BANOS

Baltic and North Sea Coordination and Support Action

The Baltic and North Sea Strategic Research and Innovation Agenda BANOS SRIA 2021

The final BANOS SRIA draft of the proposed, new, joint Baltic and North Sea Research and Innovation Programme – BANOS

BANOS CSA
Deliverable 1.5

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BANOS mission

Fostering high-level cooperative research and innovation across the Baltic Sea and the North Sea to support sustainable use of ecosystem goods and services with robust scientific knowledge and know-how.

Major research and innovation (R&I) funders of ten EU member states and two countries associated to EU's research and innovation framework: Belgium, Denmark, Estonia, France, Germany, Latvia, Lithuania, the Netherlands, Norway, Poland, Sweden, and the United Kingdom together with four transnational strategic partners – HELCOM, OSPAR, ICES and JPI Oceans – joined their forces in an EU-supported Baltic and North Sea Coordination and Support Action (BANOS CSA, 2018–2021). Together they have developed preconditions for launching the future joint Baltic and North Sea Research and Innovation Programme – BANOS. In future, BANOS aims to deliver policy relevant research and innovation in support of sustainable use of ecosystem goods and services while generating strong EU added value and impact.

In BANOS vision, to deliver a decisive and much needed boost to the sustainable marine and maritime economy, the collective R&I capacity of the Northern European region needs to be elevated to the next level through a scientifically, administratively, and financially firmly integrated R&I programme. **The core of BANOS is this Strategic Research and Innovation Agenda – the BANOS SRIA**. It marks a clear path forward while at the same time, through regular review and update, allows sufficient space for agile response to emerging needs for enquiry by scientists and innovators.

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Preface

The Steering Committee of the Baltic and North Sea Coordination and Support Action (BANOS CSA) representing major research and innovation funders of 12 countries (BE, DK, EE, FR, DE, LV, LT, NL, NO, PL, SE, UK) approved the future Baltic and North Sea Research and Innovation Programme's Strategic Research and Innovation Agenda (BANOS SRIA) on 10 May 2021. The development of the BANOS SRIA with a consideration of future knowledge demands was led by the BANOS CSA coordination office BONUS EEIG and developed with the support of the BANOS CSA consortium, its strategic partners HELCOM, OSPAR, ICES and JPI Oceans, its observers Academy of Finland, Belgian Science Policy Office and the EU Commission, a dedicated SRIA drafting team and key stakeholders.

Scoping of the future BANOS Programme was one of the immediate tasks kicked off after the start of BANOS CSA in November 2018. With the lead by BANOS CSA consortium member FORMAS (Sweden), and input and agreement by all other BANOS CSA consortium members, the task defined three overarching Strategic Objectives in June 2019: Healthy Seas and Coasts, Sustainable Blue Economy and Human Wellbeing. It also outlined related nine specific objectives and stressed that it is the ecosystem-based management that forms foremost the precondition for achieving all the objectives. The scoping process defined also three key attributes of the BANOS Programme: 'close connection to the ecosystem', 'dependence on climate impact' and 'geographic relevance to the Baltic and North Sea'.

Also completed in June 2019 was a separate task on the overview of existing priorities, status and capacity in relevant fields of research and innovation in the Baltic Sea and the North Sea regions. Led by the consortium member Jülich GmbH (Germany), it was concluded that the national research and innovation priorities in the marine and maritime fields in general were well in line with the strategic and specific objectives defined in BANOS CSA's scoping task. Among other, the well-equipped marine infrastructure and research facilities and a critical mass of marine scientists implies that BANOS countries invest substantially in marine and maritime research and innovation. Furthermore, with some of the world-renowned research institutions based in the BANOS region, the region is seen to play a fundamental role in the European Research Area, which needs to be nurtured and further developed in the coming years.

In autumn 2019, based on the scoping and review of the existing priorities outlined above as well as initial work by the BANOS SRIA expert drafting team, the development of BANOS SRIA began: in September, a dialogue session led by BANOS SRIA drafting team representatives and BONUS EEIG was organised during the ICES Annual Science Conference to seek views and define future BANOS region's research and innovation needs, and in November, an open online consultation carried out on the possible SRIA objectives and themes generated further, close to 70 suggestions.

On 30 March-2 April 2020, the BANOS CSA Strategic Orientation Workshop (SOW) convened online (due to the COVID-19 situation). It captured the considered view of all the steps above and shared with the SOW participants the fruits of the BANOS SRIA drafting team's intense working period, i.e. the very first draft of the BANOS SRIA. During the months leading to SOW, the 27 interdisciplinary marine experts forming the drafting team, coordinated and prepared the thematic parts of the SRIA under the three strategic objectives 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, and finalised it for SOW together with the BANOS CSA coordination office, BONUS EEIG. The 100 participants of SOW represented, besides the scientific community, policy makers (close to half of participants), funders, BANOS CSA strategic partners and observers, and institutions dealing with marine, maritime and socio-economic issues.

