Facilitate projects that encourage co-creation[51] of new products and services that can lead to better, quicker and less risky innovations and contribute to competitiveness of the Baltic Sea Region:

    - Multi-use pilot projects between **offshore wind and tourism/recreation** that would ensure better education about renewable energy, it's better acceptance and more immediate local benefits (i.e. through cooperative ownership of offshore wind farms). Projects should ensure the exchange of existing examples and related regulation (i.e. multi-use permitting) between the authorities.

    - Projects that promote the **combination of tourism and aquaculture** may improve the visibility of local aquaculture products, and ensure better support to the local sustainable aquaculture development, esp. the IMTA concept, and better marketing of local seafood food.

    - Projects that support the development of the **'building with nature' solutions** that can contribute to the competitiveness of the region with regard to innovation and increased climate change resilience as well as resource efficiency (e.g. innovative offshore wind farm **artificial reef solutions**, coastal erosion protection solutions, re-use of offshore structures for marine life monitoring and restoration, attractive design for tourism all-year round, etc.).

10. Roll-out of possible added value products from the UNITED projects e.g. certification schemes for the products derived from the marine space that is efficiently and sustainably used

[51] As highlighted by the new Baltic Sea Region Programme – Orientation Paper (2019) Co-creation is a concept closely linked to open innovation. It is a process, which brings different parties, including customers and other stakeholders together in order to jointly produce a mutually valued outcome through new forms of interaction, service and learning mechanism.

8 Beach-wrack/-cast

8.1 Ambition in SUBMARINER Roadmap

The SUBMARINER compendium (2012) did not consider beach-wrack/beach-cast as such, but concentrated on the increased use of reed bed areas found especially around the Swedish, Finnish and Estonian Baltic Sea coast lines. Recommendations focused mainly on the need to integrate the various uses and functions of reed beds into coastal zone management plans. Starting from better inventories and monitoring of the various reed beds; it was suggested to carefully weigh their function for biodiversity and food web stability; while also taking into account the associated benefits of reed harvesting in summer (as a biomass for biofuels) or autumn (as a nutrient removal measure). Even though somehow covered, beach-wrack was not considered as a separate topic within the original compendium.

8.2 Projects

Projects implemented during the past years have not focused on reed, but more on beach-wrack. "**Wrack**" is the natural material such as seaweed, sea grasses, driftwood, and other organic materials produced by coastal ecosystems that wash ashore on the **beach**. The **wrack** serves as a habitat as well as the primary source of nutrients to **beach** communities and is the foundation for the food chain

CONTRA (BSR INTERREG 2020-2022)

focuses on areas/beaches where the beach-wrack is removed anyway (in high-tourism season) and seeks alternative solutions for the use of beach-wrack that is removed from the beach. CONTRA was initiated with the aim to combine knowledge about the sustainable management of beach-wrack in the Baltic Sea region on national as well as international level. In **seven case studies, the ecological, social and economic aspects of the various collection and reuse options are being compiled and evaluated**.

SUBMARINERs: SDU and University of Tartu.
Weblink: https://www.beachwrack-contra.eu

Coastal Biogas (Interreg South Baltic, 2018-2021)

aims to provide solutions based on anaerobic digestion of beach-wrack to coastal regions to tackle eutrophication, contribute to the transition to a circular bio-economy by using the remaining digestate as organic fertiliser and improve prosperity.

Weblink: https://www.coastal-biogas.eu/
Partners (no SUBMARINER): FNR (DE), Roskilde University (DK), University of Rostock (DE), etc.

Analysis of beach-wrack on the island of Gotland (KTH))

In this project, beach-wrack was primarily treated as an environmental issue and harvesting the biomass was state funded through a marine policy programme as a measure to curb eutrophication.

8.3 State of Play

Despite decreasing nutrient loads, the water quality status, as well as ecosystem health of the Baltic Sea, is still regarded as poor in accordance with criteria of the various international agreements relevant for the Baltic Sea such as HELCOM. One very visible indication of the problem is beach-wrack, the organic marine material washed ashore which is both, an indication of nutrient-rich conditions as well as a source of nutrients that feed

the productivity of shallow water systems. The quantities and composition of beach-wrack landings varies temporally and spatially, depending on the coastal landscape, what is growing offshore, currents, wind and wave action. Along the Baltic Sea coastline it mainly consists of torn off eelgrass, brown, red and green macro algae, seashells, and dead animals.

Beach-wrack can cover Baltic Sea beaches for weeks after storms, rotting to a smelly soup that leaches back into water until the next storm. As a consequence, beach-wrack is a specific problem for coastal communities, particularly those whose economies rely on beach tourism. In the summer season, it is already being regularly removed as part of community beach cleaning routines in most touristic regions along the southern and western Baltic coast. **The methodologies employed and the treatment of this carbon and nutrient rich resource do not exploit its full potential for water management and pollution reduction.**

Beach-wrack working groups have been setup in Germany, Poland, Sweden, Estonia, Russia (Kaliningrad) and Denmark under the CONTRA project and led by EUCC – The Coastal Union Germany (EUCC-D) and the University of Rostock, to enhance the capacity of public authorities, public and private practitioners for improved coastal water quality in the BSR. However, for some municipalities the conversation about beach-wrack treatment for coastal water management has not even started. Other local authorities are trying hard to independently find affordable, legal and worthwhile recycling options for this valuable biomass, but are being restricted by the resources that can be spent, a lack of knowledge and a lack of cooperation. For example, in 2020 Liepaja municipal city in Latvia gave more than 100 permits to privates and companies to collect beach-wrack.

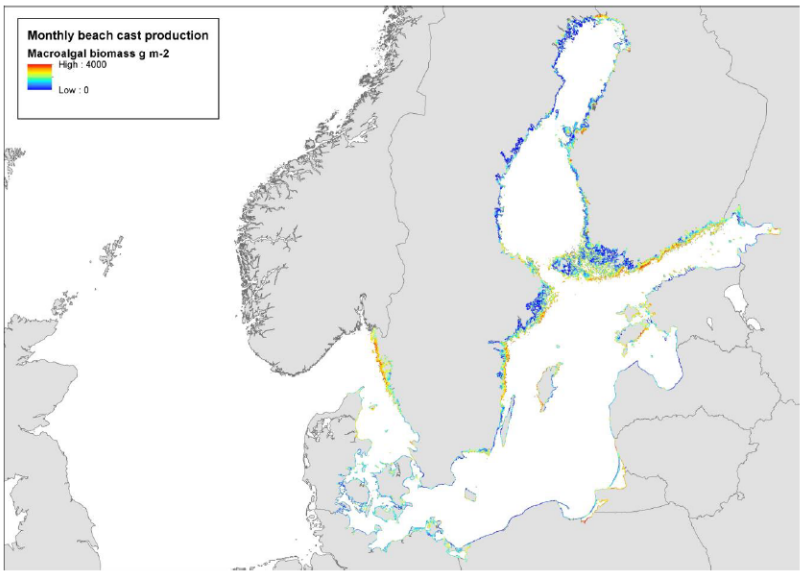


Figure 8 Monthly beach-wrack production potential across the Baltic Sea in late autumn[1]

8.3.1 Beach-wrack hot spots in the Baltic Sea

Beach-wrack production peaks at late autumn and is affected by multiple environmental variables. Higher amount of beach-wrack is expected in the late autumn months and the early winter along with the end of production season and the onset of heavier storms. Clear hotspots of beach-wrack production emerged throughout the whole Baltic Sea area (including Kattegat). The highest production values (up to 4kg per m2 per month) were observed on the west and east coast of Sweden, all along the southern coast of Finland, west coast of Estonia and in Gdansk Bay. However, some production hotspots were sporadically found even on the east coast of Finland, reaching northernmost parts of the Bothnian Bay as well as on the shores of St. Petersburg. 15 other examined spots of the Baltic sea were characterised by lower beach-wrack production potential (approximately 0 - 1,000 g per m2 per month)[52].

[52] GRASS A2.1. Assessing the PanBaltic potential of macroalgae cultivation and of harvesting wild stocks: https://submariner-network.eu/images/grass/GRASS_OA2.1_pan-Baltic_map_depicting_potential_of_macroalgal_cultivation_and_harvesting.pdf

Beach-wrack is organic by nature albeit at different stages of decay, but it can be contaminated with litter - cigarettes, plastics etc, and to the dismay of local authorities, it can land overnight in voluminous quantities reaching thousands of tons. Micro-litter is more numerous on public beaches, but it is also present in very remote areas (with lower density). With regards to costs, the most recent figures from within project CONTRA indicate that beach-wrack management is costing municipalities between 20€ - 40€ per m of beach length annually.

Figure 9 Beach-wrack landed ashore – Latvia 2020. Photo credits: Ligita Kokaine Kurzeme Region

For example, in Latvia the Ventspils city municipality collects beach cast during the swimming season, makes compost of it and uses it in the parks and greenery of the city; while in Liepaja the city communal department collects beach cast during the swimming season as well as in late autumn to be used as fertilizer or mulch in gardens. On the island of Gotland (Sweden) the harvesting is mainly executed by locally established NGOs, but the activity has to an extent also engaged farmers and other stakeholders to use the beach-wrack. As such, the system connects both formal and informal institutions to influence beach-wrack governance on the island.

8.3.2 Commercial Uses of beach-wrack

Potential business models and value chains for beach-wrack based products / services have been recently investigated in the Baltic. The recycling and re-use options currently being (re) assessed include:

Anaerobic Digestion: Use as co-substrate in an anaerobic digestion process in combination with digestate utilisation was investigated (by Coastal Biogas project). In this way, the release of greenhouse gases from decaying beach-wrack is eliminated and the nutrients recovered. The biogas yield from beach-wrack is low, but it helps to stabilise the biogas process and improves the overall biogas yield from the co-digestion. It is estimated that the biogas potential is much higher (up to 100%), if beach-wrack is transported fresh to the digester. **The nutrients in the beach-wrack together with the non-degraded parts are retained in the digestate which offsets the use of synthetic fertilisers and improves soil when applied on agricultural land.** A case study has successfully assessed the potential for biomass energy from beach-wrack in both gasification and anaerobic digestion (CONTRA case study ALREA in Kalmar, in Sweden).

Fertilizers: Experimental composting trials to optimize the beach-wrack process chain for fertilizers and soil improvement products. The process chain of beach-wrack – from the beach to the final soil product has been improved from the technical and management perspective. New beach-wrack-based soil mixtures have been developed and the knowledge of co-composting of beach-wrack deepened. **Composting of beach-wrack was identified as one of the most promising recycling solutions for big amounts of heterogeneous marine biomass from beaches.** The collaboration with other local actors especially the municipalities supplying the beach-wrack material has been intensified. Thus, **a strong local network of all stakeholders involved can be seen as the key to successful beach-wrack recycling in the Baltic region** (CONTRA case study WRACK4SOIL in Bad-Doberan/ Island of Poel, in Germany).

Soil conditioner or fertilizer (via RBS treatment): In the red bed system (RBS) dewatering of beach wrack was conducted with a water content of up 95%. The dewatering of the material is performed by gravity through a gravel bed, while the decomposition of the organic matter occurs as well. The test pilot plant has been established in summer 2020 (CONTRA case study FERTIWRACK in Swarzewo, Puck Bay, in Poland). The

end product can be used as fertilizer and this offers the advantage that it can be used very close to the coast and the processing is very cheap.

Insect production: Beach-wrack was added as ingredient in a "Guldborgsund Mix" to feed Black Soldier Fly Larvae. Fish-feed trials of Black Soldier Fly Larvae in collaboration with Danish feed companies. Nutritional value of beach-wrack, economic valuation and the business models where elaborated, combined with a clarification of possible Intellectual Property Rights (IPR) issues (case was investigated in Guldborgsund Bioeconomy Hotspot, Denmark). Legal obstacles with recycled biomass and food and feed health safety aspects were identified, and the project was terminated.

Carbonisation: Converting beach-wrack into biochar for usage in conventional coal-fired processes. The necessary laboratory experiments and analysis based on test samples have been executed (CONTRA case study, Beach-wrack Conversion, on the Island of Rügen, in Germany).

Other investigated uses include: Landfill biocovers, Coastal Protection. Other private trials with positive practical uses include **insulation mats for housing**.[53] There are also several start-ups active in the development of filling, insulation and acoustic materials such as Søuld, Dekomare, DanskTang.

Table 3 Commercial initiatives with beach-wrack

Application	Name
Building material	Søuld in Denmark is producing acoustic and insulation materials
Ornament	Dekomare is producing artifacts and ornaments in Germany
Packaging material	Nordisk Tang & Coast GRASS in Denmark is using beach-wrack as compressed or loose packaging materials
Technology provider	In Finland, Origin By Ocean is developing biorefining technologies for beach-wrack blends, and CLEWAT is developing technologies for harvesting free-flowing algae and green tides.
Trade	Schierbecker Handels in Germany has an online trading platform for alternative biomass resources and ingredients.

8.3.3 Current challenges and knowledge gaps

- Costs and cost factors for local authorities in machinery,and also in cleaning and recycling, specifically concerning for those in 'beach-wrack hotspot' areas
- Collection technologies for the careful collection of beach wrack need more development
- A confusing legal framework - particularly with respect to non-market reuse options on the beach for, e.g. coastal protection, and the waste classification
- The calculated amount of nutrient reduction from the Baltic Sea by removal of the beach-wrack needs farther research
- A lack of knowledge about the environmental pros and cons of beach-wrack removal incl. contamination levels, ecosystem service provision, and
- Societal costs and benefits from beach-wrack harvesting and use.
- Time pressure relating to 1) public demand for its removal and 2) storage/degradation of beach-wrack material for recycling.
- A lack of means to cooperate, both with neighboring municipalities and with private recycling companies/industry
- Lack of knowledge about trends and climate change impacts on beach-wrack quantities

[53] B. Chubarenko et al., Converting beach-wrack into a resource as a challenge for the Baltic Sea (an overview) (2020, in press), Ocean & Coastal Management, 105413, ISSN 0964-5691, https://doi.org/10.1016/j.ocecoaman.2020.105413.

8.3.4 Legal uncertainties

Although the use of beach-wrack for feeding Black Soldier Fly Larvae showed promising results, in EU beach-wrack is categorised as waste, thus it is not approved for feed to animals (insects are categorised as animals). Also, its use as a fertilizer, building material and other non-industrial options such as soft coastal protection measures, which can be regarded as "traditional" reuse routes, are hampered by the requirements for purity either with respect to species composition of the raw materials or with respect to pollution by heavy metals / plastics / hazardous substances.

All solution ideas to improve beach-wrack recycling have so far faced legal constraints as beach-wrack is still classed under The European Waste Catalogue (EWC) as "municipal wastes not otherwise specified".

8.4 Conclusions and Recommendations

To take beach-wrack management to the next level, it is advised to:

- Validate and control the environmental and biodiversity risks of intensive beach cleaning and beach-wrack removal against the MSFD and the new Biodiversity Strategy
- Pilot and demonstrate sustainable non-commercial beach-wrack reuse options that meet local needs for coastal protection and sand erosion.
- Resource-oriented beach manangement must be encouraged and rewarded to unlock the renewable potential of marine biomass from the beaches
- Explore technological means for avoiding sand uptake during collection operations.
- Develop a market for local products and short value chains, with the fertilizer, building and feed sectors.

Develop cost-efficient collections methods

with as little environmental impact as possible is important to improve the economic as well as ecological feasibility of using beach-wrack as a resource. Suitable harvesting technologies at sea are still needed to cover needs and particularities of the Baltic Sea, e.g. shallow waters.
In case of cast seaweed as co-substrate in anaerobic digestion, collection methods and/or pre-treatment methods that minimise the sand content need to be further developed. High levels of sand and salt increase wear and tear of mechanical devices such as pumps and agitators, and accumulates in the digester tanks.
Quality of beach-wrack deteriorates as it washes out on the beach as it dries and decays. Decaying seaweed smells bad and also emits GHG such as methane and nitrous oxide. Furthermore, collected beach-wrack ashore contains also sand that is often incompatible to processing equipment. Alternatively**, at sea harvesting of floating macroalgae** and eel grass can improve quality of quality of biomass and processing.
If we consider scaling up coast management activities, in view of technological developments, it is necessary to work further in suitable technologies for **better harvesting and drying techniques**. Such technological development needs have many common denoninators with the macroalgae farmers, so collaboration between farmers and municipalities is recommended.

Analyse technological procedures in more detail

Although constraints in the collection and processing are expected, **details of the technological procedures should be analysed and improved in more detail.** For example, an optimisation of beach cleaning technologies will reduce both the collection costs and the amount of sand mixed with the organic material. So far, the focus has been on cleaning the beaches quickly, without having a concept for sustainable use and recycling of the beach-wrack. Therefore, a holistic approach with resource-oriented beach cleaning needs to be established.

Remove legal obstacles associated with recycling coastal biomass

Amend the national definitions of beach-wrack as waste material as this prevents its effective use as resource for many different applications. Legislative action must be taken to respect beach-wrack as an entity on its own, far different from, e.g., roadside debris. It must become clear that it is far more related to, e.g., leaf litter of forests, a material which sometimes gets polluted by anthropogenic "additions" but being natural by nature. Any legal classification of beach wrack should not unnecessarily hinder its sustainable use, but nor

should it encourage unsustainable harvesting of beach wrack from natural unmanaged beaches. Re-establishment of such a status in law and administrative directives would allow for a return to beach-wrack being a resource, an increase in its use and economic value in the Baltic Sea countries.

Adress major gaps in long-term monitoring of seasonal and spatial differences of beach-wrack composition and amounts

The ecological function has only been studied on a small scale and should be evaluated with a more holistic approach involving all groups of organisms. In principle, the effects of beach management in its entirety (e.g. digging up the sediment/sand, permanent removal of organic material) on coastal ecology have not yet been investigated. Information about decomposition and residence times are scarce, especially for the Baltic Sea coast. More studies about beach-wrack chemical (nutrients, metals) composition is needed along with the calculation of a depuration rate from pollutants, as a result of removal from the beaches.

Foster better public/private cooperation

The lack of public/private cooperation and networking has been repeatedly pointed out, which hinders the development of an economic infrastructure for sustainable beach-wrack management and value chains.

Carry out Extended information campaigns

As these could change tourists' expectations of so-called clean beaches and draw more attention to near-natural beaches and the importance of beach-wrack for the beach ecosystem.

Investigate commercial uses

the more profound investigation of basic properties of beach-wrack must continue, as there are still questions concerning potentially harmful substances, also bearing in mind the substantial regional variation in its properties. Use of beach-wrack to feed black-soldier larvae has funded studies on assessment of **nutritional value, micronutrients and probiotic qualities of beach-wrack** and its market potential to feed applications, e.g. for insect production. Although legal issues were the primary obstacle in this study, as mentioned in bullet 2), valorisation of beach-wrack is also suggested.

8.5 Activities suggested for the SUBMARINER Network

1. Building on the network created within the CONTRA project, establish a post-project SUBMARINER beach-wrack Working Group to enable exchange with municipalities, companies and R&D enabling knowledge exchange in studies, tools, solutions and practices on environmental and socio-economic benefits and risks of beach-wrack collection and use, and also technology transfer with companies downstream that use beach-wrack in produce development.
2. Promote companies working with beach-wrack products and services and support in development of short local value chains.
3. Collect data on available beach-wrack, actors involved and support in organising a market place collaboration platform among municipalities, collectors and down-steam companies
4. Develop roundtables at national level to remove regulatory barriers, e.g. waste definitions.
5. Promote tech transfer activities for collecting and drying beach-wrack, and downstream processing like anaerobic digestion, composting, gasification and feeding larvae.
6. Develop ocean literacy activities, e.g. tourism campaigns under EU4Ocean on definition of clean beaches and coastal biodiversity.

