Baltic and North Sea Coordination and Support Action

The Baltic and North Sea Strategic Research and Innovation Agenda (BANOS SRIA)

A DRAFT version, 28 February 2020

Prepared for the participants of the BANOS SOW,

31 March-2 April 2020, Leiden, The Netherlands

Contents

1 Introduction

This DRAFT Strategic Research and Innovation Agenda (SRIA) has been prepared in the run-up to the Strategic Orientation Workshop (SOW) organized by the Baltic and North Sea Coordination and Support Action (BANOS CSA[1]) on 31 March – 2 April 2020 in Leiden, The Netherlands to serve foremost achieving the aims set for the SOW.

The defined scope of the future Baltic and North Sea Research and Innovation Programme (BANOS), as planned in the BANOS CSA, together with the mapped national and transnational research and innovation priorities form the backbone of the SRIA and encompasses three strategic objectives:

- Strategic Objective A: Healthy Seas and Coasts
- Strategic Objective B: Sustainable Blue Economy
- Strategic Objective C: Human Wellbeing

A precondition for achieving these objectives, as well as the nine specific objectives and a core of 31 research and innovation themes grouped under these objectives, is the ecosystem-based management approach. In addition, three attributes describing the scope of BANOS include 1) the close connection to the ecosystem, 2) dependence on climate impact and 3) geographic relevance to the Baltic Sea and North Sea regions.

The BANOS SRIA drafting team, consisting of 27 marine experts, have coordinated and prepared the thematic parts of the SRIA under the three strategic objectives together with the BANOS CSA coordination team, BONUS EEIG. The interdisciplinary drafting team members have contributed to the SRIA draft development for SOW according to their respective spheres of expertise and competences ranging from sustainable ecosystem management approaches and land-sea interconnections to development of new blue innovation and marine social economics. All parts of the SRIA are prepared with the key aim of the future BANOS programme in mind, which is, once launched, to satisfy knowledge needs for the coming decade and beyond.

The overall objective of the SOW, and the overall task of its ca. 100 invited participants, is to scrutinize the draft SRIA and agree in direct, face-to-face interactions over the 3 days on the final structure, content and expected outcomes under different objectives and research and innovation themes included in this DRAFT SRIA.

The section **2. Policy setting and dynamics** outlines the current policy landscape as the undercurrent of the SRIA, and briefly discusses the key policies related to (i) protection of the marine environment, (ii) climate change, and (iii) the sustainable blue growth agenda. In addition, also (iv) important initiatives overarching multiple policy domains are discussed. *This part will be introduced during the opening plenary of SOW on 31 March (15:00-18:00), when comments and discussion will be welcomed (see participants' instructions and the SOW agenda).*

The section **3. BANOS research and innovation objectives and themes** outlines the three strategic objectives and the respective specific objectives, and research and innovation themes grouped under these objectives. For each specific objective are detailed the 'Overall rationale', 'State of the Art and knowledge gaps', 'Impact and linkages' and for each R&I theme separately both 'State of the Art and knowledge gaps' and 'Expected outcomes'. Each of these have been written based on the following instructions provided:

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[1] To learn more about the BANOS CSA, its set-up and aims, including the establishing of the framework for the future Baltic and North Sea Research and Innovation Programme (BANOS), visit www.banoscsa.org

- **Overall rationale.** Brief justification of inclusion of the research themes related to this objective. Where appropriate, the distinction between the Baltic Sea and North Sea or, opposite, a necessity of combined/comparative studies shall be pointed out.
- **State of the art and knowledge gaps.** A brief overview of what we know and what are the knowledge gaps the future programme must fill in. It is important to cover all R&I themes included under the respective objective. References justifying each statement herein are not mandatory, but can be included if authors deem it useful, e.g. significant review studies.
- **Impact and linkages.** An overview of practical impacts delivered by R&I in this part of the future programme. If relevant, linkages and interdependencies with other parts of the programme.
- **Expected outcomes.** (max 1p of bulleted text, 0,5 is optimal) This chapter clearly provides the expected outcomes of R&I supported by the future programme. Formulations must be such as allowing readily inclusion in the call texts. Number of bullets and level of generalization shall allow covering of all expected outcomes by one or (as an exception) a limited number of R&I projects. In effect, this is the most important part as it serves as a reference for both the applicants, the proposal evaluation experts and as well the officers in charge of implementation of the projects and the whole programme. Eventually, these lists of expected outcomes will serve as a checklist for assessment of programme's achievement. Where appropriate, the distinction between the Baltic Sea and the North Sea shall be pointed out.

The group work sessions on 1 April 2020 will scrutinize all respective themes under each of the three objectives in a structured manner (i.e. see the moderators' work sheet, participants' guidance, the SOW agenda), and the outcomes of the group work will be brought to the final plenary on 2 April 2020 for a consensus sign-off.

The section **4. Impact enablers** outlines the key enablers of impact in BANOS, with which the future programme can move forward from establishing the SRIA to unlock its – and the future BANOS programme's as a whole – added value it aspires to create at regional, European and global levels. Outlined are communications, R&I impact monitoring, knowledge synthesis, collaboration across funding streams, human capacity development, open science, open data, citizen science, open innovation and R&I cooperation across the regional seas that ultimately all contribute to creating impact in the policy landscape in which BANOS will operate while supporting the ecosystem approach and long-term sustainability action particularly in the Baltic Sea and North Sea regions. The eventual implementation plan of the future BANOS programme will encompass all these enablers in detail. *This part of SRIA will be briefly introduced during the opening session on 31 March (15:00-18:00) and discussion related invited.*

The section **5. References** include these as available at the time of distributing this document (28 February 2020). *All involved are invited to ensure that the required references are communicated to the coordination team in the run-up to, and at the latest, during the SOW.*

The section **6. Some abbreviations** lists abbreviations commonly used in the following pages. (A full glossary will be compiled later for the final, publishable BANOS SRIA.) *All involved are invited to use this list as their reference point as and when found helpful.*

Finally, after incorporating the SOW contributions[2] to the BANOS SRIA, it will be published by the end of 2020/early 2021. Also, from thereon, it will maintain the character of a 'living document' entailing regular updates driven by the challenging and dynamic policy landscape and scientific and eco-technological advances of the years to come.

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[2] The SOW contributions will entail the substance related amendments and modifications to the SRIA content (based on materials prepared for the SOW). At SOW, input is not expected to any editorial, layout or other form matters related to the preparation of SRIA for publishing (by when included will be also the currently pending preface, executive summary, full glossary etc.). These will be addressed in detail later.

2 Policy setting and dynamics

The geographical scope of BANOS, as planned in BANOS CSA, includes 11 EU Member States of Belgium, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, the Netherlands, Poland, Sweden and Associate Member States of Norway, Russia and the United Kingdom. As such, the policy landscape of the Baltic Sea and North Sea regions reflects dynamic global, European and regional initiatives. Details of 14 key policies with high relevance to the Baltic Sea and North Sea are given in BOX 1. However, it should be highlighted that many more relevant policies exist and, for the Baltic Sea only, over 80 initiatives have been previously identified. Below, the current policy landscape is briefly discussed in respect to (i) protection of the marine environment, (ii) climate change, and (iii) the sustainable blue growth agenda. In addition, (iv) important initiatives overarching multiple policy domains are also discussed.

2.1 Protection of the marine environment

The Baltic Sea region has a long history of collaboration among the coastal states aiming to protect the marine environment and assure the sustainable use of the regional sea. In 1974, the Baltic coastal countries signed the Convention on the Protection of the Environment of the Baltic Sea Area (Helsinki Convention), the first single convention of its kind embracing the whole sea and addressing multiple pollution threats. Fifteen years later in 1992, an ambitious step was taken to protect the marine area further and a collective action plan was established. The Baltic Sea Action Plan (BSAP), implemented by the Baltic Marine Environment Protection Commission (HELCOM) includes the identification of measurable objectives to restore the good environmental status in the Baltic Sea by 2021.

In the North Sea region, the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) was signed at the Ministerial Meeting of the Oslo and Paris Commissions in Paris on 22 September 1992. Like the Helsinki Convention, the OSPAR Convention focusses on prevention and elimination of all types of pollution in the North East Atlantic (including the North Sea), protection and conservation on its marine ecosystems and biodiversity, and assessment of the quality of the marine environment. Currently OSPAR implements the strategy of the Protection of the Marine Environment of the North-East Atlantic 2010–2020.

The EU Marine Strategy Framework Directive (MSFD), which sets an ambitious policy goal to achieve a good environmental status (GES) of the European seas by 2020, was adopted in 2008. Unfortunately, GES is unlikely to be achieved on time and much of collective effort is still needed from the Member States. The MSDF also shares many mutual goals with the Russian Maritime Doctrine (applicable to the Baltic Sea) as well as with the recently published UK Marine Strategy with a focus on an assessment and achieving GES. The future BANOS programme aims to become the major provider of knowledge underpinning the policy measures for achieving GES in the Baltic Sea and North Sea area.

Other highly relevant policies with a focus on preserving and protecting the marine ecosystems, including its biodiversity and the environment, include the EU Common Fisheries Policy (CFP) and the EU Biodiversity Strategy (BdS). The EU policy on biodiversity is also well aligned with the global Convention on Biological Diversity (CBD).

2.2 The climate change agenda

Climate change is directly linked to seas and oceans via their role climate regulation and in absorption of heat and carbon dioxide. The regional coastal seas are also likely to play a key role in respect to climate change mitigations, including protection from storms and sea level rise and prevention of shoreline erosion. Coastal seas and associated habitats are also important sinks of ’blue carbon’, a process which leads to removal of carbon from the atmosphere, locking it for long-term storage in the seafloor sediments.

The political climate change agenda has evolved rapidly since 2016 when the Paris Climate Agreement (PCA), aiming at limiting the global temperature rise below 2 degrees Celsius compared to pre-industrial levels, was initially agreed on. Later in 2019, the agreement was ratified by 185 countries. The PCA is also closely related to many of the European climate policies, including the Long-term 2050 Strategy aiming to reduce European greenhouse gas emissions progressively until 2050. In the UK, the Net Zero Carbon Emissions Bill is currently under development, which similarly aims to achieve net-zero carbon emissions by 2050 in the UK.

Being a central overarching topic of the BANOS SRIA, climate change and its impacts on marine environment, biodiversity and resilience as well as human wellbeing will be covered and incorporated into many of the research and innovation themes. As such, BANOS aims to significantly contribute towards reaching the European and global climate targets.

2.3 Sustainable blue growth agenda and circular economy

Since the establishment of the EU Blue Growth Strategy (BGS) in 2012, increasing emphasis is put on the role of seas and oceans in the future European economy. To name a few, the offshore wind energy production is expected to increase dramatically in the North Sea in the coming decades and expansion is also expected in the Baltic Sea, although at somewhat smaller scale. The expansions of offshore wind will put pressure on the marine ecosystems and many of its effects are not yet fully understood. The role of the coastal sea as a provider of high-quality sustainable protein is also expected to increase, thus putting additional pressure on the regional fish populations.

The BANOS CSA plan of action is designed to build a programme that is fully aligned and significantly contributes to the development of the BGS. Concentrating on the issues of sustainability of the marine ecosystem services to society, it emphasizes the integral long-term sustainability requirement underlaying any development of the 'blue' economy. The plan intends to contribute to all components of BGS including: high-potential sectors such as aquaculture, fisheries, coastal tourism, biotechnology and ocean energy; essential components such as marine knowledge and maritime spatial planning; and sea basin strategies in two out of seven listed maritime areas. One of the three strategic objectives of BANOS specifically addresses the issues of sustainable blue economy.

The BGS is also intertwined to recent developments in policies related to the circular economy, e.g. the Circular Economy Action Plan (CEAP), which aim to stimulate Europe's transition towards circular economy, enhance its global competitiveness, foster sustainable economic growth and generate new jobs. Since possibilities of the circular economy are not restricted to land but extend to the European seas, the policy directly relates to BANOS and many of its stakeholders. Circular solutions are needed across industries to implement the BGS. For example, coastal seas provide a source of food production and its demand is expected to increase in future. To meet this demand, circular solutions are needed to reduce seafood and feed waste and to preserve marine resources. In addition, better recycling practices can help to tackle issues associated with marine litter.

2.4 Overarching policies

Five important overarching policies, which cover two or more of the policy areas discussed above, are directly related to the BANOS SRIA and its objectives. Of the five, two are closely connected with global policies, i.e. the United Nations Sustainable Development Goals (SDGs) and the United Nations Decade of Ocean Science for Sustainable Development (Ocean Decade), and three are European policies, i.e. the European Green Deal (EGD), EU Directive on Maritime Spatial Planning (MSPD) and EU Integrated Maritime Policy (IMP).

The SDGs are the universal call for action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere. Many of the goals are strongly interlinked. Achieving one will often support another. The most important goal, in respect to BANOS, is Goal 14 – Life Below Water. In addition, other goals including Goal 3 – Good Health and Wellbeing, Goal 4 – Quality Education, Goal 7 – Affordable and Clean Energy, Goal 9 – Industry, Innovation and Infrastructure, Goal 12 – Responsible Consumption and Production, Goal 13 – Climate Action and Goal 15 – Life on Land, can be directly linked to the BANOS SRIA and its objectives. In total, 17 goals have been adopted in a global partnership to tackle the growing inequalities, empower women and girls, and address the climate emergency.

The objectives of the Ocean Decade are closely linked with the SDGs. The Decade (2021-2030) aims to deliver science for the future we want, thus providing a unifying framework across the countries to achieve their ocean related Agenda 2030 and the associated SDGs.

The EGD is the most recent addition to the European policy landscape. It is closely linked to the European Climate Agenda aiming to make Europe the first carbon-neutral continent by 2050. It also supports the sustainable blue growth via development of green technology, circular economy and clean renewable energy production, while taking care that the natural biodiversity is maintained and protected. In the global policy context, it is also closely associated with many of the SDGs. Due to the all-inclusive nature of the policy, it is linked with all three strategic objectives of BANOS, including the Healthy Seas and Coast, Sustainable Blue Economy and Human Wellbeing. The future development of this policy will be closely followed.

In the context of blue growth and marine protection, Maritime Spatial Planning (MSP) is becoming increasingly important as multiple stakeholders are involved in using the marine resources, all with vested interest in marine space at its broadest spectrum. This includes fisheries and aquaculture, the energy sector, maritime transport, tourism, recreational use, and conservation, protection and improvement of the environment and nature. To ensure that the Member States are able to deliver on their marine spatial plans, due by the end of 2021, and subsequently achieve them, new maritime implementation strategies are crucially needed. Some of the R&I themes in the BANOS SRIA are set to assist the successful implementation process, including developing multi-stakeholder approaches of using and sharing marine space and infrastructure, and providing new solutions for ocean governance.

The EU IMP seeks to provide a holistic approach on the cross-coordination of different marine and maritime policies, including aspects of blue growth, maritime spatial planning, maritime data, knowledge and surveillance, and sea basin strategies. Development of new marine and maritime governance structures and maritime spatial planning are strongly represented in the BANOS SRIA. In addition, the European regional seas cooperation is likely to develop further in the coming decade and various commitment strategies of the collaboration efforts are currently being developed.

2.5 Alignment of BANOS objectives to current policy landscape

The future BANOS programme and its SRIA are fully aligned with the current regional, European and global policy landscape. The three BANOS strategic objectives, including Healthy Seas and Coast, Sustainable Blue Economy and Human Wellbeing, all have strong emphasis on the integral long-term sustainability and resilience of the marine ecosystem and its biodiversity, including the development of ecosystem-based management approaches. In addition, the programme intends to contribute to all components of the BGS, i.e. the high-potential sectors such as aquaculture, coastal tourism, biotechnology and ocean energy; the essential components such as marine knowledge and maritime spatial planning and sea basin strategies in two out of seven listed maritime areas. The programme will also commit to combatting climate change, thus contributing towards the goals of the EGD, by getting involved in the development of a carbon-neutral renewable energy sector and by understanding the role of seas and ocean as natural climate change mitigators. In addition, new circular solutions, for example in the aquaculture sector, will be developed. The potential threats posed by climate change to the human wellbeing, including sea level rise and securing safe food and feed supply, are also addressed.

BOX 1 Key policies and initiatives with high relevance to the Baltic and North Sea

Regional Policies

HELCOM Baltic Sea Action Plan

The HELCOM Baltic Sea Action Plan (BSAP) was adopted by all the Baltic Sea coastal states and the EU in 2007. It is an ambitious programme to restore the good ecological status of the Baltic marine environment by 2021 while supporting a wide range of sustainable human economic and social activities.

The BSAP has four main goals:

- Baltic Sea unaffected by eutrophication
- Favorable status of Baltic Sea biodiversity
- Baltic Sea undisturbed by hazardous substances
- Environmentally friendly maritime activities

The BSAP is most recently endorsed by a declaration of the Ministers of the Environment of the Baltic Coastal Countries and the EU Environment Commissioner (HELCOM Copenhagen Declaration 2013)

Links to other policies: MSDF, OSPAR NEAES, CFP, EGD, BdS, MSP, SDGs, CBD

OSPAR North-East Atlantic Environment Strategy

The OSPAR North-East Atlantic Environment Strategy (NEAES) was adopted in 2010 and it extends until end of 2020. The core of the strategy is centered around the implementation of the ecosystem approach (EA). In this respect a suite of five thematic strategies to address the main threats in the region have been identified.

- Biodiversity and Ecosystem Strategy
- Eutrophication Strategy
- Hazardous substances Strategy
- Offshore Oil and Gas Industry Strategy
- Radioactive Substances Strategy

In addition, Joint Assessment and Monitoring Programme is included to enhance the assessment of the status of the marine environment. the results of assessments are used to follow up implementation of the strategies and the resulting benefits to the marine environment.

Climate change issues are also included within the strategies' wider context.

Links to other policies: BSAP, MSDF, CFP, EGD, BdS, MSP, SDGs, CDB

European Policies

Blue Growth Strategy

The Blue Growth Strategy (BGS), established in 2012, is a long-term strategy to support the sustainable growth in the marine and maritime sectors. It emphasizes the role of the seas and oceans as the drivers for the future European economy, including the potential for innovation and growth. In the wider policy context, BGS is the maritime contribution of the Europe 2020 strategy for smart, sustainable and inclusive growth.

Five sectors with a high potential for sustainable jobs and growth have been identified:

- aquaculture
- coastal tourism
- marine biotechnology

- ocean energy
- seabed mining

BGS also aims to deliver

- marine knowledge to improve access to information about the sea;
- maritime spatial planning to ensure an efficient and sustainable management of activities at sea;
- integrated maritime surveillance to give authorities a better picture of what is happening at sea.

Links to other policies: CFP, EGD, IMP, MSP, SDGs, Ocean Decade

The Circular Economy Action Plan

The Circular Economy Action Plan (CEAP) was adopted in 2015.

The CEAP includes measures to help stimulate Europe's transition towards a circular economy, boost global competitiveness, foster sustainable economic growth and generate new jobs. It entails the complete production cycle: from production and consumption to waste management and the market for secondary raw materials and a revised legislative proposal on waste.

The proposed actions within the CEAP will contribute to 'closing the loop' of product lifecycles through greater recycling and re-use, bringing benefits for both the environment and the economy.

Links to other policies: BGS, SDGs

Common Fisheries Policy

The Common Fisheries Policy (CFP) was introduced in the 1970s and has subsequently gone through periodic updates. Currently the CFP stipulates that between 2015 and 2020 the fish catch limits should be set at sustainable limits and overfishing should be halted to ensure the long-term viability of the fish stocks.

In practical terms, the CFP set rules for managing European fishing fleets and for conserving fish stocks. Designed to manage a common resource, it gives all European fishing fleets equal access to EU waters and fishing grounds and allows fishermen to compete fairly.

The CFP has four main policy areas:

- Fisheries management
- International policy
- Market and trade policy
- Funding of the policy

The CFP also stipulates rules on aquaculture and stakeholder involvement.

Links to other policies: BSAP, NEAES, MSDF, SDGs, Ocean Decade, the UK Fisheries Bill (currently in development)

EU Biodiversity Strategy

The Biodiversity Strategy (BdS) was adopted in 2011. It consists of an ambitious strategy including six targets and twenty actions to halt the loss of biodiversity and ecosystem services in the EU, as well as to help stop the global biodiversity loss by 2020. The mid-term review of the strategy indicated progress in many areas but highlighted the need for much greater effort.

The six BdS targets:

- Protect species and habitats

- Maintain and restore ecosystems
- Achieve more sustainable agriculture and forestry
- Make fishing more sustainable and seas healthier
- Combat invasive alien species
- Help stop the loss of global biodiversity

Links to other policies: MSFD, BSAP, NEAES, SDGs, EGD, CBD

EU Integrated Maritime Policy

The Integrated Maritime Policy (IMP) has been in place since 2007. It seeks to provide a holistic, enhanced cross-coordination between different maritime policies. With this in aim, higher returns from seas and oceans with less impact on the environment are envisaged.

The IMP encompasses fields as diverse as fisheries and aquaculture, shipping and seaports, marine environment, marine research, offshore energy, shipbuilding and sea-related industries, maritime surveillance, maritime and coastal tourism, employment, development of coastal regions, and external relations in maritime affairs.

The IMP covers the following cross-cutting policies:

- Blue growth
- Marine data and knowledge
- Maritime spatial planning
- Integrated maritime surveillance
- Sea basin strategies

Links to other policies: BSAP, NEAES, MSFD, EGD, MSP

Long-term 2050 Strategy

Europe has set itself ambitions target to reduce its greenhouse gas emissions progressively by 2050 (Long-term 2050 strategy). This long-term strategic vision for a prosperous, modern, competitive and climate-neutral economy by 2050 was set by the Commission in 2018. The strategy shows how Europe can lead the way to climate neutrality by investing into realistic technological solutions, empowering citizens, and aligning action in key areas such as industrial policy, finance, or research – while ensuring social fairness for a just transition.

Links to other policies: EGD, SDGs, PCA, BGS

EU Directive on Maritime Spatial Planning

The Maritime Spatial Planning Directive (MSPD) was adopted in 2014 and the deadline for the establishment of maritime spatial plans for the EU Members States is set for 2021.

The MSP aims to work across the borders and sectors to ensure human activities at sea take place in an efficient, safe and sustainable way, while supporting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources.

Efficient MSP, which supports environmentally sustainable practices, is becoming increasingly urgent as the maritime space is becoming more and more occupied and competition for space is increasing among the multiple stakeholders involved in various activities (for example, in renewable energy, aquaculture and fisheries, maritime transport, and oil and gas industry).

Links to other policies: BGS, MSDF, BSAP, NEAES, SDGs, IMP

Marine Strategy Framework Directive

The Marine Strategy Framework Directive (MSFD) was adopted in 2008. The MSFD aims to achieve the good environmental status (GES) in EU marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend.

To evaluate and monitor the GES, a set of 11 Descriptors have been identified:

- Biodiversity is maintained
- Non-indigenous species do not adversely alter the ecosystem
- The population of commercial fish species is healthy
- Elements of food webs ensure long-term abundance and reproduction
- Eutrophication is minimized
- The sea floor integrity ensures functioning of the ecosystem
- Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
- Concentrations of contaminants give no effects
- Contaminants in seafood are below safe levels
- Marine litter does not cause harm
- Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Links to other policies: BSAP, NEAES, BdS, MSP, SDGs, EGD, CBD, Ocean Decade, Maritime Doctrine (Russia) and the UK Marine Strategy

Global policies

The Convention on Biological Diversity

The Convention on Biological Diversity (CBD) is a multilateral treaty and it entered into force in 1993. It is now one of the most widely ratified international treaties on environmental issues, with 194 member countries.

The CBD has 3 main objectives:

- The conservation of biological diversity
- The sustainable use of the components of biological diversity
- The fair and equitable sharing of the benefits arising out of the utilization of genetic resources

In 2010, the United Nations Decade of Biodiversity was announced at the tenth meeting of the Conference of the Parties to the CBD in Nagoya, Japan, where the Strategic Plan for Biodiversity 2011-2020 and its Aichi Biodiversity Targets were agreed on.

The Strategic Plan for Biodiversity 2011-2020 comprises a vision for 2050, five strategic goals and twenty ambitious targets, collectively known as the Aichi Biodiversity Targets. These aim to:

- Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society
- Reduce the direct pressures on biodiversity and promote sustainable use
- Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity
- Enhance the benefits to all from biodiversity and ecosystem services
- Enhance implementation through participatory planning, knowledge management and capacity building

Links to other policies: BdS, SDGs, EGD, BSAP, NEAES, the UK Environment Bill (currently in development)

The Paris Climate Agreement

The Paris Climate Agreement (PCA) signed in November 2016 builds on the United Nations Framework Convention on Climate Change (UNFCC) and Kyoto Protocol. The Agreement has been signed by a total of 197 countries and ratified by 185 as of January 2019.

The central aim of the Agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius when compared to the pre-industrial levels and to pursue efforts to limit the temperature increase even more, to only 1.5 degrees Celsius.

Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change.

Links to other policies: SDGs, EGD, BGS, CEAP, 2050 Strategy

United Nations Sustainable Development Goals

The Sustainable Development Goals (SDGs) form the heart of the UN 2030 Agenda for Sustainable Development adopted by all UN Member States in 2015. A 15-year plan has been set to achieve the Goals.

In total, 17 Sustainable Development Goals have been adopted to demonstrate an urgent call for action by all countries - developed and developing - in a global partnership to tackle growing inequalities, empower women and girls, and address the climate emergency. They are the universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere.

The SDGs are all-inclusively aimed at all stakeholders: governments, civil society, the private sector, and others, who are all expected to contribute to the realization of the 2030 agenda and achieving the set goals.

The Seventeen SDGs:

1. No Poverty
2. Zero Hunger
3. Good Health and Well-being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequality
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace and Justice Strong Institutions
17. Partnerships to Achieve the Goal

Many of the Goals are strongly interlinked. Achieving one will support another.

Each goal is accompanied with a set of targets and indicators to further define the progress towards achieving the Goals and their implementation. In total 169 targets have been set, of which 10 belong to the goal 14 Life below water.

Links to other policies: BSAP, NEAES, CFP, MSDF, BdS, CEAP, MSP, EGD, BGS, WFD, Ocean Decade, PCA, EGD, 2050 Strategy

The United Nations Decade of Ocean Science for Sustainable Development

The United Nations proclaimed the UN Decade of Ocean Science for Sustainable Development for 2021 to 2030 (Ocean Decade) on December 2017. It aims to deliver science for the future we want in order to provide a common framework of ocean science, which can support countries' actions to sustainably manage the oceans, seas and coasts.