The overall task under the facilitation of the BONUS EEIG office, was to scrutinise the draft SRIA and confirm in direct, online interactions the different objectives and research and innovation themes to be included in the SRIA. Some 150 suggestions received during the workshop were in turn considered by the drafting team, and the draft BANOS SRIA updated for a final commenting round of the thematic content of the SRIA by the BANOS CSA consortium members. On 10 May 2021, the consequent acceptance of the full SRIA (containing also the non-thematic parts) took place in the BANOS CSA Steering Committee. After the final preparations for publishing, the date for the launch of the BANOS SRIA was set for 22 June 2021.

We thank sincerely all who have invested their time and expertise in realising the BANOS SRIA. The policymakers and other stakeholders, the scientific community, the national funding institutions, the BANOS CSA strategic partners and observers, who all have made this possible. We are grateful particularly to the members of the dedicated drafting team, who together with BONUS EEIG, and based on the knowledge and information obtained, prepared the materials for consideration of SOW and finalised the thematic work in the months following it. All parts of the BANOS SRIA have been prepared with the key aim of the future BANOS Programme in mind, as well as the forthcoming Sustainable Blue Economy Partnership under the new Horizon Europe framework programme, and it is to satisfy BANOS region's knowledge needs for the coming decade and beyond. Finally, the development of the BANOS SRIA is a process which means that it is also designed to be updated regularly to keep it responding to the realities we operate in.

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In Helsinki and online, 10 May 2021
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Content

1. Executive Summary

The future Baltic and North Sea Research and Innovation Programme – BANOS, as has been planned in the Baltic and North Sea Coordination and Support Action – BANOS CSA, aims to deliver new solutions and knowledge for the better management of the Northern European seas while enabling the sustainable growth of the blue economy in the region.

At the heart of the BANOS Programme is its Strategic Research and Innovation Agenda – SRIA which has been developed together with a wide range of stakeholders and experts. The resulting document highlights the current knowledge gaps and bottle necks in marine and maritime research and innovation and presents related objectives and themes with concrete descriptions and outcomes. It is drawn with a view to overcome the challenges the region faces and to enable the green transition of the blue economy. Although the BANOS SRIA is complete, it should be considered as an open document that will be updated periodically as new challenges emerge. Responding to the development of scientific thinking and the emerging needs for new scientific knowledge and know-how, the intention is to reopen the BANOS SRIA for updates within 2–3-year intervals.

1.1 The Sister Seas Approach

The rationale for development of a sister seas programme that encompasses both the Baltic Sea and the North Sea dates back to 2016 when the first outline document of the future programme was published. The arguments presented then remain valid today – the two seas have much in common – making this an opportunity too good to be missed:

- Both are marginal seas and directly interconnected via the Danish Straights. The seas have the same climate and biogeographical zones, with multiple countries having coastlines along both seas.
- The ecosystems are connected through flows of water masses and migration of biota.
- Both seas are faced by similar human induced threats: climate change, coastal eutrophication, overfishing, habitat destruction, unsustainable growth of blue economy and many more.
- The busy waterways, throughout the BANOS region, generate persistent pressures upon the ecosystems as well as constitute risks of accidental pollution.
- The human activities are governed by mutually coordinated maritime policy and legislation of the EU, as well as Norway, the United Kingdom and Russia.

In addition to above, the societal similarities and political stability in the BANOS region make the collaboration and the joint management of research and innovation programme highly feasible, allowing everyone to benefit from a wealth of experience from both regional seas in a search for sustainable management approaches and conservation of marine environment and its biodiversity. As such, the sister seas approach can be considered efficient and cost-effective when same strategies and approaches are applied in both areas.

Although many of the sustainability challenges facing the blue economy sector can be considered pan-European, or even global in nature, it should also be stressed that the solutions for the challenges are most likely to be localised, taking into account the specifics of the natural ecosystems, the customs and habits of people who depend upon them, and the local climate. As such, a macro-regional programme such as BANOS, is able to deliver appropriate solutions for the region taking into account its unique ecosystems and biodiversity, which remain highly vulnerable to environmental stressors. In addition, the sister seas approach serves well the needs of the marine governance, which continues to be resolved through existing macro-regional structures: HELCOM as the governing body for the Convention on the Protection of the Marine Environment of the Baltic Sea Area and the Convention for the Protection of the Marine Environment of the North-East Atlantic, i.e. the OSPAR Convention covers also the North Sea area.