Topics not covered by original SUBMARINER Roadmap

9 Marine Litter

Solutions to Marine Litter were not considered within the original SUBMARINER Roadmap - but soon thereafter came into the forefront.

9.1 The Challenge

Plastics play an important role in the economy and daily lives but the way it is currently produced, used and discarded harms the environment. It is the main source of marine litter as it is hardly biodegradable and can have toxic as well as other harmful impacts. Despite international agreements (MARPOL 1973), millions of tons of plastic still end up in the world's oceans every year with a significant proportion also in the Baltic Sea.

According to United Nations Environment Programme (UNEP), only 15 % of marine debris floats on the sea surface; another 15 % remains in the water column, while 70 % rests on the seabed. According to the Holistic Assessment of HELCOM[54], between 50 and 300 litter items are found on every hundred meters of Baltic Sea beaches. Approximately 70 % of these items are plastic. Land-based activities generate most of the marine litter. The most frequently occurring beach litter items are attributed to eating, drinking or smoking activities (e.g. food wrappings, bottles or lids). But also derelict fishing gear is among the twenty most common items, e.g. in the Eastern Gotland and Gdansk Basin and Kiel Bay. Another important source of marine litter in the BSR comes from wastewater treatment plants,

The consequences for the marine environment are devastating in many cases. Net residues or ropes are mainly responsible for the suffering of an unknown number of seabirds and other marine life, which perishes annually as a result in the Baltic Sea. For 35 species of marine life, it is known that they regularly get tangled up in parts of garbage[55].

Marine litter can also cause serious economic damage: losses for coastal communities, tourism, shipping and fishing in the BSR. At the same time, valuable material that could be brought back into the economy is lost, once littered. Nevertheless – despite their economic and environmental benefits - more resource-efficient and circular approaches are not yet mainstreamed and cooperation on trans-boundary or cross-sea-basin level has not been implemented yet.

9.2 Legal framework

Marine litter is a cross-border problem; once it enters the sea, it has no owner. This makes its management difficult and highly dependent on good regional and international collaboration. The EU and HELCOM is ambitious to answer these challenges with legislation and other approaches:

- The Marine Strategy Framework Directive (2008/56/EG) defines good environmental status (to be achieved by 2020, meaning this year) with regard to marine litter when the properties and quantities of marine litter do not have any harmful effects on the coastal and marine environment.
- Regional Action Plans of the European Sea Conventions: The Baltic Sea Region countries adopted a 'Regional Action Plan against marine litter' in 2015 as part of the Helsinki Convention (HELCOM)
- With regard to the specific case of 'ghost nets' the review of the Common Fisheries Policy Control Regulation56 improved the Fisheries Control System with rules on reporting of lost fishing gear, e.g. through the introduction of e-reporting, and on its retrieval as well as the requirement to mark and identify all fishing gear.

Apart from retrieval of marine litter, numerous policies and legislation has been brought on its way to prevent marine litter; in other words to **take action before the litter reaches the seas**. As shown in the table XXX below, the EU has adopted policies and legislation aiming towards the improvement of waste management,

[54] http://stateofthebalticsea.helcom.fi/pressures-and-their-status/marine-litter/#litter-on-the-seafloor
[55] see: http://stateofthebalticsea.helcom.fi/pressures-and-their-status/marine-litter/#litter-on-the-seafloor
[56] Council Regulation (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy

reduction of packaging waste and increase of recycling rates (of plastics in particular), improved wastewater treatment, and more efficient use of resources in general. There are also directives drawn up to help curb pollution from ships and ports. However, as some of them have only been launched by 2018/2019, they are not yet transferred into national law:

1. One of the European Commission's 10 priorities 2019-2024 is to boost the efficient use of resources by moving to a clean, circular economy and cut pollution (**Roadmap with actions of the European Green Deal**).
    a. According to the Single Use Plastic Directive (SUPD-2019/904) and the new Circular Economy Action Plan (2020/98) as one of the main blocks of the European Green Deal[57], Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with it until 2021. The SUPD demands ambitious reduction in consumption, prohibits the placing on markets of certain plastic products[58] and foresees an Extended Producer Responsibility (EPR) for producers of single-use plastic products and of fishing / aquaculture gear to pay in a balanced and transparent manner for collection, transport and treatment, with a focus on recycling. Also, awareness-raising measures have to be supported.
    b. The **European Strategy for Plastics in a Circular Economy (COM 2018/28 final)** recognises that plastic is a significant source of marine litter pollution. It sets out that additional action on fishing gear, including EPR will be examined.
2. The **Packaging Directive (2018/852)**[59] is the EU´s main piece of legislation on the managing of packaging and packaging waste. It is based on the EU´s competence to harmonize the internal market.
3. As a general directive on waste defining key concepts, establishing major principles, and allocating responsibilities, the **Waste Framework Directive (2008/98/EC)** has always been at the core of EU waste law. Very recently, the WFD of 2008 has been amended by Directive (EU) 2018/851.
4. The **revision of the Port Reception Facilities Directive (2000/59/EG)** includes measures to ensure that waste generated on ships or gathered at sea has to be returned to land and adequately managed.
5. **Standardisation** is seen as powerful instrument for self-regulation and deregulation as it is a stable and reviewable, generally accepted and coherent process. The Single Use Plastic Directive (2019/904) is the base for the Commission to request the ESO and the related expert Group CEN to develop harmonized standards for the circular design of fishing gear to encourage preparing for re-use and facilitate recyclability at end of life by the end of 2020. The process might take at least two years.[60]
6. The **White Paper from the Aquaculture Stewardship Council** has determined that extreme weather is currently one of the major causes of plastic 'ghost gear' from fish farms entering oceans and rivers, and warns that increasingly unpredictable weather caused by climate change could exacerbate the problem.
7. The European Union is also working towards restricting the use of intentionally added micro-plastic particles to consumer or professional use products.

The next years and related monitoring programmes and assessments will show whether all these legislative approaches will really reduce the amount of litter entering the sea.

9.3 Marine Litter Actions and Actors in the Baltic Sea Region

9.3.1 HELCOM

[57] https://ec.europa.eu/knowledge4policy/publication/communication-com202098-new-circular-economy-action-plan-cleaner-more-competitive-europe_en#:~:text=Communication%20COM%2F2020%2F98%3A%20A%20new%20Circular%20Economy%20Action%20Plan,%20Geographic%20coverage%20%20%20European%20Union%20

[58] like food containers, packets and wrappers, beverage containers and cups, lightweight plastic carrier bags, wet wipes, balloons, tobacco products with filters

[59] The PD of 1994 (94/62/EC) has been recently amended twice: First by Directive (EU) 2015/720 regarding the reduction of the consumption of lightweight plastic carrier bags, then on a general scale by Directive (EU) 2018/852.

[60] https://webgate.ec.europa.eu/maritimeforum/en/system/files/collatedcirculardesign_mrag.pdf

A large number of measures have been agreed on by HELCOM over recent years, which directly or indirectly are expected to result in reducing amounts of marine litter. The 2013 HELCOM Ministerial Declaration[61] contains a commitment to achieve a significant quantitative reduction of marine litter by 2025 (compared to 2015) and to prevent harm to the coastal and marine environment. To achieve this goal the effective and timely implementation of actions as defined in the HELCOM Action Plan on Marine Litter is needed.[62]

The action plan is structured according land-based sources[63] of marine litter (around 73%) and sea-based marine litter[64] (around 27%). It also tackles the issue of education and outreach on marine litter. The actions are divided into regional, collective HELCOM actions and voluntary national actions, which are primarily of national concern and therefore fall under the responsibility of the Contracting Parties.

- The **HELCOM Expert Network on Marine Litter** was established to (i) facilitate the implementation of the Regional Action Plan on Marine Litter and; (ii) develop core indicators to be used for the 2nd HELCOM holistic assessment of the ecosystem health.

- The **PRESSURE group**[65] leads the work on marine litter in HELCOM, including addressing sources on land and coordination of implementation of the HELCOM Regional Marine Litter Action Plan in cooperation with other subsidiary bodies. The Pressure group is a permanent subsidiary body.

- In addition, the HELCOM HOD (Head of Delegation) is supporting the implementation of the **HELCOM RAP**. **Its drafting group is responsible for building teams who work on specific issues related to marine litter**. These teams are made up of national experts, suggested by administration and are mainly derived of universities and specialised institutions, e.g. for monitoring. Recently, a report on microplastics in the Baltic Sea was published by these experts, providing a common baseline for policy-makers and researchers.[66]

9.3.2 National Level

On national level, environmental agencies/ministries, coordinating the work to achieve the GES under the MSFD, are mainly responsible for the marine litter topic under the HELCOM RAP but also related to the EU legal framework on marine litter, which is currently changing rapidly. Therefore, due to a broader political and legal approach, also other ministries are involved in the marine litter topic like ministries for education, economy and capacity-building (in third countries).

The HELCOM RAP includes a measure for the implementation of the Baltic's international action plan on national level. The **first part of the measure foresees a broad-scoped general survey on sources of littering**, the next part an outline of **targets and measures for littering** and the **last part comprises the implementation of the measures until 2025**. According to this and the MSFD, all BSR countries have launched Programme of Measures (PoMs) to meet the good environmental status (GES). In some countries these measures are linked to the marine strategy like in Finland with its Marine Strategy 2016-2020.[67] Littering was a new focus area of the marine strategy, but due to a lack of information, it was impossible to carry out a thorough status assessment in 2012.

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[61] https://helcom.fi/wp-content/uploads/2019/08/2013-Copenhagen-Ministerial-Declaration-w-cover-1.pdf
[62] https://www.helcom.fi/wp-content/uploads/2019/08/Regional-Action-Plan-for-Marine-Litter.pdf
[63] E.g. land-fills and littering of beaches and coastal areas by tourism, rivers and floodwaters, industrial emissions, discharge from storm water drains, untreated municipal sewerage.
[64] E.g., derived from fishing and aquaculture, illegal or accidental dumping at sea from shipping, offshore mining and extraction.
[65] At PRESSURE 10-2019, the HELCOM group was dealing with pressures on the Baltic Sea ploughs through nutrients, storm water and micro-litter.
[66] Review of existing policies and research related to microplastics under the FanpLESStic-sea project.
[67] https://ec.europa.eu/environment/marine/public-consultation/pdf/FIN%20PoM%20of%20marine%20strategy%202016_2021.pdf

In **Germany**, to support the implementation of the Programme of Measures under the MSFD with respect to descriptor 10, a **National Round Table** was installed in 2016, led by the Ministry for the Environment. The Round Table consists of 150 experts from different sectors like fisheries, shipping, plastic industry, wastewater management, waste industry, cosmetic and wire industry as well as trade, science, education, tourism, associations, administration, artists, consultancies and NGOs. The round table discusses the proposed measures and gives concrete and operational advice for implementation. In addition, Germany (like other Baltic Sea states) established special working groups for "Litter in the Sea" with tasks like the improvement of monitoring programmes and scientific input.

These national and regional bodies are in close cooperation with actors at international level, such as UNEP/SDGs, G7/G20, FAO, EU KOM TG Marine Litter Plastic Strategy, IMO, CBD, EPA-Network.

9.4 Projects and initiatives

Until today around **52 EU funded projects have dealt with marine litter**. Most of them have focussed on 'Policy, Governance and Management', 'Monitoring' and 'Risk Assessment'. Hardly any have dealt with 'fragmentation' or 'assessment tools'. The Baltic Sea region countries have received relatively little marine litter research funding as compared to other European countries like Spain, the Netherlands and UK.

Although smaller in numbers than in the North Sea or Atlantic, also within the Baltic Sea level numerous initiatives have been launched during the last years. For instance, in 2017, the Coalition Clean Baltic (CCB)[68] has implemented the **Plastic Free Baltic** project, which has contributed to lifting up the agenda of microplastic/marine litter pollution in the Baltic Sea region, including the upstream catchment area like rivers and estuaries. In 2019, CCB started implementing the new project "**Plastic Free Ocean**" to support implementation of the EU Plastics Strategy and to address the growing pollution of the Baltic Sea by single-use plastic items, primary and secondary microplastics, and associated toxic chemicals.

Activities focused mainly on various awareness raising campaigns:
ESTONIA
- No Plastic Challenge organized by the Estonian Green Movement.
- Webinar for restaurants about single used plastics and alternatives.
- Raising awareness about the Baltic Sea and microplastic for students.

GERMANY
- Revised Consumer Guide and policy brief on microplastics in cosmetics; policy brief on plastic inputs from artificial turfs and from tyres; 2019 Plastic Atlas; brochure on 11 Tips for Plastic-Free Living.

POLAND
- At the EUSBSR Annual Forum Gdansk announced to become a plastic-free city.

Initiatives like **„Keep Sweden Tidy"**[69] foundation have been created, aiming to organise clean-up days, foster knowledge and education about marine litter issues. Similar initiatives have been established in Denmark and Finland and are drivers for new projects. More recently new ideas like the **Plastic Engineering Day 2020 (**Aarhus University, Denmark) aim to raise awareness about marine litter among students and shall inspire them to think about new projects.[70]

'**Three Seas'**, also known as the **Baltic, Adriatic, Black Sea (BABS) Initiative**, is a forum of twelve states in the EU[71], which aims to create a regional dialogue on various questions affecting the member states like

[68] CCB was established in Helsinki, in February 1990 when environmental non-governmental organizations (ENGO's) from the countries of the Baltic Sea Region became united to co-operate in activities concerning the Baltic Sea environment. CCB is a politically independent, non-profit association and at present, is a network of 23 organizations and 1 observer from Belarus, Finland, Russia, Estonia, Latvia, Lithuania, Poland, Germany, Denmark, Ukraine and Sweden. Combined, the CCB member organizations have over 890 000 members in all countries surrounding the Baltic Sea.
[69] https://hsr.se/keep-sweden-tidy-foundation
[70] https://plasticengineering.dk/plastic-engineering-day/
[71] https://eblnews.com/news/croatia/dubrovnik-forum-adopts-declaration-called-three-seas-initiative-34593

marine litter. The initial two founding institutions from Poland and Romania have committed themselves to make payments which is supported by the other countries and private investors and may foster projects in these regions with possibly special attention to local needs.

The Interreg Central Baltic project **BLASTIC**[72] monitored and mapped sources and pathways of marine litter in four areas – Turku in Finland, Södertälje in Sweden, Tallinn in Estonia and Liepaja in Latvia – to demonstrate how plastic waste finds its way from urban areas into the Baltic Sea.

In Germany, the Ministry for Research (BMBF) has funded numerous so-called **cooperative projects** on marine litter between 2017-2020. The projects (e.g. **RAU, TextileMission, ENSURE or PlastikBudget)** are highly specific covering e.g. 'the entry of microplastic through tyres or clothes' or 'an analysis of the amount of microplastic in limnic systems'. Also the **German Alliance for Marine Research** (DAM)[73] aims to strengthen the sustainable use of the coasts, seas and oceans through research, data management and digitalisation, infrastructure and transfer, including the BSR. To this end, the DAM is working together with its member institutions to develop solution-oriented knowledge and to communicate potential courses of action to politics, business and civil society. One of its focus is on marine litter, including the awarding of awareness-raising campaigns or education approaches.

The **Marelitt Baltic project**[74] (2016-2019) was a BSR Interreg project between regional administrations, WWF Poland and Germany, Keep Sweden Tidy, Maritime University of Szczecin, fish producer groups and divers associations. Covering many aspects like mapping, retrieval, recycling and prevention of ghost nets, the project has created new areas of expertise. It has resulted in an action plan called *"The Baltic Sea Blueprint"*. Several **'Fishing for Litter'** initiatives[75], run by KIMO international, are in place, also in the Baltic Sea[76], where vessels collect marine litter — similar to municipal waste collection on land.

However, the methods being used fail to collect litter below a certain size. Therefore the **problem of micro-plastics**[77] remains unsolved. Although these initiatives might be too limited to result in real improvements, they are a good way to raise awareness of the issue and engage stakeholders. The same can be said about **clean-up activities on beaches and coasts**. For example, the EEA has developed Marine LitterWatch, which includes an app to monitor marine litter on Europe's beaches. At the end, it may simply be a question of numbers. As the number of volunteers joining such activities increases, the better the topic of prevention might be spread among societies.

9.4.1 Projects with involvement of SUBMARINER Members

Despite the fact, that marine litter was not part of its original agenda, several **SUBMARINER Network** members have already been involved in a range of projects aiming to prevent marine littering from the fisheries and aquaculture sector and to find solutions to close the plastic product cycle:

Fanplesstic-sea (INTERREG, 2019-2021)

focused on decreasing and removing microplastics in the Baltic Sea. The project increased knowledge and understanding about dispersal pathways and sources through measurements in different flows in society, as well as cost-effective methods to reduce microplastics. Marine littering is one of the greatest environmental challenges of our time and plastic is one of the most common types of garbage in the sea. Microplastics are plastic particles that are smaller than 5 mm in size. The project had three key targets:

1. increased knowledge of where microplastics come from and their transport pathways
2. evaluation of technology that can reduce microplastic or reduce microplastic leakage before reaching watercourses,

[72] https://ec.europa.eu/regional_policy/en/projects/sweden/blastic-tackling-plastic-litter-in-the-baltic-sea
[73] https://www.allianz-meeresforschung.de/en/activities/
[74] https://marelitt-baltic.squarespace.com
[75] http://www.fishingforlitter.org.uk
[76] https://kimobaltic.wordpress.com/projekt/fishing-for-litter/
[77] The term 'microlitter' is used for litter particles smaller than 5 mm, which can also be much smaller (GESAMP 2015). Some studies have focused on particles as small as 20 or even 10 µm.

3. increased knowledge and commitment of decision makers through suggestions on how to implement cost-effective methods to reduce microplastics.

Submariners: LUKE (FI), LIAE (LV), KU (LT)
Baltic Partners: Swedish Water Research (lead), AAU (DK), GIWK (PL), SALT (NO), SCCCIC (LT), HELCOM (FI)

MicroPoll (BONUS, 2017-2020)

Focused on the assessment of the multilevel impacts of microplastics (MP), of associated pollutants and of attached biofilms on the ecosystem Baltic Sea. The hazard potential and impacts of these substances will be determined by i) detecting the recent status regarding MP in the Baltic Sea (abundance, composition, sources, sinks), ii) exploring the vector function of MP for associated pollutants and biofilms, and iii) *in situ* and laboratory experiments, exposing marine organisms from different trophic levels to defined levels and size classes of MP and POPs. The gained knowledge enabled a) to create spatio-temporal scenarios and simulations for MP transfer and circulation, which help to understand the mitigation processes of MP and associated pollutants/biofilms in the Baltic Sea; b) to assess the risk originating from MP and c) to develop indicators and suggest monitoring strategies regarding MP and associated pollutants. One potential application to reach good ecological status will be evaluated within the project, namely a wastewater treatment technology, which retains efficiently microplastics and xenobiotics.
Submariners: IVL (SE), NMFRI (PL), KU (LT)
Baltic Partners: IOW (lead), IPF (DE), SU (SE), TUT (EE)

Study: Incentives for collection and further treatment of old, derelict fishing gear

The study provides an overview of deposit and return systems as well as simple return options of disused nets and other fishing gear. The aim was to provide incentives to fishermen for the collection and return of these nets. The approach shall support the implementation of the Marine Strategy Framework Directive (2008/56/EG) in relation to the descriptor 10 on marine litter.
Submariners: s.Pro for 'Lower Saxonian Agency for Water Management and Nature Protection'/2018
Weblink: http://2018.sustainable-projects.eu/images/publications/Reports_PDF/Recherche_Altvater_final.pdf

AquaLit Project (EMFF / Submariner Member: s.Pro / 2018-2020)

The project, AquaLIT, aimed to increase the understanding, awareness and availability of solutions regarding marine littering from aquaculture activities. AquaLIT's main deliverables are EU wide maps on litter from aquaculture and a toolbox of innovative ideas and methodologies to be taken up by the industry.
Weblink: https://aqua-lit.eu/resources/deliverables

GoJelly (H2020)

GoJelly tests the use of jelly fish for removing marine litter particles from the sea. It addresses two environmental issues: commercially and ecologically destructive sea and coastal pollution of both jellyfish and microplastics. GoJelly will develop, test and promote a gelatinous solution to microplastic pollution by developing a TRL 5-6 prototype microplastics filter made of jellyfish mucus.
Submariners: SDU (lead), GEOMAR, CAU Kiel, CRM) (2019-2021)
Weblink: https://gojelly.eu/

Study for the Federal Environmental Agency (s.Pro/2019)

The study assessed the legal feasibility of implementing the concept of 'Extended Producer Responsibility' for 10 key single use plastic items. Another work package evaluates technical measures that are suitable for specific products from an environmental point of view.