The Ocean Decade recognizes that the science-informed mitigation and adaptation policies to global change are urgently needed, but neither science nor policymakers can accomplish that alone. As such, the Ocean Decade bolsters inclusive approaches of designing and conducting scientific marine research, which also supports the development of a sustainable blue economy.

Through stronger international cooperation, the Ocean Decade will support scientific research and innovative technologies to ensure science responds to the needs of society:

- A clean ocean where sources of pollution are identified and removed
- A healthy and resilient ocean where marine ecosystems are mapped and protected
- A predictable ocean where society has the capacity to understand current and future ocean conditions
- A safe ocean where people are protected from ocean hazards
- A sustainably harvested ocean ensuring the provision of food supply
- A transparent ocean with open access to data, information and technologies

The Ocean Decade also aims to provide a unifying framework across the UN system to enable countries to achieve all of their ocean-related Agenda 2030 priorities linked to sustainable development goals (SDGs).

Links to other policies: BSAP, NEAES, CFP, MSDF, BdS, CBD, CEAP, MSP, EGD, BGS, SDGs

3 BANOS research and innovation programme

The overall framework of the future Baltic and North Sea Research and Innovation Programme's (BANOS) Strategic Research and Innovation Agenda (SRIA), consists of the three, strongly interlinked strategic objectives: 1) Strategic Objective A: Healthy Seas and Coasts, 2) Strategic Objective B: Sustainable Blue Economy, and Strategic Objective C: Human Wellbeing. In addition, a total of nine specific objectives and 31 research and innovation themes are grouped under these strategic objectives.

The BANOS SRIA is policy-driven and solution-oriented and hence it sets out to respond to stakeholders' needs and scientific and eco-technological possibilities. It provides the basis for developing calls, projects, effective end-user and stakeholder communications and reporting about the progress and results achieved. The aim is that the future BANOS programme and the interdisciplinary research and innovation it supports through its 'backbone', the SRIA, takes a critical role in the coming decade and beyond in finding solutions for challenges facing the BANOS region and making it environmentally, socially and economically attractive and wealthy place to live.

The following pages outline in detail the ambitious BANOS research and innovation programme.

3.1 Strategic objective A: Healthy Seas and Coasts

Healthy seas and coasts are vital elements of modern societies. However, both regional seas and coasts are under an increasing amount of pressure leading to deterioration of the marine environment through eutrophication, deoxygenation and significant load of pollution. This all has negative consequences on marine ecosystem functioning, resulting in, for example, decline in biodiversity and changes in food web structure.

Scientifically sound understanding of the long-term, cumulative effects of different pressures on marine ecosystems, under the changing climate, are urgently needed. In addition, new measures and monitoring approaches that support ecosystem-based management practices are required to overcome the existing challenges, promote ecosystem resilience and reach a good environmental status in the Baltic Sea and North Sea regions. The BANOS Strategic objective A: Healthy Seas and Coasts, and its four specific objectives aim to deliver this and more.

3.1.1 Specific objective A.1: A resilient marine ecosystem

Overall rationale

The United Nations Sustainable Development Goals (SDGs) 14, Life below water, aims to conserve and use marine resources for sustainable development. Target 14.2 explicitly expresses that "...sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans and coastal ecosystems". Ecosystem resilience is a measure of how much disturbance (eutrophication, pollution, global warming) a marine ecosystem can take without shifting into a qualitatively different state or regime. Regime shifts as a response to climate drivers in the ecosystems of the Baltic Sea and North Sea have been demonstrated in the past. However, the role of compounding drivers such as eutrophication, contaminants, fisheries and physical operations are still debated and need to be quantified. Since ecosystems are open systems that continually evolve, ecosystem state or health are operational rather than conceptual terms, mainly used in environmental regulation. They address and weigh various ecosystem components to make them comparable, to monitor them over time and to ultimately illustrate obvious problems such as non-functioning regulating services (nutrient cycling, carbon storage and oxygen production), loss in biodiversity and productivity of higher trophic levels (fish, shellfish). Ultimately, resilience is a concept that deals with the capacity of self-organization. Thus, widening our understanding of the resilience of marine ecosystems in the Baltic Sea and North Sea is pivotal to safeguard biodiversity and ecosystem functions and services in a changing world.

The ecosystem approach (EA) to management is the underlying principle for environmental management strategies as formulated in the EU Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD), Maritime Spatial Planning Directive (MSPD) and the Common Fisheries Policy (CFP) and is based on the concepts of resilience and ecosystem health. An EA is an integrated management approach across coastal and marine areas and their natural resources that promotes conservation and sustainable use of the whole ecosystem. Key aspects of EA relevant to the governance of marine ecosystems include a i) broader, system-wide perspective taking in account both ecosystem interactions and human resource use and pressures, ii) emphasis on the functioning of key species and habitats, iii) acknowledgement of uncertainties and risks in these complex systems, iv) integration across temporal and spatial scales (both ecosystem boundaries and jurisdictional boundaries) and v) formation of adaptive and flexible process and decision making (Hammer 2015). The Regional Sea Conventions (RSC) are regarded as an intergovernmental effort on a regional level to implement the directives and the underlying EA (for example the HELCOM Baltic Sea Action Plan and OSPAR's Northeast Atlantic Environmental Strategy). The EA was formally adopted by OSPAR and HELCOM in "The Bremen Statement" in 2003. Thus, the European environmental policies can be regarded as an effort for the implementation of SDG14.

State of the art and knowledge gaps

Quantitative links and thresholds between management measures and regulating services as delivered by the base of the food web (biogeochemical cycles), the effects of renewable energy and aquaculture as well as direct interactions with the food web through fishing and protection measures need to be investigated. Whereas major human drivers of ecosystem state are well understood, there is still a huge lack of methods to link measures addressing these drivers to measurable effects and ecosystem functions in the food web. Further, critical components of marine ecosystem resilience, i.e. the role of habitat forming species, foundation species (common species) or keystone species (top predators) needs to be understood. What happens to the ecosystem resilience if one of these species' groups disappear/will be substituted? Much of the understanding on how the potential of marine organisms to adapt to climate change and other drivers lies in the genomic architecture of key species and populations as well as in the genomic landscape of entire ecosystems. However, this knowledge is just on the brink to deliver critical insights in environmental management and needs to be broadened. The EA as the foundation to manage marine ecosystems in the Baltic Sea and North Sea is fundamentally linked to ecosystem health and resilience. Whereas the overall principles of the EA permeate national, regional (HELCOM, OSPAR) and international (EU, global) regulations, its implementation lacks behind. To make the EA operational, one needs to develop adaptive management that is based on multiple sciences and that is constantly evolving. Especially there is a huge need to develop approaches linking ecosystem and socio-economic indicators in a holistic manner.

Impact and linkages

Major differences between the Baltic and North Seas' hydrographical conditions, biodiversity and food web structure provide a natural laboratory to study how physical and direct impacts, other human drivers, management legislations and measures affect food web functioning and ecosystem status. Ecosystem services as nutrient retention and carbon sequestration will be quantified. Effects of measures at source (eutrophication and pollution abatement measures) will be directly linked and quantified at an ecosystem service and ecosystem state level. Future changes in habitat structure and key species will be simulated by coupled biological-physical models and validated by gene analyses. Further, genetic information will be used to evaluate the potential for the restoration of key habitats and populations. The role of fisheries inducing evolutionary changes in the food web will be put forward. The role and functionality of blue carbon ecosystems as nature-based solutions for sustainable management and contributing to climate change mitigation and biodiversity hot spots will be elucidated. A long-term, multidisciplinary approach comprehensively compiling and communicating all relevant information regarding the implications of climate change and human activities will be developed for the Baltic Sea and North Sea marine and coastal environment. Policy-relevant and research-based knowledge on the state, functioning and vulnerabilities will form the basis for implementing the ecosystem approach to management across sectors (energy, fisheries, aquaculture, tourism etc.). Much will be learned from case studies and bright spots where new indicators for the BANOS area will be developed, which link human resource use, ecosystem services and environmental legislation. Studies will highlight the role of all relevant sectors and make use of the research activities in B.2.1 and B.2.2.

A.1.1 Understanding food web interactions and their services, with respect to species, population and system levels

State of the art and knowledge gaps

Food web relations play a pivotal role in the link between (changing) drivers and ecosystem state. As an example, a relationship between basal productivity and fisheries yield is expected but not straightforward, as it is extensively mediated by trophic interactions. Past studies have demonstrated large-scale regime shifts in the ecosystem of the Baltic Sea and the North Sea as a response to changes in (meteorological, climate) drivers. Such changes may be expected to occur at increasing frequency and severity in the future.

Much knowledge on food webs has been gathered in the past. Yet, fundamental problems remain. At the level of primary producers, the roles of viruses, mixotrophy, nano- and microzooplankton remain unclear. There is a lack of insight in the dynamics of mesozooplankton and its important linking function to fish. Role of benthos (both biogeochemical processes and animals) has often been overlooked. Operational models of fish stocks take food for granted and are not constrained by food web limitations, nor do they model the impact of (changing) fish stocks on the rest of the ecosystem. There is limited insight in food webs affecting the major fluxes of inorganic and organic carbon between land, rivers, coastal seas and the ocean. Small residual processes (e.g. export of organic material from the shallow Baltic Sea and North Sea to the adjacent ocean, burial of organic matter in sediments) are climate drivers at long time scales but are poorly resolved in models. There is a lack of directly observed rates: observations of food webs are typically on states, not on processes (probably with the exception of primary production). Rates are inferred from changes of state variables. Primary production rates can be measured but this is only occasionally done as part of research projects. Time series of primary production are virtually absent. New molecular and biogeochemical observation techniques have a great potential to contribute novel insights into food web processes.

Modelling plays an essential role in the analysis of food webs and in the translation between measures and effects. Modelling should be supported by comprehensive data compilations and essential new measurements. Both statistical and mechanistic modelling approaches can contribute to synthesis of ecosystem insight. Attempts at end-to-end modelling have limited success, as they may easily drive the model complexity to untenable level. There is a need for models that are both selectively targeting part of the food web and can be also combined in higher-level analyses, e.g. in ensemble model approaches. Models should be aiming at exploring responses of the ecosystem and selected important populations to human change.

Comparing the Baltic Sea and North Sea with respect to functioning of the food web and response to human measures and global change is particularly relevant. There are obvious differences in the physical settings of both seas, but also in the complexity of the food web. Comparing impact-response patterns between the two systems can be very informative on the resilience and robustness of vastly different food webs and may lead to spatial differentiation of management priorities. Moreover, the Baltic outflow has a strong impact on coastal waters along the Danish, Swedish and Norwegian coasts and occasional saltwater influxes of the North Sea have a large impact on functioning of the Baltic Sea. Therefore, it is highly relevant to understand better the exchange processes between both of these regional seas.

Expected outcomes

- An insight into the expected changes in the functioning of marine food webs as a result of changes in marine management and of global change.
- Linking changes in the drivers of the basis of the food web to essential ecosystem services of the marine systems and changes in the environmental status as defined in the WFD and MSFD.
- Where applicable, identification of critical transitions in the food web functioning that can serve as marker points to set boundaries in marine management
- In particular:
  - Improved direct measurement of fluxes in the marine food web, to provide a better observational basis on which to conceptualize and model marine food webs in the Baltic Sea and the North Sea.
  - Improved understanding of the dependence of food web structure and functioning on biogeochemical and physical forcing conditions which are likely to change in the future, such as eutrophication, aquaculture deployment and habitat changes, e.g. wind farms, sand extraction, marine infrastructure
  - Improved understanding of the dependence of food web structure and functioning on direct human interactions with the food web, e.g. due to fisheries policies or protection measures of top-level predators
  - Improved understanding of the dependence of food web structure and functioning on climate change, e.g. temperature increase, acidification, changed meteo patterns, replacement of species.
  - Improved understanding of the role which differences and interactions between the Baltic Sea and North Sea food webs and physical constraints have in food web functioning.
  - Development of improved statistical and mechanistic modelling as means to predictively link management measures to effects in the food web, especially at the higher trophic levels.
  - Contributions to the development of food web indicators and related baseline and threshold values for MSFD, OSPAR and HELCOM, and options for efficient monitoring of these indicators. This could include automated observation techniques, e.g. Ferrybox and remote sensing.

A.1.2 Understanding critical components of marine ecosystem resilience and drivers of change

State of the art and knowledge gaps

In the Baltic Sea and North Sea long monitoring and other time series are important sources of information to extract significant insights into the dynamics of the marine systems and the effects of external drivers such as climate variation, harvesting, physical exploitation, shipping etc. Also, the interactions between these different drivers need to be understood. Earlier research has shown that fishing is a main driver in many systems leading not only to depleted fish stocks but also to changed ecological dynamics, for example, damage and loss of biogenic structures, such as seagrass meadows, seaweed forests, flat oyster beds, Seapen and burrowing megafauna habitats and shifts in benthos and plankton communities. Moreover, even if fishing pressure is reduced, the ecosystem is unlikely to bounce back to the original functioning since the climate (and pollution level) has changed and other processes might be irreversible. This high level of complexity will need the integration of empirical data into modelling of scenarios. The large-scale development of wind farms in coastal waters will reduce fishing pressure and increase the availability of hard substrate within the wind farms. Also, they are likely to enhance vertical mixing and turbidity in their wake. The combined effects of these different changes on overall food web structures in the Baltic Sea and North Sea are yet unknown and may have strong impacts on the overall ecosystem status.

There is currently insufficient understanding of what are the key drivers of ecosystem dynamics and change, and what are their interactions? For example, are internal (food web) interactions or external drivers such as climate, pollution and harvesting most important, or a combination of several of these? With respect to climate effects, there is a vast knowledge gap regarding what is the direct and indirect effect on a given species. For example, some species are directly affected by climate variation, as well as indirectly impacted through the food web and subtle changes in food web linkages.

An effect of climate change is that species are changing their ranges of distribution. This leads to novel species interactions, new selection regimes and altered dispersal routes, while the ecological consequences of these effects are not known. The role of keystone species (top predators) need to be better understood: what happens when these disappear – and what happens when alternative keystone species enter a new region.

There is evidence for fishery/harvesting induced evolution, which is likely to be common. However, taking into account morphological, physiological as well as behavioural effects on target species, and all possible interactions with other components of the ecosystem, the ecological effects of such induced evolution remain, at least in large parts, unclear. Obviously, many of these effects are non-linear, and there is an urgent need to understand the underlying causes of non-linearity effects (e.g. keystone species effects, beyond tipping point effects etc.) and the interaction between two or more non-linear effects.

The role of habitat forming species (seagrasses, brown seaweeds, deep-water coral reefs, mussel and oyster reefs) for the local ecosystem are usually well-characterised, for example, with respect to biodiversity. However, an important dynamic interplay with other components of larger ecological systems remain unclear. For example, what drivers and mechanisms challenge the resilience of the habitat forming species? What are the effects of climate change, eutrophication, enhanced turbidity, decreasing populations of large size fish, and increased stress from pollution, and the interactions of these and other stressors? Furthermore, the knowledge is incomplete with respect to the role of other foundation species such as dominant species of zooplankton, phytoplankton and bacterioplankton.

Expected outcomes

- By combining data from long time-series with modelling, our understanding of the combined effects of multiple drivers (e.g. climate, pollution, fish harvesting, wind farms) in the ecological dynamics of the Baltic Sea and the North Sea will improve.
- The dynamics of semi-structured marine systems, for example, geographically or genetically structured species will be achieved by integrating ecological, genetic and oceanographic data in modelling effects of potent drivers (e.g. climate change).
- An improved understanding of the ecological effects of fishery/harvesting induced evolution, and how these effects interact with other potential ecosystem drivers, such as climate and habitat exploitation.
- An improved understanding of how marine protected areas (and networks of areas) should be designed and placed to mitigate loss of ecosystem biodiversity and function.
- A better understanding of what makes an ecological marine system more or less resilient; as part of this a better knowledge of how far/close we are to tipping points, and the relationship between resilience and ecosystem functioning.
- Understanding of the extent to which habitat-forming species such as seagrass and mussel beds can contribute to coastal protection under different scenarios of global change (combination of climate change, population growth, increased use of coastal waters for economic activities)

A.1.3 Understanding the potential of marine organisms and ecosystems to adapt to rapid environmental changes (e.g. climate change and ocean acidification)

State of the art and knowledge gaps

Changes in temperature, salinity and eutrophication in the Baltic Sea-North Sea area are much more rapid than in the open oceans due to their relatively shallow water column and enclosed (Baltic) locations. With warmer waters, these ecosystems also receive increasing numbers of new (invasive) species that add to predation and competition in native communities. Continued pressure from fishing activities add to other pressures on commercially used species, while physical exploitation and underwater constructions cause increased fragmentation of benthic habitats, or provide steppingstones for faster expansion of non-indigenous/invasive species. All these and other similar rapid changes are putting pressure on populations of organisms that must adapt, or they will risk of going locally extinct.

One urgent research question is whether populations of key species are now adapting to global and local environmental changes, or if several of these are deemed to go extinct in the near future? On the one hand, examples are added showing populations of species that can cope well with rapid evolution of new adaptations as a response of a shift in the environment, including adaptation to decreased salinity, increased temperature, and even increased levels of toxins. On the other hand, the history is also full of examples of species that have gone extinct due to habitat perturbations. What characterises populations that can respond to rapid environmental shifts? What is the role of species' life-history characteristics, demographic history, the genetic structure and content?

For example, how the genetic variation of populations is organised in the genome (genomic architecture) and how it is structured in the environment (genomic landscape) are of central importance to our understanding of the potential for populations to adapt to a changing environment. Today, this information is typically missing for even the most common and commercially important species.

The Baltic Sea-North Sea is largely a marine transition zone, characterised by a salinity gradient which in some areas are very steep. Most species (that have been genetically characterised) have established locally adapted populations along this gradient, and for some, gene flow among populations is heavily reduced, while less so for others. We need additional basic information on the genomic landscape of key marine species in the Baltic Sea-North Sea area. Based on this knowledge, we need to find out what will happen to all these locally adapted populations when both temperature clines and salinity clines will be rapidly shifted away from their current positions. Genome-wide analyses using state-of-the-art methods to assess barriers to gene flow and divergent selection, need to be combined with genetic modelling and biophysical models of connectivity and dispersal. Models also need to include what will happen during scenarios of future environments. Complementary analyses will come from ecological data and experimental tests of more classical types (e.g. reciprocal transplants and common garden approaches, descriptions of reaction norms and phenotypic plasticity).

Finally, in the Baltic Sea and North Sea, local populations of commercial fish species and habitat-forming species, such as eelgrass, seaweeds or flat oyster, are already lost in some places. It is important to analyse the role of genetic components in these losses. Research is also needed to investigate whether it is possible to restore lost populations using closely related genetic individuals. In the near future, also 'assisted evolution' might become a new tool to rescue populations of key species that are under threat from environmental change due to impoverished genetic contents.

Expected outcomes

- Detailed analyses of the genomic landscape of key Baltic Sea-North Sea species using state-of-the-art genomic approaches, including descriptions of barriers to gene flow among populations and how these have evolved.
- Models integrating connectivity from biophysical modelling, gene flow and barriers from genomic analyses, and the impact of future local environments used to predict changes in distributions of key Baltic Sea-North Sea species.
- A model-based framework usable to improve location, design and management of the Baltic Sea-North Sea network of marine protected areas with the purpose of reinforcing populations abilities to adapt to environmental changes.
- Increased knowledge about genetic aspects (positive and negative) of restoration of marine populations, including opportunities and threats using assisted evolution with examples of specific cases of relevance for the Baltic Sea-North Sea area.
- Empirical and model-based scenarios to predict impacts of ocean acidification on species with calcareous exoskeletons or body parts.

- Analyses of life history characteristics of species reacting to climate change-induced shifts in habitat suitability and improved understanding of their roles in ecosystem/food web functioning, including potential replacement by species shifting northwards and non-indigenous species (NIS) introduced by human activities.
- Implementing the underlying mechanisms of biodiversity change including evolution, dispersal, demography, species interactions, physiology and the environment in mechanistic models to predict changes under scenarios of rapid environmental change.

A.1.4 Scientific support for the implementation of the ecosystem approach

State of the art and knowledge gaps

The ecosystem approach (EA) is ultimately related to ecosystem health that is assessed by means of numerical models or semi-empirical-statistical approaches. Although the ecosystem approach and its principles are generally acknowledged, putting these them into practice has only been partly achieved to date. Management of marine environments follows a consecutive workflow; many of these have its origin in the Drivers Pressure State Impact Response approach (DPSIR) that is cyclic in nature. However, response times of the various ecosystem components have time scales ranging from hours/days (bacterial processes, algal blooms) and years (benthic and fish stocks) to decades (legacy nutrient pools) making it impossible to comprehensively capture all in one management cycle. To be able to apply an EA, one needs to know the appropriate spatial and temporal scales, use multiple sciences simultaneously and use adaptive management, i.e. management that is constantly evolving through evaluation and feedback.

Central to the implementation of the EA to management is the use of indicators to measure the impact of human activities on ecosystem components. The system of 11 Descriptors and related indicators laid down in the MSFD is supported by and further developed in the RSC in iteration with the EU level Common Implementation Strategy (CIS). Through this system, the EU Member States periodically assess whether Good Environmental Status (GES) is met. However, the formulation of coherent indicators and threshold values (targets) is a significant challenge and seriously hampered by knowledge gaps, especially on quantitative relationships between human induced pressures and marine organisms and habitats. The MSFD's aim of reaching GES by 2020 can only partly be assessed due to the lack of meaningful threshold values for both pressure and state indicators. Establishing threshold values related to ecosystem quality without an understanding of how these can be achieved by management measures is useless in a policy context. The Member States therefore tend to focus on the more imminent problems, i.e. the risk-based approach.

Main strategies applied to support the implementation of the EA from the natural sciences may be grouped into i) (further) development of coherent indicators and threshold values for the assessment of GES, ii) bottom-up models addressing climate change, eutrophication and bioaccumulation of contaminants, iii) mapping addressing biological hot spots, cumulative effects and risk areas iv) multi-species models addressing top-predators and fish/fisheries and v) holistic assessments as OSPAR Quality Status Reports, HOLAS, Ocean Health Index, NEAT etc. Further socioeconomic approaches addressed the management of human systems and pressures by i) the identification of ecosystem services that support sea-dependent lifestyles and wellbeing ii) cost-effectiveness model on a combination of abatement measures, iii) cost-benefit and 'willingness to pay' analyses. Furthermore, there is a wealth of conceptual studies on the complexity of ecosystem-based management and, in particular, the demands on both systematic learning and organized collaboration between a variety of stakeholders, agencies and decision-makers.

There is a huge need for an integrated approach linking these various models and statistical approaches, as well as their relevance to relevant activities and industries. However, the ways to combine scientific and socio-economic approaches are still highly complex and highly uncertain due to model error progression as well as lack of data and relevant indicators. Hence, there is a need to develop assessments which include human resource use, the four types of ecosystem services (i.e. provisioning, regulatory, cultural and supporting ecosystem services) and environmental legislation to address goal conflicts in assessments supporting the EA. Thus, socio-economic indicators need to be adjusted to ecosystem indicators.

Also, the resulting scenarios are often long-term and too generic to be of some practical help for decision-making processes. Therefore, projects with starting point in actual management challenges where an EA is promising to address urgent environmental problems are needed. By collaborative work between scientists, managers and stakeholders, such projects are expected to identify tools and methods for adaptive management, but also to contribute to societal learning and help identify good examples and implementation obstacles.

Expected outcomes

- Through consistent stakeholder involvement, a consensus definition of the ecosystem approach i.e. marine ecosystem-based management will be provided as well as an implementation model, which will be operationalized in all key areas of marine and coastal management.
- Establishing learning and collaboration processes that are based on concrete cases using new integrative tools and methods for adaptive management of environmental and social interactions.
- Identification of indicators and related threshold values for the assessment of the 11 Descriptors of the MSFD, supporting the developments in the RSCs and the CIS.
- Identification of indicators addressing human resource use and goal conflicts across sectors, ecosystem services, social costs and environmental legislation.
- Short-term predictions of climate variables related to living resources in combination with long-term integrated strategies including risk and vulnerability assessments towards climate resiliency.
- Developing strategies for mapping, monitoring, status reporting and restoration of key habitats and stocks.
- Developing approaches addressing collapsing ecosystem components and failures of recovery such as fish stocks and marine habitats considering non-stationarity, non-linearity, multiple drivers and regime shifts.
- Formulation of a practical definition of the EA concept in an EU setting, and its connection to key environmental and industry policies including the MSFD, MSPD, WFD, CFP and the regional sea basin conventions (HELCOM and OSPAR).

A.1.5 Coastal and marine ecosystems as nature-based solutions

State of the art and knowledge gaps

Seagrass meadows, saltmarshes, mangroves, kelp forests and reefs are distributed in shallow waters along the world's coastlines where light reaches the seafloor. They are important habitats and, through their high productivity, also take up and store vast amounts of CO_2 as 'blue carbon', and constitute natural coastal protection, as well as zones of increased pH and elevated seafloor. Increased area and functionality of these 'blue carbon ecosystems' thereby contribute to climate change mitigation and, at the same time, deliver climate change adaptation along with co-benefits such as the underpinning of marine biodiversity. Sustainable management of these ecosystems, which are among the most threatened on the globe, is, therefore, increasingly acknowledged internationally as 'win-win', 'no-regret' nature-based solutions to environmental challenges. The major threats to these ecosystems are eutrophication and associated deterioration of the submarine light environment, along with mechanical impacts, overfishing and, to some extent, climate change.

To date, the field of blue carbon ecosystems and their role as nature-based solutions have received limited attention in the Baltic Sea and North Sea regions. However, the regions' long and convoluted coastline with extensive shallow areas subjected to multiple stressors suggests a vast potential for effective ecosystem-based management to stimulate the expansion of these ecosystems and their functionality, guided by scientific insight regarding distribution areas and their connectivity, trends in distribution areas, quantification of functionality, including carbon and nutrient fluxes, resilience and feedbacks between stressors and functionality, holistic strategies for conservation, restoration and afforestation, and predictions for various stress- and management scenarios.

Along the North Sea coastal and estuarine areas, emphasis has been placed on the potential mitigation role of natural ecosystems for coastal protection. In particular, the degree to which coastal ecosystems can keep up with sea level rise and deliver coastal protection is critically depending on ecosystem health and sediment availability. Management strategies to secure long-term coastal protection from nature-based solutions are still largely lacking.

Recent developments in remote sensing technologies, logger systems, tracing of blue carbon, ecosystem modelling and climate-smart design of marine protected areas are relevant tools in this context. Importantly, in the Baltic Sea and the North Sea areas, there is a need for international collaboration and coordination to strengthen scientific research and enable maintenance and stimulation of natural ocean carbon sinks, as well as nature-based coastal protection. Of primary importance is the degree to which this can be combined with biodiversity conservation and stimulation in a changing coastal setting.