1.2 The Objectives of BANOS

The overall framework of the BANOS SRIA consist of three mutually interlinked strategic objectives, all aiming to support and enable the ecosystem-based management in the BANOS region. These are:

- Healthy Seas and Coasts
- Sustainable Blue Economy
- Human Wellbeing

The strategic objectives, which are underpinned by nine specific objectives and 32 R&I themes, are all discussed in detail in the thematic section of the BANOS SRIA. The structure of the thematic section clearly illustrates the current state of the art and bottle necks in R&I as well as explicit expected R&I outcomes that will provide concrete solutions or steps towards solving the issues in support of reaching the good environmental status in the BANOS region as well as enabling the development of the sustainable blue economy sector with minimal environmental impacts.

It should also be highlighted that the content of the BANOS SRIA is highly policy relevant and the expected outcomes are tailored towards development and implementation of science informed policies. Here the focus has been centered around the European green transition while aiming to deliver a decisive boost to sustainable marine and maritime economy sector and bringing the R&I capacity of the BANOS region to the next level.

Below more details are given on each of the strategic objectives, including a short summary of their policy relevance.

Healthy Seas and Coasts

Healthy seas and coasts are resilient and high in biodiversity. They are a prerequisite for a healthy planet as well as for human wellbeing, proving an amplitude of ecosystem services, ranging from food provision to production of oxygen and climate regulation. However, seas and coasts everywhere, including the BANOS region, are under an increasing amount of pressure leading to deterioration of the marine environment and its biodiversity through pollution with an increased range of contaminants, eutrophication and deoxygenation. In addition, new threats are emerging in response to economic development at the seas as well as in response to climate change. This all has negative consequences on marine ecosystem functioning, resulting in, for example, decline in biodiversity and possible changes in the food web structure.

Especially in support of the European Green Deal, the Ocean Decade, Sustainable Development Goal 14, Marine Strategy Framework Directive and strategies of the regional sea conventions (HELCOM and OSPAR), the R&I outputs under **Healthy Seas and Coasts** will enhance our knowledge of the marine ecosystem and its functioning, while enabling development of new solutions and strategies for environmental protection and management, minimising the impacts of blue economy, and creating new regenerative economic opportunities for local communities in the BANOS region.

Sustainable Blue Economy

The blue economy sector is in a transition period and it is expected to grow extensively in the coming decades. Simultaneously, the growth will lead to development of new industries and provide employment opportunities and jobs in support of human wellbeing. The economic growth, however, should not be done at the expense of the marine environment and its ecosystem services. Instead, all the impacts should be minimised. Where possible opportunities and new solutions should be sought that work together with nature and local communities, enabling regeneration of marine habitats and restoration of its biodiversity.

Especially in support of the Blue Growth Strategy, Circular Economy Action Plan, European Green Deal, Common Fisheries Policy and Maritime Spatial Planning Directives, the R&I outputs under the strategic objective **Sustainable Blue Economy** will deliver concrete solutions and novel approaches to issues related to sharing of the seas in the BANOS region. At the same time, the aim is to ensure that adequate space is reserved for well-connected marine protected areas. The R&I outputs are tailored also towards supporting the development of renewable ocean energies in the region as well as development of sustainable and circular practices toward use and harvest of marine global commons. Marine environment provides many unexplored possibilities for development of novel products and materials. In fact, in future such materials may replace the existing consumables that have poor ability to degrade or be recycled, or have a high carbon footprint.

Human Wellbeing

Currently, we are only beginning to understand the close relationship between the marine environment and human wellbeing. However, the intrinsic connection between the two is clearly emerging: the seas provide us much of the food that we consume, they provide us with holiday and recreation opportunities as well as livelihood and employment opportunities. Many of the environmental challenges facing the marine environment, however, also have negative consequences on human wellbeing. The ongoing climate change and associated sea-level rise are posing threats to coastal communities leading to flooding and coastal erosion. Increasing surface water temperatures are leading to development of harmful algal blooms posing health risks to people and their livelihoods.

In addition, pollution is contaminating our food supply. As such, the connection between the health of the marine environment and human wellbeing is indisputable, both needing protection and safeguarding.

Especially in support of the European Green Deal, the Blue Growth Strategy, Ocean Decade, Sustainable Development Goals and Marine Strategy Framework Directive, the R&I outputs under the strategic objective **Human Wellbeing** will provide new solution and knowledge to support food security and safety in the BANOS region. In addition, approaches to sustainable development of local coastal communities and economies in harmony with nature are supported. Here emphasis is put on co-creation processes, involvement of local communities and citizens in the process simultaneously leading to increase in ocean literacy. The increased understanding on the value of marine ecosystem goods and services to human wellbeing will encourage sustainable practices, both among the citizens and industries, as well as development of policy and governance approaches to ensure that these valuable services are available for future generation to come.