Support to the German National Round Table on Marine Litter (sPro/2020-2022)

To support the implementation of the Programme of Measures under the MSFD with respect to descriptor 10, a National Round Table was installed in 2016, lead by the Ministry for the Environment. The support project will manage the round table and coordinate necessary inputs.
Weblink: https://www.muell-im-meer.de/ueberuns-rundertisch#show-block-meerimmuell-main-menu

9.5 State of play

The **impact of the projects described above should not be under-estimated**. They have started to support the assessment of political willingness, institutional frameworks and capacity in the BSR.

- Especially the studies are **fostering the on-going adaptation of national law to EU framework legislation** and strategies and will be followed by many other topic-related analytical work.
- Projects like Blastic and AquaLit inform about monitoring gaps and **promote new monitoring and assessment approaches** related to descriptor 10 on marine litter and the achievement of GES under the MSFD until 2020.
- **Awareness-raising and capacity building** of regional and municipal societies has been supported by Plastic Free Oceans or Marelitt and is actively pushed by the World Clean-up-Day[78], which motivates a good number of BSR communities to participate in clean-ups and to take steps to reduce littering .
- Cooperation projects and a range of studies have started to assess **resource-efficiency and sustainable production**, establishing new networks between research and economy, blue economy sectors and NGOs and fostering stronger science-policy interface. In the cooperation projects, companies are part of the project development and realisation from the very beginning as they are actual group, which need to apply innovations. Innovative projects like GoJelly show the **opportunity and range of new applications for start-ups and well-established companies**, in close cooperation with research.
- Also **new regional or local initiatives** have been founded and are good models for other regional cooperation between fishermen and recyclers, which can be exemplified by the Marelitt Baltic project.

With the **new Single-Use Plastic Directive**[79] it can be expected that informed consumer choice and the change of consumer behaviours is gaining more attention in projects and will open discussions about new approaches like nudging. Moreover, **new concepts like „Cradle-to-Cradle"** (in Germany, for instance, there is a very active association which organises regularly discussion rounds with a broad range of stakeholders)[80] and the establishment of so-called **"Un-Packed" shops** are offering opportunities for innovative companies and start-ups. Other initiatives will follow, according to the new pieces of EU legislation as outlined above and will keep the spirit high to combat marine litter and to establish new economical approaches.

9.6 Conclusions and Recommendations

SUBMARINER needs to take action to become an important driver of these activities in the BSR. The SUBMARINER Network should support national and Baltic Sea wide processes by participating in research. In addition, it should actively promote and develop research ideas and participate in developing clusters of circular economy initiatives to find solutions related to land- and sea-based marine litter, including microplastic waste. In the near future, new calls are expected not only in the more narrow 'marine litter' sense but especially for promoting 'circular economy approaches' also as part of the European Green Deal initiative. Moreover, SUMARINER members should support the BSR Member States to meet their obligation under the Marine Strategy Framework Directive (MSFD) to develop national Programmes of Measures (PoMs) and to regularly monitor and report back to the EU.

9.6.1 Land-based Topics

Find ways to reduce the input of plastic waste into the marine environment, e.g.

- Analyse the use of plastic in different sectors like the building sector
- Identify direct inputs through hydro power plants and other plants
- Analyse the effectiveness of deposit schemes to reduce marine litter
- Screen legal impediments to use plastic economically
- Analyse approaches to reduce plastic waste through a better event management
- Assess how to address marine litter according the revised Waste Framework Directive in new waste management plans

Support measures to prevent and reduce microplastic, e.g.

- Organise dialogues with relevant industries / companies how to reduce use of micro beads

[78] https://www.worldcleanupday.org
[79] 2019/904/EU
[80] https://c2c.ngo/ueber-c2c-ev/wir-stellen-uns-vor/

- Support existing round table initiatives or the HELCOM RAP expert group on Marine Litter
- Provide targeted input to existing monitoring activities and establish or extend strong relations to monitoring networks like Technical Groups for Marine Litter (TGML)

Foster efforts to substitute and modify plastic products, e.g. by

- Assess the amount / mass of products and product components as well as cleaning and treatment costs at beaches in the BSR
- Estimate the cleaning and disposal costs as well as recycling potentials of suitable categories (IDs)

Reduce the amount of plastic waste through municipal targets, e.g.

- Organise workshops for a plastic-free coast in different coastal communities and their hinterland
- Legal Analysis of regulatory mandatory options like adaptation of statutes etc.)
- Guidelines for municipalities to reduce their plastic waste amount
- Step upon the Interreg Europe project CapOnLitter[81]

Promote citizen awareness

- Anchor the topic of marine litter and microplastic waste in school teaching objectives, curricula and materials.
- Consider specific professions like fishermen and provide targeted materials for these stakeholder groups.

Support the reduction of consumption by using the EPR measures under the SUPD, e.g.

- Find approaches for a litter fund: introduce and set up a fund to foster re-usable products (maybe starting with, but in the long run extending beyond, plastics) and waste prevention.
- Create both, enabling structures (e.g. institutions, new practices) and incentives to foster and prioritise the use of reusable products over single-use products (e.g. beverages in reusable cups)

9.6.2 Sea-based Measures

Foster knowledge about the sources of marine litter and microplastics

- Compile an overview of newly developed strategies and technologies for monitoring marine litter such as the use of drones, the use of satellite data and artificial intelligence, and the use of robots and underwater drones, to forecast the future of marine litter monitoring in the region.
- Collaborate with companies, which are working on such new technologies (drones etc.) like DEME or SINTEF

Support removal of already existing marine litter in the marine ecosystems of the BSR,

- Develop a road map for an environmental-friendly recovery of nets
- Demonstration projects for the removal of marine litter in estuaries and rivers in close collaboration with companies like DEME
- Develop a guiding paper about data comparability of collected waste in coastal communities and how to finance waste treatment, including up-cycling
- Support campaigns for divers to recover ghost nets and foster networks between diving associations and administration

Foster waste-related measures for fishing nets and gear (including aquaculture), e.g.

- Research and demonstration projects on alternative materials, modification and standardisation of gear, technical support to find nets by sonar systems or digital marking
- Detailed analysis of waste treatment structures and options for recycling of fishing gear (also cross-border), including pilot cases with waste treatment plants
- Pilot monitoring of fishing gear

[81] Capitalizing good coastal practices and improving policies to prevent marine litter; https://www.interregeurope.eu/caponlitter/

Support the structural establishment of the Fishing-for-Litter concept,

- Support a BSR-wide, comprehensive system to collect and treat marine litter
- Further develop the idea of an 'insurance fund' for fishermen to encourage fishermen to bring back ALDFG. Develop practical concepts, including financial and institutional aspects, and analyse a possible implementation mechanism in national waste legislations (related to the implementation of the SUP-Directive).

Analyse existing waste management on ships and in ports, foster their improvement through demonstration projects and foster reduction of pollution through ghost gears etc

- Support the development of new mechanisms to enable ship owners, fishermen and aquaculture farmers to report back their lost or abandoned waste to appropriate authorities; establishing a clear concession system to support this approach
- Develop new management practices and co-developing standards for farmers to keep an inventory of all aquaculture equipment to easily track what gear might be lost.
- Integrate other industries with similar waste materials (non-biological, construction, equipment, etc.) as aquaculture, fisheries, and agriculture into the related waste disposal and recycling logistics in order to achieve cost reductions.

Support the establishment of standardization of fishing gear

- Develop/Support harmonized standards for the circular design of fishing gear to encourage preparing for re-use and facilitate recyclability at end of life.

9.7 Activities suggested for the SUBMARINER Network

9.7.1 Mapping of marine litter / plastic waste actors

Interested SUBMARINER Network members should analyse the following aspects in their countries:

- Which initiatives are on their way? Which companies or even clusters are involved in these processes?
- Which funding opportunities are available in your country? Are these programmes open for other BSR member states?
- Do you know companies, which actively promote and research on the valorisation of plastic waste? Are you aware of bilateral/multilateral cooperation related to recycling of marine litter?

9.7.2 Establish Single Use Plastic Directive / Marine Litter Round Tables

- Follow the German example of the Lower Saxonian Government Commission (DE) and establish national round tables in different SUBMARINER countries to facilitate and foster the implementation of the SUPD into national law (using e.g. packaging or circular economy law as starting point and develop it further) as well as discussing other measures against marine litter
- Expand through such round tables the SUBMARINER network by actively approaching and using input from different stakeholders like municipal and national governances, waste experts, waste economy, specialised associations for waste recycling or small-scale economy associations and NGOs;
- Possibly, the round tables can be financially supported by the responsible ministries/agencies for circular economy and (marine) litter

9.7.3 Aquaculture / fishing gear

- Monitor/state of play of aquaculture gear in the Baltic Sea Region (the AquaLit state of play report showed severe data gaps)
- Upscale and transfer approaches for recycling of fishing and aquaculture gear throughout the entire Baltic Sea Region, based on projects like Marelitt and OSPAR round tables (at the European Conference on Plastics)
- Review the scoping paper on Marine Litter Management Practices for the Aquaculture Industry in the Baltic Sea Region
- Taking up RAPML actions, e.g. action 58 which refers to education activities for fishermen and suggest a new 'sister' project to the HELCOM region based on the OSPAR „Design and Recycling of Fishing Gear" project.

10 Maritime Cultural Heritage

10.1 Ambition

The Baltic Sea Region underwater and maritime cultural heritage forms a rich and diverse tangible and intangible assemblage on national and international level and an underwater landscape when seen as one Pan-Baltic entity. Its cultural heritage forms a finite, non-renewable and irreplaceable assemblage that has cultural and societal values. The sea floors are not only home to ship wrecks, they also harbour remnants of human settlement from prehistoric times when these seas were still dry land. Therefore, Underwater Cultural Heritage (UCH) can be linked by its nature to the sea.
But also coastal zones with their historical lighthouses, settlements etc. should be considered. Hence we use the term Maritime Cultural Heritage (MCH).

This **cultural heritage is not enjoying sufficient protection**. Gravel and sand harvesting, wind turbine construction, cable laying and fishing activities could lead to these archaeological traces being lost forever. Also looting and un-experienced diving affect these sites.

One of the main challenges for those working with MCH is the **lack of data and insufficient knowledge how to assess the different pressures on MCH**. There is a lack of mandate, e.g. for planners to include MCH into their maritime spatial plans and a lack of criteria for the identification of MCH sites. Information about MCH is not disseminated well between different sectors and MCH is therefore often neglected when planning new projects in the sea. Cultural heritage is yet not automatically included in risk and impact assessments and archaeologists often have limited time to assess the value of discovered sites during, e.g. cable-laying activities.

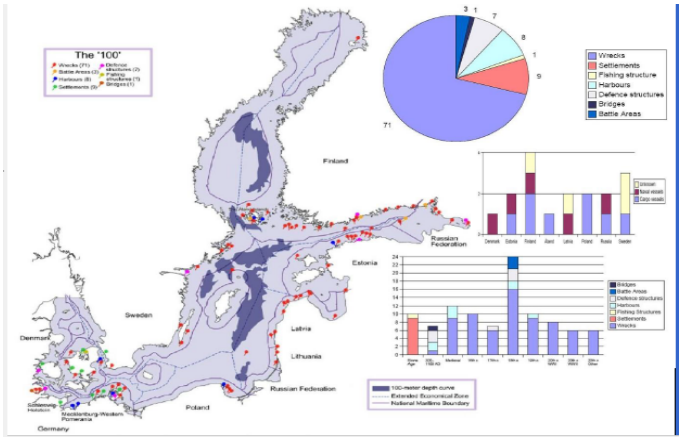
Awareness-raising among different sectors and the public is necessary to effectively protect MCH and on the other side, promote their sustainable use where feasible. One important way to show the wealth of the heritage is to bring it visually or in real to museums for those who cannot dive.

10.2 Projects

Since 2000, the Working Group on Coastal Heritage has prepared several poster exhibitions and films, which have documented the common coastal and maritime heritage of the Baltic Sea.[82] Meanwhile, the BSR Underwater Heritage Working Group of the CBSS has been engaged with various projects dealing with management and research of underwater cultural heritage in the Baltic Sea or collaboration on the European level. These projects have followed one another; such as MoSS[83], Rutilus[84], the MACHU project[85], Nordic Blue Parks[86] and SASMAP project[87].

[82] Films: *The Baltic – A sea of connections, compilation of m/s Gamle Oksoy's Voyage around the Baltic Region* (2016); *From faring to tankers* (Norway 2016); *Architecture of equality* (Norway 2016); *Lighthouses of Rozewie* (Poland 2016); *Jurmala invites* (Latvia 2016); *The Soviet border guards at Saaremaa* (Estonia 2016); *Finland – Land of treacherous rocks and historic beacons* (Finland 2016); *Steamers of Stockholm today* (Sweden 2016).
Poster exhibitions: *Herring a shared heritage* (2013); *Historic Ships* (2007); *A Future for Our Past* (2007); *The Baltic Harbours Gateways to the Future* (2005); *Baltic Lighthouses* (2003).
Leaflet: *Baltic Ships Contemporary Challenge* (2010).
[83] Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites (MoSS) financed by the EU Culture 2000 Programme 2002-2004.
[84] Strategies for a Sustainable Development of the Underwater Cultural Heritage in the Baltic Sea Region (RUTILUS), financed by the Nordic Council of Ministers 2004-2006.Lead Partner and report by the Swedish National Maritime Museum.
[85] Managing Cultural Heritage Underwater (MACHU), financed by the EU Culture 2000 Programme 2006-2009. https://www.machuproject.eu/
[86] http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/divers/nordic-blue-parks/
[87] SASMAP Collaborative Research Project financed by the EU Seventh Framework Programme 2012-2015. http://sasmap.eu/

- The **Moss** project (2001-2004) targeted monitoring, safeguarding and visualizing North-European shipwreck sites.
- The **Rutilus** project exchanged data about protection by law in territorial waters and EEZ; underwater archaeological education; tourism strategies; diving and conservation equipment. The project report, *Strategies for a Sustainable Development of the Underwater Cultural Heritage in the Baltic Sea Region*, included as an appendix the joint 100-list of most important wrecks of the Baltic Sea. It was an early effort to get a comprehensive overview of underwater heritage assets in the Baltic Sea[88].



- The **Machu** project (*Managing Cultural Heritage Underwater*) gathered information about underwater cultural heritage accessible to researchers, policymakers and the public through the construction of a web-based GIS application and an interactive website designed to increase access to underwater cultural heritage for the public.
- The **Nordic Blue Parks** 2009 project formulated criteria and guidelines for sustainable blue trails and set up trails to test the concept using the existing underwater nature and cultural trails.
- The **SASMAP** project included collaborative research to develop new technologies and best practices in order to locate, assess and manage Europe's underwater cultural heritage.

These projects brought forward a regional awareness of the underwater cultural heritage. The generated insight and valorisation of the significance of the underwater heritage has been gradually infiltrated through governmental management levels and planning processes bringing forth MCH as an important issue to be considered when developing plans for other sectors, maritime uses, technology and recreation.

BalticRIM (INTERREG BSR, 2017-2020)

initiated with the help of the SUBMARINER Network, was the logical continuation of these processes, contributing to the preservation of maritime heritage of the Baltic Sea and linking it to the development of the first round of maritime spatial plans as a result of the EU MSP Directive. The aim of the BalticRIM project was to raise awareness and develop appropriate information and tools, which would enable planners to consider MCH within their plans. Also the project sought to showcase possible co-uses, e.g. of tourism at cultural heritage sites.

SUBMARINERs: MIG (PL), CORPI (LT), Klaipeda University (LT) Uni Tartu (EE), SUBMARINER Secretariat

10.3 State of play

10.3.1 Protection of MCH

The most important conventions related to the protection of MCH in the Baltic Sea region are: The **UNESCO Convention on the Protection of the Underwater Cultural Heritage** (2001) sets general principles for the UCH governance: the complete prohibition of the commercial exploitation of underwater cultural heritage and in situ preservation as the first option of protection. The rules also cover aspects such as project design, conservation, documentation, and reporting. Both the **Council of Europe's Landscape Convention** (Florence Conventions, 2000) and the **Convention on the Value of Cultural Heritage for Society** (Faro Convention, 2005), display current objectives of heritage management, encouraging participatory involvement and public access to heritage and stress the role of public heritage bodies as public servants to facilitate these processes.

So far, this international law is only partially implemented within the Baltic Sea Region:

[88] Rutilus report 2006, page 77.

- **Missing designation of an authority** responsible for MCH in the EEZs in some BSR countries
- Inconsistent implementation of the Convention for the Protection of the Archaeological Heritage of Europe (Valletta, 1992), in particularly regarding the underwater heritage
- With exception of Lithuania **no Baltic Sea region country has ratified the UNESCO Convention** on the Protection of the Underwater Cultural Heritage
- About **40% of the Baltic Sea is not protected** by any national heritage legislation.

10.3.2 Regional cooperation

During the third Conference of Baltic Sea States Ministers for Culture in 1997, the importance of strengthening the common identity in the BSR was stressed. Special attention was to be given to cultural heritage cooperation that could balance the development gaps of heritage management and generate common heritage approaches. The Ministers addressed respective national heritage agencies to identify, launch and coordinate regional activities and projects on cultural heritage. As a result the Baltic Region Heritage Committee (BRHC) was nominated. The Committee selected the underwater heritage and coastal culture as central thematic maritime Baltic Sea topics for closer expert cooperation. The Working Groups on Underwater Cultural Heritage and on Coastal Heritage were established in 2000. **Regular professional networking and cooperation between heritage experts have continued ever since in form of sharing data, management and heritage policies and best practises as well as creating common projects**.

The main outcome of the BRHC regional cooperation are the Heritage Forum events and BRHC reporting prepared for the CBSS Ministers of Culture conferences.