Expected outcomes

- Quantification of the area distribution of blue carbon ecosystems, including temporal trends and spatial gradients in distribution area as well as associated functionality such as carbon and nutrient fluxes.
- Assessment of resilience and feedbacks of blue carbon ecosystems in relation to multiple stressors.
- Strategies for identification, characterization, maintenance and stimulation of carbon sinks in the Baltic Sea and North Sea areas.
- Development of these tools and establishment of marine protected areas are done by management, including establishment of well-managed and climate smart marine protected areas, as a nature-based solution to climate change and other environmental challenges.

3.1.2 Specific objective A.2: Seamless governance linking land, coast and sea

Overall rationale

The governance system relating to the marine environment and its resources is complex and, in many respects, inconsistent and uncoordinated. It extends over multiple levels, including different geographic scales and sectors, and includes both formal and informal ways of determining authority to make decisions, how decisions are made and how account is rendered. The overarching policies include international conventions, but also EU, regional and national marine and maritime policies. At the heart of these policies is the ecosystem approach (EA), which is an integrated management approach across coastal and marine areas and their natural resources that promotes conservation and sustainable use of the whole ecosystem.

The HELCOM Baltic Sea Action Plan (BSAP) and the OSPAR North East Atlantic Environment Strategy (NEAES) form the basis for common agreements within the respective convention areas, while for EU Member States, the marine environment is protected by measures taken under multiple directives, including the Marine Strategy Framework Directive (MSFD), Water Framework Directive (WFD), Habitat Directive (HD), Birds Directive (BD). In addition, EU directives aimed at specific pressures, such as the Nitrates Directive, Common Fisheries Policy (CFP) and Common Agricultural Policy (CAP) regulate respective activities and thereby also affect the state of the marine environment.

Several marine policies require the achievement of objectives relating to the status of the marine environment. Objectives, such as ‘good ecological status’, ‘good water status’ and ‘favourable conservation status’, however, need to be defined. In practice, this takes place by defining threshold values for good status for various indicators that have been selected to represent the diversity, functioning, and drivers of ecosystem change. This in turn requires a fundamental understanding of past environmental conditions, ecosystem resilience, and response to increased and decreased loads of pollutants and other pressures.

To reach the desired state, the defined objectives need to be further operationalised into measures and rules of consideration. Programme of measures (PoMs) and action plans are therefore developed under several EU directives and regional policies while national programmes for measures are typically underpinning the regional agreements.

While the governance and policies that concern the marine environment are dispersed, it remains that:

- Several pressures on the marine environment originate from economic activities or consumption that takes place on land or in coastal areas, thus the understanding of impacts from land-derived direct and indirect pollutants is essential for the development of measures to improve the state of the sea.
- All relevant economic sectors, as well as consumption patterns relevant for marine pollution, should be consistently managed, taking into account economic 'level playing field' on the one hand and cumulative impacts on the other hand.
- EU Directives and national legislations are not necessarily coherent, thus there is a need for cross-sectoral governance, good combinations of policy instruments that complement each other, and harmonization of the practical implementation of policies.
- Consistent data about the costs and impacts of alternative mitigation measures, as well as policy instruments, are needed to efficiently combat environmental problems of regional seas and to equitably divide burdens between multiple sources.
- The active role of stakeholders and civil society has increased recently in marine protection. There is need to develop governance structures that encourage private-public partnerships and civil society to get involved with marine protection, account for multiple sectors and make use of the ecosystem-based management

State of the art and knowledge gaps

Many EU directives and regional strategies are lacking in implementation (see e.g. HELCOM 2018). There are also gaps between current policies and governance to enable the introduction and implementation of an ecosystem-based approach in marine governance, good ecological status, circular economy, blue economy, as well as inclusive and equitable development [add ref].

The formulation of coherent indicators and threshold values (targets) to reach good environmental status (GES) is seriously hampered by knowledge gaps, especially on quantitative relationships between human induced pressures and marine organisms and habitats. Establishing threshold values related to ecosystem quality without an understanding of how these can be achieved by management measures is on the other hand useless in a policy context. Both OSPAR and HELCOM have developed 'Science Needs Agendas' (OSPAR, 2019) and identified priority areas for research. These commonly include: further development of indicators and associated threshold values, understanding of cumulative effects on the ecosystem, development of measures and assessment of effectiveness of measures to reduce pressures. The 'Science Needs Agendas' further specify research needs.

Another challenge is coherence of implementation of policies between countries and between regions. OSPAR and HELCOM are tasked to ensure coordination for their respective areas, and at the same time EU Member States collaborate at the level of the EU. There is no comprehensive overview of the current level of divergence in the operational implementation of marine policies which is required to enable action for convergence.

Ocean governance also includes enforcement and control operations to protect the marine ecosystem or human uses that depend on good water quality. Fast feedback mechanisms are needed in case of hazards that occur irregularly, e.g. oil spills from ships or microbial pollution that threatens mariculture and recreation. Next to development of new technologies (see A.4.2) science can help to improve organizational aspects of these short-term management cycles.

Impact and linkages

This part of the programme is intended to give knowledge about how human activities affecting the coastal and ocean ecosystems are governed and to contribute to a more efficient and coherent marine policies and management.

The specific objective A2 is highly interlinked with other objectives and themes of the SRIA, for example:

- Understanding resilience and function of ecosystems, the objective of A1, is fundamental for the management of the marine environment and for reaching a good environmental status and contributes to reaching the objective of A2 – a seamless governance.
- Understanding how new technique for ecosystem modelling, assessments and forecasting that provide holistic evidence-based decision support, can be integrated in a changing governance system as addressed in A2.3 and A2.4.
- Outputs of theme B2.2 on the benefits of changes in ecosystem services and environmental state to society can be used together with information on costs and cost-effectiveness of measures from A2.2. to compare the costs and benefits of environmental policies.
- Demonstrating options for seamless governance promoting shared international responsibility of earth's interlinked marine ecosystems and their resources (B1).
- Understanding what management tools can promote sustainable harvesting and advance innovative industrial uses of both new and underutilised marine resources (B1) and technological solutions for sustainable, circular and bio-based blue economy (B3).
- Demonstrating pathways to a governance system that by improving the capacity to extract, produce and process marine resources reduces risks and optimizes opportunities for human wellbeing (B1) while adapting to a changing climate (C1 and C2) support a better implementation of the CFP, MSFD and MSPD, Bioeconomy Strategy and efforts towards EU's 2030 Biodiversity Goals thus delivering on key aspects of the New Green Deal. Short-term (management) response cycles strongly benefit from novel techniques and approaches in monitoring and assessment (A.4.2).

A.2.1 Understanding the impact of land-derived pollution, litter and nutrients on the status of the marine environment and ecosystem services (e.g. fish stocks, aquaculture and tourism), including ways to reach good environmental status

State of the art and knowledge gaps

Due to the different water residence time in the Baltic Sea and North Sea, and the brackish character of the first, the impact of land-derived pollution is more severe on the Baltic Sea ecosystem as a whole. Notably this is the case with the extent of cyanobacteria blooms and anoxic bottoms covering the entire central parts of the Baltic Sea whereas nuisance algal blooms such as phaeocystis are more confined to the coastal shallower sites in the North Sea. Our process understanding how nutrients trigger phytoplankton blooms and anoxia are mainly based on investigations addressing inorganic nutrient cycles. However, the dynamics and fate of terrestrial organic matter in dissolved and particulate form and related nutrients are hardly understood and need to be elucidated since they are a major fraction of the total riverine loads. They are also foreseen to increase with climate change at least in boreal areas. Coastal ecosystems that maintain the highest biodiversity and supporting ecosystem services as nutrient retention and carbon sequestration (often called 'the coastal filter') are especially impacted by land-derived pollution whereas eutrophication is often regarded as the most important factor causing ecosystem degradation, besides bio-accumulation of contaminants and physical disturbances as dredging etc. However, links between land-derived pollution and benthic biomass, biodiversity patterns and ecosystem functions are not quantitatively understood as well as paths and timescales for ecosystem recovery. Contaminant levels in organisms are generally higher in the Baltic Sea, although some contaminants are enriched in marine species, notably top predators, also in the North Sea. However, knowledge on the effects of contaminants on marine species is extremely limited. The effects of marine litter and microplastics are currently under investigation, a wealth of research projects have been recently launched and reviews on this subject are not yet comprehensive. As current policies focus on prevention as a first step, it is of crucial importance to understand sources and pathways of marine litter into the marine environment.

The shift from high loads of a limited number of chemicals emitted from point sources in the past, to diffuse sources of many, often unknown, chemicals as of today, challenges society's chemicals management. High levels of persistent organic pollutants (POPs), such as dioxins, organochlorine pesticides and PCBs, as well as heavy metals, notably mercury, have negatively impacted organisms in the marine environment. These pollutants still remain in concentrations that may negatively impact the aquatic system, as they are persistent and thus remain for a long time in the environment. Yet, concentrations of the classic POPs are generally decreasing in the marine environment, due to actions taken to reduce their emissions, although legacy pools of pollutants still pose certain challenges. Today, many point sources have been regulated and sources of pollutants are distributed in the watersheds and are more diffuse. Wastewater treatment plants collect the many chemicals in use in our modern society. However, they are removed far less than 100%, thus, many are released to the aquatic environment. The current focus in management, such as in the WDF, on the comparison to environmental concentrations of a set of priority substances with their respective environmental quality standards, is questioned. The reason for this is that the assessment focuses on a minor part of the number of chemicals present in the environment, and mixture effects are excluded from the assessment. Nevertheless, environmental policies still use these quality standards and hence better underpinning with ecotoxicological data reflecting marine conditions and species is requested.

Expected outcomes

- A mechanistic understanding of nutrient retention processes and nutrient legacy pools; their time scales, in both coastal environment and the open sea.
- Mechanistic understanding of adaptation and evolution of key phytoplankton functional groups and their lifecycle strategies as a response to changed inorganic and organic nutrient loads, N:Si:P ratios as well as climate change related variables.
- Feedback loops between land-derived nutrient loads, benthic biodiversity, carbon sequestration and carbon air sea-exchange across coastal seascapes.
- Mechanistic understanding of time scales and mechanisms for ecosystem/biodiversity recovery after decades of increase land-derived nutrient loads and related degradation.
- Indicators for the assessment of the effect of regulatory and management actions with focus on contaminants, with particular emphasis on legacy pool and internal cycling.
- Indicators for and tools to identify emerging contaminants, including transformation products, and forms of litter including microplastic. This includes the advancement of non-target and suspect screening methods.
- Contributions to the development of harmonised monitoring methods for litter, including micro and nanoplastics, in marine and coastal waters and rivers discharging into the sea.
- Knowledge on how the current exposure of marine organisms to the complex mixtures of chemicals and potential toxicity may cause adverse effects in organisms, populations and ecosystems, as well as on their functional traits.

A.2.2 Evaluation of effectiveness and cost-effectiveness of various pressure mitigation actions,

State of the art and knowledge gaps

Evaluation of the effects and cost-effectiveness of measures is a requirement under EU directives and also an ambition for HELCOM and OSPAR. Due to the time-lag in the recovery of ecosystems, it is rarely suitable to use data from coastal and offshore monitoring programmes to assess the progress, since it may take decades (i.e. for biological parameters) or even a hundred years or more (e.g. for concentration of nutrients, persistent pollutants and plastics) for the effect of measures to be detected in state variables at sea. Thus, in order to evaluate PoMs and assess the need for potential new measures to reach good status, the reduction in pressures needs to be measured and evaluated closer to the sources of pressures and their future impacts on state of the environment need to be projected. Estimates on the costs of measures are crucial for determining how to achieve the environmental targets with the least costs, resulting in cost savings to society and more efficient use of resources.

Knowledge on the effectiveness and costs of existing and potential new measures in the Baltic Sea and North Sea regions is, however, often limited. This concerns a broad range of topics, such as measures to reduce the input of litter and noise, restoration of coastal and marine habitats, effect of marine protected areas, and areas closed for activities, such as fishing. For hazardous substances and eutrophication the situation is somewhat better, since these topics are covered by the WFD; in evaluating the progress on implementation of the WFD PoMs the effect of measures to reduce nutrients and chemicals in the catchment areas has been at least partly assessed. In the case that information exists, it is however often of local character and potential effects for larger areas, e.g. marine regions, is rarely available. Cost estimates are frequently based on expert evaluation and qualitative, instead of modelled monetary estimates.

Thus, there is an overall need to collect information on and evaluate the effects and costs of marine environmental protection measures, in general, as well as to develop models for the assessment of the effects and costs of measures over time and in relation to inaction or measures in existing policies. Additional knowledge is also needed on the probability distribution on the effects and costs of measures, as well as the synergistic/antagonistic impacts across alternative measures. Such information is required to reliably compute and develop cost-effective combinations of measures and to inform policy design, e.g. agri-environmental and other policies.

In can be noted that in the Baltic Sea region there are ongoing activities to analyse sufficiency of measures which will provide more detailed information on topics where there are particularly large gaps in information on costs and effect of measures. Furthermore, in OSPAR and for the MSFD, economic and social analyses are being performed and methods developed to determine benefits and costs of the respective PoMs.

Expected outcomes

- Approaches and models for evaluation of effectiveness and cost-effectiveness of measures at the level of regional seas.
- Quantitative evaluation of effectiveness, monetary costs and cost-effectiveness in existing and potential new measures, e.g. measures planned or proposed in PoMs under EU directives and under RSCs.
- Understanding about the (a) magnitude of uncertainty and (b) seasonal patterns associated with the effects and cost-effectiveness of potentially most promising mitigation measures. The information can be described in terms of probability distributions.
- Methods to design monitoring strategies that support identification and monitoring of effective measures, e.g. close to source and with sufficient temporal and spatial resolution to distinguish measures from natural variability.
- Synergies (a) across the most promising mitigation measures in mitigating given pressures (b) measures that contribute to the mitigation of several pressures.

A.2.3 Evaluation of synergies and conflicts of targets and innovative solutions to assess environmental status in relation to different environmental targets, taking multiple stressors into consideration

State of the art and knowledge gaps

To meet the requirement of different policies, EU Member States and RSCs are developing indicators and associated threshold values for state variables to define the desired environmental status in the marine regions. The indicators and threshold values are used to assess if good ecological/environmental status is reached. In order to reach the desired status, pressure indicators and reduction targets for pressures have in some cases also been developed, e.g. nutrient reduction targets for the Baltic Sea as agreed through HELCOM. Definition of target levels for other pressures can be expected in the future due to requests under the MSFD and commitments under the RSCs. There are, however, several potential limitations in the assessment and target systems that are being developed in European marine regions.

For instance, threshold values are not necessarily compatible, i.e. it has not always been tested if threshold values for state variables can be reached concurrently for all variables that are used as basis for status assessments.

Reduction targets for pressures are also not necessarily calibrated with threshold values for state variables. Such gaps are partly due to lack of knowledge of quantitative pressure-state relationships and lack of access to suitable ecosystems models but may also originate in suboptimal collaboration between expert groups tasked with the development of these targets.

In addition, threshold values and targets agreed under one policy, such as for coastal waters under the WFD, are not necessarily calibrated with targets agreed under policies related to offshore waters, such as the MSFD or agreements under RSCs. It can be noted that such evaluations are currently carried out with regard to input of nutrients in the Baltic Sea and North Sea regions but in-depth studies vary between pressures and regions and the effect of multiple stressors have typically not been taken into account.

EU directives furthermore provide guidance for how to assess environmental status that do not always concur with assessment methods used under RSCs or under other EU directives. For example, the EU Habitats directive require that the assessment of marine populations is done for the waters of the Member States while in HELCOM and OSPAR, in line with the requirements of the MSFD, assessments are instead done at the level of populations and does not consider national borders. This can result in dissimilar assessment results using the same data.

A further complication is the inconsistency in terminology used in the different directives and RSCs. Key concepts like environmental objectives, environmental quality standards, threshold values, targets and reduction targets have different legal effect and functions, according to different legislation. The inconsistent terminology leads to confusion and delay in implementing national legislation and thus in achieving the objectives.

These types of discrepancies between policies may result in incoherent development of measures and failure to reach reduction targets for pressures that are meant to address the same issue, namely the improvement of the state of coastal and marine waters. An accurate and consistent assessment of environmental status, within and between policies, is also central since the status establishes whether countries are required to take measures to improve the status.

Expected outcomes

- The aim is to provide methods and recommendations on how the implementation of marine policies can be streamlined to improve coherency and accuracy in assessments of environmental status and definition on reductions targets for pressures. This could encompass i.a.:

- An evaluation of compatibility of thresholds values for state variables across descriptors/topics within marine regions,
- An evaluation of compatibility of threshold values for state variables and associated targets for pressures within marine regions, where not done before, taking into account also the impacts of multiple stressor,
- An evaluation of compatibility of threshold values for state variables and targets for pressures across policies, where not done before, including coastal and offshore waters,
- An evaluation of the functions and legal effect of concepts linked to environmental objectives and standards and how to develop a more consistent terminology.
- Comparative analyses of approaches for setting threshold values and pressure targets in the Baltic Sea and North Sea regional and identification of underlying reasons for possible differences
- Comparative analysis of approaches for assessing environmental status within and between EU policies and RSCs and underlying reasons for tentative dissimilarities

A.2.4 Development of alternative policy instruments and new governance structures, which respond to current and future sustainability challenges.

State of the art and knowledge gaps

The marine governance system is expected to mitigate conflicts about marine resources and ecosystem services and support social welfare and ecological sustainability. Policies and objectives like the ones stated in the Agenda 2030, WFD, MSFD, BSAP, NEAES etc. are expected to drive institutions to deliver change in human behaviour in relation to the environment as well as in relation to equitable access to and distribution of resources. However, to a high degree, the delivery of such change is lacking. This is obvious in relation to climate change and the dramatic speed of the loss of biodiversity, also in the marine environment.

There are many studies analyzing the reasons for implementation of marine policies failing or succeeding. Often these analyses relate to a specific policy instrument or specific policy. There is, however, a need to better understand the gap of implementation on a more overarching level, the bottlenecks, gaps or (problematic) redundancies as well as links or lack of links between the different policies and policy instruments. Such analysis should cover different sectoral and environmental policies in a critical systems perspective and address also processes such as MSP or ICM that aim to coordinate between various policies. In addition to policy coordination and mainstreaming, reasons for the implementation gaps may stem from social implications of marine and maritime policies. The research should thus also shed light on the distributional outcomes of policies and policy-mixes, the impacts of policy development on existing rights regimes, including livelihoods and communities, how participation is enacted in formulation of policies, how such processes vary in different institutional contexts, and whether possibilities exist for foregrounding concerns like community and equity. It is also important to understand the difference in regard to successful use of policy instruments, between the two regional seas and to explain the reasons for such differences. Insufficiency of the existing marine protection measures causing critical gaps in effectiveness of measures or simply lack of measures, needs to be understood and addressed by alternative policy instruments.

There is also a clear lack of integration between different policies, creating inefficiencies and conflicts in relation to the key objective of these policies. An EA and sustainable blue economy are likely better achieved when having a systems perspective and integrating policies.

As a reaction to the failure of formal institutions to deliver change, numerous examples exist on how businesses, NGOs and the general public take own initiatives to drive change (Ocean Clean Up, Baltic Sea Action Group, restoration projects, climate strikes etc.). These reactions can also be seen as a complement and a driver for new policy instruments or use of policy instruments in new contexts. New technology opens opportunities for (new) social, economic and ecological data to the decision-making process, for example by collecting data through cloud sourcing, and 'double checking' findings done through models. The use of citizen-science can not only give new data but also increase awareness on existing plans and goals and take advantage of citizens being 'out in the field'.

Expected outcomes

- Evaluation of the strengths, weaknesses, drivers and obstacles within the existing governance framework, to deliver transformation towards implementation of the specific objectives of the WFD MSFD, MSPD, BSAP, NEAES etc. in relation to sectoral policies and implications to the potential of marine governance to provide for inclusiveness and deliver equitable outcomes.
- Analysis of the interplay between different policies and policy instruments, particularly in relation to provide synergies and coordination in implementation of measures and policies.
- Clarification of the potential of available policy instruments and policy mixes for delivering on the jointly agreed goals, generally and in relation to more specific coastal and ocean areas.
- Evaluation of new governance mechanisms/initiatives that make use of voluntary action of civil society and/or companies (e.g. public-private partnership, voluntary action on ecosystem restoration, low impact blue economy) and an increasing involvement of stakeholders from different interest groups in knowledge production and conflict resolution.
- Research on social implication of policies and policy development: distributional outcomes, impacts on existing rights regimes, livelihoods and communities, how participation is enacted in marine governance.
- Recommendations on how to integrate relevant policy areas, sectors, and administration levels necessary to be engaged in organizing a rapidly transforming use of the ocean, (taking into account all SDGs) as well as how to use different sets of policy instruments and design institutions, under a process where stakeholders are given real power to influence the process.

A.2.5 Develop fast feedback mechanisms from maritime observation to support surveillance and control activities, evaluation of management measures and risk-assessment.

State of the art and knowledge gaps

The major emphasis of this topic is how risks associated with hazards can be minimized or prevented by dedicated monitoring and processing of data in short term (management) response cycles, e.g. risk management and surveillance and control activities to enforce legislation and licenses.

Storm surge forecasting is a good example of well-organised collaboration between countries and institutions and integration of data sources and modelling. Storm surge warning systems use measurements at sea (e.g. wave buoys, water level gauges) and meteo-forecasts to feed operational and continuously running models that are capable of issuing early warnings for potentially dangerous situations. In general, the systems are well-established and running smoothly.

The aim of research under this topic is to support and improve the reaction to other forms of hazards at a similar level of storm surge forecasting.

The Bonn Agreement (North Sea) and HELCOM RESPONSE (Baltic Sea) are well-established platforms for regional cooperation in preventing and combating marine pollution from ships and offshore installations; to carry out surveillance as an aid to detecting and combating pollution at sea (both direct discharges/spills and air pollution); and for cleaning up after maritime disasters and pollution offences.

These pollution events, and other hazards such as disturbances by underwater noise caused by e.g. the construction of wind farms, seismic surveys or detonation of dumped munitions and also risk of collision of birds and bats with wind turbines, require fast feedback mechanisms between measuring the level of disturbance or pollution and operational responses. Examples related to the Bathing Water Directive and regulations regarding seafood safety are early detection of microbial pollution (pathogens or toxic algae) that threaten mariculture or hinder recreational activities. Furthermore, detection of unexpected patterns and the identification of the need for additional research when these appear is important.

These short-term management cycles include impact assessment (ex-ante and ex-post) as well as evaluation of the quality of the process, effectiveness of the planning decisions (ex-ante and ex-post), relevance of the plans, etc. In addition, tools for efficient organisation of monitoring and data management and techniques for fast sampling/data collection, analysis and data processing are required. Innovative monitoring techniques and automated data handling systems create opportunities to shorten the period between measuring and reporting/evaluation.

Knowledge needs related to Bonn Agreement and HELCOM RESPONSE are improvement of response technologies, equipment and other operational means, in particular on integrated surveillance sensors, response technology to respond to accidents at night and in bad visibility, under bad weather conditions, on the detection and recovery of containers lost at sea, accidents involving heavy oil and hazardous and noxious substances, and on accidents involving new generations shipping fuels. Also, research to improve enforcement of licenses for the construction and operation of wind farms in relation to preventing effects of underwater noise on sensitive sealife (harbour porpoises) and collision with birds and bats is needed. With regard to microbial pollution improvement of early detection and reporting of toxic algal blooms and surface blooms of blue-green algae and early warning for bathing water quality risks is needed. Furthermore, solutions are needed for big data management and procedures to analyse data stemming from continuously recording operational oceanographic devices to signal out exceptional events. These analyses are time-consuming and require high skills in interpretation, hindering the fast reaction in the management cycle.

This theme links with theme A4.2. For both themes project proposals should give due attention to user needs and dissemination of research outcomes, e.g. through involving user groups.

Expected outcomes

- Inventory of what systems are currently operational and for which purpose, what the strengths/weaknesses are, how integration of data sources and international co-operation could be improved.
- Understanding of governance aspects and the international co-ordination of data collection and management for the purpose of surveillance and control.
- Investigation of what novel routine measurement techniques are available (e.g. continuous recording of harmful algal blooms, pollution levels, oil spills, noise, sensitive marine mammals, birds and bats near windfarms) and what parameters those can monitor. Examples are flow cytometers, HF radar, remote sensing, aerial/drone surveillance, noise recording networks, and possibly other means. Overviews of these could be based, e.g. on the outcomes of JERICO and similar projects where lots of expertise have been built up.
- Methods to analyse and interpret the masses of data that are generated by automated sampling devices. E.g. artificial intelligence (pattern recognition, decision trees) could play an interesting role in this development. Exploration of these possibilities, and/or an example applications.
- Assimilation of modelling results and novel in-situ monitoring data to provide fast-feedback decision making systems, e.g. automated assessment tools / risk assessment tools / online data visualization tools.
- Tools to improve data management and metadata/data transparency and availability (following FAIR principles).
- Analysis of the governance of short-term management cycles and related workflows. How to organize an operational government service responsible for such risk aversion, how to feedback from experience to organization etc.

3.1.3 Specific objective A.3: Digital Ocean - Competent ecosystem modelling, assessments and forecasting

Overall rationale

Human pressure on seas and oceans has increased considerably over the past decades and has created new needs for predictive modelling capacity. Large-scale problems of eutrophication, release of toxic substances and fisheries pressure are no longer the main issues, as new challenges due to global change and extended exploitation of energy, food, minerals and other resources are taking over the stage.

In response to these challenges, the MFSD, OSPAR, and HELCOM all emphasize the need for a more comprehensive approach to management. OSPAR defines the ecosystem approach as "*the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity*".

Driven by the rapid growth of digital technologies in computing power and data collection and storage capabilities, entirely new opportunities for advanced modelling, assessment and forecasting are currently developing. This theme highlights three different aspects of this contemporary development and invites research contributions to further the development and application of advanced technologies in a management-oriented context.

The theme covers new methodologies for advanced machine learning techniques in section A.3.1, the compilation and exploitation of large existing databases for better inclusion into management in section A.3.2., and advanced new conceptual modelling in relation to the social-ecological system in section A.3.3. The emphasis on the power of data, be it in methods to better exploit real-time sensor platform generated data streams, or exploitation of carefully compiled and documented large datasets from the past decades, requires close links between data-driven and mechanistic modelling approaches. Conceptual developments on tipping point behaviour, as emphasized in section A.3.3, stresses the need for continued scrutiny of system dynamics for the unexpected, and makes a strong call for better integration of social and natural sciences in a common and novel conceptual framework.