1.3 Beyond R&I Calls

Although generation of new knowledge, solutions and innovation via implementation of transnational R&I calls are foreseen as the core activities of the future policy-driven BANOS Programme, it also aims to go further and achieve:

- Financial integration
- Admirative integration
- Strong visibility and lasting impact
- Strong EU-added value
- Scientific integration

For this purpose and to deliver on objectives and ambitions of BANOS, ten dedicated and closely interlinked measures, so-called impact enabling strategies, have been designed to turn the outputs of academic research and cutting-edge innovation into practical impact for benefit of the society. These specific strategies range from communication and dissemination to open science and innovation, and from knowledge synthesis and impact assessment to regional collaboration and beyond.

1.4 From Vision to Action

The dynamism associated with ongoing refurbishing of the EU R&I landscape and the onset of the next Framework Programme, Horizon Europe (HE), makes it challenging to have a streamlined work plan for implementation of the BANOS SRIA. Nevertheless, a set of recommendations for converting the vision into functioning implementation mechanisms of BANOS is foreseen.

It is recommended to structure the BANOS implementation into a series of annually updated planning cycles each covering approximately two years with more precise planning for the first year and more tentative for the second. This approach would allow combining the medium-term predictability, desired by funders and implementers of R&I as well the potential users of new knowledge, while maintaining flexibility needed for agile response to urgent new knowledge needs.

The main instrument of implementing the BANOS SRIA will be a transnational R&I projects selected for funding in centrally arranged competitive calls for proposals, and strongly supported by additional impact enabling activities. The thematic composition of each of the calls will be formulated in BANOS work plans. The whole call administration process, from the beginning with submission of proposals and completing with final scientific reporting and stock-taking of performance indicators will be managed on a web-based BANOS Electronic Programme Service System (BANOS EPSS). Participation of countries in the calls is anticipated to follow the 'variable geometry' approach. It is recommended that BANOS seeks opportunities for tying its calls with such initiatives as e.g. thematically relevant European partnerships, the Interreg Programmes operating in the BANOS region as well as programmes supported by European Structural and Investment Funds.

The envisioned co-funded European Partnership Climate Neutral Sustainable and Productive Blue Economy, from here on referred to as the Sustainable Blue Economy Partnership (SBE Partnership), funded under the Framework Programme HE is seen as potentially the most promising platform for implementing the BANOS SRIA through embedded calls and other forms of cooperation. It is expected that the high level SRIA of the SBE Partnership will become a common umbrella for all European regional seas' R&I initiatives, including BANOS. While the SBE Partnership will serve as a platform for jointly addressing the issues requiring pan-European approach and securing strong impact at European and global arenas, BANOS may implement its own complementary activities tailored to address the specific challenges faced in the BANOS region in a most fit-to-purpose way. The proposed planning approach built on annually updated work plans would support necessary synchronisation of activities of BANOS and the SBE Partnership.

2. Unlocking Possibilities of Sustainable Blue Growth in Northern European Seas

***BANOS mission:** Fostering high-level cooperative research and innovation across the Baltic Sea and the North Sea to support sustainable use of ecosystem goods and services with robust scientific knowledge and know-how.*

Researchers and Innovation Turn Challenges into Solutions

Major research and innovation (R&I) funders of ten EU Member States and two countries associated to EU's R&I framework: Belgium, Denmark, Estonia, France, Germany, Latvia, Lithuania, the Netherlands, Norway, Poland, Sweden, and the United Kingdom together with four transnational strategic partners – HELCOM, OSPAR, ICES and JPI Oceans joined their forces in an EU-supported Baltic and North Sea Coordination and Support Action (BANOS CSA). Together they have developed preconditions for launching the future joint Baltic and North Sea Research and Innovation Programme - BANOS. In future, BANOS aims to deliver policy relevant R&I in support of sustainable use of ecosystem goods and services while generating strong EU added value and impact. In BANOS vision, to deliver a decisive and much needed boost to the sustainable marine and maritime economy, the collective R&I capacity of the Northern European region needs to be elevated to a next level through a scientifically, administratively, and financially firmly integrated R&I programme. The core of BANOS is its Strategic Research and Innovation Agenda (BANOS SRIA) marking a clear path forwards while at the same time allowing sufficient space for agile response to emerging urgent needs for enquiry by scientists and innovators.

The idea of the future 'sister seas' programme dates back to 2013 when geographic extension of BANOS predecessor, the joint Baltic Sea Research and Development Programme (BONUS), was first considered. In 2016, an outline of the future Baltic and North Sea Programme "Towards sustainable blue growth" was published. In this document, three mutually interlinked strategic objectives of BANOS SRIA were first formulated. These strategic objectives echo the well-known 'sustainability triangle' (Fig. 1), transpiring in BANOS as:

- Healthy Seas and Coasts
- Sustainable Blue Economy
- Human Wellbeing.