Furthermore, the **BSR Working Group on Coastal and Underwater Heritage** is fostering cooperation among BS states, administration and other stakeholders and can be a good partner for the SUBMARINER Network. The group suggests, promotes and initiates projects and actions for co-operation in the BSR region and stresses the importance of the long-term heritage protection and of strategic co-operation between authorities and others in order to facilitate a sustainable use of the coastal heritage assets. The first effort was to organize the **first BSR Heritage Forum in Gdansk** under the title “Baltic Sea Identity”. The Working Group has also produced documentary films, travelling exhibitions, poster exhibitions, books, booklets and seminars.
The Copenhagen Declaration of the fifth Conference of the CBSS Ministers of Culture in 2001 expressed their intention to strengthen cooperation on the study of the underwater cultural heritage and to support specific projects. They asked the BRHC to examine the perspectives of co-operation on the protection based on the provisions of the UN convention on the Law of the Sea (1982). In 2016, the Annex to the Warsaw Declaration, endorsed at the meeting of the Deputy Foreign Ministers of the CBSS, promoted the joint activities on underwater and coastal heritage.

10.3.3 Responsible Bodies

Each BSR country has its own national, federal and/or municipal responsible authorities to protect and manage MCH. These MCH administrations cover both, MCH and CH on land. Seldom, governance structures foresee the exchange with other ministries/agencies to assure the protection or use for blue economy in a coordinated and transparent way. Pojects like BalticRIM are important to highlight missing links and support a better cooperation.

Several actors, networks and projects have built and brought forward a regional awareness of the Baltic Sea underwater cultural heritage. Due to the long and continuous history of seafaring and excellent preservation conditions, including (nearly total) absence of the wood-eating organisms, UCH of the Baltic Sea has unique coverage. The generated insight and valorisation of the significance of the MCH has been gradually infiltrated through governmental management levels and planning processes bringing forth the BSR MCH as a part of factors to be considered in development plans for other sectors, maritime uses, technology and recreation.

10.4 Activities suggested for the SUBMARINER Network

Enhance knowledge about MCH and collaborate with relevant stakeholders/bodies

Research and education in the relatively young field of underwater archaeology should be expanded, and research conducted in states bordering the Baltic Sea should be coordinated. It is recommended to establishing a close collaboration between marine, geological and archaeological research.

Some specific approaches:

- Establish Southern and Northern Baltic cultural trails
- Find new alliances with other sea basins like the Mediterranean Sea to develop new projects
- Showcase MCH Blue Economy examples and bring together operators from different sectors, using results of projects like BALTACAR, BalticRIM etc.
- Promote scientific concepts like the cultural heritage landscape approach as well as the evaluation of the intrinsic and economic benefit of such landscapes (often with a land-sea interaction component) in pilot cases and active dissemination. It has to be assessed how these concepts and results could be regionalised in different BSR areas.
- Enlarge existing networks to foster ocean literacy related to MCH and multi-use; cross-topic research and cooperation between teachers, natural science groups at universities and social science should be promoted; all SUBMARINER Network partners should assess the practical options and funding for those projects in their countries

Foster blue growth and support initiatives to bring MCH closer to those who cannot dive

- Promote the multi-use concept at sea and raise awareness that multi-use can be applied for heritage sites combining tourism, protection and the sustainable use of nature and heritage sites like outlined in the MUSES Project89; step upon the pilot cases conducted during the BalticRIM project and use these networks and promotion activities for further concepts / projects.
- Collect knowledge about the cultural heritage found at the bottom of the Baltic Sea and cooperate with state museums, maritime and naval museums, as well as city museums and geo-parks as they play an important role at disseminating this information
- Strengthen BSR-wide cooperation VASAB-HELCOM MSP WG, BSR Heritage Committee and Blue Economy experts for joint approaches and use past VASAB-HELCOM sessions and BalticRIM webinars to keep cooperation between stakeholders high

Further Integration of MCH into MSP

Launch and ensure early and continuous formal and informal discussions, capacity building and cooperation with planners, MCH authorities and other stakeholders. Use the on-going Capacity4MSP project to continue cooperation and develop new project ideas, such as:

- Establish regular communication between national MCH and MSP authorities, VASAB-HELCOM MSP WG and the BSR Heritage Committee and BSR Working Groups on underwater cultural heritage and on coastal cultural heritage. Use SUBMARINER Network meetings for back-to-back workshops on specific issues.
- Share good practices and the outcomes of different MCH & MSP and other related projects nationally, internationally and cross-border and cross-sectors.
- Due to the small size and scale of MCH, MSP should produce creative and flexible protection measures, especially if the MSP is legally binding and there is no adequate legal protection for UCH. The SUBMARINER Network could actively develop such solutions.
- Identify planning options, which increase MSP cross-sector/ cross-border and land-sea aspects covering MCH in the decent way
- Develop a toolbox for planners: Support MSP authorities with solutions on how to integrate MCH and provide precise planning options to increase cross-sectoral and trans-boundary MSP approaches.

[89] https://muses-project.com/

Strategic Actions Fields: Achievements and Recommended Future Steps

11 Actors Mapping / Match-Making

One of the most important activities identified for the SUBMARINER Network secretariat as set out in the SUBMARINER Roadmap 2013 was the continuous identification and matching of public and private actors involved in new marine uses as to achieve better and faster results with less resources.

To that end, the following activities were foreseen to be undertaken:

Collect information, establish and maintain a BSR-wide database on:	Status	Projects
• Research institutions, researchers and experts;	YES	ALL
• Companies;	YES	Blue Platform
• Intermediaries and transfer organizations;	Partially	Alliance
• Past and ongoing activities and projects;	YES	Blue Platform
• New research and project ideas;	Partially	ALL
• (Bio-)technical equipment;	Partially	Alliance
• Available education in various levels;	Partially	Alliance
Support actions for		
• information and contact exchange among new marine use stakeholders;	YES	ALL
• ongoing communication across EUSBSR stakeholders and related BSR projects;	Partially	Blue Platform
• facilitate contact & information exchange, networking & coordination with other networks;	YES	ALL
• organisation of sectoral and cross-sectoral match-making events;	YES	SmartBlueRegions Alliance
• facilitate good practice transfer from traditional maritime sectors as well as terrestrial bio-economy stakeholders to SUBMARINER cases	NO	
• Identify potential linkages between natural and socioeconomic research and introduce research results of both disciplines to each other;	YES	BBG, GRASS
Include marine sectors into BSR region wide research and technology development projects, which integrate knowledge for whole the catchment area of Baltic Sea, e.g. energy sector, waste treatment, CO2 capture and storage, socio-economic aspects.	Partially	

Over the course of the past seven years, the SUBMARINER Network for Blue Growth fulfilled this mission: Not only does the network encompass by now 40+ members; we have involved more than 260 different organisations within our projects as direct or associate partners.

As by now we have by now identified and mapped almost 3000 individual actors throughout the Baltic Sea region working in more than 1.700 different institutions.

	SE	DE	LAT	PL	DK	LIT	FI	EE	RU	*Total*
Number of Institutions	233	265	112	357	285	44	226	79	103	**1704**
Number of Actors	497	551	211	526	381	72	462	155	119	**2974**

Out of these 1700 institutions, we have by now already identified more than 650 companies working within the blue bioeconomy throughout the Baltic Sea Region.

ORGANIZATION TYPE	SE	DE	LAT	PL	DK	LIT	FI	EE	RU	TOTAL
ASSOCIATION/NETWORK	48	23	22	56	33	2	22	18	*4*	***228***
BUSINESS SUPPORT	12	20	2	35	10	3	18	5	*0*	***105***
COMPANY/ENTERPRISE	63	108	11	105	166	5	126	23	*70*	***677***
PUBLIC AUTHORITY	56	25	31	87	32	14	23	16	*11*	***295***
RESEARCH	46	81	26	66	28	17	27	10	*15*	***316***
TOTAL	225	265	112	357	285	44	222	76	*101*	***1687***

By far the largest number of companies identified come from the traditional fish aquaculture sector (mainly in DK); however also a remarkable number of companies have already been identified, which work with algae and/or blue biotechnology.

Company/enterprise	SE	DE	LAT	PL	DK	LIT	FI	EE	RU	Total
Algae	8	32	2	37	29	2	3	6	0	**119**
Blue biotechnology	9	53	3	20	31	4	8	10	0	**138**
Energy	2	7	1	19	8	0	59	3	1	**100**
Environment	2	18	0	1	1	0	2	1	0	**25**
Fish aquaculture	24	52	1	30	110	0	33	0	23	**273**
Mussels	16	9	0	3	8	-	-	1	0	**37**
Other	14	23	3	31	10	1	5	0	0	**87**
Reed/beach-wrack	0	7	1	2	4	-	-	3	0	**17**
	75	**212**	**14**	**150**	**207**	**7**	**130**	**29**	51	**875**

Even though a number of some 700 companies working in this sector throughout the entire Baltic Sea Region is still low; it still shows an enormous relative growth as compared to the figure a decade ago, where it was difficult to identify any company involved in this sector.

At the same time the figure points to the fact, that it is worthwhile for the SUBMARINER network to act as the overarching association of these companies directly rather than being the upper cluster of possible national blue bioeconomy clusters; which – with a few exceptions[90] – are not existing in the other Baltic Sea Region countries due the lack of a critical mass.

The need for SUBMARINER to pro-actively target companies as new members to the network has also been confirmed by the survey undertaken within the Blue Platform project. Almost all (95%) of the 65 interviewed actors expressed the need to involve companies more strongly, in order to ensure the long term survival of the network.

11.1 The SUBMARINER Accelerator

The SUBMARINER Roadmap (2013) as well as the 'EU Sustainable Blue Growth Agenda for the Baltic Sea region' stressed the good potential of blue biotechnology for the region; but showed at the same time that the sector was immature. Actors, expertise, and resources within R&D were scattered across the region, working in isolation, with hardly any tangible products on the market. On top, in the highly specialised and research-driven blue biotechnology sector, individual Baltic Sea Region countries cannot have all the capacities and resources required to form the complete value chains needed to realise full-scale commercial product development (Figure I).

The BSR needed a specific networking platform with a systematic transnational science-business cooperative approach to create the critical mass of actors to converge and convert **science outputs into marketable products**.

As a response to this need, the *Alliance* project started in 2016 under the auspices of the SUBMARINER network. Led by GEOMAR Helmholtz Centre for Ocean Research Kiel, the consortium originally consisted of 26 project partners. These included some of the major research institutes of the region; business and technology parks; an initial group of SMEs as well as the SUBMARINER Network secretariat as the main communication and coordination hub.

Over the course of the past years, these partners have developed an **accelerator programme** that carries out the continuous search for "cases"[91]; pitching and matchmaking events as well as a **mentoring programme with a flexible service offer**. As shown by some of the results achieved, the *Alliance* has by now successfully established and piloted a new niche **innovation and product development support mechanism** operating across borders in the BSR.

[90] BAMS – Blue Bioeconomy Cluster for Northern Germany / National Mussel Association – Sweden / BlaMat Project – Sweden /Danish Aquaculture Assosciation

[91] Service receivers, i.e. companies, spinoff projects of universities, municipalities etc. with a new business idea

- Three cases were able to **commercialise newly developed products** (Baltic Probiotics, Furcella, and Nordic Seafarm) and two cases had ready prototypes (CRM and Biome).
- Three more cases won prestigious innovation awards; enrolled in international accelerators and succeeded in **securing further investments** (Vetik, SFTec, and Hoekmine).
- More than half of the *Alliance* cases have **concluded partnership agreements** with suitable partners across their value chain, within as well as outside of the *Alliance* network.
- All partners reached the next technology readiness level

Until today, the SUBMARINER Alliance has successfully identified and provided advise to more than 34 start-ups originating from all around the Baltic Sea Region. Cases joined at all stages of the value chain, from bioprospecting to full commercialisation, with the majority (66%) using algae as the biological resource for developing their products. Products target a broad spectrum of market applications, from food and food supplements to healthcare and cosmetics, bioremediation, materials, and energy.

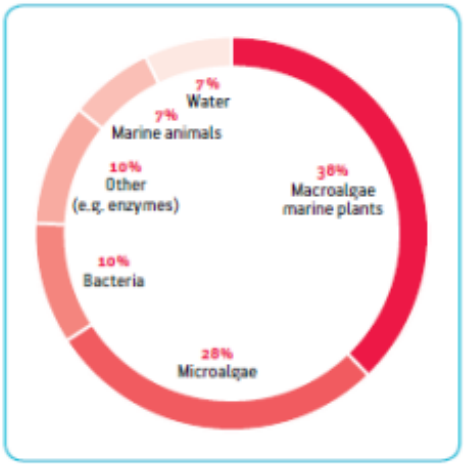


Figure IV Used biological resources for product development.

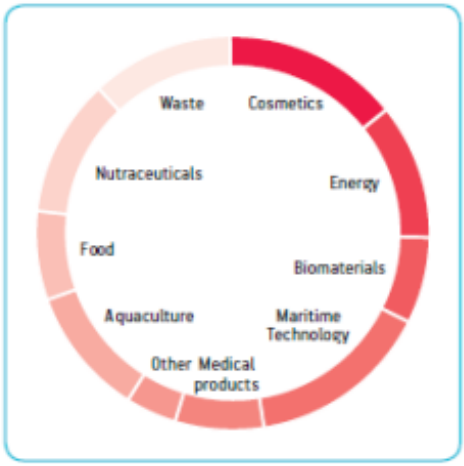


Figure V Target markets of offered products.

11.2 Findings from three years of Alliance mentoring practice

A blue economy – rather than a blue biotechnology - network

Matchmaking within the Alliance led to partnerships across all elements of the value chain, from biomass sourcing to necessary equipment to market access. Against this background, the Alliance is part of the entire SUBMARINER Network, offering transnational networking across all bioeconomy sectors and actors. Even though scientific/ technical support often requires specialised blue biotechnology knowledge, the matching of partners covers a much greater span.

Without 'blue detectives' – no new cases:

- In contrast to the world of electronic start-ups, the community of potential new blue business cases with people behind them who want to act as entrepreneurs rather than researchers, is very small. **Therefore ALL SUBMARINERs are called for to pro-actively search for good potential cases.**
- The experience of the various recruitment activities showed that even in times of border-crossing interdisciplinary social networks, **individual personal contacts are indispensable to lower barriers and create mutual confidence**.

Finding the right mix of mentors is crucial:

- **Mentoring only works when the mentor is genuinely interested in the cause of a case,** leading to a win-win situation for both parties. Mentoring is a 'voluntary' exercise and therefore has to be in the interest of the mentor and be based on his/her experience; rather than asking for extra work.
- Often **cases can best help each other**. Rather than seeing each other as competitors, cases gain from collaboration with fellow entrepreneurs throughout the region in order to jointly create the market conditions necessary for their individual success.
- The **initial assessment is a crucial service** to cases, often inducing a refocus of their initial business idea and strategy – and thus saving them a lot of expensive 'learning' time.

- **One mentor alone will often not be able to meet the demands of a case**; a genuine network of cross-disciplinary expertise is required as to guide a case through the entire product development value chain.

Networking and matchmaking among blue specialists are in high demand by all:

- The so-called 'mentors' forum' – the monthly telephone conference of all mentors – is crucial for presenting and discussing the various cases among the mentors and finding the right match for a specific problem/issue of the given case (Figure VI).
- Whereas virtual communication forms are by now – in view of the COVID-19 pandemic – the new reality; entailing also advantages in view of resource efficiency; **physical meetings and get togethers** will hopefully soon be possible again as they are essential for valid assessments and creation of true partnerships.

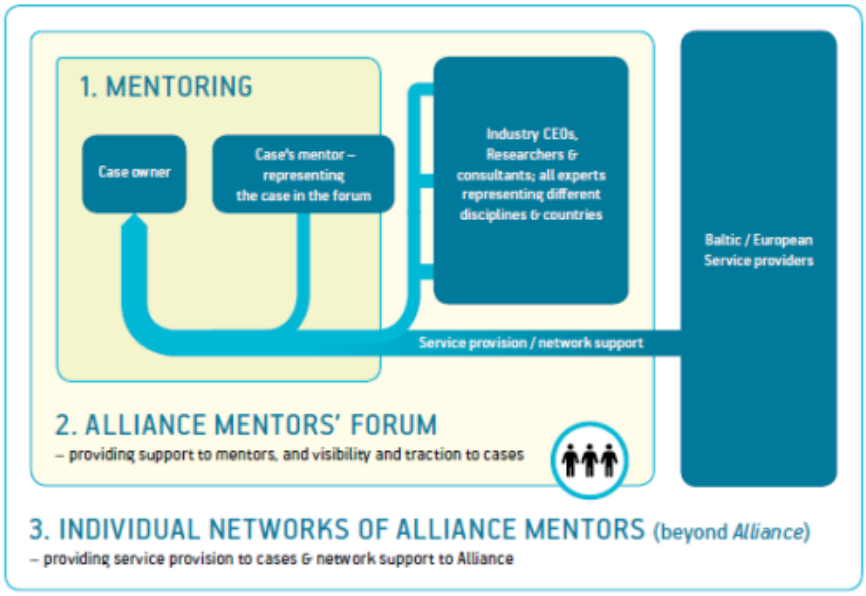


Figure VI Scheme presenting the mentors' forum of the *Alliance*, and relationship with a case.

Scientific/ technical support forms the heart of the transnational *Alliance* service:

- As a unique feature of the science-business partnerships created through the original Alliance project, the **scientific/ technical support was 100% tailored to the needs of a case**.
- As foreseen in the needs analysis for the initial *Alliance* project, provider(s) of the scientific or technical expertise were often **experts and infrastructures from another country**.
- Whereas within the *Alliance* project duration it was possible for scientific institutions to offer such services as 'part of the project', it remains to be seen how details on service delivery or access to infrastructure and biomaterial can be negotiated between cases and the given mentor or service provider on transnational basis outside a specific project framework. Such contract negotiations often prove to take up a lot of time as they are outside the realm of responsibility of the people directly involved.

Need of large scale biomass rather than biobanks

- The need of creating and maintaining a database on the **biological resources** available at *Alliance* partner institutions should no longer be part of the SUBMARINER network work. On one hand such services was in much less demand than originally assumed; on other hand other much larger EU wide initiatives (such as EMBRIC BIoBANK / MIRRI) are much better placed to maintain such specialised overviews.
- Start-ups/companies using larger marine organisms (e.g. macroalgae or mussels) are not in need of such biobank samples, but **access to large scale biomass** in view of commercial production. Creating contacts between relevant biomass producers and those in need of this biomass should be part of the SUBMARINER Network match-making services.

Business knowledge is also vital in early stages of the product development chain:

- There are not many experts who unite blue biotechnology expertise and business know-how in one person (and are ready and willing to act as a case mentor).
- To remedy this skills gap, the *Alliance* developed a quick business assessment guide and trained its scientific mentors on how to apply it in their work with cases. Thus, the *Alliance* also raised capacities within universities or research institutes by **sensitising their staff for potentially good spin-off ideas**.
- The follow-up Alliance+ project has shown, that voluntary mentors are not willing to take on board such task, in case they need to learn something outside their normal work, in order to fulfil this role. The

SUBMARINER accelerator will therefore need to expand its collaboration with **business service providers and entrepreneurs** as to address the demand for business development expertise by cases.

- Furthermore, the *Alliance* will continue to **create, sustain and intensify collaborations with other existing accelerators**, such as the BlueBioValue accelerator of the Portuguese BlueBio *Alliance* or the various programmes under the EU Blue Investment Platform. It is important, however, that these institutions and programmes not only recognise but also contribute towards the important work undertaken by the *Alliance* in searching for and preparing cases to become 'investment ready'.

Supporting the *Alliance* cases means supporting the UN SDGs

- The Alliance has shown that the support services developed really do accelerate blue economy business development throughout the region. They have also proven to be of high value to the research itself providing a continuous feedback on what is required by the market and society.
- The Alliance has developed a set of criteria, which ensures that the new blue economy ideas promoted should not only be innovative, but also meet all sustainability criteria.
- As shown in Figure 12, all cases truly contribute to advancements in reaching the UN Sustainable Development Goals within the region.