State of the art and knowledge gaps

The possibilities for advancing data-driven approaches to problems of understanding and managing marine ecosystems, have exploded in the past decade. New machine learning methods are conquering more and more fields of society and have large promises for application in marine ecosystem understanding and prediction. However, few consolidated examples of these applications exist to date, partly related to the difficulty of simultaneously observing and measuring all essential components of ecosystems, bridging between time scales, and ensuring consistency of the data analysis e.g. with mass balance and hydrodynamic transport rules. It is expected that machine learning will find many useful applications in resolving processes and phenomena that are difficult to represent in mechanistic models e.g. the composition of phytoplankton communities and the development of harmful algal blooms (HABs). At present, development of the field is expected to be fostered by demonstration projects that critically investigate and apply the possibilities of this class of methods to real-world problems.

Enhanced communication protocols and streamlined databasing have allowed to compile large databases on essential ecosystem components at a European scale, e.g. in the framework of the European Marine Observation and Data Network (EMODNET). With technical barriers decreasing, the preparation of data products that can be fed into the workflow of governing authorities becomes an attractive, but non-trivial possibility. The problems are related to data availability (which may have political and military reasons), but also, scientifically and technically, in the multidisciplinary nature of the endeavour and the requirements for appropriate computational infrastructure. Data from depth soundings, geology, biogeochemistry, ecology and physics need to be combined in a way that they become useful to users, in an interactive mode that also allows for improvement based on user feedback and requests. Working out this example for seafloor data will contribute considerably to the proper representation of this important ecosystem component into management considerations.

The non-linearity of natural system dynamics is known to provoke unexpected shifts in ecosystem structure and function, generally indicated as tipping points and often related to cascade effects in food webs. Tipping points are an important study subject in diverse fields, from global change studies to fisheries and wetland dynamics. It is slowly being incorporated into the conceptual framework of social-ecological system thinking; there is a wealth of publications brought up by the resilience alliance, however, we lack practical implementation of these concepts. Not only do tipping points in the natural system cause peculiar challenges for management, also the social system can be highly non-linear and subject to the same types of positive feedback and multiple stable states. When conceptually viewing the development of social-ecological systems in the face of large and possibly non-linear changes, conceptual exploration of the dynamics of the linked system is needed as a ground base for future development of knowledge, management and governance systems.

Impact and linkages

This topic is impacting the future development of predictive modelling capabilities by emphasizing and exploring new possibilities that better integrate current digital developments into the study and management of marine systems. The topic is explorative and will provide example cases that can inspire other similar developments in the future. It will provide case studies with immediate applicability, although the methodological and conceptual developments are probably the most important impact.

The topic is linked to:

- A1.1 Understanding critical components of marine ecosystem resilience and drivers of change
- A2.5 Develop fast feedback mechanisms from monitoring results to evaluation and risk-assessment.
- A4.2 Development and use of automated observation techniques and platforms to enhance monitoring practices in respect to sustainable ecosystem management, and weather and climate models/forecasts. Examples of these techniques are satellites, ferryboxes, smart buoys and remotely operated vehicles.
- B.1.1 Sustainable harvesting/extraction and use of marine living and mineral resources.
- C1.1 Sustainable and safe fisheries, aquaculture and food production in the sea and on land under the changing climate.

A3.1 Development of machine learning methods for ecosystems data analysis and models

State of the art and knowledge gaps

In the last decade, machine learning methods have shown remarkable performance in many new areas, and in particular for supervised learning of regular data types, deep learning methods have revolutionized automated analysis of data. These methods are now making inroads in many fields and are beginning to see adoption in marine science and management.

Currently, machine learning methods are most mature for supervised learning, i.e. when large training data sets labelled with ground truth is available, and in many cases rival human accuracy. Unsupervised methods (e.g. learning a probability density function over the data) are also starting to develop, and generative models (GANs, VAEs) now exist that can create realistic synthetic data. The field is in rapid development, with advances in model architectures, learning schemes, and regularization as the methods are brought to new fields and data sets.

Ecosystems are complex, with a multitude of relationships and interactions that are nonlinear and whose parameters are often not known with a high degree of accuracy. Machine learning models, and in particular deep learning models, excel at modelling highly nonlinear data, but learning the high number of parameters necessary requires large amounts of data. Ecosystem models are currently often mechanistic, and use interaction with predefined parameters, as opposed to estimating them from raw data.

Recent advances in sensor and sensor platform technologies have made it possible to collect orders of magnitude more data at rapidly decreasing cost. However, it remains challenging to simultaneously measure all relevant ecosystem components at high resolution, and to cover the widely diverging time scales (compare daily time scales of phytoplankton to decadal time scales for cod population development). Currently, the most promising applications of machine learning are in operational problems (short-time forecast based on a limited set of observations, e.g. the development of harmful algal blooms and their possible toxic effect on shellfish culture areas) or in a hybrid operating mode with existing models, where classical model concepts (e.g. mass balance, transportation and mixing pathways) can be combined with rich data sources on part of the ecological processes. Since the subject is not well constrained by traditions and possibilities have not been fully explored, we are in a need of well worked-out examples of applications of artificial intelligence in ecosystem forecasting. This will be the emphasis of the present sub-project.

Expected outcomes

- Exploration of the possibilities and limitations of data-driven methods in the understanding, forecasting and management of marine ecosystems
- A case study where the use of 'big data', generated by automatic measurement platforms, is integrated into short-term or long-term forecasts of ecosystem development.
- Demonstration of the usefulness and limitations of deep learning models and generative models for ecosystems as an alternative/supplement to mechanistic/physical models
- Use of data-driven techniques to resolve important ecological processes (e.g. species or functional group composition of plankton) that cannot be easily resolved in mechanistic models, but may need to be constrained by classical model concepts (e.g. mass balance considerations)
- Applications of data-driven analysis in decision support systems at short to medium term (see also A2.5)

A.3.2 Improved, ecologically relevant modelling of underwater landscapes and the associations between species and abiotic parameters

State of the art and knowledge gaps

Over the past decades, considerable efforts have led to a substantial improvement of the detailed mapping of the underwater landscape of the Baltic Sea and North Sea. We currently dispose of bathymetric maps with relatively high (100 m scale) resolution, supplemented in selected areas with higher (up to 1 m scale) resolution. Chemical and physical variables, such as temperature of the water at different depths, salinity, oxygen, nutrient and chlorophyll concentrations in different parts of the water column, granulometry of the sediments and others have been extensively monitored and existing datasets have been compiled, e.g. in the framework of EMODNET (ref. To portal). Human activities, such as fisheries pressure, offshore constructions, mineral extractions, transport routes etc. have been charted and the information is available at high resolution.

In addition to this information, we also have extensive compilations of biological data on the occurrence, biomass and numerical density of many biological populations in the Sea. The EMODNET Biology holds, as an example, over 4 million records of species occurrences for the Southern Bight of the North Sea. These compilations are being made available increasingly as species distribution maps.

New technological developments facilitate the further refinement of the available maps. Acoustic methods map the seabed physical characteristics (roughness, grain size, vertical layering) with ever increasing precision, allowing classifications of many different types of bed. Automatic monitoring devices, ferry boxes, new tools to probe composition and function (e.g. primary production) of phytoplankton are being developed, satellite and coastal radars provide synoptic high-resolution images of an increasing range of variables.

The availability of consistent large-range high-resolution physical and ecological models, e.g. in the EU's Earth Observation Programme (COPERNICUS) framework, give access to important structural characteristics of the seascapes, such as (residual and actual) current velocity, wave impact, bottom shear stress, salinity, residence times etc.

Field experimentation and sampling of proxies has improved our understanding of essential processes, such as benthic-pelagic exchange of organic matter, nutrients, oxygen and dissolved inorganic carbon (DIC). We have improved insight in the processes affecting carbon exchange between rivers, coasts, shelf seas and the ocean, even though much remains to be explored.

There are also pressing needs to improve the spatial planning of (increasingly extensive) human and economic activities in seas that are rapidly changing because of ongoing global change. Sustainability of activities and preservation of biodiversity values requires careful evaluation of the vulnerability of areas that will be exploited or changed by human activities. The background of increasing quality and quantity of spatial data and models, increasing awareness of the importance of spatial variability in the structure of the seascape, as well as increasing need for spatially well-tuned activity planning, opens up a scope for spatially-oriented research of the marine landscape. The biodiversity characteristics of communities, their liability to global change and their vulnerability to disturbance by human activities will be central to this part of the research. The combination of datasets and models yielding qualitatively diverse data as a background for improvements of spatial decisions is a major scientific challenge that will be taken up in this topic.

The research will take both structural and functional characteristics of communities, their links to the abiotic environment and to global and human induced drivers, into account. It will make use of space-covering, high-resolution geophysical methods (acoustic or otherwise) to provide detailed habitat maps. It will provide a background for the establishment of optimization algorithms for the planning of protected areas, as well as areas to be used for a diversity of human exploitation. Optimization will explicitly take into account useful indicators of biodiversity and functional integrity of the ecosystem.

Expected outcomes

- Exploring a synoptic approach to the characterization of the abiotic environment in marine landscapes, taking into account the vast data availability as compiled by EMODNET, COPERNICUS and other data sources.
- Providing statistical and, where applicable, conceptual and mechanistic models revealing the correlation structure between the available data sets and classify landscapes at different spatial scales of resolution.
- Relating the landscape characteristics to the structural and functional characteristics of the biological communities, as documented by the available internationally collected datasets (e.g. EMODNET, HELCOM, OSPAR, ICES and others). It will highlight areas of high biodiversity and analyse how overall biodiversity depends on the complementarity of different landscape types.
- Investigating the vulnerability of different communities and their functional characteristics to global change and to local or regional anthropogenic pressures. Based on vulnerability and indicator values, it will propose methods to optimize spatial use patterns of marine landscapes, with respect to the preservation and/or strengthening of natural ecosystem services, such as biodiversity values and functional services.
- Informing governing authorities, such as regional sea commissions, the European Commission and national authorities, of methods to optimize the sustainability of marine activities, in view of the inherent landscape properties of the Baltic Sea and North Sea and the preservation of ecosystem health.

A.3.3 Development of models to predict tipping points or cascade effects in biological systems, including identification of the drivers of the changes and their impact on biota

State of the art and knowledge gaps

From a system dynamics perspective, the occurrence of tipping points as a result of non-linear interactions is a topic of considerable interest. Where positive feedback interactions are present, systems are likely to be characterized by the existence of alternative stable states. Biological or biophysical interactions tend to keep the system in a particular state over a range of driving conditions but may 'tip over' into a different state when thresholds in the drivers are exceeded. As a consequence, the system will exhibit hysteresis requiring considerably stronger efforts than simple restoration of previous driver levels, in order to force it back into the original stable state. The concept has been applied extensively in the research of eutrophication and has received great attention in the contexts of climate change and fisheries. In fisheries, in particular, the non-linear interactions often follow from cascading food web interactions, leading to complex responses of the system as a whole following simple driver changes such as increase in temperature or of the fishing pressure, usually in the top of the food web.

Empirical studies in the Baltic Sea and North Sea have led to the description of 'regime shifts', operationally defined as breakpoints in multivariate time series. The relationship between these empirically observed regime shifts and the theoretical tipping points is unclear. Whereas it can be expected that a regime shift will be observed when a tipping point is crossed, the reverse is not necessarily true, as the underlying dynamics may differ.

From a management perspective, occurrence of tipping points is of great importance. There is especially a need to understand cumulative impacts of different pressures caused by human activities on ecosystem components and ecosystem functioning. Understanding system dynamics and identifying critical ranges where system behaviour may drastically change, can serve as a scientific basis for defining safe operational space within which (limited) change to the system will only produce gradual changes of important ecosystem characteristics, whereas exceedance of the safe limits may lead to (almost) irreversible change in response variables. Increasingly, these management considerations are incorporated into the scientific study of tipping points in a social-ecological context. Desirability of different ecosystem states, as well as risk perceptions dependent on ecosystem state, form an integral part of this approach. This links to the development of indicators and threshold values for good environmental status.

Although conceptually and methodologically difficult, tipping point behaviour of managed marine social-economic systems presents one of the major scientific challenges in the analysis of societal transformation in a changing world. Ranging from global climate tipping points, over regional fisheries-induced cascades and ensuing tipping points to local problems where decision-making time lags destabilize a community's ability to prevent, e.g. a lake from entering an undesirable state, recognition of the non-linearity of the problem and the importance of feedbacks and time lags is an essential step to improve system management. This is currently an active field of research.

Expected outcomes

- An analysis of cascades and other causes of tipping point behaviour in marine systems, and the application of the concept into the design of social-ecological management systems that combine two urgently needed extensions of our current knowledge on tipping points and their importance for the management of marine systems
- Making use of the contrasting characteristics of the Baltic Sea and North Sea to investigate the likelihood of occurrence and the importance of tipping point behaviour in shallow shelf seas. Preferably a limited study system will be identified, investigated for (potential) tipping point behaviour and compared across both seas.
- Investigation on how society can react to systems exhibiting tipping point behaviour. This involves the delineation of clear signs of approaching tipping points, methods of detection and communication,

and response systems to the behaviour of the natural systems. It includes non-linear behaviour and possible tipping points within the social system and considers the coupled system dynamics.
- Identify data needs and monitoring/modelling approaches that support detection of (changes in) causal relationships and integrations of results and allow societies to cope with non-linear behaviour of natural systems.
- Draw from particular examples to generalize how tipping point behaviour can be incorporated into ecosystem-based management approaches and determine the need for such evolution.

3.1.4 Specific objective A.4: Efficient techniques and approaches for environmental monitoring and assessment

Overall rationale

Many societal needs require the assessment of the marine environmental status, as well as relevant pressures and impacts, which should be based on a comprehensive understanding of the dynamics and functioning of the ecosystem. These needs are formulated in a number of policy documents at the global, European and regional level, such as the SDG Goal 14 “Life below water”, EU MSFD, WFD, HD, etc., and regional conventions of marine environmental protection in the Baltic Sea and North Sea areas. The observational programmes to gather the data for required assessments have been in place in European marine areas for decades already. However, both our knowledge about the functioning of marine ecosystems and observational technologies are continuously advancing, and new threats for the marine environment are emerging. Thus, the approaches for monitoring and assessment should evolve as well. Furthermore, the constraints in available resources call for cost-efficiency and better coordination of the efforts at the regional level.

Although the ecosystems of the Baltic Sea and North Sea have apparent differences, the questions to be solved to secure cost-effective and scientifically sound marine environmental monitoring and assessment are often similar. These questions are related to the joint organization of monitoring, systems and methods for data handling and analysis, taking into account diversity of sources and increasing amounts of data, tackling new emerging threats and their impacts, such as micro-litter, underwater noise, and pharmaceuticals as well as other micropollutants. The species and habitats impacted by these pressures differ in the Baltic Sea and North Sea, but there are common principles and technologies which should be agreed for both regions. Moreover, the advancement in specific topics of concern could be at different levels in the Baltic Sea and North Sea regions. Thus, the cooperative efforts to exchange knowledge and avoid duplication are very much needed.

State of the art and knowledge gaps

Among the shortcomings of the existing monitoring programmes are the high costs and not always sufficient confidence of assessments. Partly it could be assigned to too little regional and institutional coordination and fragmented development of the observational programmes regarding the themes (MSFD Descriptors), as well as slow inclusion of the state-of-the-art methods and technologies into the programmes. Also, insufficient knowledge on characteristics and impacts of less studied pressures, such as litter, underwater noise and pharmaceuticals hinder harmonized implementation of respective parts of monitoring.

For instance, biological monitoring of the marine environment is very costly today, and it restricts our current level of information about the ecosystem with extensive spatial and temporal dynamics. Although the inclusion of eDNA methods into the programmes could have a huge potential for monitoring the fauna and flora of coastal ecosystems like the Baltic Sea and North Sea, there are many open questions, which should still be answered. While some examples of applying remote sensing and high-frequency automated observations in the monitoring and assessment systems are available, e.g. HELCOM chlorophyll-a – a core indicator deploying the EO and ferrybox data, we need to demystify the satellite data and convince the authorities about the reliability of automated observations and applicability of model results for status assessments. Joint actions covering both sea areas should lead to a better understanding of the impacts of marine litter, underwater noise and micropollutants and suggestions of cost-effective monitoring techniques for these themes of high societal interest.

Impact and linkages

The EU MSFD and WFD promote ecosystem-based management and require comprehensive monitoring and assessment of the status of the marine environment. The strategic objective A.4 is directly related to achieving the GES in the Baltic Sea and North Sea, and the outcomes contribute to a better understanding of the functioning of ecosystems and better governance of marine natural resources (linked to A2). This is especially valid for the less studied and emerging threats to the marine ecosystem. Furthermore, the development of environmental monitoring programmes will contribute to the other needs of the society for ocean information and data as outlined in the United Nations Decade of Ocean Science for Sustainable Development and European Ocean Observing System (EOOS) initiative.

A.4.1 Application of powerful DNA approaches to monitor ecosystem resilience and changes

State of the art and knowledge gaps

DNA sequencing technology is developing continuously, and what is not possible today, might be possible tomorrow. Biological monitoring of the marine environment is today very costly due to high costs for ship-time and sorting of samples. This restricts our current level of information in an ecosystem with extensive spatial and temporal dynamics. A combination of automatic underwater vehicle (AUV) sampling with environmental DNA analyses (eDNA) will open almost unlimited possibilities for monitoring the fauna and flora of coastal ecosystems like the Baltic Sea and North Sea. However, much research is needed before the eDNA technology can serve such a purpose for large-scale marine biological monitoring. Also, other DNA approaches, such as metagenomics of pooled samples of fish egg and larvae, phytoplankton and zooplankton, would potentially become powerful tools in biological monitoring.

The strength, but also the dilemma, of the eDNA technology is its sensitivity. With only a few pieces of DNA, it is possible to establish which species left the fingerprint. A primary requirement is a high-quality genome library, including as many as possible of the species encountered in an area. This library needs to be produced based, at least in part, on traditional taxonomic methods and calibrated to the DNA sequences, including the intraspecific variation present. Such calibration will most likely also lead to a taxonomic revision of groups of organisms for which no earlier genetic data (barcoding sequences) exist.

One issue to address in research and development of eDNA methods is how data can be made quantitative or semi-quantitative in order to get at least an approximate estimate of the population size of target species. A DNA signal in a lake will tell us that ’species A’ is present in the lake, but how should a DNA signal in an open coastal area be interpreted? A signal from ’species B‘ can be brought by ocean currents, rather than represent a species present in the area. Moreover, how large is the area (in the absence of currents)? Will signals of earlier local species also be around in the form of fragments of DNA that are still present in the water column or leaking out of the sediments? Investigations, including both laboratory tests and full-scale ground-truthing combining traditional monitoring techniques side-by-side with eDNA sampling, will most likely be needed to understand these issues better.

Expected outcomes

- Libraries covering the genetic variation within and among species of important marine species commonly targeted in monitoring of pelagic and benthic habitats.
- Meso-scale empirical data exploring sensitivity and precision of eDNA methods in highly controlled environments, and in manipulated field experiments. Complementary data from real, open-

environment, sampling and ground-truthing. Data that describe the spatial and temporal variation in eDNA signal and how the signal can be interpreted.
- Models developed to support the interpretation of eDNA signals. For example, models taking into account hydrodynamic and topographic conditions of coastal waters and how the eDNA signals are affected.
- Research illustrating the potential to extract quantitative or semiquantitative information from eDNA signals.
- Strategies to use metagenomics in pooled samples of, for example, groups of plankton, including descriptions of bioinformatic pipelines for filtering of data and down-stream analyses.

A.4.2 Novel techniques and approaches in monitoring and assessment for sustainable ecosystem management and weather and climate models/forecasts.

State of the art and knowledge gaps

Novel and powerful monitoring techniques, including remote sensing and high-frequency automated observations, have become an essential component of the observing systems in the oceans, as well as in the Baltic and North Sea. Although the environmental monitoring and assessment systems would benefit from the integration of these technologies, e.g. by increasing the confidence of assessments, they are not a common part of the existing programmes yet. There are several aspects that need to be addressed to break the barriers and widen the use of remote sensing and high-frequency observations in environmental monitoring, and, thus, to increase the cost-efficiency.

The pelagic environment is highly dynamic, and ship-based monitoring alone does not resolve the temporal and spatial variability since an increase in resolution would cause an abrupt rise in costs. The hydrographic background has not been taken into account well enough to date in the status assessments despite the fact that without the detailed analysis of related natural variability neither proper assessments nor evaluation of the effectiveness of measures can be conducted. There are several EU-wide and/regional actions and projects to coordinate the development and provision of operational marine services (COPERNICUS, EuroGOOS, EOOS, JERICO projects, AtlantOS, EuroSea, etc.). The operational station network in the Baltic Sea and North Sea at present consists of a large number of coastal tide gauges and off-shore fixed platforms, including Smart Buoys and MARNET stations. Fixed profiling stations, as well as ARGO floats and gliders, have been used for research purposes at least for a decade now. Biogeochemical sensors (oxygen, chlorophyll, CDOM, turbidity) are attached to these devices and nutrient analyzers, pCO2, pH, and CH4 sensors, imaging flow cytometry, spectral fluorescence and absorption methods, etc. have been tested. However, these data streams are not employed for environmental assessments in full yet. The doubts are related to the availability and reliability of sensors, quality of data and comparability of results with the conventional methods.

Targeted actions are needed for developing approaches to integrate these sensors, platforms and analysis techniques into the monitoring and assessment systems. A major aim should be to enhance cross-disciplinary and regional cooperation significantly. Furthermore, when designing an environmental monitoring programme, other marine data needs such as operational oceanography and climate change related research should be taken into account. Cost-efficiency of observations is achieved when the measurements meet the requirements of multiple programs, e.g. a platform collects data for operational forecasts, includes sensors that feed the indicator-based environmental assessments, and produces time-series of essential climate variables. As important as following the common guidelines and quality standards for a regional environmental monitoring programme is the aim that the measurements meet the quality standards for several systems/programmes.

Expected outcomes

- Development of new sensors and improvement of emerging sensors, platforms and approaches, including in-situ technologies and remote sensing (e.g. satellites, drones, radars), for marine research, monitoring and assessment.
- Demonstration of how new technologies (already available and applied in marine research) can be integrated into the marine environmental monitoring and assessment systems, resulting in increased cost-efficiency of the monitoring programmes and higher confidence of indicator-based assessments.
- Approaches of including Earth Observations and numerical modelling combined with high-frequency in-situ monitoring in the environmental status assessments leading to more detailed analysis of natural variability and increasing spatial and temporal resolution that enable a better assessment of effectiveness of measures; evaluation of reliability of Earth Observation (EO), automated in-situ and model data for assessments.
- Recommendations for regional observation systems and good/appropriate data management to serve multiple uses/stakeholders/policies to fill in gaps, avoid duplication and increase the value of a single measurement / data point.

A.4.3 Innovative techniques for monitoring and long-term solutions for micro and macro debris in aquatic environments.

State of the art and knowledge gaps

Marine debris, identified as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment, is widespread and common in all marine environments globally. The majority of marine debris is composed of plastic and to date it has been estimated that between 27-66.7 million tons of plastic can be found in the world's oceans (Eunomia, 2016).

There is currently no single definition for microplastics. According to NOAA (Arthur et al., 2009) microplastics are pieces of plastic smaller than five millimetres, but many scientists prefer smaller than one millimetre as a standard definition. Microplastics are omnipresent in coastal and marine environments and can be originated by the degradation or fragmentation of larger plastic items. In addition, microplastics can also end up directly in the environment (e.g. via the domestic washing water, wear and tear of tyres via surface runoff, synthetic paint, loss of plastic powders and pellets).

Marine litter and plastic debris are widespread in the Baltic Sea and North Sea regions and the adjacent beaches. In the Baltic Sea, plastic makes up approximately 70% of the beach litter and the highest densities are found in the Gulf of Finland, Bothnian Sea, and Northern Baltic Proper (HELCOM). Plastic represents approximately 90% of all beach litter recorded during surveys in the North Sea region and is an order of magnitude higher for the Northern North Sea compared to the Southern North Sea (OSPAR). Widespread distribution of litter items, especially plastic, was also discovered on the seafloor of the Greater North Sea (OSPAR). The abundance of litter items on the seafloor increases from north to south, which can be attributed to larger human induced inputs, rivers, prevailing winds or currents (OSPAR). In the Baltic Sea, plastics constitute on average around 30 % of the number of items found on the seafloor and 16% of the weight (HELCOM). A distinct part of the plastic debris in these areas consists of abandoned, lost or discarded gear (ALDG) from fisheries or aquaculture activities, which can cause significant harm to marine life leading to wildlife being entangled, injured and even killed. The differences among sub-basins are attributed to actual differences in littering, as well as in the levels of beach cleaning. The shape of the coastline, winds, and the direction of water currents may also play an important role in determining where litter accumulates.

Also, military debris, including unexploded ordnance/ammunitions (UXO), are found in the Baltic Sea and North Sea, causing a potential high-risk health hazard both to humans and wildlife alike. For UXO buried in the sediment, there is still a lack in capacity to identify these objects through common monitoring techniques, especially in challenging environments, e.g. containing biogenic gas. Innovations in chemical sampling and analysis techniques and in biomarkers can give a more accurate insight into the chemical components being released from these objects and their effects on marine life.

During the next decades, it is estimated that the global plastic input to our seas and oceans will increase. For microplastic particles, a 50-fold increase is expected by 2100 compared to present-day concentrations. Therefore, actions are needed to combat the litter both to prevent from entering the ocean but also to clean up the existing litter. As 94% of the marine litter that enters the sea ends up on the seafloor, innovative clean-up activities should focus on or at least include seabed litter. Although, technological clean-up solutions alone are not sufficient to solve marine plastic pollution issues. Combining multiple strategies (including removal and prevention) are needed to eliminate ocean plastic contamination in the long-term. Partnerships that encourage innovation in relation to the prevention/clean-up of marine litter should be promoted. The education and involvement of citizens should also be prioritized. Clean-up activities by citizens are widespread throughout Europe and contribute also to awareness raising among citizens. Raised awareness in turn is likely to contribute to prevention of plastic pollution.

Preparing and launching an extensive long-term monitoring programme for plastics (e.g. ICES guidelines) in the marine environment is required to collect the necessary data to provide information on sources, presence, behaviour and effects of litter and microplastics on marine ecosystems. Funding models are required to support marine litter monitoring (seafloor and beach) and microplastic monitoring (i.a. development of international/regional harmonized techniques for e.g. the Baltic Sea/HELCOM and North Sea/OSPAR regions. Especially for micro/nanoplastic monitoring, there is an urgent need to progress in development of biotic indicators and simple, cost-efficient detection techniques. Sampling, detection and identification methods are still challenging for the smallest microparticles and the nanoscale. Moreover, improvements are needed related to the automated characterization of samples. Besides the need to work on establishing thresholds (i.a. environmental assessment criteria, background assessment criteria), also safe limits coupled with spatial variability of marine micro-litter in the environment (SAPEA 2019) are priorities.