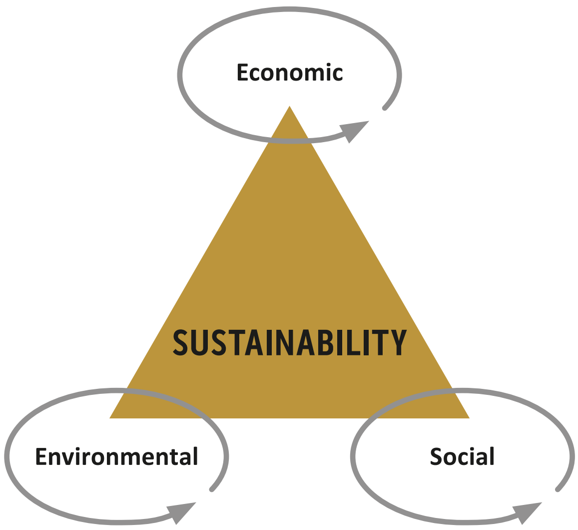

Figure 1. Sustainability tringle. Redrawn from Smythe, 2014.

Ecosystem-based management, as a critical condition in achieving any of these strategic objectives, serves as a pivot of the whole BANOS SRIA and defines the necessity of a holistic, multi- and interdisciplinary approach to R&I.

The section analysing the dynamic landscape of relevant policies justifies the core of BANOS SRIA – its thematic content. The cross-cutting message of the policy landscape analysis underlines the urgency of irreversible transition towards an integrated governance and management of human activities exploiting marine services that is informed by robust scientific evidence. Such concepts as, e.g.

ecosystem-based management, integrated maritime spatial planning as well as holistic assessment and valuation of ecosystem services, are our vehicles towards this goal.

For an R&I programme to make a difference, much more than a series of high-quality R&I projects is required. Building on the rich experience of BONUS, the BANOS CSA team developed a whole array of 'impact enablers ', each detailed in a dedicated report of the CSA. The BANOS SRIA includes a concise section outlining these closely interlinked impact enablers and their crucial role in achieving the aim of the future Programme. A brief and open-ended vision on implementation of the future BANOS Programme is presented in the concluding section of the SRIA.

In a nutshell, the key concepts born and tested already in BONUS and remaining equally valid for the future BANOS constitute of these:

- Seek ways to promote genuine interdisciplinarity; the answers to today's grand challenges depend equally on the natural and societal sciences
- Strive for a seamless integration between academic research and industrial and societal innovation, but do not underestimate the complexity of this objective – it is far from trivial and itself calls for innovative solutions; innovative industries could contribute to any of the SRIA themes
- Focus on issues that are too complex for any individual state to resolve but at the same time too specific to be effectively addressed by broader collaborative networks
- Prioritise the questions we 'need-to-know' to achieve sustainability above those that would be 'nice-to-know'[1]
- Pursue truth that does not end with original primary research; invest in critical review and synthesis of our knowledge to take a stock of what we know and what we do not know
- Bring science beyond laboratories and academies; nurture and support all forms of strengthening the impact of R&I for benefit of society; accept building 'ocean literacy' as an equally important task of the Programme.

Recognising that nature does not know the borders set by humans and hence the regional sea basins are the basic units for restoring and maintaining good environmental status and achieving genuine long-term sustainability of marine ecosystem services, BANOS will focus its attention to those issues where solutions can be to a large extent achieved by implementing a regional sea scale approach, such as,

- Resolving structure, functioning and linkages of ecosystems and to distinguishing between the effects of natural and anthropogenic drivers upon them
- Achieving good environmental status by coordination of national and international efforts in monitoring, assessment and management
- Optimising sustainable exploitation of ecosystem services and global commons by considering interests and activities of all relevant actors
- Achieving optimum of innovation potential by promoting interdisciplinary and collaboration across the region.

Having defined this overarching priority, BANOS team reiterates its openness to align as much as possible of implementation of this SRIA with the possible future European Climate Neutral Sustainable and Productive Blue Economy Partnership (SBE Partnership) and its high-level SRIA, to contribute to Mission Starfish and to collaborate with the relevant R&I initiatives in European sea basins and beyond.

1 Credit for this expression belongs to Prof. Mike Elliott (UK) – long-time advisor of BONUS and BANOS CSA

3. Policy Landscape and Dynamics

The geographical scope of the BANOS region encompasses 11 EU Member States of Belgium, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, the Netherlands, Poland, Sweden, two EU Associate Member States of Norway and the United Kingdom as well as the Russian Federation. As such, the policy landscape is an overlay of global, European, macro-regional, national, regional and local strata.