Figure 12 The number of cases contributing to the different UN Sustainable Development Goals (SDGs).

- Financing the Alliance is therefore an investment of the Baltic Sea Region countries into their future.

11.3 Recommendations

A critical mass of actors and activities is necessary for the sustainable development and support of blue bioeconomy in the BSR. To tackle innovation challenges, intensive **clustering** is needed. Even though national blue bioeconomy clusters are slowly evolving also at sub-regional or national level, there is also the concrete need for tight and unimpeded transnational collaboration between these actors and activities. Transnational network hubs play a key role in connecting partners and creating complete value chains, transferring the technologies, cross-fertilisation of ideas, creating innovation banks, and fostering cross-cutting innovation. The network's functionality is a result of good tools but also the hard work and expertise of the blue detectives and mentors to reach out, expand, and invite their peers into the SUBMARINER network.

Enlarge and broaden the SUBMARINER network

Even though we have worked with many actors within the blue bioeconomy over the past years, we still need to broaden the scope of the *SUBMARINER network* and intensify collaboration with:

Companies – as a primary target group

- As potential end-users and/ or clients for the start-ups and SMEs, companies – and especially also bigger companies - are the most important target group to be taken on board in the coming years of the SUBMARINER Network
- Only by working more with and for companies, the SUBMARINER Network can evolve into the true blue bioeconomy cluster within the Baltic Sea Region.
- Companies are also increasingly targeted by EU funded projects (esp. Horizon / BBI-JU) as the important game-changers to realise the transformation from a fossil based economy.

- Companies are the ultimate proof of concept that there IS an increasing economy in the blue. A good collaboration with them, will help the SU(BMARINER Network and also its non-company members to proof to policy makers and sponsors that our joint work 'makes a difference'.

R &D Institutions (and their technology transfer / innovation offices)

- The actors mapping has shown that SUBMARINER is still missing on some of the other R&D institutions active within the blue bioeconomy throughout the Baltic Sea Region.
- Next to continue to strengthen our collaboration with relevant researchers; we also have intensify our collaboration with the 'spin-off' and 'start-up' assistance offices, often being part of the universities, as to raise their awareness that they can send any relevant 'blue clients' to the SUBMARINER accelerator.

Business Support Institutions and their Networks

- Experience shows that chambers of commerce and other business support institutions (e.g. the European Enterprise Support Network) very rarely have 'blue bio-economy' clients. Not even the 'maritime network' of the EEN has over the past months featured one single blue bio-economy company request. Almost all of them relate to shipping, energy of fishery.
- It is important to expand and strengthen our collaboration with these institutions / networks as they may have more potential clients in future, which they can transfer to the SUBMARINER accelerator, while in turn we can integrate their business development expertise in our service portfolio

Investors / Business Angels

- Over the past months especially in running the Alliance+ programme, we have been able to substantially strengthen our knowledge on **business angels, funding agencies and investors**, which may provide the necessary finance to start-ups and SMEs involved in the blue bioeconomy.

11.4 Activities suggested for the SUBMARINER Network

11.4.1 Collaborate and provide services to companies

SUBMARINER Product / Company Catalogue (funded by Nordic Council)

- Based on the list of 650 companies already identified in all Baltic Sea Region countries, we plan to extract a catalogue of innovative and sustainable products and services already available by companies from within the region.
- The catalogue will enable us to shed a clearer picture onto the already existing 'blue bioeconomy' throughout the region.
- The work shall be the entry point for attracting those companies to become member within the SUBMARINER network and co-create network and other service formats with them

Future business canvas scenarios

- Together with other SUBMARINER network partners, we suggest to facilitate an exercise to showcase 'future blue bioeconomy business canvas' pathways

Hackathons / Ideations

- Companies will be invited to submit concrete challenges faced by them to which they seek a solution. It is suggested that the SUBMARINER network should host on a regular basis (once / twice a year)

11.4.2 Continue to integrate outputs and results from specific research projects

It is vitally important to continue to jointly capitalise on knowledge generated across all blue bioeconomy projects, including topic-specific research, by integrating tools and findings into the knowledge base of the SUBMARINER Network members. The SUBMARINER Network, acting as an umbrella "blue cluster", leverages generated data and knowledge for empowering key actors to make knowledge-based decisions and identify future actions. Currently, the Blue Platform project (2018–2021, Interreg BSR), coordinated by the SUBMARINER secretariat, enables us to do so and to continuously maintain the 'SUBMARINER / Blue Platform' website hub.

- In future times, the **SUBMARINER secretariat** should be chosen **as the regular communication and dissemination hub** in each blue bioeconomy project or that SUBMARINER members **automatically make the transferable results available** – ideally not only at the end of the project duration, but continuously over the course of each project.
- In addition, we should make more use also of short **'lunch time' webinars**; where **project results are made available** on a voluntary basis by individual project members – as to increase the visibility as well as public discourse over project achievements.

11.4.3 Prepare a 'blue economy' funding guide

Actors along the (blue) biotechnology value chain are dependent on different types of financing. Financing depends on the specific needs (e.g. R&D, prototype development, upscaling, etc.) and funding sources can have geographical restrictions. Therefore, a **funding guide** within blue biotechnology would be of great value to assist the actors in finding appropriate funding solutions for their specific needs.

11.4.4 Lobby for a continuous transnational blue assistance programme

The SUBMARINER Network plays an important role in coordinating efforts towards knowledge integration on a more systematic and long-term basis. The business plan scenarios developed under the *Alliance* project show that it may be financially possible to continue providing basic network and matchmaking services on a small scale and on a self-sustained basis through contributions from the network members.

Promote inter-regional funding pool

The sustained operation of the accelerator services will, however, require strategic public or private funding: Many of the funding possibilities are regional, which may prevent the use of transnational value chains. An inter-regional funding pool could solve this problem. For example, a transnational fund based on common challenges and animating RIS3 priorities could be made available for flagships. SUBMARINER Network as a flagship already has the mandate to help the EUSBSR reach its targets, but is not receiving strategic support and operates through collecting membership fees and participating in public-funded projects (Interreg, Horizon); a common fund could support operations of the flagship.

Promote transnational innovation voucher system

Furthermore, a trans-national innovation voucher system would benefit blue biotechnology start-ups and SMEs in the BSR and beyond, as it would allow financing the *Alliance* pre-acceleration services. The innovation voucher system could be financed by European Regional Development Funds from the Baltic and Nordic regions and states. A new mechanism has been examined by the EU since 2018 and is fully aligned with Research and Innovation Smart Specialisation Strategies (RIS3). It is called #Component5 and is a promising opportunity that would enable the long-term existence of the *Alliance* and its innovation support ecosystem, currently not covered by any transnational funding scheme.

11.4.5 Increase and improve coordination and cooperation with other blue accelerators

In parallel to the SUBMARINER Network and the *Alliance*, numerous new niche networks and specialty accelerator programmes exist or have emerged since 2016. Instead of creating yet another network infrastructure, intensification of collaboration between existing accelerators appears to be the most pragmatic way forward. The *Alliance* has already teamed up with other spear-heading networks, such as EMBRC-ERIC, BioMarine, the Portuguese BlueBio*Alliance* and the Bio-based industry consortium. The SUBMARINER Network plans to intensify these existing collaborations in the near future and open to new ventures.

11.4.6 Creative Workshops / Getting out or making use of SUBMARINER comfort zone

- Organise SUBMARINER Hackathons in order to get more innovative ideas (also as part of the accelerator) => Involve companies and present their challenges to multi-dicsiplinary teams of students from our SUBMARINER members => get these teams to work 48h on possible solutions of these challenges in a creative environment => give an 'award' to the teams with best ideas
- Organise creative workshops (with non marine people – business, designers, etc.)
- Disruption of existing projects by invited scientists from other sciences _ open sessions

11.4.7 Regional / national circular economy solutions & demonstration projects with industry

The circular economy concept should be a central component in local and regional economies, which have a suitable scale for closing resource-loops, creating sustainable circular ecosystems and designing participatory community-based innovation schemes.

The SUBMARINER Network can build on existing cooperation with the Council of the Baltic Sea States and the CPMR Baltic Sea Commission, regional and municipal agencies as well as businesses and engage in testing and improving circularity in their territories, economic sectors, value chains and services.

A major challenge is how to effectively apply the circular economy concept beyond traditional resource recovery in waste and water sectors. This could be obtained through the demonstration of territorial systemic circular solutions in one territory and their replication in other areas to achieve the policy targets of the European Green Deal, the Circular Economy Action Plan[92], the Bio-economy Strategy[93] and the European Industrial Strategy[94].

The SUBMARINER Network can support the development of long-lasting (apart from projects) 'circular territorial clusters' as socio-economic and environmental systems composed of all relevant actors and dimensions to implement, demonstrate and facilitate the replication of at least one circular systemic solution. Each cluster could have a Circular Economy Action Plan (CEAP) in which the proposed systemic solution is embedded.

92 https://ec.europa.eu/environment/circular-economy/
93 https://ec.europa.eu/research/bioeconomy/index.cfm?pg=policy&lib=strategy
94 https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

12 Data / Tools / Environmental Monitoring

12.1 Ambition

The SUBMARINER Roadmap 2013 called for a more structured approach to fill the gaps identified within the SUBMARINER Compendium 201 on blue biomass resources and the environmental impacts associated with their increased use.

Among others the following actions where foreseen to reach this objective:

	Status	Projects
• Establish and implement BSR-wide best practices for monitoring and systematic mapping of: o biomass resources (macroalgae, reed) o nutrient resources and CO2 sources for microalgae cultivation	YES No	GRASS CONTRA
• Identify and recommend institutional structures for permanent monitoring, data-sharing and visualization	No	BlueBioSites
• Link the data sets with surveys and mapping of other local (terrestrial) resources and demand for biogas or any other biomass refinery process	No	
• Develop a system to support the use of existing monitoring data (e.g. water depth, hydrographical – biological – use – exposure data) to identify best sites (environmental and cost-effectiveness) for mussel and macroalgae cultivation and fish aquaculture sites	Partially	BBG GRASS InnoAquaTech BlueBioSites
• Conduct systematic research on the role of reed beds and harvesting, macroalgae and mussel harvesting and cultivation on local biodiversity and water quality	YES	BBG CONTRA GRASS
• Assess consequences for nutrient regeneration, biogeochemical cycling and benthic habitat deterioration arising from increased sedimentation and sediment oxygen uptake by mussel cultivations	YES	BBG Ecopelag Optimus
• Assess the relationship between offshore, attached, living macroalgae stocks and beach-wrack macroalgae in terms of biomass, density and annual production rates of stocks of attached, living macroalgae to support the derivation of sustainable quantities of beach-wrack and free-floating algal mats that can be removed	Partially	GRASS
• Further investigate feed supply and efficiency for fish aquaculture sites	No	BalticFeed

12.2 Projects / State of Play

As shown in the table above, numerous projects implemented within the SUBMARINER Network have addressed the issue of improved data sourcing enabling better environmental impact assessments.

As shown in chapter XX, the BBG project together with other mussel related projects has been able to provide better evidence on the **sedimentation caused by the studied mussel farms; which was highly local and less than expected with no oxygen depletion was noted in the near-bottom waters**. Negative impacts of mussel farms are likely to be minimal when placed in suitable locations. It is important to continue the environmental monitoring at the mussel farms with the focus on bottom conditions, e.g. oxygen levels and benthic fauna.

The **Operational Decision Support System** (ODSS) developed by SUBMARINER member, University of Tartu/Estonian Marine Centre (Jonne Kotta), showing areas for macroalgae and mussel growth potential throughout the Baltic Sea Region has been one of the **key outputs of projects implemented** – facilitating the start of a more systematic blue bio sites mapping. No such mapping has, however, been undertaken so far for nutrient & CO2 sources for microalgae cultivation. Regarding assessment of possible (marine) fish aquaculture sites; Finland and Denmark have undertaken national studies. Whereas in Finland the 'fish aquaculture' spatial plan developed in 2012 is still taken as basis for current decision making; the sites identified in open Danish sea have, however, been contested on political level.

In order to promote a systematic and cost efficient approach for environmental monitoring of blue bio sites, the project application 'OperationalPilots' was submitted in 2016 under the leadership of SYKE and numerous

other SUBMARINER members as partners. The project was, however, not approved for funding. At same time, an increasing number of initiatives are running under this theme at EU wide level – often connected to the EU wide long term EMODNET initiative.

12.3 Recommendations and next steps

12.3.1 SEED Money Project BlueBioSites (2020-2021)

The currently running project 'BlueBioSites' aims to develop a 'large scale' project with the objective to develop a Baltic Sea wide effective system for the identification and monitoring of Blue Bioeconomy sites covering not only mussel & macroalgae cultivations; but also fish aquaculture, microalgae as well as reed harvesting sites.

The project does not only focus on data and information necessary to identify new sites; but also the monitoring of existing sites; and shall provide recommendatiions on the most effective technology means to generate such data (taking into account technology advancements made in AI, sensors, drones, camreas and submarines).
SUBMARINER project partners: SUBMARINER secretariat, University of Tartu, KTH), CORPI, LIAE, GMU, SDU

12.3.2 ALGARITHM EU-wide Algae and Shellfish Study (proposal submitted Sept. 2020)

To date, the production of macroalgae and shellfish is very low in European seas and this situation is due to the lack of and/or a scattered nature of a basic background knowledge on the production potential of macroalgae and shellfish in the region as well as regulatory constraint. In order to fill this knowledge gap, a EU wide consortium, led by SUBMARINER members, has submitted a proposal for an EU wide study tendered by the European Commission (Call for Tender / ENV.C.2/SER/2013/0041 2).

The aim of Algarithm is to assess the potential of shellfish and macroalgae to recycle nutrients and the greenhouse gas emissions from their production and thereby to add to the evidence base that will support the planning of aquaculture at lower trophic level for the European sea regions.

The proposal foresees to provide a synthesis of a large number of recent measurements of farmed seaweed and shellfish growth in the European Seas and to develop a new model chain for predicting CO2 assimilation, nutrient removal and recycling potential as a function of growth across key environmental gradients. The farm-scale estimates will be upscaled to predict the total area of farms needed to make a meaningful contribution to a Green Deal and will give information on the expansion possibilities on local scale.
SUBMARINER project partners: s.Pro, University of Tartu, IVL, KTH
Decision expected by Spring 2021

12.3.3 Project on Underwater noise pollution / sea floor integrity:

Establish a wider link to role to MSFD descriptors on 'saving good environmental status' not only in view of nutrient emissions or hazardous substances: i.e. by **extending the definition of pollution especially also to "underwater noise pollution" and "sea floor integrity".**
Promote related solutions /measures and align national efforts for monitoring of the underwater noise (e.g. impact from different sources to different marine life measurement etc.) throughout the Baltic Sea Region.

12.3.4 Projects that would support the integration of monitoring practices as part of other activities such as offshore wind farms and centralised data collection practices:

Namely, existing structures offshore can be used to monitor the environment and support the data collection efforts on impacts and changes in marine environment. A regional, transnational projects would allow for the agreement on and standardisation of monitoring parameters, methods, data, etc.

13 Access to Pilot Sites & Facilities

13.1 Ambition

By the time of the SUBMARINER Roadmap launch 2013, only some pilot mussel farm sites and recirculating aquaculture sites existed; but not one single macroalgae cultivation or multi-use case. The overall objective was to establish more such pilot sites around the Baltic Sea Region to enable empirical research.

Concretely the roadmap called for the following types of pilot sites:

	Status	Projects
IMTA: investigate site-specific solutions with varying combinations of fish, algae and mussel farming at one site in order to find optimal technical and economical solutions	Partially	BBG / AquaVitae One case: Musholm / DK
RAS technologies in combination with specific sites around the Baltic Sea	YES	InnoAquaTech
Pilot sites for **agar production**	No	
Mussel cultivation pilot sites	YES	BBG / Ecopelag OPTIMUS /German Study
Macroalgae cultivation pilot sites	Partially	SeaFarm / GRASS (only sites at West Coast)
Pilot sites for **reed harvesting**	Partially	CONTRA (use of Beach-wrack)
Microalgae cultivation pilot site(s) for multidisciplinary research around uses for large-scale cultivation, including test sites for nutrient removal from waste streams;	Partially	No project; but examples in Sweden / cases in *Alliance* accelerator
Biorefinery pilot sites	Partially	Macrocascade ????
Wave Generation	No	

13.2 Projects / State of Play

As shown in the table above as well as the individual topic chapters, a number of pilot sites have indeed successfully been established over the past years.

Mussel Cultivation (Baltic Sea Proper)	1. Musholm, DK (8 ha – depth 0-3m) 2. Limfjorden, DK (XXX???) 3. Horsens Fjord, DK (XXX???) 4. Kiel Farm, DE (0,21 ha – depth 0,5-3m) 5. Greifswald Bay, DE (XXX???) 6. St Anna Farm, Kalmar, SE (4 ha – depth 1-10m) 7. Byxelkrok, Kalmar Sound, SE (1,2 ha – depth 3-6m) 8. Västervik, SE (960m2 – depth 0-4m) 9. Hagby Farm, SE (1380m2 – depth 1.5-5m) 10. Ecoplega Stockholm, SE ???? 11. Pavliosta, Latvia (625m sizal rope – depth 5-7m) 12. Vormsi, Estonia (126m rope – depth 0-3,5m)
Macroalgae Cultivation Saccharina latissima (all Western Baltic)	• 2 farms in Germany (Coastal Research & Management & XX) • 3 farms at the Swedish Western coast (Nordic Seafarm AB, Royal Institute of Technology (KTH) & Kristineberg Research Centre, Bohus Seaculture) • 2 farms in Denmark (XX, XX)
IMTA	1. Musholm, DK: Fish and Mussel Cultivation (see above)
Recirculating Aquaculture Systems / Aquaponics	2. RAS for fish and microalgae production (DK, Guldborgsund Zoo) 3. Aquaponic: FishGlasHaus (DE, Rostock) 4. RAS for shrimps with geothermal energy (LT, Klaipeda) 5. RAS for shrimps (PL, Gdansk)
Multi-Use	1. Offshore Wind & Tourism (Copenhagen, DK) 2. Several cases related to UCH & Tourism
WasteTreatment by Algae	SwedishAlgaeFactory – but unclear whether a real pilot site yet

As can be seen some progress has been made especially in establishing more mussel farm sites. However, only two farms (Musholm and St Anna) can be claimed to be of 'larger' size and with the exception of Kiel, none of them operate on commercial basis, yet. The Musholm mussel and fish farm was also the ONE and ONLY IMTA test site within the Baltic Sea. However, in view of political shifts in DK the concession for this test site was taken back again in 2019.

Both for wave energy and agar production pilot sites, SUBMARINER Network partners applied for funds, but were not successful. Thus these uses are no longer art of SUBMARINERs priority topics at Baltic level scale. Wave energy is, however, a topic around other sea basins also to be set in combination with other uses. Microalgae cultivations as waste water treatment options are also mainly promoted by the SwedishAlgaeFactory, a Swedish start-up, which has been operational since 2016. So far, however, they seem to be more successful in promoting microalgae in solar panel material and other high value applications.

For Blue Biotechnology the SUBMARINER Alliance identified numerous test laboratories throughout the Baltic Sea Region (see chapter XXX).