Standardization and quantification of plastic flux and stock from land to ocean must be improved and documented. Automatic monitoring systems (e.g. multi platforms with sensors) are critically needed for litter monitoring. These include (satellite) remote sensing approaches, which can be challenging in aquatic environments. Yet, sustained observations allow for accurate quantification of plastic litter in seas and oceans, including its three-dimensional distribution. Also modelling approaches would be required for quantification of fluxes from specific sources and dominant transport routes that would support also effective policy for planning remedial action.

Expected outcomes

- A harmonised and standardized long-term monitoring strategy for the Baltic Sea and North Sea allowing for regional assessment of marine litter (on e.g. MSFD, OSPAR or HELCOM levels), including both macro- and microplastics.
- Full-scale model of sources and fluxes of micro- and macro-litter from land to the sea, validated with observations in rivers.
- Full-scale 3D model of how all plastics move through the ocean, making it possible to answer the fundamental questions to the distribution of marine plastic litter in the seas and oceans. This model should include both inputs of litter from land and from operations at sea.
- Detection of plastic accumulation regions in the Baltic Sea and North Sea with the aid of satellite maps.
- Automated microplastic detection workflow for marine samples, providing insights on the level of microplastic pollution and providing a knowledge base for future global modelling studies and risk assessments.
- Reduction and prevention of plastic inflow due to technological and industrial innovation, combined with socio-economic analysis and involvement of citizens.

- Novel techniques for the identification of buried ammunition.
- Improved chemical sampling and analysis methods and biomarkers for monitoring released chemical substances from UXO.
- Methods to remove large concentrations of macro-litter from accumulation hot spots.
- Better understanding of effects of plastic litter to ocean and human health.

3.2 Strategic objective B: Sustainable Blue Economy

The coastal and regional seas are of high socio-economic value, providing natural resources and wealth, and supporting local industries and communities. The role of the seas as a provider of healthy food, especially protein, is likely to increase in future. In addition, marine space is becoming an increasingly competed interest. The expansion of offshore energy, fisheries and aquaculture sector, tourism and marine transport all have vested interest in using it.

A comprehensive protection of marine ecosystems requires development of sustainable, circular blue solutions and practices to ensure the healthy seas and coasts of the future generations. The Strategic objective B: Sustainable Blue Economy, and its three specific objectives, aim to appraise the socio-economic value of different ecosystem services of the Baltic Sea and North Sea areas, while not neglecting the sustainable management practices. In addition, the aim is to provide innovative tools for comprehensive planning and management of maritime activities, mitigating the trade-offs among different uses and support the development of new, sustainable and circular innovation in the region.

3.2.1 Specific objective B.1: Sustainable resource management of marine commons

Overall rationale

The sustainable management of natural resources is an accepted policy goal across the globe with multiple high-level policies supporting the implementation through various instruments, including e.g. the New Green Deal's objective to "*protect, conserve and enhance the EU's natural capital*". However, while most terrestrial ecosystems, resources and production can be managed exclusively through national legislative frameworks, the governance of marine environments and their ecosystem services often demand an intense international collaboration in order to provide even the most basic attempts to manage resources sustainably. To emphasize the necessity of shared international responsibility of earth's interlinked marine ecosystems and their resources, the existence of a 'marine commons' has been suggested as an appropriate concept for communication purposes to highlight the management needs of resources and areas which are either beyond the jurisdiction or political reach of a single state.

A key step towards delivering such solutions are therefore the cooperation between regional sea basins and their R&I activities and links between neighbouring management frameworks (i.e. HELCOM and OSPAR) that must be enforced, to provide the holistic evidence-based decision support for overarching EU policies such as the CFP, MSFD and MSPD.

State of the art and knowledge gaps

To unlock the full potential of the BANOS-area's marine resources, recent innovation programmes have supported efforts related to advancing the use of both new and underutilised biomasses, and their sustainable management. However, much work remains to cover the full potential related to improving the capacity to extract, produce and process many marine resources. Present management tools are also not yet in a state which allows integration of all relevant knowledge including the impact of climate change, which the recent global IPCC report on oceans (2019) finds "*are already observed on habitat area and biodiversity, as well as ecosystem functioning and services*" in coastal ecosystems. Adapting management and value chains to oceans which are projected to "transition to unprecedented conditions" over the 21st century, thus present significant scientific and innovation endeavours, which will have to draw on all present knowledge to model future scenarios in order to mitigate impacts.

Impact and linkages

In support of multiple SDG targets (e.g. 2, 12, 13, 14), this part of the BANOS programme will deliver smarter management tools, close key knowledge gaps for sustainable harvest and advance innovative industrial uses of both new and underutilised marine resources of which some are presently considered waste products. This will advance Member States' ability to adapt their coastal value chains to mitigate the impacts of climate change, and support progress towards better implementation of the CFP, MSFD and MSPD, Bioeconomy Strategy and efforts towards EU's 2030 Biodiversity Goals thus delivering on key aspects of the New Green Deal. To deliver this, key advancements from the programme's other parts will therefore be needed, including e.g. improved understanding of the sea basins' resilience, general ecosystem service characteristics and options for seamless governance.

B.1.1 Sustainable harvesting/extraction and use of marine living and mineral resources

State of the art and knowledge gaps

The Baltic Sea and North Sea are home to complex and intensively used ecosystems, which have long supported a wide range of human activities. The long-term sustainability of these activities rely on environmental conservation and mitigation of the impact of exploitation of marine resources in both sea basins. Direct harvesting of marine goods by fishing and mining has thus had both immediate and long-term effects on the renewal of the resource being extracted, its marine environment and the structure of the ecosystem in which it is embedded.

The growth potential of the EU sea fisheries, especially in terms of supplying protein and polyunsaturated fatty acids (PUFAs) is limited, while the world population and the demand for protein and PUFAs keeps increasing. In addition, about 20% of the worldwide catch of wild marine fish are processed to fishmeal and fish oil, two major resources for marine aquaculture, a sector that is projected to expand linearly in the next 10 years with a resulting growing demand for fish feed. Meeting this demand (for both human consumption and fish feed or supplements) may also serve the broader industry. With no additional raw material expected from capture fisheries, any increase in fishmeal production will need to come from using by-products or alternative resources. Although fish by-products have a lower nutritional value as feed, other industrial uses have been gaining attention (e.g. biofuel, nutriceuticals, natural pigments, cosmetics). Many scientists are seeking alternative sources of PUFAs. Large marine zooplankton stocks are thus exploited by dedicated fisheries. More generally, zooplankton could be utilized to alleviate the pressure on traditional forage fish used to feed farmed fish. Zooplankton could also be a better raw material to manufacture healthier sea products, with possibly lower contaminant content than higher trophic level fish. Research has also evidenced that other marine ecosystem components could be considered for food, feed, marine biotech or other industrial purposes, including seaweeds, microalgae, marine sponges, bryozoans and cnidarians. Considering the hard-pressed situation of the aquaculture and other industrial sectors worldwide, commercial harvesting of such alternative resources, which have remained largely untapped in EU waters, is likely to develop in the coming decades. This would obviously open windows of opportunity for new fisheries as well as new technologies but will at the same time generate potentially high conservation risks. Zooplankton, in particular, serves a pivotal role in the marine food web and in the functional biodiversity of marine ecosystems, so their exploitation could alter a range of ecological processes.

Sand and gravel extraction has experienced a steep increase in consumption (a world-wide threefold increase over the last two decades), as well as demands for new dredging sites. That demand is expected to rise even further in the future, inter alia, to cope with the infrastructural challenges posed by sea level rise and the need for land reclamation. There are only few alternatives to sands and aggregates extraction to meet that demand, although using dredged material from maintenance or capital dredging could also be considered in the future. Although sand and gravel could be considered a renewable resource, the (geological) rate at which these resources are renewed is such that it is more realistic to regard them as non-renewable and as such non-sustainable. In addition, the economic opportunities brought about by an intensification in gravel and sand extractions would need to be balanced with related environmental challenges (e.g. alteration of coastline, habitats and of various ecological functions).

Overall, long term sustainable use of marine resources based on extraction of biomass or minerals is unlikely to be possible without the basic knowledge of the environmental, socio-economic and ecological context (i.e. socio-economics, natural variations in e.g. life cycles, stock sizes, habitat use and demands, resilience to ecosystem change and other pressures) and access to updated data. This will also require fostering of the development of greener fishing and mining technologies, as well as appropriate ecosystem- and economic-based decision-making tools (e.g. assessment and predictive models, indicators, thresholds) needed to support increasingly adaptive marine resource management. It appears particularly crucial to evaluate the conservation threats the exploitation of marine resources could create, and balance these with the benefits their utilization could provide for the industries, in a circular economy perspective. This is particularly true for untapped resources, for which knowledge is generally poor. In addition to this, sustainable exploitation encompasses not only sustainable extraction, but also the effective sustainable use of the resources tapped. This translates, for example, into the most efficient use of sandy material for coastal defence or beach nourishment.

By providing both a benchmark and the state of the art of the feasibility of sustainably harvesting new and existing marine resources, the R&I projects will develop science in anticipation of impacting economic development and political decisions. The projects will consist of multi-disciplinary, collaborative approaches to address the nexus between the management of natural resources and ecosystems, and the economic impacts and innovation for aquaculture, fisheries, mining and other industrial sectors. Case studies will be drawn from the Baltic Sea and North Sea regions, which offer contrasted marine resources, environments, ecosystems and human activities.

Expected outcomes

- Maps of non-indigenous/ newly discovered species with exploitation potential in the Baltic Sea and North Sea.
- Evaluation tools for assessing the extent, volume and quality of the available sand and aggregates resources in the Baltic Sea and North Sea in relation to the future demand and the potential socio-economic and ecological impacts of extraction. The tools would be used in consultation with authorities, end-users and stakeholders.
- Improved knowledge of biotic and abiotic marine processes including life cycles and distribution of living resources and resilience to current and emerging pressures.
- Improved knowledge base and strategy on the ecosystem and socio-economic effects of exploiting traditional and alternative marine living and mineral resources, including a substantiated framework to assess the most efficient use of available resources.
- Improved knowledge on the industrial potential of innovative utilisation of fish by-products and novel marine bio-resources, along with the conservation and technological challenges their exploitation and subsequent processing will involve.
- Sustainability assessments (e.g. life cycle) of representative value chains using marine resources enabling identification of key areas for improvement as well as comparisons with terrestrial value chains.
- Decision Support Tools (DST) to support the sustainable extraction of resources, including innovative ways of and the use of alternative material, e.g. ecosystem models, 3D subsurface models of the available mineral resources; deployment and improvement of methodologies to deal with model uncertainties, indicators, thresholds and reference points.
- New innovative technologies and tools (i.e. molecular, satellite, data driven, fishing gear, extraction gear, etc.) to advance low impact extraction of marine resources.
- Integrated management plans including performance analyses and ways to improve present approaches (i.e. more adaptive management) and the risks of lack of knowledge on key parameters.

B.1.2 Explore possibilities for innovation in seafood and zero food waste throughout the entire production system, for example, through valorization of bycatch and recycling of waste.

State of the art and knowledge gaps

To unlock the full potential of the Baltic Sea and North Sea fisheries and aquaculture industries, innovation is needed throughout the entire production, processing and retail system across the different species presently being harvested. This also includes waste products and bycatch which are increasingly being recognized as unused resources, only waiting to be exploited to support the expansion of a circular, bio-based European economy. The potential is significant as up to 70% of aquatic resources end up as waste or low value products in some value chains.

The demand for research and innovation within this field has been recognised for several years with work being carried on particular value chains through EU programmes such as COFASP, Blue Bio and direct Horizon 2020 projects such as DiscardLess (2014-2020) and Bio-based Industries' (BBI) WaSEAbi (2019-2023). However, to address the BANOS area's specific opportunities, dedicated work is needed across the entire local commercial value chains, which use marine biomasses to bring the whole sector forward.

Key knowledge gaps are particularly related to the regulatory challenges imposed by e.g. the CFP's discard ban, which increases the need for solutions related to e.g. traceability, mixed fisheries and demands for infrastructure with better onboard catch separation and cooling abilities to improve the quality and shelf-life of products. Progress within traceability has been seen in recent years where DNA-based methodologies for instance have been explored. Similarly, advancements of blockchain technology have also been consistently tested in other parts of the world for their potential to aid traceability efforts. The adaptive capacity of the value chains is also challenged in other ways. Climate induced range shifts of key stocks and the introduction of new aquaculture species to increase EU's own production, are for example both changes which will demand considerable adaptation from all parts of the value chain.

The potential in cross-cutting technological solutions to the adaptation challenge is broadly recognised, with several examples of known gaps. For example, are the extraction of omega 3 fatty acids from fish waste (e.g. fish livers) and bycatch (e.g. starfish) still problematic, just as several types of cultivation of marine organisms including macroalgae is not yet viable due to lack of growing and harvesting technology to produce commercially relevant yields. Similarly, opportunities also include the potential for extracting e.g. antioxidants, proteins and lipids from process water in the seafood industry.

Innovation to overcome technological bottlenecks experienced by the industry related to biological valorization, logistics, harvest and growth systems are therefore all key components in efforts to increase the commercial viability of fisheries and aquaculture, and their ability to contribute with both sustainable and healthy products for the world's growing population.

Expected outcomes

- Commercial potentials clarified for presently unused or underutilised marine living resources available to the BANOS area's fisheries and aquaculture industries.
- Value chains with enhanced ability to scale-up production of low trophic organisms, including seaweed, mussels, etc. from the BANOS area.
- New potential products based on current discards and waste, including processing water from the BANOS area's seafood value chains.
- Identified and advanced possibilities of present fisheries and aquaculture value chains in the BANOS area to deliver high quality products with long shelf-life, through innovation in e.g. storage and sorting tools, selective gear in order to reduce waste at both the producer and consumer level.
- Research and innovation illustrating the potential for creating new local value chains based on sustainable aquaculture in the BANOS area.

- New traceability opportunities for marine resources from the BANOS area throughout value chains, in line with relevant policies and e.g. consumer expectations.
- Strategies for addressing policy and contamination related challenges experienced by the BANOS area's stakeholders, e.g. environmental agencies, fisheries, aquaculture, feed and food industries, and explore options for viable solutions.

B.1.3 The development of multifactorial marine spatial planning management tools as knowledge bases for the competing demands of space utilization and ocean challenges.

State of the art and knowledge gaps

As EU Member States are implementing the EU Directive on Marine Spatial Planning (MSPD) and expected to prepare maritime spatial plans by March 2021, we are approaching a unique situation in which all EU waters are spatially planned, including Exclusive Economic Zones where such are claimed. In the Baltic Sea that will be a major change in the governance landscape as this is the first round of MSP planning for most of the countries. In the North Sea region MSP planning has somewhat longer history proceeded much with some countries already in their third planning cycle.

In the situation post-2021, new tools to support MSP are needed. This completes the initial exercise and the scope of the tools that will be needed will shift from the preparation of plans to the tools needed for monitoring, evaluating reviews and updating of the existing plans. The tools used during their first planning cycles will have to be adapted to respond not only to the changes in the use of the seas and marine environment, including the climate demand, but also taking into account the reviews, comments and progressive insight gained during the previous planning rounds. Changed demands for the sea space are mainly driven by the urgent need for the transition to renewable energy, in line with the Paris Agreement and the EU Green Deal. In the shallow North Sea and the Baltic Sea, this includes development of wind farms at an unprecedented large scale. In brief, the new tools are needed for update rather than layout of the plans.

As a first step, stocktaking of the consequences of MSP planning in Europe is needed, to reflect the important shift induced in regional sea areas where it is implemented for the first time. MSP has taken a prominent role and has potential of becoming one of the most accepted approaches to reform ocean governance. However, while introducing MSP legislation and planning systems, the EU countries have not replaced any of the existing frameworks yet. In addition, as MSP is a relatively new development in most of the countries, it remains to be seen how profound a change, and which benefits, it can deliver. The MSP's ability to improve the performance of marine governance has been challenged, for instance in an empirical analysis of the first MSP plans in English waters. The MSP practices have also been criticised for maintaining the agendas of dominant actors. Stakeholder participation includes listening to stakeholders but does not give them sufficient power to really influence the process and decisions – hence the risk of business as usual. This stocktaking, giving insight in the realisations can serve as a basis and framework for further development of MSP practices, tools and even the MSP theory.

Potential additional aspects that will have to be identified within an MSP will have to be studied. At the moment, projects are being carried out on the inclusion of cultural heritage, for example, but especially the methods for incorporating and assessing cumulative effects within the preparation of the plan are aspects that will have to be actively taken into account. Extensive research and collaboration on cumulative effects is ongoing, and the challenge will be to provide the tools to optimally incorporate this knowledge into the MSP process. As the basis of cumulative effects assessment quantitative information about pressures from human activities and impacts on ecosystem components is required, complemented by threshold levels indicating desirable state and acceptable changes. This assessment framework is progressively being developed under the MSFD and should find its way into MSP scenarios.

The socioeconomic aspects of an MSP, e.g. charting how the results and products of the sea are distributed and the influence of decisions at sea on the coastal communities, will need to be considered in the MSP process.

MSP is a political process to debate and decide about the use of the sea areas. One cannot calculate the optimal solutions that would then be turned directly into a plan, but with the help of the tools and especially with the help of good quality deliberative processes one can help the planners and stakeholders, not only in understanding consequences of alternative planning solutions but also in revealing new possibilities for developments and collaborations. Although MSP is currently mainly aiming at realizing a balanced spatial distribution of different activities, part of the future perspective may also lie in making the distribution not only spatial, but also taking into account and as such also enabling and facilitating simultaneous multi-use and consecutive co-use, based on the specific needs and services of different ecosystems and activities. MSP should therefore be a platform that is usable by government, industry, academia and civil society alike.

In order to support this aim, DST should be further developed. A review of existing DST showed that "Results revealed that DST developments should consider both spatial and temporal dynamics of the ocean, and new tools should provide multi-functionality and integrity; meanwhile they should be easy to use and freely available" (Pinarbaci, 2017) . Discussions between Baltic Sea countries indicate the challenge of using tools that are developed in one country as they are often built on national data infrastructures and data practices. This should be a topic to address and develop tools that work transnationally and are transferable in practice (easy and cost-effective to use, able to handle different types of data, etc.), working directly with the planning authorities on this.

Expected outcomes

- An evaluation of existing national plans – both in terms of their functioning in the national and regional policy landscape and in assessing the effectiveness of the plans in facilitating the national decision-making process.
- Comparison of MSP systems between countries and their transboundary coherence and impacts, including knowledge on effective collaboration procedures and methods.
- The development of a framework for future iterations of MSPs, including the existing and new methods for including and assessing good environmental status and cumulative effects, with attention on the inclusion of socio-economic aspects and the cross-border coherence of the plans and with indication of the knowledge gaps.
- Identification of (existing and required) data streams relevant to MSP (big data) of both spatial use and presence of ecosystem service provisioning.
- Development of methodologies to enable connecting MSP to existing and new data flows (ship data, environmental monitoring) during the planning and evaluation phase of MSP, to create effective permanent data flows that build towards automated assessments.
- Development of DST for MSP, enabling to include climate change as a precondition, but also taking into account the effects of the proposed planning on the climate and on ecosystem services.
- Development of DST for MSP to facilitate and assess current and future national and cross-border evolutions and developments.

3.2.2 Specific objective B.2: Understanding the value of ecosystem goods and services

Overall rationale

Popularized as part of the Millennium Ecosystem Assessment in the early 2000s and further developed in research projects (such as the UK National Ecosystem Assessment (NEA)) and by international efforts (such as Common Classification of Ecosystem Services (CICES)), the concept of ecosystem services now offers widely applied and accepted approach for identifying and communicating the impacts of nature on human welfare and wellbeing. Implementation of international and European policy frameworks (such as UN Sustainable Development Goals, EU MSFD, EU 2020 Biodiversity Strategy) assume that the concept of ecosystem services, and their value, is operationalized in a manner that enables quantitative projections as response to changes in ecosystem state, pressures, societal trends and policies. In particular, increasing efforts to use ecosystem-based approach in the policy processes (e.g. OSPAR NEAES, HELCOM BSAP, EU MSFD and MSPD) require explicit linking of ecological and social systems.

State of the art and knowledge gaps

Quantifications and valuations of ecosystem services serve multiple purposes. Assessments and simulations increase our understanding about the rich spectrum of ecosystem services, interactions and feedback mechanisms associated with their provision, and also the relative importance and contribution to our consumption and production possibilities, health and wellbeing. Information about the positive and negative consequences of investments, abatement measures and policy instruments are needed in cost-benefit analyses in order to assess the need for policy intervention and to rank policy alternatives. Quantitative information about the current levels of final ecosystem services is needed for national accounting.

The concept of ecosystem services is well established. However, the actual applications that make use of the concept by a) communicating the contributions of nature to the great public, b) providing inputs to assessments and cost-benefit analyses and c) providing inputs to relevant policy processes are still rare. For example, there is a need for clear and intuitive visualizations and demonstrations of past, current and future flows of ecosystem services built on internally consistent groupings and representations of ecosystem services.

Market and non-market valuation methods as well as non-monetary techniques are used to value ecosystem services and changes in the attributes of the marine ecosystems. Several ecosystem assessments and valuation studies have been conducted both for the Baltic Sea and North Sea. However, approaches that synthesize valuation research results, obtained from various sources and properly accounting for partially overlapping elements of total value are still missing. Also, we miss detailed information on spatially and temporally explicit values, which enable detailed assessments of the provision of and demand for ecosystem services. Well-balanced assessments of the impacts both on the future prospects of blue economy sectors, and the health and wellbeing of consumers, are needed. Also, projections of yet less studied but potentially important ecosystem services are needed.

Impact and linkages

This specific objective contributes to the implementation of the regional programmes both in the Baltic Sea and North Sea (HELCOM BSAP and OSPAR NEAES), several EU policies and strategies (such as Blue Growth Strategy, Common Fisheries Policies (CPF), Integrated Maritime Policy Directive on Maritime Spatial Planning (MSPD), European Green Deal, Strategy for the Baltic Sea Region (EUSBSR)), and current UN initiatives (SDGs and UN decade of Ocean Science). It also supports member states the European Commission's contribution to ongoing IPBES work. Together with specific objectives B.3 (Smart Seas) and B.1 (Sustainable Resource Management), this objective provides overall understanding and creates new knowledge about the prospects for sustained utilization of goods and services from marine environments. Quantification of ecosystem services is improved through advances in modelling and monitoring marine environments (specific objectives A.3 and A.4) and contributes to the seamless governance (A.2). There are also direct linkages with safe food and feed (C.1).

The projections of ecosystem services at spatially and temporally scales relevant for research communication serve users of marine environments and the public to plan economic activities, marine protection and recreational visits. Spatially and temporally explicit ecosystem service values contribute and can be used as inputs to national and international policy processes. In particular, attempts to assess the aggregate value of changes in the provision of multiple ecosystem services (including the impacts on the prospects of blue economy, human health and wellbeing) will allow basis for assessing the benefits of implementing a policy, and ranking policy alternatives. Linking the ecological and social systems thus supports the implementation of the ecosystem-based approach.

B.2.1 Integrated analyses of the ecosystem and social-economic system, describing and quantifying linkages between human activities, pressures, state of the environment, ecosystem services and human welfare to support the implementation of the ecosystem approach in marine policies

State of the art and knowledge gaps

The ecosystem approach, a guiding strategy in many marine policies (EU MSFD and MSPD, HELCOM BSAP and OSPAR NEAES), requires considering the interconnectedness within the ecosystem but also between the ecological, social and economic systems. Considerable information exists on the different elements of the chain, such as activities, pressures and state of the marine environment, but there is insufficient knowledge on the interactions between the elements, as well as impacts on human welfare. Thus far, integrated assessments of the marine environment that explore and quantify the interlinkages across different ecosystem components, sectors and activities and human welfare have been to a large extent missing or focused on specific links, for example between two components. Decision-support frameworks relevant to key stakeholders and policymakers that are based on integrated assessments are needed to 1) operationalize the ecosystem-based approach, 2) evaluate how the marine environment affects human welfare, 3) allow for improved consideration of impacts on key environmental goals, including the UN SDGs and EU, regional and national policies. This requires establishing and assessing explicit links and feedbacks between the economic activities using the sea, state of the sea and human welfare.

The work should be based on a strong conceptual framework for linking drivers, activities, pressure, state, ecosystem services and human welfare, and seek to build on existing frameworks and approaches, such as one of the variations of the DPSIR framework and concept of ecosystem services. There is a need to move from conceptual frameworks and strategies towards operationalizing these frameworks with relevant data and models and explore the possibilities of combining quantitative and qualitative data. For integrated assessments, it is necessary to cover all elements in the chain, i.e. drivers, activities, pressures, state (including ecosystem services), impacts (human welfare) and response (policies and measures). The frameworks should be capable of integrating climate change impacts and spatially and temporally explicit data on the elements, such as that provided in B2.2, as well as support the ongoing work of OSPAR and HELCOM.

The social-ecological systems (including economic interactions) are complicated and may even have characteristics of complex adaptive systems. It is likely that integrated assessment frameworks cannot cover all components of the systems, at least with data of equal quality and extent. Thus, it is important to be transparent of those components that are excluded from the assessment frameworks, as well as communicate clearly such limitations and consider complementary approaches to cover some of the gaps.

Assessments should start by evaluating stakeholder needs for integrated analyses in the policy area. Knowledge should be developed for the linkages between ecological and social systems, including how the contribution from human activities using marine waters to the economy and human welfare is dependent on other activities and the state of the marine environment; how activities affect pressures and further the state of the marine environment; how the state of the marine environment affects the provision of ecosystem services; how human welfare is affected by changes in the status of the marine environment and/or provision of ecosystem services, also in monetary terms; as well as what are the impacts of measures and policies on marine uses, state of the environment and human welfare. Additional information is needed on the limitations of integrated assessment frameworks and possibilities of filling the gaps with existing and new research, as well as complementary approaches.

Expected outcomes

- Assessment of potential utilisation of and need for integrated assessments in marine decision-making on different scales.
- Description of the conceptual framework, approaches and methods used for the integrated assessment.
- Operationalized framework with quantitative and qualitative data and results for the interlinkages between the elements of the framework, including measures, activities, pressures, state, ecosystem services and human welfare.
- Limitations of the assessment framework and possibilities to fill in the gaps.
- Results and implications for implementing the ecosystem-based approach to support national and international marine policies.
- Assessment of linkages between marine policies based on the framework.