During the recent years, the policy landscape has been highly dynamic with an accelerating impact on the development of sustainable blue economy sector. On a global level, for example, this process has been pushed forwards by the onset of the United Nations Decade of the Ocean Science for Sustainable Development (2021–2030). The Ocean Decade in brief, aims to support efforts to reverse declining ocean health while engaging with a range of stakeholders worldwide in creating improved conditions for sustainable development of the ocean. This action is also closely linked to the 17 UN Sustainable Development Goals (SDGs) and with the Goal 14 specifically targeting the sustainable use of the ocean, seas and marine resources.

On the European level, the transition to a new EU policy cycle in 2019 and the onset of the next Framework Programme Horizon Europe (HE) has resulted in a rapid development of a novel growth strategy, the European Green Deal (EGD). It aims to make the EU's economy sustainable by turning climate and environmental challenges into opportunities. In recent times, attention to EGD has accelerated also due to the COVID-19 pandemic, which has demonstrated the vulnerability of the society to natural disasters and deterioration of the environment due to biodiversity loss. In addition, the pandemic has shown us the vulnerability of the current economic practises and the respective value chains across all sectors, thus including the blue economy. With close links to blue economy sectors, and a clear focus on sustainable development and growth, EGD now aims to put a green spin on the EU's Blue Growth Strategy (BGS) without adding any further expense on the ecosystem services.

On a macro-regional and European scale, Brexit has had many consequences on the policy development and sectoral collaboration in the BANOS region. In respect to the development of the blue economy sector and R&I landscape, the most prominent changes have been related to formulation of new UK (marine) environment and climate policies, such as the UK Marine Strategy and Net Zero Carbon Emissions Bill that together are replacing the former EU policies in the UK. The now confirmed participation of the UK in the HE, however, will largely enable the continuation of the R&I collaboration as previously.

In the following section the above mentioned and other key policies with high relevance to the aims and objectives of BANOS are discussed in more detail. Here, BANOS strongly acknowledges the importance of development of science informed policies, and the discussion is organised under three, often interlinked, specific topics: (i) the protection of the marine environment and its biodiversity, (ii) climate change and climate neutrality and (iii) development of sustainable blue economy. The discussion is primarily restricted to selected policies with shorth summaries also outlined in Box 1 (see below). However, many more highly relevant strategies and policies also exist, e.g. over 80 initiatives were identified for the Baltic Sea alone in an analyses carried out by BONUS earlier. These policies are often closely interlinked and supportive of one another. Yet, fragmentation is known to exist at all geographical scales and there is a continued need to combat any sectoral silos.

3.1 Protection of the Marine Environment and its Biodiversity

The Baltic Sea region has a long history of collaboration among the coastal states aiming to protect the marine environment and its biodiversity while also assuring the sustainable use of its ecosystem services. 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. Next step was taken in in 1992, when the scope of the Helsinki Convention was extended to include the whole Baltic Sea drainage basin. Fifteen years later in 2007, a collective action plan, the Baltic Sea Action Plan (BSAP) implemented by the Baltic Marine Environment Protection

Commission (HELCOM), was established aiming to restore the good environmental status of the sea. The HELCOM BSAP is currently being updated including identification of new targets and measurable objectives to restore the good environmental status in the Baltic Sea. Here the predecessor programme of BANOS, BONUS, has pioneered a globally unique policy-science tandem with HELCOM, delivering policy relevant results and knowhow to many management issues facing the Baltic Sea. Another, highly relevant initiative to the region is the EU Strategy for the Baltic Sea Region (EUSBSR). It is the first macro-regional strategy in the EU, and it focusses on three key objectives related to saving the sea, connecting the region and increasing prosperity.

In the North Sea region, the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention), including the North Sea region, 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 its jurisdiction area, protection and conservation on its marine ecosystems and biodiversity, and assessment of the quality of the marine environment. As the HELCOM BSAP, the OSPAR North-East Atlantic Environment Strategy (NEAES) expired in 2020 and is currently being updated.

The EU Marine Strategy Framework Directive (MSFD), which promotes Ecosystem Approach to Management (EAM) and sets an ambitious policy goal to achieve a good environmental status (GES) of the European seas by 2020, was adopted in 2008. Unfortunately, GES targets have not been achieved to date and collective efforts are still needed from the EU Member States. The MSFD 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 in the region.

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), the EU Biodiversity Strategy (BdS), EU Water Framework Directive (WFD) and the global Convention on Biological Diversity (CBD). In addition, cross-sectoral policies, such as EGD, emphasise need to revert biodiversity loss and cut pollution. The protection of the marine environment (and raising awareness of the issue) is also central to the UN SDGs and the UN Decade of the Ocean.

The three BANOS strategic objectives, including Healthy Seas and Coasts, 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. As such the future BANOS Programme aims to become the major provider of knowledge underpinning the policy measures for achieving GES in the Baltic Sea and the North Sea area.