13.3 Recommendations and next steps

As indicated across all chapters, all these pilot sites need to be upscaled to real demonstration size. Whereas the empirical research has shown good and promising results at pilot scale; it is necessary in the next years to transfer these results to full scale; in order to cross-check, whether the same results can be achieved. Moreover there is still a dramatic lack of concrete sites especially around the Baltic Sea proper.

14 Technology Development & Transfer

14.1 Ambition

The objective as set out in the 2013 SUBMARINER roadmap was to 'develop environmentally friendly and cost efficient technologies suitable for Baltic Sea conditions taking into account knowledge and technologies from terrestrial resources'.

In order to do so, the following actions were foreseen:

	Status	Projects
• Collect information about technologies and scientific expertise available at national level; • Match-making between technology providers and users; • Introduce technologies and know-how available in other BSR countries to national research organisations and companies; • Offer study visits, meetings, easy websites for registering needs and offering services.	YES	BBG InnoAquaTech Alliance SmartBlueRegions GRASS AquaLIT
Scout for pilot installations and technology providers; enhance information exchange between technology providers and users, foster technology developments: • Underwater mussel and macroalgae farming technologies crucial for Baltic Sea conditions (i.e. ice / open coasts);	YES	BBG / GRASS / SeaFarm
• Environmental friendly reed and beach-wrack harvesting technologies;	YES	CONTRA
• Sustainable Fish Aquaculture solutions; such as multi-use with wind parks and new IMTA / RAS production methods	YES	InnoAquaTech / UNITED
• Water treatment technologies using blue biotechnology or algae cultivation	Partially	Alliance cases
• Microalgae cultivation technology suitable for seasonal fluctuations of temperature and light in the BSR;	No	
• Scale-up processes necessary for getting raw materials, valuable ingredients or cells from marine organisms for Blue Biotechnology products;	Partially	Alliance
• Adapt and develop biosensors suitable for marine resources;	No	

14.2 Projects / State of Play

As can be seen from Table XXX above, the SUBMARINER Network initiated projects have almost all substantially contributed to an exchange and transfer of suitable technology as well as adaptation of technologies suitable to Baltic Sea region conditions.

Most notably, new technologies used within the Baltic Blue Growth project, substantially increased the production and harvest of blue mussels within the Baltic Sea proper, providing evidence that such cultivations could be established at places, where they are most needed in view of nutrient uptake.

At the same time all projects showed that there is still a long way to go in view of finding the most efficient and effective technologies for blue bioeconomy applications. Various pilot cases also had to go through tough learning curves; e.g. two of the five BBG pilot farms lost their equipment during the course of winter storms; and harvests were lost either due to predators or non-suitable storage.

14.3 Recommendations and next steps

14.3.1 Foster ongoing knowledge and technology exchange within SUBMARINER Working Groups

As the legacy of the Baltic Blue Growth mussel cultivation project, the SUBMARINER secretariat has taken the initiative to establish a permanent, open working group gathering all players interested in the advancement of mussel cultivation throughout the Baltic Sea Region. So far the working group has gathered approximately every 3-4 months in form of 2-3 hours long video conferences. Such set up is far from ideal – but offers at the

same time a resource efficient way of at least safeguarding a continuous knowledge flow from more experienced mussel experts to 'newcomers'.

The SUBMARINER accelerator equally continuously sources new start-ups or existing companies, who are interested in finding collaboration partners to accelerate their blue bioeconomy business ideas. In numerous cases, technology development and transfer plays a role in the cases in addition to other development challenges. As an example the accelerator has successfully connected the 'ModHEAT® drying technology' developed by SFTec (Finland) with numerous blue biomass producers.

Also InnoAquaTech and SmartBlueRegion projects successfully organized study tours and/or match-making workshops in order to promote technology transfer around specialized blue economy topics, such as modern aquaculture systems, offshore energy and shipping technology. Whereas the cooperation among SmartBlueRegion partners somehow dispersed after the end of the project, InnoAquaTech partners partially continue such exchange efforts as part of the ongoing AquaVIP project. A similar type of working group, such as the one around mussels, has so far, however, not been able to be established under the auspices of the SUBMARINER network. This is even more a pity as companies had signaled that they would also use such services in the event that they would need to be paid for.

- All SUBMARINER members should continue to **initiate dedicated study tours for companies** within the blue bioeconomy to regions either within or outside the Baltic Sea Region, which host companies, which are further advanced.
- Moreover dedicated **pitching sessions / match-making sessions** for companies from within the SUBMARINER region should be organized on a regular basis – not necessarily physical – but resource-effectively also on virtual basis.
- The SUBMARINER network secretariat is willing to **host dedicated thematic working groups, e.g. on RAS systems, Seaweed Cultivation and other Blue Bioeconomy (Technology) topics**. This can, however, only be maintained in case of a core group of additional active members.

14.3.2 BlueBioTech Seed Money Project (2020-2021)

Despite the achievements of past projects in advancing blue bioeconomy technology, there is still an enormous need for developing and finding better technology solutions, which enable both a financially as well as environmentally sound blue bioeconomy to develop further within the Baltic Sea region:

- Better solutions are required in view of **drying, harvesting, processing techniques** and especially general **upscaling** of micro- and macroalgae, mussel or RAS cultivations.
- **Aquaculture systems have to be advanced as to meet the zero emission targets**; while nevertheless being economically feasible (e.g. combining open cages with nutrient uptake systems beneath the cage and/or further advanced forms of integrated multitrophic systems).
- **Intelligent combinations of renewable energy technologies with aquaculture biorefineries** (e.g. by using heat pumps, geothermia, hydro-accumulation or synthetic gas from hydrolysis) can lead to cost reductions, which are necessary to enable RAS systems to work economically
- **Innovations are also immanent in the management of the sites themselves**, using new technology for controlling the health and growth of the respective fish or plants.
- Technology development is also an enabler as **submerged or more offshore systems** reduce negative environmental impacts as well as visual disturbance.
- **Block chain technology, artificial intelligence, digitalization and big data** are just a few of the buzz words in innovation, which also have an enormous effect on enabling more sustainable blue bioeconomy and improved consumer communication (e.g. through more transparent product value chains).

The **BlueBioTech seed money project aims to identify the main technology and innovation needs within the industry with focus on Baltic Sea specific and relevant requirements**. The main project shall not only foster technology development, but also effective technology transfer among technology providers and users. It shall not only draw from expertise within the sector itself; but also build on samples of other industries looking for combinations/synergies across the entire blue-green spectrum.
SUBMARINER project partners: Klaipeda Science and Technology Park, CORPI, GMU, KTH

15 Regional energy solutions with marine resources

15.1 Ambition

The SUBMARINER Roadmap 2013 set out the objective to 'encourage appropriate consideration of marine resources in energy planning in order to create markets for climate friendly energy production'.
To that end the following set of actions were foreseen:

	Status	Projects

• Develop concepts for integration of marine resources in regional plans on renewable energy and climate protection ensuring the use of marine and terrestrial resources, e.g. wind mills, solar energy, biogas;
  • Introduce concept of smart combinations of uses, where a systematic approach to biomass use beyond the energy sector complements the biorefinery concept;
  • Develop economic models for use of marine resources in renewable energy production and well as regional studies & models
	Partially	COASTAL Biogas / CONTRA

• Develop a placement strategy for biorefineries including marine resources around coastal regions; • Improve networking among biorefineries across BSR; • Use experience of forestry and agriculture in blue refinery concepts:	Partially	COASTAL Biogas / CONTRA
• Encourage technology development and continue to refine the process of biogas from marine resources; • Optimize techniques and logistics for harvesting biomass, transport to biogas plants, and for refining products;	Partially	COASTAL Biogas
• Promote use of small scale wave energy generators	No	Wave Project rejected

15.2 Projects / State of Play

The COASTAL Biogas concept is implemented at full scale at Solrød biogas plant in Denmark. In 2019 1,522 tons of cast seaweed were collected and co-digested in the Solrød biogas plant. In this way nutrients are physically removed from the Baltic Sea, which contributes to mitigation of eutrophication. The nutrients are recycled through the anaerobic digestion process and utilised as an organic fertiliser, offsetting the use of synthetic fertilisers. Problems with odours from rotten seaweed is eliminated for the benefit of tourism and recreation, and the water quality is improved. Finally, carbon dioxide and methane emissions arising, when the seaweed decays on the beach or in the waterline, are eliminated as well. Instead, a high-quality biogas is produced in the controlled anaerobic digestion process.

What is important is to collect the beach-cast when it is still wet, as if it decays and dries ashore about half of biogas is lost to the atmosphere. In Denmark, all input streams to anaerobic digestors have a limit on Cadmium if the digestate is to be used as an organic fertiliser. In other countries, the limit on Cadmium is on the output stream (digestate) for it to be used as an organic fertiliser. In either way, high content of Cadmium in the seaweed hampers the possibility to use seaweed for co-digestion

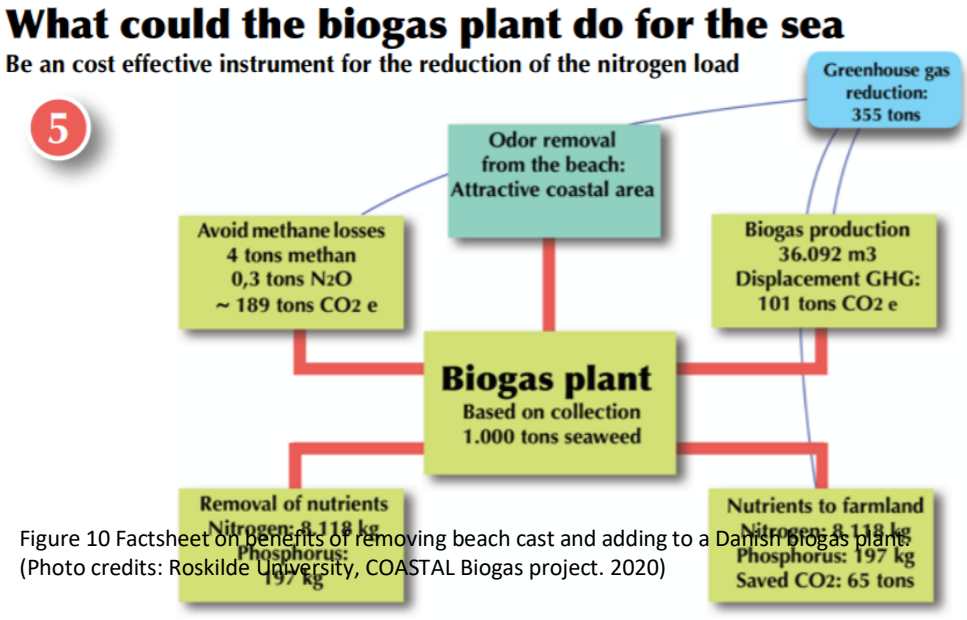


Figure 10 Factsheet on benefits of removing beach cast and adding to a Danish biogas plant. (Photo credits: Roskilde University, COASTAL Biogas project. 2020)

and obtain the associated socio-economic benefits.

15.3 Recommendations / Next Steps

1 Development of heavy metal removal techniques would benefit the possibility to use marine biomass as a resource, independent of whether it is used for energy production, nutrient recovery, animal feed products, or for contributing to lower levels of heavy metals in the Baltic Sea for the benefit of all living species there.

2 In order to be able to implement the concepts in development in a holistic manner further investigation into the challenges, which were discovered during the projects is needed. It is imperative that stakeholders and policy-makers learn how to shape the framework.

16 Introduce ecosystem service payments

16.1 Ambition

The original ambition as set out under the 2013 SUBMARINER Roadmap was to 'develop an accepted approach to valuation of ecosystem services and propose compensation mechanisms for the provision of ecosystem services by new marine uses'.

A very comprehensive set of activities were foreseen to lead to that objective:

	Status	Projects
Assess the applicability of new marine uses on ecosystem services for different sub-regions of the BSR	Partially YES	BBG / GRASS ALGARITHM
Proactively liaise and inform EU, HELCOM and relevant Priority Areas of initiatives related to valuation and compensation of ecosystem services	YES	Mussel WG
Develop a practical BSR-wide methodology for valuation of ecosystem services, as the basis for ecosystem services compensation schemes	Partially	BBG
Develop recommendations and proposals for establishment of ecosystem service compensation schemes based on: • Analysis of existing and proposed (if any) compensation mechanisms; • Assess the role of private sector and NGOs and get them involved; • Consider and assess various possible schemes, e.g. via taxes (polluter pays, provider of ecosystem services gets subsidized), national and transnational models; possible voluntary initiatives (e.g. Baltic Sea friendly coastal municipality); market opportunities (e.g. farmers buy aquaculture products for fertilizer or biomass, N quotas);	YES	BBG ecosystem service payment study
Generate life cycle assessments and techno-economic models pertinent to local conditions in the BSR to critically examine the costs and benefits of new uses and technologies compared with existing solutions	YES	BBG ecosystem service payment study
Assess the role of Blue Biotechnology products with respect to benefits to ecosystem services	YES	ALLIANCE SDG case analysis

16.2 Projects / State of Play

As part of the BBG mussel cultivation project, the SUBMARINER network secretariat undertook a very comprehensive study on the introduction of possible ecosystem payment schemes[95]. The study focused on mussel cultivations as a possible sea-based measure to deal especially with the already existing internal nutrient load as well as continuous nutrient inflow from non-point sources. Even though the study concentrated on mussel cultivations as the currently only existing sea-based measure, it could also be transferred to e.g. algae cultivations, which show similar results in view of nutrient uptake.

16.3 Conclusions and Recommendations

Mussel farms need to be officially accepted as an additional measure at given sites to reduce nutrient load and thus being part of the accepted mix of supported abatement measures.

- Support needs to be provided for mussel farms to get 'certified' to be an ecosystem service provider.
- While payments should be based on quantifiable parameters such as P/N uptake or water clarity; a clear, common and cost-efficient monitoring scheme should be adopted to showcase these positive.
- Payments should be at least equal to that given to land-based measures.

Mussel farming can be included in a cost-effective abatement mix.

- Compared to other measures it is in the mid-range in terms of costs –and even has positive externalities

[95] Angela Schultz-Zehden, A. Steele, B. Weig: 'How to turn payments for ecosystem services provided by Baltic Blue Mussel farms into reality?', 2018, Study / Fact Sheet

- In some instances, land-based measures are not possible or too costly due to e.g. lack of land.
- For sea-bed measures only mussel cultivation is sufficiently developed.

Ensure that incentives to reduce nutrient are not impeded

- Nutrient trading as a scheme is worth considering: But any scheme involving offsetting has to ensure that restrictions on nutrient polluters (e.g. agriculture) remain as strict as before

Examine the financial instruments, which are already available in the region / country.

- Mussel farms should receive public support (e.g. by EMFF) as a reflection of the higher costs related to the fact that mussel farms are still first movers and thus far from being standardized.
- The EMFF can be used to lower the overall production costs by providing support to the investments related to the establishment of the farm; but also other supporting activities.

Provide support to overcome 'first movers' to reach critical mass

- The more mussel farms are established, the lower their cost and the higher the additional positive services provided by the mussels produced; e.g. as an alternative protein source for the feed industry. Any future public or private support schemes should also provide support and forum to mussel farms to set up cooperative solutions for joint use of infrastructure and collective supplier to a given feed industry.

A payment scheme in which the benefactor pays is a good alternative for success.

- There is a clear willingness to pay for clearer water among the population in Baltic Sea countries, which politically justifies payment scheme for mussel farming
- Benefactors may be individuals, private foundations, enterprises as well as regional authorities.
- Beach house owner / hotels / tourism benefit from clearer water and could pay a small tax or fee for the ecosystem service provided by mussel farmers.
- Enterprises may fund a mussel farm as part of their Corporate Social Responsibility programme.

Go local (or regional) backed by national support

- In short run, there is a much higher possibility implement a ES payment on a local / regional level, particularly when involving local stakeholders in a coordinated effort to influence national policy
- It is, anyhow, a case by case decision, on whether a mussel farm is the best additional measure in a given place depending on how effective and feasible any other land-based measures would be

Let the beneficiary be the owner or buyer of the services of the mussel farm

- Create a good mix of responsibilities and risk sharing: set up a scheme where the beneficiary (municipality, private foundation, donor enterprise) is the owner of the farm or guaranteed buyer; but a private company is the operator

Mussel farm operators have to organise themselves as to speak with one voice !

Whereas we currently still lack the showcase, that such payment scheme has been realized in one of the Baltic States; the efforts of SUBMARINER and contributing projects have led to progress within the political arena:

The Ministerial Declaration adopted at the 'Our Baltic' Conference, held 28th Sept 2020, postulates:

*We RECOGNIZE with concern that **large amounts of phosphorus have accumulated in lakes, coastal waters and in the Baltic Sea** during the past decades due to anthropogenic activities, resulting in an enhanced internal flux of phosphorus between sediments and the water thereby exacerbating eutrophication; to this end we **ENCOURAGE further improving the knowledge base regarding the nature and dynamics of internal nutrient reserves and the development of measures to remediate these internal fluxes**, provided that commonly agreed regional principles and an adequate risk assessment framework are in place in HELCOM to meet the necessary environmental requirements.*

*We will clearly IDENTIFY ... under the Water Framework Directive (WFD), the gap to good status and we will **DESIGN the Programmes of Measures** in order to (1) close that gap, ..., ..., and (3) **ensure that the programs of measures are adequately funded.***

We will PROMOTE ecologically sustainable sea-based measures, where appropriate with potential for eutrophication abatement such as mussel cultivation and blue catch crops.

Moreover, as noted in the Aquaculture legislation workshop organised by the Swedish Board of Agriculture in November 2019 – there are indications that mussel farming may become an approved sea-based measure under the Water Framework Directive.

16.4 Next Steps

As noted under the Algae and Mussel Cultivation topic chapter, future actions of the SUBMARINER Network secretariat and its members in relation to promoting ecosystem service payments will be:

- Promotion of ongoing sharing and collection of monitoring data from the given farms (regardless under which project they are funded) – with at least a minimum set of comparable data sets – as to continue to gather an empirical basis on the positive environmental impacts of these low trophic cultivations (BlueBioSites / possibly Algae & Shellfish study)

- Promotion of optimal site selection for possible new farms to be established with focus on sites, where the mussel and/or algae cultivation can achieve highest impact for nutrient and phosphor uptake (BlueBioSites)

- Promotion of collaboration between the various farms and calculation of optimal process – as to achieve critical mass necessary to use mussels or algae in feed products (BalticSeaFeed).

- Representation of SUBMARINER Network members' interest in relevant bodies; e.g. HELCOM Observer status.

17 Unlock financing for innovative uses of marine resources

17.1 Ambition

The ambition as set out under 2013 SUBMARINER Roadmap was to 'Improve access to finance for collaborative projects involving private and public stakeholders.'

To that end the roadmap foresaw the following set of actions:

	Status	Projects
Collaborate with investment funds, venture capital organizations, etc. : • Establish contacts with public and private financing organizations; • Identify offers, interests and needs by financing bodies and possible fields of cooperation; • Raise awareness among researchers, research institutes and other stakeholders on requirements of "bankable" projects; • Study and assess innovative forms of knowledge brokerage; • Initiate individual and multilateral meetings and consultations.	YES	ALLIANCE+ InnoAquaTech
Improve relationship between public research and private companies: • Raise awareness among industry on project opportunities and benefits to be gained from participation in public funded programmes and seek their active input and vice versa; • Study and assess challenges for private-public collaboration; • Identify, assess and disseminate good practices of private and public collaboration, develop "vademecuum / guidelines"; • Organize and attend workshops showing case studies on how companies and research can collaborate; • Encourage and assist networking and concrete development of Public-Private Partnerships at regional and local level.	YES	ALLIANCE+ InnoAquaTech
Develop applications to both public and private funding programmes: • Inform SUBMARINER Network partners on funding opportunities and their specific requirements and vice versa; • Develop strong triple-helix project partnerships based on partner institutions strengths.	YES	ALLIANCE+ UNITED All future projects

17.2 State of Play

As shown under chapter 11.1 describing the SUBMARINER Accelerator for Blue Growth, we have together with all our members lived up to the actions foreseen within the 2013 SUBMARINER Roadmap. Especially through the work of the *Alliance* projects, SUBMARINER has attracted so far more than 40 applications to its Accelerator services and we have also reached out to more than 60 public and private investors.