B.2.2 Spatial and temporal analysis of the contribution of ecosystem services and environmental changes to human welfare

State of the art and knowledge gaps

At present, the concepts, definitions and classifications of ecosystem services (ES) are already well-established and have also been adapted to the context of marine environments. There is a relatively large amount of information on the provision, benefits and value of ES that is non-spatial and non-temporal. However, spatially and temporally explicit approaches, data and results are largely missing, in particular for marine environments, as well as results that can be directly linked to marine policies.

There is a need to cover both monetary and non-monetary values of ES, as well as conduct additional research on ES that have been studied less or that are considered of the most importance in the BANOS areas. Many existing studies on the benefits from ecosystem services are case-specific without generalization possibilities. Future studies should be designed as such that the results can be transferred to other contexts, including national accounts (B2.4), especially if all relevant countries/areas/ecosystem components cannot be covered with primary studies.

To improve the knowledge base on ecosystem services and the usability of the results for policy purposes, there is a need to produce spatially and temporally explicit data and mappings of the demand and value of ecosystem services from natural and semi-natural systems under different management scenarios. To this end, spatially explicit and internationally coordinated valuation studies on the monetary and non-monetary value of changes in the environment and ecosystem services are needed, to provide coherent information on the impacts on human welfare from (positive and negative) changes in the status of the marine environment and/or provision of ecosystem services. These studies should enhance our understanding of the motivations and determinants of social and economic values of ecosystem services in different areas and management scenarios. An important consideration is assessing how to incorporate existing and new information on ecosystem services into marine policies and decision-making.

Expected outcomes

- Spatially explicit approaches and methods to identify and value ecosystem services and environmental changes.
- Data and results from case studies on the spatial and temporal distribution of the demand and value of particular ES and environmental benefits, to assess (negative and positive) impacts on human welfare under different scenarios.
- Reasons behind spatial and temporal variation of ES demand and values.
- Recommendations on how to incorporate the value of ecosystem goods and services as part of informed marine decision-making, e.g. EU MSFD and MSPD, Biodiversity Strategy, Regional Sea Conventions (HELCOM, OSPAR) policies.

B.2.3 Incorporation of ecosystem goods and services into national accounts (cf OECD, UN environment)

State of the art and knowledge gaps

There is an increasing demand for statistics on ecosystem services (ES) in order to properly balance desires for economic growth and development and environmental sustainability. The UN System of Environmental Economic Accounting (SEEA) contains an internationally agreed set of standard concepts, definitions, classifications, accounting rules and tables to produce internationally comparable statistics for natural assets such as water resources. The SEEA Experimental Ecosystem Accounting (UN 2014) offers a synthesis and provides a platform for the development of ES at national and subnational levels.

At the European level, two EU strategies foster the development of ecosystem accounting. The EU Biodiversity Strategy for 2020 encourages Member States to assess the state of ecosystems and their services, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national levels. The EU Green Infrastructure Strategy aims at maintaining current green infrastructure and restoring some of the degraded ecosystems.

Several EU countries have programmes on environmental-economic accounting, but the actual applications are still under development. The typologies and approaches have been developed in projects such as Mapping and Assessment of the Ecosystems and their Services (MAES), Knowledge Implementation Project on the Integrated system for Natural Capital and Ecosystem Services Accounting (KIP-INCA), Mapping and assessment of integrated ecosystem accounting (MAIA), and Pan Baltic Scope. Common International Classification of Ecosystem Services (CICES) provides the ES typology relevant for accounting purposes.

The main gap of knowledge is operationalizations of the existing frameworks as part of national accounting or systems that can be included as elements of national accounts. To this end, balanced information is needed about the value of tangible ecosystem goods and services exchanged in markets and more intangible services. Inventory system of marginal changes in the provision of alternative ecosystem services is needed. These may include condition assessments (including sustainability appraisals).

Expected outcomes

- Applications & case studies that build on existing frameworks (e.g. SEEA) and relevant typologies (e.g. CICES) to create meaningful operationalizations of marine ecosystem services for the accounting purposes.
- Accounting tools that help to measure progress towards the national goals or SDGs.
- Research results that help at full integration of economic-environmental accounting with the national accounts.
- Methodological developments in the analysis of uncertainties and the quality of data in accounting. These may include a) comparisons of alternative approaches, b) comparison of assessments based on alternative data sources, and c) new valuation methods relevant for natural capital accounts.

3.2.3 Specific objective B.3: Smart Seas - sustainable, circular and bio-based blue solutions

Overall rationale

Since centuries, our oceans have been economically used. They play a prominent role in logistics, nutrition, energy production and provision of biotic and abiotic resources. However, most of the past and present economic activities have not been designed with sustainability in mind. Thus for the past century, we have seen exploitation rather than sustainable use, which is the goal of SDG 14: "*Conserve and sustainably use* *the oceans, seas and marine resources for sustainable development*". To overcome this challenge, we need a broad initiative for innovation in smart seas, to bring our industries up to date with the present urgent demand for increased sustainability through circular use of materials and bio-based solutions and exploit the potential of clean energy.

On the European policy level, this objective is directly contributing to the combination of economic development (BGS, BSAP, EUSBSR, IMP), sustainability and circular economy (CEAP), and renewable energy from the oceans (EGD, EU Climate Policies). The idea of Smart Seas is the key concept to overcome the conflict between economic use of our oceans on the one hand and on the other hand protecting and even improving the environmental status of the Baltic Sea and North Sea.

State of the art and knowledge gaps

In some instances sustainable use of the oceans has already been achieved - most of times triggered by legislation. Furthermore, the society can rely on basic technology developments and find new innovative applications for blue solutions. Globally we already see the first good examples of this approach, e.g. Integrated Multitrophic Aquaculture, involving multiple trophic levels. A benefit of this approach, using a combination of fish, mussels and algae, could, for instance, lead to reduction of harmful emissions seen in traditional aquaculture. Large scale commercial multitrophic production is still missing, though considerable progress has been seen in e.g. Canadian case studies.

Additional potential is offered by circular economy. Various technical installations, for example associated with oil industry and offshore energy, have been built in the seas over the past decades. Before installing new ones, it should be examined if existing structures can be reused and transformed for another purpose.

Successful concepts do not only combine knowledge from life sciences and several technical disciplines - it always has to be aligned also with legislation and offer a business case to approach the market.

Digitalization is another trigger for smart solutions. With a large number of reliable and cheap sensors for monitoring, surveillance and inspection, large amounts of data can be collected and semi-automatically analysed with means of artificial intelligence. Digital data is in many cases the key ingredient to shape the solution and is continuously necessary for monitoring of environmental state and soundness of operation. Novel combinations of data, services and business models have proven to be the foundation for economic growth.

Impact and linkages

This objective is in the core of the BANOS SRIA. It tries to solve the conflict of ecology and economy by using the Baltic Sea and North Sea to have a commercial benefit on the one hand but doing it smart and sustainable. This is one of the core ideas of the Blue Growth concept and other policy documents for the Baltic and North Sea regions. Several challenges of mankind can only be solved if we actively make use of marine space. However, we should not make the same mistakes as on land when looking on extensive agriculture or massive intrusion in the environment with surface mining. In order to reach this goal, the proposed R&I activities of this specific objective are closely related to the following objectives: A2 and A4 for carefully monitoring impact of economic activity, implementing adequate governance structures, and dealing with digital sensor data, B1 for the specific activities related to the living and other marine resources as well as maritime spatial planning as an underlying framework, and C2 covering coastal activities and interaction between coast and sea.

B.3.1 Secure, clean and efficient renewable energy

State of the art and knowledge gaps

Our seas and oceans can play an important role in providing secure, clean and efficient energy for our societies. Ocean energy will be an indispensable contribution for a decarbonized energy concept of the next decades. While offshore wind is already an established business, approaches to harvest the power in the oceans (wave energy, tidal energy) are still in its infancies. Due to the harsh conditions (e.g. salt water, pressure, low temperature, ...) the technical solutions are extremely challenging and need additional research and development to provide commercial solutions. Even though the energy extraction from the sea seems to be more topical for the North Sea, it is worth to explore its role in the Baltic Sea as well - at least as a first step in qualifying new technical solutions for the later use in more harsh environments. The objective should not only contribute to the development of new power stations but should also consider the whole lifecycle of systems.

Increased robustness of offshore systems is still an important focus of research and development. New concepts such as smart materials or 'Internet of Things' offer a potential to increase not only the robustness but significantly improve efficiency, availability and safety of the installations. Specific R&I is necessary to exploit the potential of those approaches for the area of offshore energy.

The concept of multi-use of marine space needs to be further explored as one of the possible approaches towards enhanced sustainability. Feasibility of Integrated Multitrophic Aquaculture within offshore wind farming areas depends on different factors, in particular technological implementation, biological feasibility and environmental sustainability of the enterprise should be investigated.

Maintenance, repair and overhaul procedures of the subsea structures today need diver operations which is not only costly but also risky. There is a need for autonomous underwater robots that can replace divers in complex technical operations.

First wind parks in the Baltic Sea built in the early 90s run out of use. Hence the challenge of decommissioning becomes more and more relevant. We must find smart solution offering a maximum cost efficiency, environmental soundness and safety.

Over time, power plants typically increase in size. This increases overall production efficiency but results in complex products that are difficult to install and maintain. To provide local energy for offshore activities (e.g. aquacultures or ships anchored in the roadstead), decentralized small plants could provide, if available, renewable energy for local consumption.

Cable infrastructures are often a limiting factor for growing the number of ocean energy installations. Available concepts for power-to-X (X as a placeholder for hydrogen, ammonia, liquid fuel etc.) must be qualified and tested at larger scale on the Baltic Sea and North Sea, including the necessary logistic processes.

The process of spatial planning, environmental impact assessment and permitting is quite diverse in the different regions of the Baltic Sea and North Sea and often result into significant delays in project plans. Legislation is not adapted to new technologies and smart ideas for blue economy which encumbers innovation.

Expected outcomes

- Improved prototypes of tidal and wave energy generators with robustness and efficiency increased by at least 20%.
- An overarching network of offshore testbeds to enable efficient research, testing and demonstration on innovative energy solutions taking into account the different conditions in the Baltic Sea and North Sea.
- Technical solutions to increase the life span of offshore energy installations by innovative technologies, new methods for monitoring, robot-based repair and refurbishment.
- Comparative studies of Multitrophic Aquaculture within offshore wind farming areas for the Baltic Sea and North Sea.
- Demonstration of underwater robot technology for unmanned robot technology for repairs and overhaul of subsea structures.

- Concepts for sustainable decommissioning and recycling of offshore energy installations including offshore wind.
- Pilots of decentralized small offshore energy installations and demonstration of their application in selected use cases.
- Power-to-X pilots to demonstrate alternatives to traditional power transmission via sea cable, e.g. by creating, storing and delivering hydrogen or liquid fuel for storing and delivering energy.
- Concepts for streamlined and harmonized marine spatial planning and planning approval procedures that offer flexibility for innovation. A focus should be on novel concepts for environmental impact assessment and compensation measures.

B.3.2 Sustainability of marine infrastructures

State of the art and knowledge gaps

Infrastructure is the backbone of a society. More and more of our infrastructure is at least partially related to sea. Maritime infrastructure includes a broad spectrum of technical structures, e.g. e bridges, offshore windfarms, coastal protection, oil and gas pipelines, energy and communication cables and ports. These objects have a limited lifetime and most of them are not designed with sustainability as a guiding principle. Furthermore, such installations offer potential to be combined with additional uses beyond their initial purpose.

Compared to other application areas, the application of digital technology is relatively small in marine infrastructure. More sensors and smart evaluation of digital data could help to improve monitoring and maintaining required structures and extend their lifetime.

Planning and engineering of marine infrastructures are limited to their primary function. Industry and administration have sophisticated procedures and tools to support this approach. However, secondary function such as semi-natural ecosystem services could be combined.

Marine infrastructures are typically decommissioned after their life cycle ends. Their potential for establishing new functions instead of expensive transport and disposal is not extensively researched. There is a need for flexibility in regulation and new concepts to plan and build with old material.

Novel materials such as basalt fibres have already been used in some research projects and have proven environmental soundness and robustness in saltwater. However, their broad application in marine infrastructures has not been exploited so far.

Expected outcomes

- Concepts and IT tools for life-cycle assessments of different offshore infrastructures and their components, evaluated in the light of both relative and absolute sustainability criteria, while identifying both governance and economic challenges for implementing the best options.
- Pilot installation of IoT and related technologies in a real-world offshore structure in the Baltic Sea or North Sea to jointly monitor the state, efficiency, maintenance needs and environmental impact.
- Pilot installations demonstrating how present and future offshore and coastal infrastructure could be engineered to add value (in addition to their primary function) by supporting the restoration of biodiversity, semi-natural ecosystem services, and resilience in marine and coastal ecosystems in support of ecosystem-based management.
- Technical guidelines for upcycling present and future marine infrastructures and their components found in the BANOS area, i.e. use infrastructure materials such as concrete to e.g. capture pollutants, create artificial reefs to upcycle materials.
- Identification and qualification of new materials (e.g. basalt fibers) for sustainable applications in marine infrastructures. Due to the different water characteristics, the Baltic Sea and North Sea serve as two separate target areas or test cases.

B.3.3 Towards a smart blue economy

State of the art and knowledge gaps

Taking into account the availability of huge amounts of new sensors, digital data, novel ways of mass data processing (including AI) and a growing level of autonomy of robotic systems - even in complex situations - it is time to think about completely new ways of maritime economy. This objective B3.3 is intended to open the minds and induce some blue skies research that might have a mid-term or long-term impact to the industry. It should open the door for disruptive ideas by broadening the scope of sustainable maritime activities, by application of artificial intelligence and robotics, observation and measuring techniques, smart sensors, big data and connectivity, and for blue bio economy also in combination with recent molecular and veterinary approaches.

Digital economy is based on efficient generation of digital data by low-cost sensors in combination with easy access to distributed data and automatic data analytics using AI. After successful examples of digital value chains in application areas such as industry 4.0 or the energy sector, it is now time to focus on maritime applications for a smart blue economy. Initiatives started in other application areas (such as the Industrial Data Space) could serve as a blueprint for a maritime digital platform. First pilot that typically have a regional scope can be connected between the Baltic Sea and North Sea to create added value.

Today's digital projects in context of smart blue economy are always designed to meet the primary function of the initiator. Similarly to the shortfall of B3.2, we also waste potential if we do not open sectoral data bases and enable additional usage of the data. However, this needs additional research to identify design rules or best practices for this approach.

For the blue bioeconomy, high global growth rates are expected for especially aquaculture, with recent projections suggesting that aquaculture could be able to provide protein for more than half of the world's population. The rearing of many species is, however, still in its infancy, and thus lacking behind e.g. the knowledge level and technology available for rearing of most terrestrial animals and plants. Closing this gap through technological innovation and expanding use of sensors will be a key to deliver high-precision aquaculture practises and systems.

The environmental impact of both aquaculture, fisheries and other maritime activities often depend on where the use of marine space takes place. Supporting marine spatial planning through the use of smart technology therefore also represent a priority across the BANOS area, which is one of the most heavily used marine spaces in the world. Present marine spatial plans are only emerging, with considerable needs for cross national and industry collaboration to reduce trade-offs between users to enable multiuse of areas.

Similarly do the stakeholders in the given area also have the potential to advance multiple digital service concepts, where sensors placed on e.g. ships, fishing gear, aquaculture, wind farms, oil rigs etc. could provide valuable data sources on environmental parameters, which could be of value for both public and private stakeholders.

Expected outcomes

- A prototype of a maritime digital platform combining data sources of BANOS region and online services. This should not only enable regional value chain in the Baltic Sea and North Sea but also bridge the gap to create cross-sea value chains.
- Demonstrators for commercially exploiting 'digital bycatch': many stakeholders collect digital data as part of their daily business. Typically, this data is only used by them and not provided for third parties. Even though it is not intended, others could make use of data that was not triggered by them and include such in their business model.

- Best practice examples of spill-over innovations: Digital technology that has been developed and used by marine researchers or public authorities often has an application potential in blue economy. This should be identified and practically demonstrated.
- Technology prototypes to enhance productivity and sustainability in the BANOS area's blue bioeconomy including integrated solutions for advanced life cycle management of species in aquaculture and improvement of e.g. welfare survival rates and growth through the use of state-of-the-art technology, innovative feed or biotech solutions. The peculiarities of the Baltic Sea and North Sea have to be taken into account.
- High-precision breeding programmes developed for multiple species of fish, macroalgae, bivalves etc. through the use of state-of-the-art sensors for monitoring, breeding tools and approaches developed with inspiration from e.g. agriculture practises.
- Well-tested prototypes of offshore aquaculture systems, including advancing the level of automation for monitoring, observation and maintenance.

B.3.4 Technological aspects of development of new recyclable materials, pharmaceutical substances, food products and natural fabrics from marine resources.

State of the art and knowledge gaps

The use and uptake of new technology is widely recognized as a key to identify opportunities and develop products faster, cheaper, better and more sustainably in many industries including those depending on biotic or abiotic marine resources from the Baltic Sea and North Sea. Many marine resources have, however, not been extracted earlier nor necessarily explored to any significant degree for its potential uses. This includes, in particular, biomasses from many low trophic organisms and most marine micro-organisms where large unexplored bioactive potential has been suggested based on metagenomics and genomic analyses.

Among recent biotechnological cases are for example the insights received from the study of the functions and adaptations of marine microorganisms, with clear pathways from discoveries in basic research to new opportunities for application in the biotech and the pharmaceutical industry's value chains. This includes discoveries of new drugs, enzymes, probiotics etc. covering for example analgesic, immunomodulating and anti-inflammatory uses. Continued exploration, identification and characterisation of marine organisms is thus a key to ongoing innovation given their very different adaptations than their terrestrial counterparts, yielding different chemical scaffolds, carbon sources etc.

From a biomass perspective, new aquatic biomasses are also increasingly finding their way into new value chains encompassing both industrial ingredients, cosmetics, textiles, feed and food. For example, immunostimulating feed based on marine resources are increasingly being tested and used in e.g. agriculture and aquaculture as health management tools. Similarly, new ingredients from e.g. algae are increasingly identified and recognized for the ability to prolong the shelf-life of certain food products, just as e.g. chitin and its modified polymer chitosan from shell carrying marine animals can now be used in textile production. Even fish skin has now been found possible to process so that it now can be used as a textile akin to leather.

For the food industry, significant development is also ongoing to live up to the increasing demands of consumer safety and food quality. Novel processes such as ultrasound and ozone treatments, fast cooling, infrared heating, pulsed electric fields and light are here just some of the examples of ongoing approaches being piloted.

In order to harvest, produce, process or extract compounds of interest, refining, automated handling and other supporting logistics must necessarily be developed alongside product innovation in order to make production scalable and commercially viable. In the BANOS area, these demands therefore translate into a need to advance the opportunities related to future commercial production of products derived from macroalgae, bivalves and fish species in the Baltic Sea and North Sea, as the diversity of viable businesses is still low.

Expected outcomes

- Identification/Discovery of new types of materials and natural fabrics based on marine resources of BANOS area, which can be produced, used and recycled in ways which is more sustainable than their present alternatives.
- Research and innovation demonstrating how to develop or apply state-of-the-art technology (sensors, biotech etc.) to systematically search for marine compounds with pharma, nutrition or industrial potential.
- Research results on new chemical scaffolds in molecules from marine organisms and their potential to advance future discoveries of drugs and enzymes.
- New marine microbial cultures including pure, probiotic, living biocontrol etc. relevant to the bio-based and pharmaceutical industries.
- Technological solutions which advance the logistic ability to produce and process marine organisms safely, sustainably and in commercially relevant quantities in the BANOS area.
- New extraction technologies and opportunities for marine biomasses harvested or produced in the BANOS area, enabling extraction of high value compounds such as fatty acids, antioxidants and other bioactive compounds, where current technologies do not work.
- Technology which can refine or automatically handle larger quantities of marine biomasses from the BANOS area to produce either new or more sustainable food, feed, fabrics and other bio-based products.

3.3 Strategic objective C: Human Wellbeing

The human wellbeing is intrinsically connected to and impacted by the sea. The coastal areas are heavily populated with almost half of the EU population living less than 50 km from the sea with the seaside being Europe's most popular holiday destination. Much of the food that is consumed is produced in the local regional seas; safe food relying on healthy marine ecosystem, which is devoid of contaminants and pathogens, and environmentally sound management practices. There is also an increasing amount of research data suggesting a link between human wellbeing and access to coastal environment, proving opportunities for relaxing, exercise, creativity and recreation. Climate change and associated phenomena, e.g. sea level rise and increase in extreme weather events, are also going to pose new threats on human wellbeing.

BANOS Strategic objective C: Human Wellbeing, and the associated two specific objectives, aim to provide a new knowledge base that supports human wellbeing, including health aspects and a fair access to the benefits of ecosystem services among citizens in different regions and states, and representatives of different groups in the society and people of different occupations. In addition, it promotes strong interdisciplinary research approaches, connecting natural sciences and humanities, which is critically needed to tackle the existing and future challenges and to provide solutions to overcome them.

3.3.1 Specific objective C.1: Safe food and feed

Overall rationale

Human health and wellbeing in the Baltic Sea and North Sea regions is intrinsically connected to and impacted by the seas, and these aspects of the blue economy will be explored in C1. Understanding factors that affect human wellbeing in this complex system can only be achieved with an interdisciplinary approach involving all regional states, drawing on expertise across diverse range of disciplines and strengthening transnational collaborations. The impact of changing the Baltic Sea and North Sea ecosystems due to the changing climate and environment on human health and wellbeing should be characterised with state-of-the-art tools in order to simulate developments for the period up to 2030.

In relation to human health and wellbeing, a key objective will be to ensure the security of aquatic food supplies derived from the Baltic Sea and North Sea and their catchments, Aquatic food security can be achieved by ensuring that the food supply is sufficient, safe, sustainable, shock-proof and sound. In this context, ‘sufficient’ means that the food supply is sufficient to meet the needs and wants of society; ‘safe’ requires that food production poses minimal risks to people and the environment and the food produced is safe to eat; ‘sustainable’ means that food is available now and for future generations; ‘shock-proof’ relates to resilience to shocks in production systems and supply chains, and a ‘sound’ food supply is one that meets legal standards for animals and people and the ethical expectations of society. In the current context the issue of sustainability of food supply will be mainly addressed under Specific Objective B.1, while subtopic C.1.1 will address the effect of changing environment and climate mainly in reference to the sufficient, shock-proof and sound aspects of aquatic food security, whilst subtopics C.1.2. and C.1.3 elaborate the ‘safe food’ elements and hazardous pollutants of different origins.

In reference to food safety, existing models that assess impact on human health should be updated, and potential risks and their mitigation addressed with appropriately adjusted guidance and policy documents. Furthermore, both the Baltic Sea and North Sea present significant pollution with persistent bioaccumulative toxic (PBT) substances with direct impact on food chain safety. Besides the risks associated with accumulation of harmful substances directly in fish and seafood, extended risk assessment of food web will be required, taking into account toxic contaminant combinations present in regional fish meals. Mitigation of these pressures and risks requires similar innovative solutions best delivered in a concerted research and innovation action by all regional states. Altogether, the research activities of C.1 will address the principal knowledge gaps related to changes in food webs due to changing environment and combining with the impact of hazardous substances.

State of the art and knowledge gaps

Any moves towards improving the security of future aquatic food supply will need to be taken into account, e.g. likely climate-driven changes in the marine environment and their consequences for food species and the ecosystems that support them. Worldwide, the production of fish from capture fisheries has peaked and it is unlikely that these fisheries will provide further increases in food supply. Recent increases in fish production have instead come from aquaculture, so in the short to medium term, even before climate-driven impacts on wild fish stocks are considered, the balance between wild and farmed sources of food production is likely to change. It will be important to understand the potential social, economic and environmental impacts of this shift as a baseline against which the impacts of further, climate and environmentally driven changes can be evaluated.

Climate change is forecast to lead to substantial changes in the distribution and productivity of wild fish stocks, with a general northward shift in distribution forecast. This will be particularly problematic for stocks in the Baltic Sea where the scope for northward shifts in distribution of marine species is limited by the enclosed nature of the sea basin and the decreased salinity of the northern parts of the Baltic Sea. Even in the North Sea, decreased range and productivity of some of the key commercial stocks is likely. While there may be some compensation in terms of increased availability of more southern species, this would have implications for selling the catch in a market geared-up for more traditional species. Although the productivity of wild fish stocks in the Baltic Sea and North Sea is likely to be adversely affected by climate change, there are some indications that the forecast changes will lead to improved growing conditions for aquaculture. At the same time, compared to other sources of animal protein, the production of greenhouse gases associated with fish production is relatively low, hence there may be reasons to anticipate that the proportion of protein coming from aquatic sources may increase in the short to medium term. Overall the changing context implies the need for integrated, sea-basin level risk assessments for aquatic food production in the Baltic Sea and North Sea, and for the development of portfolio-based approaches for managing food sources.

A wide range of PBT substances and marine toxins that present health hazards not only for humans as part of the diet directly, and via animal feed, has been identified but needs further analytical assessment. For instance, differences in fish meal hazardous substance profiles and farm animal (poultry, swine, cattle, farmed fish, etc.) physiology will modulate hazardous substances in animal products for human consumption. Fish-consumption advisories issued by the European Food Safety Agency (EFSA) to protect human health do not completely extend to fish by-products fed to farmed animals. Animals (especially farmed fish) that are fed fish meal can extensively bioconcentrate hazardous pollutants in protein matrices and fat, which is then passed on in the components of derived foods. Since 2012, EFSA has published five relevant guidance documents and scientific opinions on different marine PBT. However, these guidance documents have to be integrated and interpreted from the regional long-term perspective. Interdisciplinary expertise would be required from scientists across the Baltic Sea and North Sea regions in order to review and update food and feed safety guidance with state-of-the-art knowledge and consideration of emerging and novel food technologies.