3.2 The Climate Change Agenda and Reaching Carbon Neutrality

Climate change is directly linked to seas and the ocean via their role in climate regulation and in absorption of heat and carbon dioxide. The regional coastal seas are likely to play a key role in climate change mitigation, including protecting the coastal areas from storms and sea level rise. Coastal seas and associated marine habitats are also important sinks of 'blue carbon', a process which leads to removal of carbon from the atmosphere and locking it in a long-term storage in the seafloor sediments. Restoration of disturbed areas and protection of the coastal habitats with high CO_2 absorption capabilities can thus be used to fight against the climate change and atmospheric CO_2 rise.

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. Climate action is also central to the EGD, and includes a more immediate, at least 55 %, reduction aim of net greenhouse gas emissions by 2030. In the UK, the Net Zero Carbon Emissions Bill is currently under development, which aims to achieve net-zero carbon emissions also by 2050 in the country.

Being a central overarching topic of the BANOS SRIA, the impacts of climate change on marine environment, biodiversity and resilience as well as human wellbeing will be covered and incorporated into many of the R&I themes. In addition, the future Programme also commits to combatting climate change, thus contributing towards the goals of the EGD and other climate policies, by increasing understanding of the role of seas and the ocean as natural climate change mitigators and developing new innovative solutions to protect the coastal areas while simultaneously supporting the health, resilience and biodiversity of the marine environment. As such, BANOS aims to significantly contribute towards reaching the European and global climate target and the associated policies.

3.3 Development of Sustainable Blue Economy

Since the establishment of the BGS in 2012, increasing emphasis has been put on the role of seas and the ocean in the future of European economy, including all the high-potential sectors such as aquaculture (including mariculture), fisheries, coastal tourism, biotechnology and ocean energy. However, any development of the blue economy must also concentrate on the issues of long-term sustainability of the marine ecosystem services to society as is also stipulated in the regional strategies of HELCOM and OSPAR (BSAP and NEAS respectively).

The renewable energy sector has especially high affinity to the BGS. The rapidly expanding offshore wind energy sector is expected to be delivering green energy to BANOS region in future, thus also supporting the climate policies and the EGD. The expansions of the offshore industries, however, is going to put new pressures on the marine ecosystems and many of its impacts are not yet fully understood. Thus, the expansion must follow principles of EAM as outlined in the MSFD.

Any expansion of blue economy sectors will increase spatial demands in already very crowded coastal sea areas. As such, Maritime Spatial Planning Directive (MSPD) 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 EU Member States are able to deliver on their maritime spatial plans, due by the end of 2021, and subsequently achieve them, new maritime implementation strategies are crucially needed.

The sustainable blue economy is also strongly supported, among other, by the EGD and Circular Economy Action Plan (CEAP). Here, the aim is to stimulate Europe's transition towards circular economy, enhance its global competitiveness, foster sustainable economic growth and generate new jobs. Circular solutions are needed across marine industries to make the practices greener and to put less pressure on the limited natural resources. Circular practices can also help to tackle issues associated with marine litter.

The EU Integrated Maritime Policy (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.

The BANOS SRIA is fully aligned and aims to significantly contribute to the development of the sustainable blue economy in the BANOS region. Concentrating on the issues of sustainability of the marine ecosystem services to society, it emphasises the integral long-term sustainability requirement underlaying any development of the blue economy. The SRIA intends to contribute to all components of BGS including the high-potential sectors such as aquaculture, fisheries, coastal tourism, biotechnology and ocean energy. In addition, the SRIA outputs will deliver new solutions to address MSP as well as developing multi-stakeholder approaches of using and sharing marine space and infrastructure and providing new solutions for ocean governance.

BOX 1. KEY POLICIES AND INITIATIVES WITH HIGH RELEVANCE TO THE BANOS REGION

Regional Policies

EU STRATEGY FOR THE BALTIC SEA REGION

The EU Strategy for the Baltic Sea Region (EUSBSR) was launched in 2009, being the first macro-reginal strategy in Europe. It is an agreement between the Member States of the EU and the European Commission to strengthen cooperation between the countries bordering the Baltic Sea in order to meet the common challenges and to benefit from common opportunities facing the region. The Strategy is divided into three objectives, which are also the three key challenges of the Strategy: (i) saving the sea, (ii) connecting the region and (iii) increasing prosperity.

Links to other policies: HELCOM BSAP, BGS, CFP, MSFD, MSPD

HELCOM BALTIC SEA ACTION PLAN

The HELCOM Baltic Sea Action Plan (HELCOM 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
- Favourable 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, MSPD, SDGs, CBD

OSPAR NORTH-EAST ATLANTIC ENVIRONMENT STRATEGY

The OSPAR North-East Atlantic Environment Strategy (OSPAR NEAES) was adopted in 2010 and it extends until end of 2020. The core of the strategy is centred 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. Launching of a new North-East Atlantic Environment Strategy 2030 is expected at OSPAR Ministerial Conference in October 2021.