Concretely we are by now in regular contact with 5 investors[96], who have already participated in one or more of our pitching events organized approximately twice a year. As a result, Our cases had the opportunity to come in contact with concrete funding options either from the public or private side; with numerous cases having succeeded in raising additional finance.

In addition, the SUBMARINER Network secretariat is continuously informing members as well as its 'accelerator' cases on the increasing number of 'blue financing' opportunities – as for instance provided by the EU Blue Invest facility or the Portuguese Blue Bio Alliance. Companies are also increasingly called for to participate in public funding programmes, esp. within the Horizon scheme. To that end SUBMARINER has approached numerous companies within the H2020 UNITED project.

The past years have shown that the challenge is not so much, that there is a lack of venture capital on the market for blue projects, but that there is a **lack of suitable companies**:

[96] Research Council Norway, NewCo Helsinki, Valinor, Kroslid Invest, European Circular Bioeconomy Fund

- For some companies the administration coming with public funding (e.g. Horizon, Interreg) is too high, or the time frame of applications is too long to meet the company development needs. Also, some regulations obstruct private companies financial support (e.g. de minimis regulation for aquaculture/seafood producers). In some cases, companies were also not willing to provide open access to results (share Intellectual Property) achieved with that funding.

- On the other side are the early start-ups, which are not yet 'investment ready' and thus require the pre-acceleration and incubation services, as those provided by the SUBMARINER Network. In these cases, it would be more important that the SUBMARINER Network would get the funding necessary to provide 'innovation vouchers', which the start-ups could use in order to pay for the supporting transnational accelerator services required to bring their venture to the 'investment readiness' stage, thus bridging the "valley of death". Such a scheme could be compatible with Smart Specialization Strategies (S3) and the hopefully upcoming Interregional Innovation Investment mechanism (I3).

17.3 Next Steps

As described before, the emphasis of future actions is not so much on changing or adopting a new approach or project, but merely to sustain and expand with those services, which have worked so well especially within the SUBMARINER mentoring programme & its Accelerator.

17.3.1 Increase collaboration with big companies

In addition to reach out and involve potential public and private investment funds and business angels; we will need to intensify also our work with bigger private companies as the potential clients of the blue economy start-ups or sponsors of the acceleration services. Finally, we should (inter-)connect blue clusters that want to sustain and attract talent and investment locally for solving common challenges, be it regional and global.

17.3.2 Develop and Test new ways of funding Blue Bioeconomy / Marine litter

- Marine Litter Fund: Insurance & Fishery Fund
- Compensation / Water Improvement Fund
- Innovation Vouchers

17.3.3 Demonstrate Multi-Use

- Roll-out of possible added value products from the UNITED projects e.g. certification schemes for the products derived from the marine space that is efficiently and sustainably used,
- Spin-off projects on regional development coupling aquaculture and tourism in the Baltic
- Multi-use or 'system design' solutions that can contribute to the current topics and issues including the climate change (e.g. innovative coastal protection design including artificial reef for restoring the biodiversity and attractive design for tourism all-year round). E.g. Climate action, environment, resource efficiency and raw materials

17.3.4 Promote 'blue' public procurement & public-private partnerships (and ecosystem payments)

'Innovation partnerships' should be established as to foster **sustainable 'blue' procurement** (see previous chapter) – **not only for products but also ecosystem services** (combining blue biotechnology solutions with waste water treatment // combining modern recirculating aquaculture systems with power plants) as well as developing a **BSR wide minimum 'standard' for public procurement of environmental monitoring technology** (see previous chapter). To that end the following actions are suggested:

17.3.5 Projects fostering 'smart' combinations in public procurement

BSR initiatives on public procurement for sustainable blue products (and services) – fostering public-private partnerships to foster 'smart' combinations of blue innovations (e.g. in the energy / waste / water treatment sector).

17.3.6 Projects fostering alignment of national funding programmes, regulations & licensing

BSR wide initiative to compare and align public support (including funding) programmes; as well as regulations and licensing procedures for blue production sites as well as blue products & services. Foster multi-

use solutions; e.g. by moving away from single purpose licenses towards multi-purpose licenses for the use of the sea resources.

17.3.7 Building a Community of Practice

The Baltic Sea could benefit from developing a Community of Practice initiative, building from the similar initiatives in the North Sea, that connect multiple (ocean and coastal) sectors and enable joint idea generation, co-creation of multi-sectoral / multi-disciplinary solutions, and synergies across sectors, ensuring a more integrated approach to use of coastal and marine resources.

18 Create better legal and regulatory conditions

18.1 The Ambition

The objective as stated in the SUBMARINER Roadmap 2013 was to 'Reduce vagueness in current legislation and regulations in view of innovative uses of marine resources'.

To that end the following actions were foreseen:

	Status	Projects
Assess the existing integration of innovative uses of marine resources in relevant EU Directives and establish a dialogue with relevant national authorities and respective EU Directorates	YES	BBG, GRASS
Foster a joint interpretation on how to reach targets set by the relevant EU Directives (e.g. Natura 2000, WFD, MFSD) with regard to "harvesting" marine resources (e.g. macroalgae, reed);	Partially	BBG, GRASS
Consider how new uses of marine resources shall be taken into account in Maritime Spatial Planning and Integrated Coastal Zone Management Plans (i.e. develop pilot plans in various regions, develop criteria for "suitable sites");	YES	BalticRIM, BBG, BlueBioSites
Draw recommendations for EU policy on Baltic Sea resources uses	Partially	All projects not relevant
Draw recommendations and encourage BSR-wide agreement on integrating reed and mariculture cultivations as an environmental remediation measure under the HELCOM BSAP	YES	BBG
Draw recommendations on creating incentives for combinations with offshore wind parks	YES	MUSES
Draw recommendations for a common approach to use fish aquaculture as a suitable measure for restocking	NO	-
Assess tools for ensuring the exploitation rights for all actors involved in finding, development and commercialization of Blue Biotechnology products.	YES	ALLIANCE

18.2 Projects / State of Play

As shown above, legislation, regulation and MSP were or are at the core in numerous SUBMARINER projects: Both BBG and GRASS assess, how mussel or algae cultivation are covered in the various EU Directives and whether those promote or place a barrier to them. BBG, GRASS, MUSES as well as BalticRim have developed guidelines for how to consider mussel or algae cultivation, multi-use as well as maritime cultural heritage aspects within Maritime Spatial Plans.

Only in view of Fish Aquaculture, the SUBMARINER Network did not pursue a dedicated project; but merely organized two workshops (within the Blue Platform project) to showcase best practices, differences and problems of how Marine Fish Aquaculture is treated within the legislation and regulation by the various Baltic Sea Region countries.

Real positive change achieved within this field was, as expected, minor, but nevertheless remarkable:

- As shown – mussel cultivation is now for the first time – accepted as a possible sea-based measure under the new HELCOM Baltic Sea Action Plan
- The Finnish government is pursuing a pro-active policy for promoting sustainable fish aquaculture taking into account also the use of Baltic Fish Feed and other compensatory measures
- Algae – and Mussel Growth Maps were at least taken into account in the preparation of the Estonian MSP
- Multi-Use as well as Underwater Cultural Heritage are repeatedly earmarked by Maritime Spatial Planners to be of high relevance

To that end, the **Interreg BSR Capacity4MSP** (2019-2021) project aims to collect main lessons learned from past projects and initiatives across the Baltic Sea and use them to increase the capacities of planning authorities across the Baltic Sea. The SUBMARINER Network secretariat therefore continues to stay in dialogue with MSP Authorities in view of their role in the promotion of innovative and sustainable uses of marine resources.

19 Public Awareness

19.1 The Ambition

The SUBMARINER Network's declared view has long been that products from innovative and sustainable uses of marine resources will fall on fertile ground only in a market in which consumers are aware of the benefits of sustainable blue products and are motivated to contribute to solutions.

The objective as set out within the SUBMARINER Roadmap 2013 was to '*raise awareness on environmental functions / services provided by new uses of marine resources and create markets for new products from marine resources.'*

To that end the following actions were foreseen:

	Status	Projects
Carry out public awareness campaigns:		
• Create information material on potential of new and innovative sustainable marine resources	Partially	All projects
• Identify and create success stories (local, regional, national)	YES	Blue Platform
• Undertake regional and national campaigns on value of ecosystem services and nutrient recycling for various stakeholder groups;	Partially	BBG, BluePlatform
• Produce and disseminate "SUBMARINER" newsletter and/or magazine;	YES	SUBMARINER
• Create cooperation with media to integrate them into public campaign	Partially	BBG
Conduct market surveys on products from marine resources	Partially	GRASS
Carry out information campaigns, workshops and involve companies on: • new and local fish species (regional level) • development of new fish and chicken feed • organic fertilizers; • blue biotechnology applications; • reed as ecological insulation material;	Partially	BBG Alliance Blue Platform Fucosan BalticProBlue Sea to Fork
Support establishment of a Baltic Sea Brand and Distribution Network for: • Fish from BSR aquaculture; • Mussel meal products and organic fertilizers; • Cosmetics, health care and wellness products; • Products from Baltic Sea organisms such as agar from 'algae Furcellaria'	No	BalticProBlue Sea to Fork

The need for a targeted public awareness campaign in cooperation with relevant Baltic companies was reiterated in 2017 as a result of the large scale stakeholder process leading to the Implementation Plan for the Baltic Blue Growth Agenda as well as in the SUBMARINER 'Better of Blue' (2017) conference declaration.

19.2 Projects / State of Play

As shown above, public awareness activities have been part of numerous SUBMARINER projects over the past years. Within the GRASS project a detailed market survey has been carried out on the interest and acceptance of consumers for seaweed based products. And especially the BBG mussel cultivation project received substantial media attention.

All this is, however, far from a full scale public awareness campaign.

The BalticProBlue as well as the BBG Ripples Extension project; both of which focused on joint public awareness campaign did not receive funding – mainly due to the fact that the INTERREG BSR funding programme mainly targets public authorities.

19.3 Next Steps

It may have been that these earlier applications were 'before their time'. Currently (2020) in view of the European Commissions 'Green Deal / Farm to Fork' strategy and the 'Ocean literacy' campaign (see below) – there are more opportunities open to realize such consumer oriented initiatives.

Based on the (initially not successful) BalticProBlue and ERASMUS+ Blue Schools applications; the SUBMARINER Network has together with some of its key members – submitted the EU wide Sea2Fork application under the Horizon Green Deal Call.

Even if this initiative may not receive initial funding; we will pursue such applications further under Horizon Europe, INTERREG and Nordic Council – based on the good partnerships already established both within the Baltic as well as across Europe – as we see it as key to create a market pull in parallel to a product push.

The Baltic Company Catalogue initiative, initiated by SUBMARINER and approved by the Nordic Council for funding, is an important step in creating the links to the number of companies already active in this field.

Sea2Fork – The Blue Food Movement (Horizon Green Deal, 2021)

Sea2Fork (S2F) aims to mainstream the uptake of healthy and sustainable Blue Food by EU citizens. S2F will increase the knowledge, availability, and acceptance of untapped, low-trophic aquatic resources (i.e. seaweeds, bivalves, small pelagic fish, freshwater species and side streams). By assessing, improving and developing attractive and affordable food products, S2F will stimulate demand from European consumers, including the most vulnerable and disadvantaged. S2F will also work with popular food (i.e. bakeries, dairy) to serve as carriers for healthy marine ingredients, many of which have anti-obesity effects.

S2Fs' system innovation process will be catalyzed by a series of boot camps and food labs, bringing together more than 700 scientists, chefs and companies across Europe to foster widespread uptake of Blue Food innovations, co-creating solutions to meet current consumers' needs.

Making use of the latest technologies (3D printing) and S2F partners' excellent facilities, we expect to develop at least 25 new popular products. In parallel, the S2F open data system will build on and improve tools/apps (FishChoice, Miils) already successfully on the market, providing customized information (health, sustainability, nutrition) for professionals and end-consumers.

Blue Food will be promoted by thousands with online and physical interactions (i.e. cooking classes, living labs, school programs, tastings) and an annual Blue Food Week campaign to inspire consumers to expand their daily diet. S2F will not only rely on the market influence of its partners (IKEA, COLRYUT, ASC), but will also work strategically with a multitude of opinion makers (i.e. chefs, influencers), governmental authorities and health/obesity experts. The 'Blue Food Vision and Roadmap 2040' to be developed with all stakeholders will show the joint strategy to ensure maximum positive impact on Europe's environment, economy, health and society contributing to meet UN SDGs and a post COVID19 recovery.
Funding: € 12 million (approval pending)
SUBMARINERs: KTH, SUBMARINER secretariat, UGOT, Innovatum, SDU, SYKE, CAU, LUKE, NMFRI

Strategic Actions not foreseen in the SUBMARINER Roadmap 2013

20 Smart Specialisation for Blue Growth

20.1 Ambition

In 2015, at the time of the elaboration of the follow-up actions to the 2013 SUBMARINER Roadmap, the need to facilitate network initiatives at the regional level became evident. These initiatives are as necessary as networking at the pan-Baltic and European levels, as they serve to connect the levels with one another. As a result the SUBMARINER Network developed the project "Smart Blue Regions" which aimed to enable officials from public administrations in six coastal regions at the Baltic Sea to trigger more and sustainable growth in the marine and maritime sectors. The regions' officials could have done business as usual; but instead these six regions (all of them members of SUBMARINER) decided to take a more innovative approach: To use their Research and Innovation Smart Specialisation Strategy (RIS3) as a basis for creating a transnational innovation eco-system for blue growth by cooperating with their potential competitors (other regions at the Baltic Sea).

20.2 Projects

Smart Blue Regions (BSR INTERREG, 2016-2019)

wanted to generate "Blue Growth" for their regions. As innovative instrument for achieving this the public authorities had identified their newly elaborated RIS3 for setting the ground for the innovative and sustainable use of marine resources. They aimed to increase their capacity to implement specifically RIS3 targeting Blue Growth in order to trigger blue networks across the BSR that would ultimately benefit also the blue sectors in their specific regions.
SUBMARINERs: Ministry of Economic Affairs, Transport, Employment and Tourism Schleswig-Holstein, LIAE, MIG, Regional Council of Southwest Finland; Association of Local Authorities of Ida-Viru County, Riga Planning Region, Pomorske in the EU Association
Weblink: www.smartblueregions.eu

Land-Sea-Act (BSR INTERREG, 2019-2021)

aims at developing a multi-level governance agenda on blue growth and spatial planning in the Baltic Sea region that balances local communities' and small scale businesses' interests with large scale development and investment interests.
Weblink: https://land-sea.eu

Other projects in the Baltic Sea region dealing with Smart Specialisation (but not particularly blue economy):

BSR Stars S3

Stimulating smart specialization ecosystem through engaging SMEs in open innovation processes:
http://www.bsr-stars.eu/bsr-stars-s3/

EmpInno

S3-Empowering for Innovation and Growth in Medium-Sized Cities and Regions: https://old.empinno.eu/

LARS

Learning Among Regions on Smart Specialization : https://www.lars-project.eu

20.3 State of Play

The project Smart Blue Regions (SBR), completed in 2019, triggered important changes in the six involved regions:

1. The Riga Planning Region developed a strategy for blue growth smart specialization – the Maritime and Coastal Smart Specialization Strategy (MCSSS) for the Riga Planning Region.
2. In Southwest Finland the internal Plan for "Blue Growth" RIS3 implementation was developed jointly with regional stakeholders.
3. The process of advancing blue growth in Ida-Viru region was focused on revising the "Regional Development Strategy 2019-2030" e.g. by the establishment of a 2.5 km2 business park suitable for aquaculture production and the development of a small harbour network.

4. In Skane the international innovation strategy was updated in 2018 / 2019 with significant input from the SBR project.
5. In Pomorskie two companies developed through the project the idea for "A multi rotor system for offshore wind turbines" and identified international partners to build the prototype.
6. In Schleswig-Holstein the monitoring system for blue growth was introduced and tested.

On the transnational level the project partners fed the results and outcomes of the SBR project into the SUBMARINER network, which they use as a hub for projects, initiatives and activities in the field of blue growth. The project documented how RIS3 is being implemented in the partners regions (what are the different administrative layers / organizations involved) and pointed out some lacks and possible improvements in the different partner regions. A comparative analysis of the governance, the functional processes and the implementation systems in the regions has been made, in order to inspire some good practices also beyond the cooperation area.

RIS3 will continue to be an important policy instrument for regions also in the new programming period 2021-2027. As innovative and sustainable uses of marine resources often go hand-in-hand with long and complex value chains the transnational networking is a pre-requisite for achieving blue growth. SBR has shown that RIS3 can play a pivotal role in this process.

SBR cooperated closely with the "MA Network" in the BSR. While the MA Network wants to make regional mainstream ERDF funding also available for transnational activities, the SBR project demonstrated approaches for developing specific targeted cooperation in the field of blue growth; filling administrative change with entrepreneurial life.

The project also produced maps of blue growth focus areas according to the respective RIS3 documents in the whole BSR. It also mapped different groups of blue growth actors (BSOs, universities, and research institutes) in every region of the BSR.

20.4 Conclusions and Recommendations

The lessons learned from the Smart Blue Regions project include the following recommendations:

- Working with RIS3 should include a **broad and frequent dialogue with stakeholders**. It is a challenge to get more ownership and cooperation. We need **stronger legitimacy of both RIS3 and blue RIS3, especially in the business world**. Identifying priority areas, as well as methods to enhance growth, benefits from having a "bottom-up" approach. The companies create the growth. If they are not heavily involved and do not understand and accept the benefits of RIS3, the whole RIS3-ambition will only be a bureaucratic exercise.

- The concept of RIS3 and Blue Growth should be more well-known, understood and accepted amongst stakeholders. Blue Growth, particularly, is often not known, either in the business world or among regional planners It is necessary to **spread the message of what benefits RIS3 and Blue Growth strategies are intended to accomplish for regional development**.

- RIS3 should be living documents with the possibility to adapt to changing circumstances during the planning period, to ensure that the strategies are kept alive and updated. The **RIS3 implementation should be made more flexible during its 7-year implementation**. Acknowledge that changes will occur during such a long period.

- **Clusters are crucial, and their role should be further developed**. They should be an arena for regional cooperation, as well as for the exchange and development of knowledge. They should aim to match businesses with each other, as well as match business and research. They should be a forum where public and private money converge for the same goal. All these require further developed methods of working, both within clusters and together with other sectors.

- More resources should be dedicated to interregional collaboration, as well as international collaboration. The RIS3 process should promote transnational cooperation within the EU as there are many lessons to learn from one another. Partners noticed that the same difficulties occur in each region, such as the challenge of involving stakeholders, and that there is a need to improve the methods and measures used by working groups and clusters for business development, to be more beneficial for the stakeholders. At the same time innovative and sustainable uses of marine resources require an intensified transnational cooperation between enterprises in order to make blue growth happen.