Impact and linkages

The overall goal of C.1 is to perform necessary R&I activities required to draft a roadmap on how to increase the Baltic Sea and North Sea food and feed security until 2030. Health benefits for the regional population will be provided via adoption of common regional policies and updated guidance documents. Sustainability is a key element of aquatic food security, hence there is a close link with subtopic B.1.1. Understanding and predicting how climate change will affect the spatial distribution of toxic Harmful Algal Blooms (HABs) interlinks with subtopic C1.1. New methods will be incorporated in rapid test kits to evaluate a wide range of toxic HABs in water and seafood, and novel mitigation measures preventing or minimizing the consequences of toxin impacts on seafood. Close collaboration and consultation process will be established with EFSA's Panel on Contaminants in the Food Chain (CONTAM). Activities will produce an updated list of toxic substances with highest relevance to human health and wellbeing both in the Baltic

Sea and North Sea regions, accompanied with review of potential sources of the toxic substances and update for corrective measures. The impact of food safety subtopic C.1.2. and C1.3. R&I activities will be achieved with review and update recommendations and policies. Evaluation of exposure levels and health risk assessment among population, identification of sensitive population groups and strategies for reduction of the impacts for the sensitive population groups will be part of the roadmap. Meantime, studies of the balanced food production between aquaculture, capture fishery and terrestrial sources and understanding economic, social and environmental impacts of switching will be assessed by C1.1. Broad, sea-basin level risk assessments for aquatic food production are also anticipated as part of C.1.1. Overall, this work will result in common policies formulated as all three C.1 subtopics converge in aspects that affect human wellbeing in the region.

C.1.1 Aquatic food security in a changing environment

State of the art and knowledge gaps

For the aquatic food supply to be secure it needs to be sufficient, safe, sustainable, shock-proof and sound. There is a scientific element to all of these aspects of aquatic food production, although it is perhaps strongest in relation to safety and sustainability. Reflecting this, these two components are primarily addressed elsewhere; the 'safe' element in themes C.1.2. and C.1.3, and sustainability in theme B1.1. The current theme is intended to focus mainly on the other elements of aquatic food security and also to look at the broad question of aquatic food security in the context of environmental variations driven by climate change and other factors.

Ensuring sufficiency of supply requires the treatment of living marine resources more as components of a system than as individual species. This allows for more focus on their potential contribution to human food supply as well as on possible trade-offs between different species and between different means of production (capture or aquaculture) in the light of climate-driven environmental changes. The broader context of animal protein from aquatic vs. terrestrial sources also needs to be considered given the relative benefits of the former in terms of reduced greenhouse gas production. By nature, any policy decisions taken in relation to these trade-offs should ideally be informed by a strong evidence base. The research areas needed to provide this evidence would include understanding the relative health, social, economic and environmental impacts of any change in the balance between different fisheries and aquaculture practices.

To an extent, shock-proofing of aquatic food supply is ensured by having a diverse portfolio of food sources at any one time. This allows interruptions to supply due to e.g. a fishery collapse, disease outbreak or supply chain disruption, to be mitigated by increasing supply from other sources. However, the system would be more shock-proof if it were better able to anticipate and respond to any such events. This could be achieved by a combination of research into the drivers of such shocks together with an appropriate risk assessment approach.

Ensuring a sound food supply mainly involves all aspects of the food production process meet current ethical and moral standards in relation to the people, animals and environment involved in or affected by the production system. Key areas where research could contribute to this aspect of aquatic food production are in relation to improved handling and slaughter of marine species and in improved traceability of marine food products.

Any moves towards improving the security of future aquatic food supply will need to take into account likely climate-driven changes in the marine environment and their consequences for food species and the ecosystems that support them. This context is likely to have negative impacts on food security, e.g. through leading to changes in the abundance and distribution of commercially important fish species or pathogenic organisms. Contemporary frameworks to address these issues, e.g. the ecosystem and one health approaches, are multi-disciplinary and multi-sectoral. It is anticipated that any research undertaken within this theme would reflect this. Similarly, the spatial scale of any research should recognise that aquatic food security needs to be addressed as a minimum at a national scale, but in the present context would be better addressed at a sea-basin scale.

Expected outcomes:

- Studies of the balance of food production between and aquaculture and capture fishery sources, and also between aquatic and terrestrial sources; understanding economic, social and environmental impacts of switching.
- Improved understanding of consumer choice under changing supply; anticipating how markets may respond under changing availability of different food species.
- Studies of the implications of climate change for aquatic food supply, e.g. how are changing conditions in the Baltic Sea and North Sea likely to impact food supply and the incidence of pathogens.
- Improved national and basin-level risk assessments for aquatic food production in the Baltic Sea and North Sea catchments.
- Improved methods for fish handling and slaughter in capture fisheries and aquaculture.
- 'Trawl to table', improved methodology for traceability of marine food products at all stages of the production process.

C.1.2 Update of strategies for reduction of health risks from toxic substances in regional sea food and feed chains

State of the art and knowledge gaps

Persistent bioaccumulative toxic (PBT) substances that end up in fish are health hazards not only for humans as part directly of the diet but also as a constituent of animal feed. Omnivores and especially ruminants that are fed contaminated fish meal can pass hazardous pollutants to eggs, meat, and dairy products. Differences in fish meal hazardous substance profiles and farm animal (e.g. poultry, swine, cattle, and farmed fish) physiology modulate hazardous substance in animal products for human consumption. Fish-consumption advisories issued by European Food Safety Authority (EFSA) to protect human health do not extend to fish by-products fed to farmed animals. Animals (especially farmed fish) that are fed fish meal can extensively bioconcentrate hazardous pollutants in protein matrices and fat, which can then be passed on in the components of derived foods.

EFSA guidelines present safety concern for fish caught from the Baltic sea (e.g. herring and salmon), and the available data concerning contaminant levels support the more specific recommendations established by Swedish and Finnish food safety authorities. EFSA's advice concentrates on the most relevant heavy metals and persistent organic contaminants, namely methylmercury, dioxins and dioxin-like PCBs. Baltic herring is the key commercial species in the Baltic Sea in terms of volume, but its use for human consumption is low and instead, most of the catch is used as feed in farming. In the North Sea concentrations of contaminants in wild fish are generally below EFSA quality standards.

In 2012, EFSA published "*Scientific Opinion on the risk for public health related to the presence of mercury and methylmercury in food*". Because of the lack of specific information on methylmercury and inorganic mercury in data collected, the exposure assessment was based on the data submitted for total mercury. Also, Scientific Opinion on Brominated Flame Retardants (BFRs) in "*Food: Brominated Phenols and their Derivatives*", an assessment of the level of possible health concern for high consumers of fish, molluscs and crustaceans was performed.

In 2014, EFSA also published "*Scientific Opinion on health benefits of seafood (fish and shellfish) consumption in relation to health risks associated with exposure to methylmercury*". In 2015, EFSA reviewed different tolerable intakes of dioxins and dioxin-like PCBs in food and feed and accepted a request from the European Commission for a comprehensive risk assessment for animal and human health.

In 2018, two scientific opinions assessed decontamination processes for dioxins and PCBs from fish meal by extraction and/or replacement of fish oil. EFSA publishes its first comprehensive risk assessment of dioxins and dioxin-like PCBs in food and feed, reducing the tolerable weekly intake seven-fold based on new data and methods and indicating a health concern due to exceedance of the new TWI across the EU population. However, the toxicity of the most harmful dioxin-like PCB may have been overestimated due to use of internationally-agreed values known as 'toxicity equivalency factors' (TEFs).

In 2019, EFSA's Panel on Contaminants in the Food Chain (CONTAM) launched an open consultation on the draft scientific opinion on the risks for animal and human health related to the presence of chlorinated paraffins in feed and food. This document presents an estimation of the human dietary exposure to chlorinated paraffins via the consumption of fish.

As a pragmatic approach, the EU maximum levels of toxic metals as well as dioxins and dioxin-like PCBs in fish/ other seafood should be used as intermediate target levels and adjusted for agricultural/aquacultural products where fish meal is used in feed. Current regulatory framework is based on the Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed. However, this framework may not be optimal for a number of hazardous substances and/or their combinations specifically present in the Baltic Sea and North Sea regions. Interdisciplinary expertise would be required from scientists across the Baltic Sea and North Sea regions in order to review and update food and feed safety guidance with state-of-the-art knowledge and taking into account emerging and novel food technologies. Expertise fields include: (1) Exposure assessment – expertise is required especially in relation to dietary exposure assessment of chemical contaminants including knowledge on food consumption surveys; (2) Chemistry – organic, inorganic, analytical chemistry, food and feed processing in the area of chemical contaminants; (3) Human and veterinary toxicology (in risk assessment of chemicals) – absorption, distribution, metabolism, excretion (ADME) of substances (toxicokinetics and toxicodynamics), sub-chronic and chronic toxicity (repeated dose studies), genotoxicity and mutagenicity, developmental and reproductive toxicity, carcinogenicity, allergenicity and immunotoxicity; (4) Toxicological tests in experimental animals – interpreting toxic effects of chemical contaminants in farm and pet animals; (5) Animal nutrition – animal exposure from fish feed and oil based feed assessment.

The goal is to review and update current recommendations and to draft a roadmap on how to increase the Baltic Sea and North Sea food and feed safety by 2030. This entails propositions for the governance and management of the region. In particular, updating policies to include current agricultural practices that use fish meal or fish by-products produced in the region is needed. Updated regional risk assessment of toxic contaminants in the food chain including fish meal indicating that food safety objectives should be applied with the consideration of the impact of regionally derived fish meal on human health.

Expected outcomes

- Updated guidelines of toxic substances with highest relevance to human health and wellbeing. This should include toxic metals (mercury, lead and cadmium) and organometals, POPs (persistent organic pollutants), such as organohalogens, PCBs, PAHs, TBT, DDE, HCH, PFAS/PFAO metabolites and dioxins, and other potentially harmful chemicals, e.g. pharmaceuticals, pesticides, plastic additives and personal care products (e.g. phthalates) and other 'emerging contaminants'.
- Review of potential sources of the toxic substances and update for corrective measures.
- Evaluation of exposure levels and health risk assessment among population.
- Identification of sensitive population groups and areas. These can be used in a suitability assessment for new areas for aquaculture.
- Strategies for reduction of the impacts for the sensitive population groups.
- Adjustments made to risk assessment framework and the necessary techniques/ models to quantitatively assess the risks for humans and the environment, e.g. REACH - ECHA

C 1.3 Prediction on the prevalence and reduction of the impacts of marine toxins, including from cyanobacteria

State of the art and knowledge gaps

Marine toxins originating from harmful algae or cyanobacteria may accumulate in seafood and cause health risks such as paralytic shellfish poisoning, diarrhetic shellfish poisoning and hepatotoxin poisoning. The frequency, intensity and distribution of harmful algal blooms (HABs) resulting in toxic events in the Baltic Sea and North Sea is changing due to climate change. In the Baltic Sea, cyanobacterial HABs (cHABs) are a particular concern. The presence of these toxins warrants constant monitoring of aquaculture facilities. When concentrations in seafood exceed regulatory limits, this results in the closure of aquaculture facilities and significant economic losses. Toxins are detected through analytical techniques based on chromatography and mass spectrometry, protein-based immuno-assays, or via effect measurements evaluating toxicity in mice or, more recently, in vitro cell tests. For emerging toxins and their metabolites, there is a need for improved analytical procedures. Combinations of improved in vitro tests and improved sensitivity in untargeted, high-resolution mass spectrometry promise a better detection of a wide range of marine toxins.

Efforts are made on a global scale to monitor the occurrence of HAB events. However, many blooms of harmful algae may go unnoticed, since continuous monitoring is often limited to locations with aquaculture facilities. New developments in molecular biology such as '–omics' techniques can be applied for a better understanding of HAB formation and toxin development in experimental studies, supporting the prediction of present HABs. They can also lead to a better observation of HABs in the field by using metagenomics or meta-transcriptomic approaches. Fast and accurate field observations can assist early warning systems, upon which managers of aquaculture facilities can act by harvesting earlier or later, or provide mitigating measures. Enhanced and automated use of in situ imaging techniques and flow cytometry, on autonomous vehicles or moorings, combined with molecular lab-on-chip assays will improve the fast detection of early stages of HAB formation. Research on the improvement in the interpretation of hyperspectral satellite imaging is expected to contribute to a better evaluation of HABs.

Understanding the mechanisms leading to the formation of HABs (including cHABs) may enable aquaculture and fisheries stakeholders as well as policy makers to develop strategies to avoid negative impacts of HABs, e.g. through efficient monitoring efforts, responsive harvesting strategies or smart choices for the location of aquaculture facilities. It is clear that nutrients and temperature play a role in the formation of certain HABs, but there are many complex ecological interactions involved (e.g. mixing of the water column, prey interactions for mixotrophic species, grazing…). For many algal species, knowledge is lacking on the factors leading to the formation of HABs in the Baltic Sea and North Sea basins. New developments related to blue growth can induce such factors, e.g. nutrients released by aquaculture facilities. Climate change is affecting seawater temperature, pH and nutrient content due to altered runoff and stratification. These changed conditions may alter the formation of HABs. Controlled experiments at micro- or mesocosm level and extensive high-resolution monitoring efforts are needed to generate knowledge on the formation of HABs, taking into account regional non-HAB species relevant for the Baltic Sea and North Sea to study competitive advantages. Results from these experiments, combined with improved field observations of HABs in concertation with oceanographic measurements, are needed to feed data-driven and mechanistic models to predict the occurrence of HABs and their consequences for toxins in seafood in both sea basins. In turn the comparison between modelling hindcasts and extensive innovative monitoring is needed to test and improve our understanding of bloom phenomena.

HABs differ in nature between the Baltic Sea and North Sea. In the Baltic Sea area harmful algal blooms are mostly cyanobacterial blooms affecting recreation and tourism. These high-biomass blooms are fuelled by high nutrient concentrations and are strongly affected by temperature and vertical mixing in the water column. On the contrary, harmful algal blooms in the North Sea area are typically affecting (shell)fish aquaculture. These blooms induce shellfish toxicity and fish mortality already at low biomass and much less affected by nutrient availability. Therefore, the response of HABs to changes in nutrient availability and climate forcing is likely to differ between the Baltic Sea and North Sea. As such, BANOS region can serve as a model system to study the effect of nutrient and climate change drivers on future cHABs. These studies to elucidate these expected responses should include ecophysiological mechanisms involving other microbial communities and biota and take into account regional human induced nutrient effects.

Modelling HAB formation is still very challenging at present, due to the many factors involved and complex elements such as mixotrophy in many species. Multidisciplinary research including physiology, biochemistry, systems biology and ecological modelling can result in models that identify conditions leading to HAB formation and this wayassist management action.

Mitigation of HABs and their effects is not straightforward as this aims to reduce one algal species while not affecting the others. Specific viruses have been suggested as well as species-specific nanotechnology tools. Such methods deserve further attention, incorporating research on potential non-target effects. Methods exist for physically separating cultured fish from harmful algae and these can be optimized through research and innovation. An interesting research avenue for shellfish aquaculture is whether toxin depuration times can be shortened by certain treatments. Finally, more holistic measures such as ecosystem restoration and integrated multi-trophic aquaculture are suggested to mitigate HAB effects.

Expected outcomes

- A mechanical, trait-based understanding of the biological and abiological factors that lead to the formation of HABs.
- Understanding of the influence of the Baltic Sea outflow on HAB occurences along the Swedish and Norwegian coasts.
- Improvement of the capacity to predict the development, movement and quiescence of HABs.
- Understanding and predicting how climate change will affect the spatial distribution of toxic HABs.
- Sensitive warning systems capable of detecting the early stages of HAB development.
- Cost-effective monitoring schemes using a combination of screening methods and new pipelines to analyse data from early warning systems (imaging, genetic, remote sensing), including artificial intelligence.
- Improved analytical methodologies and innovative in vitro toxicity assays to detect emerging toxins and their metabolites in seafood.
- Increased knowledge of the relation between concentrations of toxins and their metabolites in seafood and the absorption, distribution, metabolization and excretion process within toxin vectors.
- Advanced molecular approaches to detect the toxicity of HAB species near real time.
- New methods incorporated in rapid test kits to evaluate a wide range of toxins in water and seafood.
- Novel mitigation measures preventing or minimizing the consequences of toxin impacts on seafood.
- Screening method for vulnerability of potential new aquaculture sites for HABs.

3.3.2 Specific objective C.2: Safe and accessible coast

Overall rationale

The proximity of the sea promotes human wellbeing in many ways. The view of the sea, recreation on or by the sea and eating seafood directly promotes our health and wellbeing. Indirectly the wealth and wellbeing of coastal communities is promoted by economic activities near the coast. Traditionally harbours and fisheries are important economic sectors and more recently tourism, aquaculture and marine renewable energy are economic sectors with increasing importance for coastal communities. In many areas living close to the sea bears the risk of coastal flooding and erosion. Sea level rise and more extreme weather in combination with increasing coastal populations and economic development lead to a strong increase in flood risks and associated economic losses. Reducing these risks and optimizing opportunities for human wellbeing requires careful planning and balancing of developments in coastal areas. For example, critical infrastructure and valuable cultural heritage should be protected as much as possible from flood risks; coastal defence structures should have minimal impact on the opportunities for enjoying the seafront; changes in sea levels may affect the accessibility of harbours in the future and new tourist residences should not be developed in areas that are prone to coastal erosion and flood risk. Planning of developments in coastal areas needs to be supported by a sound understanding of risks and opportunities under different scenarios of global change and societal developments and of the value of various seascapes to ocean and public health. Developments that reduce the accessibility of coastal areas to the general public may be difficult to express in economic values while balancing with other uses of the coast but are still crucial to take into consideration. Therefore, the effects of different types of coastal landscapes on the wellbeing of local residents and tourists need to be better understood. In a changing world, coastal economies also may need to adapt.

State of the art and knowledge gaps

Future sea levels, flood risks and erosion rates are highly uncertain. When adapting coastal defences and coastal developments to climate change, this uncertainty is problematic. There is a need for resilient climate adaptation strategies that can deal with different scenarios of climate change and societal changes and can be adjusted when things develop differently than expected. These scenarios should be supported with estimations of water level extremes, wave climates, sediment transport and coastal erosion under different scenarios of global change. This requires a better understanding of what changes are to be expected in terms of climate change, changes in land use and use of marine waters and how the natural system will respond to these changes. The scenario studies will make clear if present coastal defence strategies will be effective for the future as well or if alternative strategies need to be developed. Similarly, different options for economic developments can be evaluated, including tourism, aquaculture and marine renewable energy. To attract tourists to coastal areas year-round, sustainable blue tourism options can be developed that may also promote the wellbeing of local residents.

Impact and linkages

The research under this objective provides scientific support for marine spatial planning (MSP) and integrated coastal zone management. It will enhance our abilities to plan developments in coastal areas, anticipating on expected risks due to climate change and optimizing human safety and well-being in coastal areas. In this way it supports the implementation of the EU Floods Directive (FD), the EU Marine Spatial Planning Directive (MSPD) and the Hyogo and Sendai Frameworks.

Climate change adaptation strategies do not only require knowledge on changing natural conditions but also on possibilities to adapt coastal economies and on the value of different options for further development (blue tourism, aquaculture marine renewable energy) on human wellbeing of local residents and visitors.

The research on safe and accessible coasts is strongly linked to the research subtopics A.1.4 and A.1.5, providing information on a science-based ecosystem approach and the potential of nature-based solutions, particularly for coastal defences and blue tourism. Understanding the impact of climate change and pollution to habitat forming species under topic A.1.2 will help to understand the impact on habitats that are relevant for coastal defences and coastal erosion such as seagrasses, dune areas and mussel beds. To gain a better understanding of risks and well-being benefits in coastal areas big data approaches (A.3) can be very powerful. The development of approaches for adapting coastal economies under climate change is also linked to the development of sustainable and bio-based blue solutions for economic activities at sea (B.3).

C.2.1 Challenge-driven transformation of (local) coastal economies (or areas)

State of the art and knowledge gaps

The risks to coastal areas vary between different areas of the Baltic Sea and North Sea. Coasts along the southern North Sea suffer from coastal erosion, which is strongly affected by waves and reduced influx of sediments from rivers. The rocky coasts along the Baltic Sea do not have this problem. In the north of the Baltic Sea, sea levels are not rising but declining due to the isostatic rebounding that is still occurring after the last glaciation. Therefore, these areas do not suffer from an increasing flood risk due to sea level rise, however, increase in the storm surges may cause intense flooding in future as the frequency of the storms is likely to increase.

The accessibility of coasts may be limited in the future. Everywhere in the Baltic Sea and North Sea the accessibility of harbours may be affected by changes in sea levels, wave climate and sediment transport. In the southern North Sea many new wind farms are planned for sustainable energy supply. It is yet unknown what will be the effect of such extensive wind farms on wind, waves and sediment transport and indirectly on coastal erosion rates and shipping.

Countries also differ strongly in the way they manage flood risks and coastal erosion. In the Netherlands, the national government takes the responsibility to make sure that the coast remains at the same location. To this end, beach nourishments are done to support the dune landscape that forms the natural coastal defence. In the UK, different approaches are taken for different parts of the coast. For some a ‘managed retreat’ approach is followed whereas for other areas the ‘hold the line’ approach, similar to the Netherlands, is taken. In Denmark, the coastal defence is the responsibility of local governments. For many coastal cities, it is a challenge to adapt the coastal defence to increasing flood risks without compromising cultural heritage and harbour activities.

Coastal tourism and harbours are important economic sectors throughout the Baltic Sea and North Sea. The importance of fisheries and the consumption of fish and seafood differs between countries in the region. In the Nordic countries, fish is a more important part of traditional food patterns than for example in the UK, Netherlands and Denmark. This may play a role in the willingness to change coastal economies between countries. In the UK, there is generally more (scientific) attention to the benefits of the sea and nature in general for mental health than in many other countries. In some Nordic countries such as Norway and Finland, living with nature is traditionally an important part of the culture. In these countries it is relatively common for people to own a cabin in the country. In Finland, a large part of the coast is owned by private people for holiday homes. This may play a role in the accessibility of the coast for people in general.

Marine renewable energy developments are common throughout the Baltic Sea and North Sea. The use of marine waters for wind farms often conflicts with fisheries. Fishing boats are considered a collision risk for the wind farms and therefore the fishing boats are excluded from the wind farms. So extensive wind farm construction is likely to lead to declining fishing activities. On the other hand, the wind farms provide new economic activities in the field of construction, maintenance and energy supply near the coast. The nearby energy supply can for example support data centres on the coasts. Although one economic activity is replaced by another, this does not mean that former fishermen will find employment in the new economic activities due to marine renewable energies or increasing tourism activities. The possibilities for existing and new activities at sea can be hampered by ammunition, including chemical warfare substances, that have been dumped in the Baltic Sea and North Sea after the World War II. The bomb cases are becoming less and less strong with time, which poses risks for economic activities at sea.

There is no simple solution to adapt coastal areas to climate change and changing economic sectors. Regional differences in natural and societal conditions require different solutions. But they can all be based on sound scientific understanding and use similar approaches for balancing the different risks and benefits. Collaboration between different areas can boost learning and testing of promising approaches.

Expected outcomes

- Understanding of impacts of spatial planning / use of coasts on human health and wellbeing as a scientific basis to take these impacts into account in integrated coastal zone management / marine spatial planning.
- Understanding of impacts of climate change, marine renewable energy developments on safety of coastal regions, through changing water levels, weather extremes, wave climate and sediment transport, as a scientific basis for development of scenarios for coastal developments.
- Framework for balancing coastal management and development options for optimal human wellbeing, social equity and nature.
- Strategies to adapt coastal areas and economies to climate change and changing societal drivers (e.g. growing need for marine renewable energy and tourism and declining potential for fisheries). These options should provide innovative solutions for coastal areas faced with challenges of global change and strive for optimal human wellbeing, social equity and nature.
- Mapping and monitoring of risks due to dumped ammunition after the World War II. Develop mitigating measures to reduce these risks for fishermen and tourist in coastal waters and beaches.

C.2.2 Developing innovative and sustainable blue tourism and recreation

State of the art and knowledge gaps

Coastal and maritime tourism is one of the five sectors focused on in the EU Blue Growth Strategy, representing one third of the maritime economy. The tourism sector has grown fast, with a 7% annual increase in turnover during the past ten years. Various sustainability indicators for tourism exist, many of which build on indicators described by the UN World Tourism Organization. There is currently no standardized set of sustainable tourism indicators that can be used for assessing the sustainability of blue tourism development in the Baltic Sea and North Sea region. Circular economy approaches are not widely adopted in the blue tourism sector. Innovations in this field can be a means to increase the sustainability of blue tourism and recreation.

Much of the blue tourism and recreation is seasonal, with socio-economic gains concentrated in the summer months. Many coastal destinations perform efforts to increase the tourism outside the high season. Research on how to attract visitors year-round and diversify the tourism and recreation offer is necessary. The Baltic Sea and North Sea hide interesting information from the past, from paleo-landscapes to shipwrecks, each with their own history. These have an underused potential for all-season touristic exploitation.

The growing blue economy in the Baltic Sea and North Sea regions entails many new infrastructure developments at sea or near the coast, such as wind farms and aquaculture facilities. Similarly, new coastal infrastructure is being developed to protect the coast from erosion and from increased flood risks associated with sea level rise. Dikes, dune reinforcements or storm surges may affect blue tourism. Knowledge is lacking on how such developments impact blue tourism and how negative impacts can be minimized, while positive impacts maximized. Next to increased flood risks, and extreme weather events climate change will impact blue tourism and recreation in other ways. Shifting target species for recreational fisheries, changes in the frequency of harmful algal blooms, sea temperature changes shifting the attractive season for water-based recreation. There are many uncertainties about how coastal tourism will be affected by climate change. Prediction of such effects can be a basis for adaptation strategies of sustainable coastal tourism.

By nature, the coast is limited by the sea in terms of surface area. This creates pressures and spatial competition between tourism infrastructure, preservation of natural coastal habitats – which can be an asset for sustainable recreation and tourism – and other land uses, such as harbour facilities, blue industry and residential areas. Scientifically supported integrated coastal zone management should take into account the value of different coastal land uses, including the indirect value for recreation and tourism.

Studies demonstrated the positive effect of coastal proximity and/or exposure to blue spaces on human health, mainly in the UK, but also in Belgium. It is not clear yet if this is universal throughout the Baltic Sea and North Sea regions, to what extent this effect occurs in tourists and how this is related to recreational activities. If such an effect is present, informing coastal tourists about it may promote sustainable actions, in order to preserve the coastal environment.

Expected outcomes

- Innovative and diversified touristic and recreational infrastructure to sustainably attract tourists to the coastal environment year-round, e.g. innovative ways to disclose cultural, historical and geological information on sub-sea landscapes and heritage to coastal tourists by means of virtual reality.
- Insight in how new maritime infrastructure developments can affect coastal tourism, recommendations for actions and design to increase positive effects of blue economy developments on coastal tourism, e.g. can a maritime identity be an asset for blue tourism?
- Effective climate change adaptation strategies for blue tourist infrastructure and recreational activities.
- Sustainability indicators applicable to blue tourism in the BANOS area (both ecological indicators and indicators reflecting cultural heritage).
- Novel approaches for integrated coastal zone management to reconcile the protection of natural coastal habitats with touristic development and sustainable forms of ecotourism.
- Knowledge on the health benefits of blue tourism and recreation, recommendations to improve such health benefits by promoting relevant activities and appropriately managing marine environments.
- Novel applications of circular economy in the blue tourism sector, e.g. in material use for leisure boating or in the hotel and restaurant sector.
- Insight in the socio-economic groups that contribute to coastal tourism in the BANOS area, and how the recreational offer can be diversified to attract certain groups of interest, e.g. young people.
- Governance structures, approaches and infrastructure that encourage and facilitate operators to develop pro-nature services (e.g. restoring cultural and/or natural attractions) for conscious travellers.

4 Impact enablers

Through the generation of crucial new knowledge, management practices, technology and innovation, the future joint Baltic Sea and North Sea Research and Innovation Programme (BANOS) aims at bringing about change in the Baltic Sea and North Sea regions, creating better environmental conditions and possibilities for sustainable development. To secure the highest possible impact of research and innovation at all levels, a set of dedicated measures will be designed. These measures are aimed at all phases of implementation; from criteria for evaluation and monitoring of the impact of funded projects to increasing the programme's contribution to human capacity building and skills development, especially for non-academic employers. Special attention is given to the unhindered dissemination of new knowledge and data, fast innovation diffusion and the engagement of broad society. A thorough communication strategy including tools for stakeholder engagement is developed, and the potential of research synthesis is investigated for increasing the relevance and uptake of project results for better management practices and policy. The latter, together with the other impact strengthening measures aim to support the impact of the European Partnership '*A climate neutral, sustainable and productive Blue Economy*' as planned within Horizon Europe.

4.1 Strategy towards effective communication of the results of R&I

WHY: In order to enable strong and the most desirable public presence, active stakeholder engagement as well as effective, multi-flow knowledge and eco-innovation dissemination need consideration from the very start of the programme. The development and implementation of a tailored communications and stakeholder engagement strategy forms the backbone of the communications approach and addresses the brand, engagement tools, activities and tailored plans that provide opportunities for the programme to grow and engage purposefully in BANOS region and wider. Every effort will be made to seek and seize opportunities to enhance dissemination of the R&I results under a strong and inclusive brand. Communication about the new programme will increase its impact by an increased number of different stakeholders applying to calls, participating in projects and implementing the results generated.

WHAT: Strategic and tailored messaging will be put in action that provide a consistent, inclusive and fit-for-purpose image, messages, values and voice that together form a strong BANOS brand. This enables effective realization of communications and dissemination efforts according to target audiences, as well as deep understanding of the new programme itself. Multi-level and multi-directional communication flow will ensure wide dissemination effort which aims to gain support and buy-in for BANOS and its results across different key knowledge and eco-innovation end-users and other stakeholders.

HOW: This effort entails development and implementation of the new brand for the broadened geographic scope. It also includes forming of a map of primary and secondary stakeholders, related initiatives and co-operation potentials, as well as development of a fit-for-purpose communications and engagement strategy. In addition, platforms are developed, also online, to be used for systematic and reciprocal stakeholder consultation and other engagement as necessary in support of the BANOS programme.

4.2 Strategy of R&I impact monitoring and assessment

WHY: Globally there is a growing demand to understand the impacts of research and development projects. Reasons for the increased interest are multiple, including the growing demand for evidence-based policies and governments wanting to understand returns of their investments in science, innovation and technologies. Impact evaluations help governments and R&I funding institutions to decide where to channel the future investments in order to maximize the returns and public benefits. Therefore, effective impact monitoring and assessment protocols should assist in evaluating the societal benefits of public investment in research, development and innovation.

WHAT: A systematic approach, which builds on the BONUS experience and the best practices identified among the BANOS CSA partners and in literature, is developed to ensure a successful impact assessment of BANOS programme and its funded projects in the future. The strategy will encompass: (i) assessment of both academic and social impact of R&I; (ii) impact assessment at both the programme- and individual project levels; and (iii) impact monitoring in real time during project implementation as well as ex-post impact assessment allowing certain time lapse for impact materialising.

HOW: The project impact assessment will be carried out periodically, primarily as part of the project reporting. The following measures have been identified to date to be important aspects of future project impact assessment methodology:

- The impact assessment will follow the concepts of the Research Impact Pathway, which provides a logical framework for recording of activities, outputs, outcomes and ultimately impact.
- A set of performance indicators will be chosen for the assessment practices. The concept of productive interactions will be considered when deciding on the final indicators. The indicators may be adapted to serve best for research- and innovation-focused projects.
- In addition to performance indicators, the periodic reporting should contain open self-assessment questions, providing more details of a project impact.
- To assess the real impact, a post-project impact assessment strategy is critically needed.
- To ensure high-quality reporting, appropriate guidance should be provided to ensure that the researchers understand the principals and importance of the impact assessments.
- Genuine orientation towards societal impact shall be embedded already at the proposal stage and be supported accordingly through the proposal evaluation and selection process.
- Provisions for systematic collecting and reporting of impact shall be embedded in the grant agreements with the Programme beneficiaries.
- Stakeholder engagement is needed to deliver impact. Hence, projects will need to develop a clear stakeholder engagement plan at the proposal phase and follow it throughout the lifespan of the project.

The programme level impact assessment will be based and modified from the BONUS experience and a panel assessment is favoured. Additional, bibliometric analyses may be chosen for specific research

4.3 Strategy of knowledge synthesis as enabler of greater research impact

WHY: Effective scientific synthesis, dissemination and knowledge transfer are the key elements to translating research results into societal benefits, including improved environmental policies and management, technical innovation and sustainable development, as the ultimate aim is giving clear and scientifically robust answers to questions posed by managers, policy makers and innovators.

WHAT: Two activities are central; the first one designed to develop an improved process to synthesize primary scientific information. The synthesis process will use transparent and evidence-based methodologies for scoping, collecting, assessing and synthesizing research to answer management/policy relevant questions. The research synthesis process will take into account scientific findings from a wider survey of the respective scientific field(s), including BANOS funded projects. The second activity is centred around developing methods/mechanisms for effective co-designing, collaboration and communication of the outputs from syntheses to a wide range of stakeholders. With an underlined link to 1.1, this will include identification of target groups, further tailoring of syntheses to target audiences and delivery of syntheses' results using appropriate strategies and channels. These two activities are complementary and will proceed in parallel.

HOW: Systematic research synthesis is a relatively new practice to managers and policy makers, and it has only to a limited extent been funded within coordinated calls. Thus, an evaluation of its potential regarding management and policy would be useful before implementation in a new programme. In addition, selection methods, evaluation criteria and guidance tools need to be designed, to enable funding and selection of projects that will have the anticipated impact. Selecting the most appropriate knowledge synthesis tools will be achieved employing the best available practice, including assessment of the success and lessons-learned by the ongoing BONUS synthesis projects.

In addition to synthesis methods, an optimal process for improved design of project questions including stakeholders, dissemination and knowledge transfer will be designed, listing methods/mechanisms for different stakeholders, tailoring communication, strategies and channels, taking into consideration stakeholder fatigue and time limitation of stakeholders as well as considerations on providing the right answers at the right time.

4.4 Building collaboration across marine and maritime funding streams

WHY: A joint effort is needed to tackle marine and maritime issues, which one country cannot solve on its own. This approach is expected to lead to significantly stronger impact and EU-added value. To achieve this, an improved cooperation and collaboration between Horizon Europe, European Structural Investment Funds and other transnational initiatives and funding streams are critically needed. Because each of the funding streams targets specific groups of actors, collaboration among these funding streams will enable creation of inclusive multi-actor knowledge systems involving all parties contributing to, or having a stake in, development of sustainable blue economy, i.e. scientists, innovators, governments and public authorities at different levels, industries, as well as citizen organizations. Alignment of research and development activities has already been on the European agenda for a long time, but has not yet been successfully achieved.

WHAT: The future BANOS programme, as planned in the BANOS CSA, aims not only to increase the effectiveness and transparency but also lead to synergies and avoidance of overlaps in marine and maritime funding via collaboration with other relevant Multiannual Financial Framework (MFF) programmes, and related initiatives and activities. This will include, but not be limited to, identification and mapping of relevant actions and specific recommendations based on the emerging opportunities in the next MFF funding period. In addition, synergies and joint opportunities for sharing knowledge and best practices with appropriate parties, e.g. Interreg and European Maritime Fisheries Programmes will be sought, and ways how to achieve this will be identified.

HOW: To put the collaboration in action, the following is required:

- Identification of possibilities how to align different European funding streams.
- Identification of a best approach how to systematically share knowledge and best practice with the other initiatives.
- Formalization of the collaboration through regular activities, such as participation in advisory board meetings, hosting joint education activities and policy related working group meeting etc.
- Identification of possible synergies in research and innovation funding, for example, in respect to counter financing between Horizon Europe and Interreg Programmes as well as between Horizon Europe and the European Maritime and Fisheries Fund, leading to enhanced synergies between programmes as well as utilization and further development of project results.

4.5 Human Capacity Development Strategy

WHY: The EU Blue Growth Strategy identified the need for skilled and suitably qualified graduates in marine, maritime and engineering sciences in order to ensure innovation in Europe’s Blue Economy. It acknowledges that sustainable blue economy will require an appropriately skilled workforce, able to apply the latest technologies in a range of disciplines. The ‘Blue Careers in Europe’ initiative refers to the mismatch between the knowledge and competences acquired throughout the educational path and those required on the job market in the maritime industries across Europe. There is a disconnect between marine graduate training priorities and the needs and expectations of future non-academic employers. In The Rome Declaration, the European marine science community acknowledges this by calling for “*innovation in the provision of undergraduate and postgraduate training and enhancing skill sets and* *career pathways for marine professionals*". The Declaration also stresses the need for education and training to foster cross-disciplinarity. There is broad agreement on the need to tackle this 'skills gap' in the marine and maritime sectors, and to do this in a EU-wide approach.

WHAT: The BANOS Human Capacity Development Strategy focuses on different aspects of human capacity building and skills development (HCD), including cross-disciplinarity, transferable skills, internationalization, industry collaboration, continuous professional development and life-long learning. It aims for a long-term strategy to ensure appropriate academic and soft skills for the next generation of marine scientists. The strategy builds on existing experiences at global and EU level (offer), and needs assessments (demand) at national and sea basin scale. It explores innovative approaches in training and education (MOOCs, webinars, internships, e-learning, activity-based-training, summer schools…). Recommendations will cover training and skills development in areas going from knowledge transfer, open science, open data and research data management practices (FAIR data), to the inclusion of citizen science in research. The Strategy aligns to specific HCD needs as identified through the BANOS Strategic Research and Innovation Agenda.

HOW: This task assesses scope, typologies, types and context of current HCD initiatives, at global, EU and institutional level. Following the adoption of the SRIA, the task will align the 'demand' associated to the specific (sub)areas of the SRIA to the potential 'offer' by means of strategic recommendations and principles for HCD. Once agreed by the Steering Committee, these principles are translated into rules of participation of the future programme. Participants will have to meet a set of HCD requirements and develop an ex-ante HCD plan. Monitoring and evaluation of the HCD plan will be part of general project evaluation and ultimately enable assessment of the programme outcome and impact in terms of HCD.

4.6 Strategies supporting firm establishing of 'open science'

WHY: Open science policy has developed progressively in the EU. In 2018, the Directorate-General for Research and Innovation published Open Science Policy Recommendation (OSPP-REC) including both general recommendations to the Member States and more specific recommendations to different stakeholder groups. Of specific importance for the BANOS programme are the recommendations to the research funding organizations.

The open science policies will be implemented in Horizon Europe. They will, for example, require research data to be FAIR (Findable, Accessible, Interoperable and Re-useable), they will engage and involve citizens, civil society and end-users in co-design and co-create processes and promote responsible research and innovation. (see Next steps in EU fact sheet 2)

WHAT: Open science is an umbrella term that describes sharing via internet any kind of output, resources, methods or tools, at any stage of the research process. For instance, access to publications, research data, software/tools, workflows, citizen science, educational resources, and alternative methods for research evaluation including peer review. The goal for open science has been put together in eight ambitions (see EU fact sheet on open science)

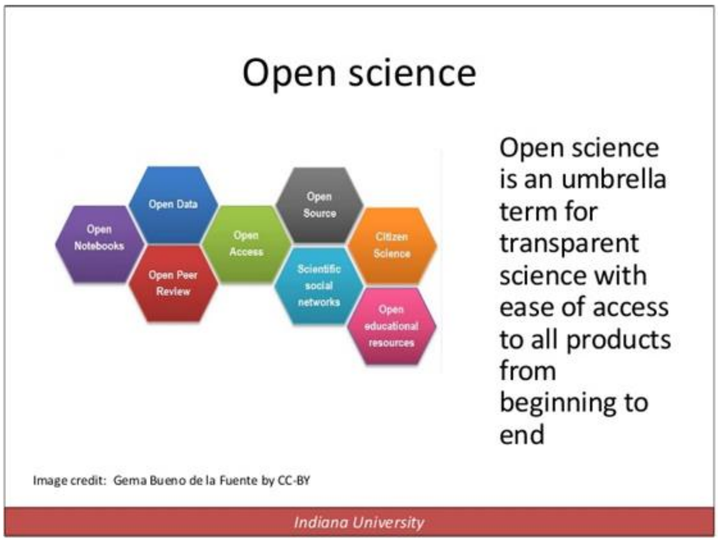

Figure 1. From keynote talk by Beth Plale (science advisor for Public Access at National Science Foundation (NSF)) at BASARIM 2017, Istanbul, Turkey14-15 Sept 2017.

HOW: The strategy for implementing open science in the BANOS programme will be developed during 2020 on the basis of the above referred EU document and the deliverables from the different tasks in BANOS CSA.

4.7 Open data strategy

WHY: Knowledge and innovation are of central importance to the generation of sustainable blue economy. Broad access to data enhances multiple aspects of the research and innovation process. It helps to build on previous achievements, improving the quality of new results. It encourages collaboration and the avoidance of duplication, resulting in greater efficiency. It speeds up innovation by enabling faster uptake by the market, which translates to faster growth. Lastly, access to data makes the scientific process more transparent, boosting involvement of citizens and society. A sound strategy for open data will increase uptake of the data generated during BANOS, and therefore increase the impact of the programme as a whole.

The central policy dictating the BANOS strategy for open data is the Open Data Directive. This EU Directive provides a common legal framework for the re-use of publicly funded research data, based on the FAIR data principles and the maxim "*as open as possible, as closed as necessary*". Research data must be open by default, allowing only for exceptions related to security, privacy, intellectual property and legitimate commercial interests. In addition, the Directive introduces the concept of high-value datasets, thereby stipulating extra requirements for certain thematic categories of data.

WHAT: This Directive will be compulsory for all EU Member States from 17 July 2021 onwards, so the main strategy for open data in BANOS will be to follow the Open Data Directive and fulfil its minimum requirements. Among the twenty BANOS CSA consortium members, strategic partners and observers, twelve agree that BANOS should be fully compliant to the Directive, none are outright opposed, and eight express partial agreement. While the partners of BANOS CSA accept the necessity to comply with the Open Data Directive in general, a number of issues exist:

- Concerns about current non-compliance by the involved institutions: eight parties consider themselves compliant, most others are drafting a new policy or awaiting decisions on a higher level (e.g. national).
- Concerns that some partners may be left behind because of the difficulties in implementing the Directive. Suggestion that BANOS should aim for full compliance, but not as an absolute requirement.
- Concerns that data may be 'held back' by participants rather than published, to avoid the effort of preparing data for re-use.

- Advise to follow the requirements of the publishers, implying that not all data must be open immediately.
- The UK and Norwegian BANOS CSA members support, in general, the same principles, but they are not de facto bound to specific stipulations as outlined in the EU Directive.

HOW: The BANOS Steering Committee shall agree on the participant requirements for R&I data management and sharing, which will subsequently be included in the rules of participation and/or grant agreement of the future programme. Fulfilment of these obligations by the participants needs to be monitored. The most evident way for monitoring, as practised by eleven members of the consortium, is through self-reporting by the participants in the form of a Data Management Plan (DMP). BANOS will need to provide a DMP template, similar to the one provided under H2020[4]. Additional implementation measures, such as allocated budgets for the facilitation of data sharing, need to be discussed in the BANOS Steering Committee.

4.8 Strategies supporting citizen science

WHY: The benefits of citizen science are easy to acknowledge, and the environmental engagement of citizens in the countries around the Baltic Sea and North Sea provides a large potential for a broad co-operation between scientists and citizens. The involvement of citizens will make a better understanding of the marine ecosystem, it demonstrates how the marine environment is influenced by humans while stimulating the awareness for the protection of the sea.

WHAT: In the BANOS programme, as planned in the BANOS CSA, we will use the definition of citizen science formulated by the European Commission´s Digital Science Unit 2013. They emphasize that citizens can have different roles in research. Besides providing researchers with, for example data, tools and local knowledge, the co-operation with citizens may also create a new scientific culture. The Horizon Europe framework fully supports the Open Science Policy, including citizen science.

The European Citizen Science Association, ECSA, launched in 2013, has the mission to encourage the growth of the Citizen Science movement in Europe. ECSA has defined 10 principles as guidance for co-operation between citizens and researchers.

In the BANOS programme, the base for citizen science will be the ECSA principles and examples in the European Marine Board’s policy brief *Marine Citizen Science: towards an engaged and ocean literate society.* Furthermore, as inspiration for the BANOS partners some examples of published and ongoing marine citizen science projects are presented in this document.

HOW: The points below are specific guidance for engagement and cooperation with the civil community within the future BANOS projects.

- BANOS encourages new innovative ways for knowledge transfer that helps to bridge the gap between the scientific community and the public.
- BANOS contributes to the international development of marine and coastal citizen science.
- BANOS stakeholder analysis in BANOS Coordination and Support Action, CSA, is the basis for reaching citizens. See Task 3.2 (*Forming comprehensive analytic map of the new joint Baltic Sea and North Sea research and innovation programme programme´s stakeholders*) and Task 3.4. (*Forming the future joint Baltic Sea and North Sea research and innovation programme´s stakeholder platforms*)
- BANOS scientists endeavour to involve the civil community where possible, realizing that most scientific projects have some part(s) that would benefit of involvement from the civil community.
- BANOS will explore the possibilities to use technologies like different mobile applications for easy reporting of data or getting reports about project activities in order to involve civil citizens in research projects.

Prior to starting a citizen science project, the roles of citizens and researchers must be clearly defined. It should consider the specific training of scientists and the added value of involving and creating awareness of citizens. The research financers must acknowledge that involving citizens has a cost, and that the funding needs to be accordingly.

4.9 Strategies and instruments stimulating innovation diffusion and 'open innovation'

WHY: 'Blue research' can effectively underpin and successfully foster sustainable blue economy. On the other hand, innovation for blue economy often requires research on different levels and from different disciplines, including natural and engineering sciences as well as social sciences and humanities. In the past, the human aspect of innovation, especially innovation implementation, was often neglected, potentially resulting in unexpected opposition of stakeholders and citizens. The new BANOS Programme will aim at crossing the old divides between scientific research, economic development and societal interests.

WHAT: The following questions will be relevant to answer:

- How can the new programme best foster and support responsible innovation?
- Which strategies and instruments will best serve the goal of bridging the gaps between research, innovation and societal needs?
- How can the programme as a whole exert a positive impact on relevant fields of innovation and sustainable blue economy in the Baltic Sea and North Sea regions? Which structures or activities are needed to achieve this goal?

HOW: If a specific task has not yet reached a stage allowing formulating finite answers to the questions above, preliminary approximations or placeholders can be included for specific thoughts. It will still allow to receive some stakeholders' input and feedback during the SOW. The following possibilities can be investigated:

1. *CAPACITY BUILDING FOR DELIVERING IMPACT*
   BANOS could facilitate skill transfer from (academic) research to companies within the Blue Economy sector, acting as a hub for existing platform that facilitate this knowledge transfer between research and industry.

2. *HARMONISING AND OPTIMISATION OF INNOVATION FUNDING INSTRUMENTS*
   Key words for future BANOS funding instruments: flexibility and diversity. BANOS should built a portfolio of instruments to include companies and involve public authorities. BANOS should also target a specific Technological Readiness Level, focusing on low- (Discovery & Research) to mid-level (Innovation) TRL's. Funding instruments should not be too complicated, and be maximally open for participation of private companies. Funding instruments should be formulated such to stimulate harmonization and implementation across the participating BANOS countries.

3. *RESPONSIBLE AND SUSTAINABLE (OPEN) INNOVATION*
   Technological development requires innovation, but BANOS should also include societal and ecological impacts of those technological innovations. It is important that funders that participate in a BANOS project show some flexibility in their funding model. That might stimulate companies that do not want to be involved during the whole project period but only during a certain stage. This situation is not yet common practice. Therefore, it should be looked into what the limits and boundaries are by the different funding parties in different BANOS countries.

4. *REQUIREMENTS FOR INNOVATION DEVELOPMENT*
   Creating impact: from research towards innovation towards society.
   What is needed to involve other partners, such as the industry in BANOS? First of all, we need to know what their needs are. They need clarity in objectives and in targets. For example quantitative targets for the desired societal impact, environmental impact, system impact. In other words: what is the legal framework? Lack of clarity seems to be the most important bottleneck for industries to

participate in research projects. Therefore, industry needs a clear level playing field. On the other hand, industry needs a business case to join a research or innovation programme. What type of industries could be interested in BANOS? Focus should be on the mid-range companies.

5. *EXPLORING THE POTENTIAL FOR MARINE MULTI-USE AREAS*
   Multi-use can have far afield effects, cumulative effects and sequential effects. In order to understand such effects we need to understand the system first. Multi-use seems to be the overarching framework of BANOS, but that does not mean that that we only need multidiscipline projects. Single-discipline projects are needed as well. Overall: BANOS should not always be focused on multi-use, though the aspect of multi-use should always be considered, also in single-discipline research. Finally, multi-use is not only about areas but also about multi-use of knowledge: Different countries working on the same challenges creating and sharing new knowledge

4.10 Strategies building systematic cooperation among Europe's regional seas' R&I programmes

WHY: The recent years have seen a rapid development of the joint R&I initiatives and networks in all Europe's regional sea basins: BLUEMED Initiative and CSA in the Mediterranean , All ATLANTIC Cooperation for Ocean Research and innovation supported by AANCHOR CSA and the Black Sea CONNECT initiative and CSA in the Black Sea. Benefits from systematic cooperation and collaboration among the regional seas' initiatives are manifold. Many of the issues requiring more knowledge and awaiting innovative solutions are global and thus a cooperative R&I effort could bring better and more cost-efficient results. Moreover, collaboration in implementing various programme-level R&I support activities, as dissemination of results to different stakeholder groups, science – policy interaction, human capacity building etc. can significantly strengthen the impact at pan-EU level. Finally, but equally importantly, each of the regional seas' initiatives has accumulated rich experience in different aspects of building and implementing collaborative R&I effort of the Member States and third countries. Sharing this experience would be of a great mutual benefit.

WHAT: Considering multiple benefits of collaboration and cooperation among the research and innovation initiatives in Europe's regional seas; BANOS is open for systematic and diverse cooperation and will proactively network with these initiatives. The cooperation will include i.a. such forms, as (i) mutual alignment of the research and innovation agendas, (ii) joint or coordinated calls for R&I proposals, (iii) thematic clustering of synergetic projects, (iv) a spectrum of joint support activities and (v) sharing the experiences gained in program development and implementation.

HOW: If established, BANOS together with other regional seas' initiatives and JPI Oceans is looking forward towards successful integration into the European partnership 'Climate-neutral, sustainable and productive blue economy'. Recognizing the sea-basins' as basic units for (i) achieving good environmental status and (ii) harvesting the full potential of marine ecosystem services, while taking (III) into account the environmental and geopolitical specifics as well as (iv) variable maturity stages of the joint programming effort, our strategic preference is a pan-EU partnership built upon distinct sea-basin pillars, each governed at regional sea level. The matters of pan-EU level would be governed by a partnership board representing all participating states.

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(the list will be completed and updated for the final BANOS SRIA)

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6 Some abbreviations

Some abbreviations commonly used in this DRAFT BANOS SRIA (version: 28 February 2020):

BANOS	Baltic and North Sea Research and Innovation Programme
BANOS CSA	Baltic and North Sea Coordination and Support Action
BD	Birds Directive
BdS	EU Biodiversity Strategy
BGS	Blue Growth Strategy
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CEAP	Circular Economy Action Plan
CICES	Common Classification of Ecosystem Services
CIS	Common Implementation Strategy
CFP	Common Fisheries Policy
DIC	dissolved inorganic carbon
DPSIR	Drivers Pressure State Impact Response approach
DST	Decision Support Tools
eDNA	environmental DNA analyses
EFSA	European Food Safety Agency
EGD	European Green Deal
EMODNET	European Marine Observation and Data Network
EO	Earth Observation
EOOS	European Ocean Observing System
EA	Ecosystem approach
ES	ecosystem services
EU	European Union
EuroGOOS	European Global Ocean Observing System
EUSBSR	EU Strategy for the Baltic Sea Region
FD	EU Floods Directive
GES	Good environmental status
HABs	Harmful algal blooms
HCD	Human capacity building and skills development
HD	Habitat Directive
HELCOM	Baltic Marine Environment Protection Commission
HELCON BSAP	HELCOM Baltic Sea Action Plan
IMP	EU Integrated Maritime Policy
JPI Oceans	Joint Programming Initiative Healthy and Productive Seas and Oceans
KIP-INCA	Knowledge Implementation Project on the Integrated system for Natural Capital and Ecosystem Services Accounting
MAES	Mapping and Assessment of the Ecosystems and their Services
MAIA	Mapping and assessment of integrated ecosystem accounting
MSFD	Marine Strategy Framework Directive
MSPD	Maritime Spatial Planning Directive
NEA	UK National Ecosystem Assessment

NIS	Non-indigenous species
Ocean Decade	United Nations Decade of Ocean Science for Sustainable Development
OSPAR Convention	Convention for the Protection of the Marine Environment of the North-East Atlantic
OSPAR NEAES	OSPAR North East Atlantic Environment Strategy
PCA	Paris Climate Agreement
PoMs	Programme of measures
POPs	Persistent organic pollutants
PUFAs	Polyunsaturated fatty acids
R&I	Research and Innovation
RSC	Regional Sea Convention
SDGs	United Nations Sustainable Development Goals
SEEA	UN System of Environmental Economic Accounting
SRIA	Strategic Research and Innovation Agenda
UN	United Nations
UNFCC	United Nations Framework Convention on Climate Change
UXO	Unexploded ordnance/ammunitions
WFD	Water Framework Directive