- Use RIS3 to strengthen and broaden the support structure for innovation. Traditionally, many regions have experienced close cooperation between certain parts of industry and the academic world, such as between pharmaceutical, automotive industries and the ICT sector. However, to enhance Blue Growth, other sectors and small and medium-sized enterprises need more active cooperation with the research sector to strengthen their innovation capacity. **New methods that focus on strengthening innovation capacity within industries connected to the blue sector and cooperation between large and small companies within the blue industries play a crucial role**.

20.5 Next Steps

Even though coastal sub-regions and municipalities play a role in all SUBMARINER projects, a dedicated working group of 'Blue Regions' has not evolved out of the SmartBlueRegions project under the SUBMARINER network roof. The SUBMARINER networks secretariat was not eligible to be partner in the Smart Specialization Platform project as it had not been directly been part of SmartBlueRegions; and none of the participating regions wanted to participate.

Cooperation of regions is continued instead under the CPMR Baltic Sea Commission – and here specifically the working group on 'Maritime Affairs'. So far, however, almost no region from Poland and the Baltic States is member of the CPMR. At same time separate networks of regions continue to be created on 'project basis' e.g. around the South or Central Baltic (due to the related INTERREG funding schemes). Examples are the regional networks of 'CONTRA', Coastal BioGas or AquaVIP. In no case these regional networks are linked to RIS3 strategies; but rather around specific blue bio economy activities.

As regions and their blue clusters play a crucial role in the actual implementation / realization of the ambitions voiced by the SUBMARINER network, we advocate for the following future actions:

- **Revive the close connection to the CPMR Baltic Sea Commission** and jointly identify activities to be taken on board, by regions as part of the new SUBMARINER roadmap
- **Offer 'project related' regional networks** (e.g. interested in view of use of beach-wrack/CONTRA or promotion of coastal biogas/Coastal Biogas) **the SUBMARINER Network as their 'roof' post-project time** as to continue their cooperation and better link to other related blue bioeconomy initiatives
- **Strengthen collaboration of regions at 'blue' cluster level**; esp. by developing an application under currently COSME Cluster call

21 Ocean Literacy

21.1 Ambition

The topics of ocean pollution and biodiversity loss have in recent years gained attention and made the transition from scientific to public concern. Not least due to the active campaigning of many individuals and organisations, this has enabled the entrenchment of "blue" environmental topics on the political agenda. Policy actors from the European Commission to local authorities have formulated and begun to implement plastics prevention strategies and more policy mechanisms are focusing on circularity and sustainability. It is important to build on this momentum and capture the imagination of millions of citizens (and consumers) across Europe and beyond – specifically promote the health of the world ocean.

To this end, awareness raising in general has been succeeded by "Ocean Literacy" (OL) as the newer, more concise and focused approach to the task at hand. As the invaluable role of the oceans for the health of our planet and its population is becoming more and more recognised, more people are becoming aware of the specific importance of the oceans, the cumulative effects of individual actions and the iterative nature of this relationship. The concept of Ocean Literacy aims to increase this awareness and understanding of the relationship between people and the ocean and goes one step further. It aims to provide the tools, methods and approaches for taking action – not only in a formal educational context, but also targeting society as a whole.

What is Ocean Literacy?

Ocean Literacy is defined as an understanding of the ocean's influence on you, and your influence on the ocean. Ocean literacy is a way not only to increase the awareness of the public about the ocean, but it is a way to encourage all citizens and stakeholders to have a more responsible and informed behaviour towards the ocean and its resources.

Source: Unesco International Oceanographic Committee, Ocean Literacy Portal

Why Transversal Action Field?

Promoting a good level of ocean literacy among the general population (through the use of differentiated target groups) is actually integral to achieving the declared goals and ongoing activities of SUBMARINER Network.

- Better awareness of "How we affect the ocean and the ocean affects us" among the general population (with a non-exclusive emphasis on the younger generations) will help to establish the link to consumption behaviour and the need for and value of sustainable uses of marine resource in relation to consumer goods (blue biotech, food and beyond).

- Raising OL amongst policy makers that are not already concerned with marine and maritime topics helps to put our topics on the political agenda and bridge the science-policy gap. The emphasis here is on the interconnection between land-based events and their consequences for the ocean.

- Increased OL (backed by the efforts at EU level) should also encourage our topics to be higher up the funding priorities at sea basin level.

- OL among the parallel target groups of school pupils and young adults is also a key to raising awareness of and enthusiasm for the green-blue economy and job market

21.2 State of Play

Ocean Literacy is a hot topic and worldwide many initiatives are already in existence, including numerous projects, the recently launched EU4Oceans coalition (see below), as well as the IOC Ocean Literacy Portal and online Toolkit. It is an approach set to be promoted during the United Nations Decade of Ocean Science for Sustainable Development. As such, this is a very fitting time for our Network and its members to solidify and intensify our actions in this field.

As shown in the previous chapter, the concept of awareness raising for ocean-related issues has long been established and indeed a part of many of Submariner members' activities. For example: our members' work to achieve recognition of ecosystem services and compensation measures and to get policy support for public funding in these.

At a grassroots level, there is a huge amount of activity in Ocean Literacy across the Baltic, within our membership and beyond. An initial, non-exhaustive mapping of OL activities (conducted by our Network's founding member s.Pro within the EU4Ocean coalition) found 78 organisations and projects already active in the topic. A topical leader in the field is SUBMARINER Network member University of Gothenburg, with its Centre for Sea and Society. Furthermore, OL as a topic features prominently in the SUBMARINER-backed projects Blue Platform, Blue Generation and Ocean Blues.

21.3 Ocean Literacy projects with SUBMARINER involvement

EU4Ocean coalition (DG MARE, 2020-2023)

The coalition is an EU-wide initiative to promote ocean literacy by enabling exchange and connecting actors. Thematically, it looks into ocean literacy around the topics of:

- Climate and ocean
- Food from the ocean
- Healthy and clean ocean

It is structured into an online platform with diverse membership, a youth platform for 16-30 year-old ocean activists and an initiative to build a Blue Schools network.

SUBMARINER Network's founding member s.Pro is subcontracted in this project as the organisational focal point for the Baltic Sea region. In this capacity, s.Pro has involved the Network in the ocean literacy stakeholder mapping and activation. In 2021 there will be a sea basin event, uniting all the ocean literacy stakeholders across the Baltic.

Blue Platform

Submariner's platform project spans the entirety of the blue bioeconomy in the Baltic. A strong emphasis is placed on connection and communication. Its online hub (hosted on the Submariner website) provides an entry point to information not only for existing blue bioeconomy professionals but also to those looking for more information on "Career, Youth and Ocean Literacy". The planned conference "Better off Blue 2.0" in 2021 will involve ocean literacy as a transversal theme throughout its programme.

Blue Generation and Ocean Blues

The objective of the Blue Generation Project is to inspire and engage young people between 15 and 29 years to pursue a sustainable career in a Blue Economy sector. Submariner Network is one of the project's five Expert Partners, working closely with the six Beneficiary Partners to bring more opportunities closer to home. Submariner member University of Gothenburg's Ocean Blues project makes another case for the benefits of ocean literacy, especially among the younger target groups. With its action-oriented formulation of educational materials, OL is a key tool in countering the feeling of impotence and futility that many people (especially the younger generations) feel in light of the seemingly intractable climate crisis. It's community-building connectivity can have positive effects both individually and collectively.

21.4 Ocean literacy in schools

A key action point for the spread and long-term success of ocean literacy is its entrenchment in schools. Not only in the science curriculum but again as a transversal theme of knowledge, ocean literacy needs to "arrive" in schools. The Portuguese Ministry of the Sea runs a programme called "Escola Azul" (Blue School), which "distinguishes and guides the schools that work on Ocean Literacy, creating an Ocean Literacy community that brings together schools, the sea sector, municipalities and other entities with an active role in marine education."

Based on the Portuguese example, the SUBMARINER Network and its partners have been working on an initiative to promote the Blue Schools idea in the Baltic. So far, the funding has unfortunately not been granted but this remains a priority within the OL action field for this Roadmap (see recommendations below).

21.5 Recommendations

As outlined above, this is the first time Ocean Literacy is being included in the SUBMARINER Roadmap as a transversal action field in its own right. The following recommendation represent a starting point and are open to revision.

The meeting of existing OL stakeholders across the Baltic in the framework of the EU4Ocean launch event in September 2020 resulted in some reinforced key messages:

- The **need for interdisciplinary work to really drive OL forward**: exchange between scientists (primary researchers) and educational professionals on the one hand, but also bringing in the expertise of marketing and campaigning experts, public authorities, NGOs and more.
- The two sides of the OL coin: better and enhanced knowledge, but also a stronger sense of emotional connection to the ocean.
- Making visible that the Baltic Sea (and the global ocean) is not a separate entity to the rest of our daily concerns, even in the realm of environmentalism. The **strong connections between land and sea issues** must be central to OL activities.

Using its involvement in the EU4Ocean coalition, SUBMARINER Network has initiated the informal Baltic Sea working group on ocean literacy. This is an open group, with initial membership of representatives from 18 organisations both within the SUBMARINER Network membership (SYKE, GEOMAR, University of Gothenburg a.o.) and beyond (CBSS, BONUS, Nordic Council a.o.). Our recommendations for actions are the result of discussions with the working group as well as consultation with the wider community of actors.

Use SUBMARINER's position as an information hub for blue bioeconomy to enhance the visibility of Ocean Literacy and its integration into existing awareness raising activities.

- Establish a library of existing ocean literacy material (with a Baltic focus) to be hosted on the Blue Platform website, categorised by material format and target group.
- Develop a network with twin emphases on education centres (incl. museums and aquaria) with their primary research supporters on the one hand and schools and supporting organisations on the other. This will be coordinated by our OL partners Gdynia Aquarium and European Association of Marine Science Educators.

Work on a unified approach targeting consumers as a key group for the promotion of ocean literacy.

We want to work with NGOs and retailers among others to achieve this. A project under the "Farm to Fork" section of the European Green Deal call of Horizon 2020 has been submitted, targeting the promotion of sustainable marine foods, particularly among vulnerable groups. If funded, this would provide the starting point for work in close collaboration with major retailers and direct promotional work.

Involve the media and arts sector

We recommend a strong emphasis on cross-disciplinary engagement in OL, starting with the **involvement of the media and arts sector** to reach out and bring in the target groups that are not already aware and interested. This should be reflected in the eligibility criteria and priorities setting of the programming bodies in a position to promote this approach on a national, sea basin and European level.

Work towards a European "blue food movement" (closely related to recommendation #3).

This is a way of connecting OL to established efforts in citizen science and a starting point with an obvious, engaging and practical application. Many resources such as handbooks on sustainable fish consumption with a seasonal and local variation already exist but would benefit from collective presentation. We also recommend working with e.g. aquaculture associations in order to expand the perception of sustainable consumption here, and to go beyond fish to include all ocean-resource based consumer food products (especially with a view to the growing importance of seaweed farming for the Baltic).

Integrate Ocean literacy into the funding logic of programmes

In order to achieve these strategic actions, it is essential that ocean literacy (even as a facet of citizen science more generally) becomes integrated into the funding logic of programmes throughout the Baltic and beyond. This includes both research-oriented programmes as well as those aimed at broader collaboration and regional integration.

We recommend two essential aspects:

- Adopt OL as a concern in the evaluation criteria for proposed projects' communication and exploitation activities. There has already been an ongoing effort to integrate communication efforts transversally across project activities and the same logic should apply to ocean literacy as a key component of communication goals.
- A very effective way of promoting the application of citizen science and ocean literacy would be for funding bodies to create a dedicated Coordinating and Support Action for this field. This would enable the better support of cross-sectoral efforts connecting e.g. skills development in businesses, public authorities, schools and individual contributors.

22 Restore biodiversity and ecosystem services

22.1 Ambition

Protecting and restoring the integrity of Baltic coastal ecosystems and their capacity to deliver a wide range of essential ecosystem services, thus putting Europe's/Baltic Sea biodiversity on the path to recovery by 2030 as required by the EU Biodiversity Strategy is fundamental to achieving the European Green Deal objectives. Avoiding loss of biodiversity has also the potential to help avoid threats to human health in the future.

What is Ecosystem Restoration / Conservation ?

Restoration is the support to the recovery process of ecosystems degraded by anthropogenic disturbances towards a dynamic stable state, aiming at either the return of habitats to a natural state (re-wilding) or a state similar but not the same to the state existing before restoration. Both 'active' restoration (implying pro-active action of humans, often through some kind of ecological engineering) and 'passive' restoration (halting/decreasing pressures on the ecosystems and letting the natural dynamics of biodiversity do the job) are considered

Conservation means ensuring that the arrays of ecosystems are maintained, and that species, populations, genes, the complex interactions between them as their evolutionary potential, persist into the future, considering the intrinsic value of biodiversity and maintaining its potential to meet the needs and aspirations of future human generations[1]

The continued degradation of the coastal ecosystems and their services affects biodiversity, climate change, and enhance the risk of severe ecological disasters and pandemics. The European Green Deal and its Biodiversity Strategy request **urgent restoration efforts for damaged coastal ecosystems** to increase biodiversity and deliver a wide range of ecosystem services:

- Biodiversity in Baltic as part of Europe should be back on a path of **recovery by 2030**; ecosystems and their services are preserved and sustainably restored at coasts and the sea through improved knowledge and innovation.
- Assessment, valuation and trends of natural capital and ecosystems services, including socio-economic benefits, should be **integrated into decision making in policy and businesses**; policy maker get expert support to determine how to prioritise and deliver ecosystem restoration at scale throughout Europe; science base is provided for planning and increasing protected areas, maritime spatial planning and MPAs design with ad hoc flexible ecosystem based management.

Why a Transversal Action Field?

Many of the SUBMARINER topics and actions support biodiversity and ecosystem restoration. So far, however, we have not explicitly framed them around this specific goal. Hence, **SUBMARINER will establish 'Marine Biodiversity and Ecosystem Restoration' as a new transversal focus area for strategic actions.**

R&I in the SUBMARINER Network will address the multiple challenges in this area, including by enabling transformative changes and develop a **long-term strategic research agenda for Baltic biodiversity**:

- **Understanding biodiversity decline and addressing its main drivers** through data-driven science, integrated multidisciplinary knowledge, new tools, models and scenarios, will support Europe's policy needs and boost global biodiversity science.
- **Develop tools** to guide decisions, inform and implement policies on environment, water, health, climate, disaster risk reduction, coasts, protected areas management, bio-economy, blue economy, marine spatial planning, and responsible business practices.
- **Consult local and regional company clusters** (e.g. regional Blue Clusters) and identify key stakeholders in the field of innovation, restoration and conservation.
- **Through multi-actor labs** (interactive brainstorming sessions) promote the regional cooperation to boost innovation in the field of restoration approaches.

22.2 Projects / State of Play

Many Submariner members have past, on-going and future projects related to coastal ecosystem restoration.

NordSalt (Biodiversa H2020-ERA.NET 2021-2024)

will assess the extent and plant community biodiversity in Nordic Salt and coastal marshes and evaluate how these ecosystems provide climate and coastal protection related benefits to society (ecosystem services). The project has particular focus on carbon sequestration (so called « Blue Carbon ») and net greenhouse gas emissions (CO2 and methane). Furthermore, historical changes in the distribution of Nordic coastal marsh habitat types (ranging from salt marshes to salt meadows to reed beds) and associated changes in community biodiversity related to climatic and local pressures, including management practices such as grazing, will be assessed. The goal of this project is to assess the nature, diversity and extent of Nordic coastal marsh habitats, to evaluate their role in climate regulation (net greenhouse gas emissions and Blue Carbon storage) and to assess their vulnerability and change in ecological functions under future climate change scenarios, local environmental pressures and management decisions.
Submariner partners: SDU (DK), LUKE (FI)

Sund Vejle Fjord (with municipalities, SME's)

The multi-year project "Sund Vejle Fjord" aims to improve the environmental situation in Vejle Fjord. As part of the project, eelgrass will be planted and mussel banks will be built in the fjord, and to protect the eelgrass, stone reefs will be established and crabs will be fished up.

Gyldensteen Coastal Lagoon (Aage V Jensen Nature Foundation, Denmark).

Large scale restoration of 214 ha Gyldensteen Coastal Lagoon by managed realignment (coastal realignment – seagrass, stone reef & mussel restoration will happen in the next 5 years. Gyldensteen Coastal Lagoon was established in 2014 in Denmark by the deliberate breaching of dikes to allow the coastline to migrate landward and soils to be flooded. This bioengineering approach, also known as **managed realignment** or **coastal retreat**, flooded an area of 214 ha that was used for agricultural purposes since 1870. The goal of the project is to restore nature and form new coastal ecosystems, which have a potential high value for **marine biodiversity** and wildlife. Furthermore, CO_2 emissions are reduced and carbon is sequestrated when agricultural soils are flooded with seawater providing important climate mitigation measures. We have followed nutrient and carbon pools, green-house gases and succession of macrophytes, benthic fauna and documented the presence of birds. We found that particle resuspension from the previous agricultural soils has consequences for the development of benthic fauna communities and blue mussel beds. Currently, we are working on implementing additional restoration interventions to hinder the particle resuspension and boost biodiversity. These include 1-2 ha size restoration by sand-capping of the soils, seagrass transplantation and establishment of stone reefs. SDU will monitor light improvement, and overall impact on flora and fauna biodiversity, small fish and bird life.

Reelgrass, Danish Research Foundation

Investigation of environmental stressors for eelgrass recovery

22.3 Recommendations and Next Steps

The SUBMARINER Network secretariat has taken the role to coordinate and synthesize the formation of an Ecosystem Restoration Working Group.

SUBMARINER will screen, facilitate and develop a series of actions and proposal to address the upcoming opportunities (such as BSR Interreg, BANOS, HEU). In addition, the SUBMARINER Network is about to seek stronger contacts to alliances active in restoration like NORA (Native Oyster Restoration Alliance) or NEAMO (North Atlantic & European Shellfish Centre).

Restores Project (Horizon Green Deal)

A project under the "Restoring biodiversity" section of the European Green Deal is currently under development, targeting the transformational change by helping policy makers and restoration practitioners to identify gaps, opportunities and potential partnerships and to upscale processes to marine regions and across gradients.

The following next steps represent a starting point and are open to revision.

1. Mapping of:
    - Competences of SUBMARINER members
    - possible collaborators & stakeholders (field & topic specific)
    - focus areas (differentiated fields/networks)
    - events (where do we have to be / where could we be)
2. Organize seminars / workshops (all thematic): **Connect the ecosystem restoration community with relevant players in policy and the industry**
3. Coordinate **policy information** and activities: Take a collective and coordinated approach towards lobbying for changes in legislation and funding programmes
4. **Intensify collaboration with NGOs and LIFE project owners** to establish or strengthen networks and promote restoration processes stepping upon existing work
5. Widen the scope of the SUBMARINER WG on restoration biodiversity, so that it is more in line with currently popular wider **concepts such as "climate change mitigation" / "environmental protection services" / "multi-use".** This would allow for the easier linking and promoting exchange among different interests within the Network.
6. The topic should be framed as to **provide better help directly to municipalities**. It is suggested to start an exchange of ideas with on-going LIFE project on restoration to exchange approaches – such as allowing a converted areas to recover, removing human pressures, controlling invasive species, allowing wetlands to get flooded regularly, or reintroducing habitats that were formerly present. It could also broaden the networks on local and regional levels with people who experience the benefits of functioning ecosystems, with minimal management.