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

European Policies

EU 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 emphasises the role of the seas and the ocean 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, MSPD, SDGs, Ocean Decade

EU 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

EU 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. Revision of CFP is due in 2022.

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

BOX 1. CONTINUES

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 are:

- 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, HELCOM BSAP, OSPAR NEAES, SDGs, EGD, CBD

THE EUROPEAN GREEN DEAL

Set in 2020, the cross-sectoral European Green Deal (EGD) aims to make the EU's economy sustainable by turning climate and environmental challenges into opportunities. The policy is targeted towards everyone, from policymakers to industry to citizens with an emphasises on joint action to achieve the goals. More specifically the EGD sets to

- Boost the efficient use of resources by moving to a clean, circular economy
- Restore biodiversity and cut pollution
- Make Europe carbon neutral by 2050

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 the ocean 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: HELCOM BSAP, OSPAR NEAES, MSFD, EGD, MSPD

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, HELCOM BSAP, OSPAR 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 minimised
- 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: HELCOM BSAP, OSPAR NEAES, BdS, MSPD, SDGs, EGD, CBD, Ocean Decade, Maritime Doctrine (Russia) and the UK Marine Strategy

EU WATER FRAMEWORK DIRECTIVE

The EU Water Framework Directive (WFD) was adapted in 2000. The management of WFD is based on protecting water by natural geographical formations: river basins. It commits EU Member States to achieve good quality and quantitative ecological status of all water bodies, including rivers, lakes, estuaries, groundwater and coastal marine waters (up to one nautical mile from the base line of territorial waters).

The WFD has four main objectives:

- Protect/enhance all waters (surface, ground and coastal waters)
- Achieve "good status" for all waters by December 2015
- Manage water bodies based on river basins or catchments
- Involve the public

The Directive is implemented through six-year recurring cycles, plans published in 2009, 2015 and 2021.

Links to other policies: MSFD, HELCOM BSAP, OSPAR NEAES, BdS, CBD, SDGs

Global Policies

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 three main objectives:

- Conservation of biological diversity
- Sustainable use of the components of biological diversity
- Fair and equitable sharing of the benefits arising out of the utilisation 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. In October 2021 Conference of the Parties to the CBD will adopt a post-2020 global biodiversity framework.

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

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 realisation of the 2030 agenda and achieving the set goals.

The 17 SDGs include:

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: HELCOM BSAP, OSPAR NEAES, CFP, MSDF, BdS, CEAP, MSPD, EGD, BGS, WFD, Ocean Decade, PCA, EGD, 2050 Strategy

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) in 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 ocean, seas and coasts.

The Ocean Decade recognises 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 aims to respond 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
- An inspiring and engaging ocean where society understands and values the ocean

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: HELCOM BSAP, OSPAR NEAES, CFP, MSDF, BdS, CBD, CEAP, MSPD, EGD, BGS, SDGs

4. The Strategic Objectives of BANOS

The overall framework of the BANOS SRIA consists of the three mutually interlinked strategic objectives:

A. Healthy Seas and Coasts
B. Sustainable Blue Economy
C. Human Wellbeing

all aiming to support and enable the ecosystem-based management in the BANOS region (Fig. 2).

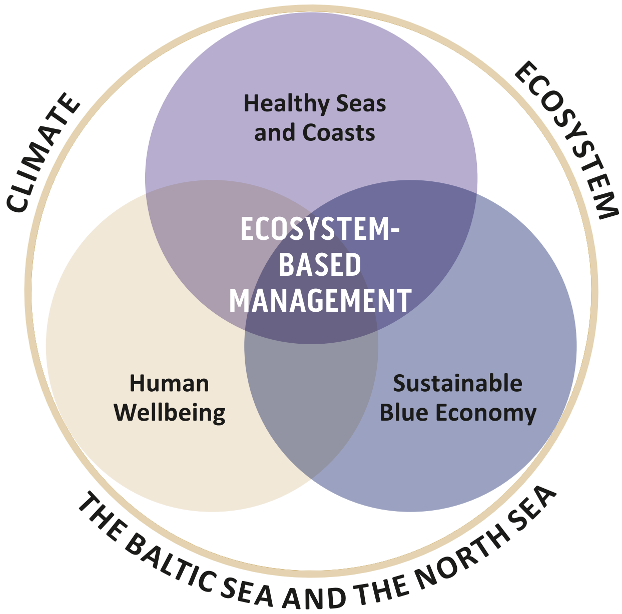

Figure 2. Three mutually interlinked BANOS strategic objectives: A. Healthy Seas and Coasts, B. Sustainable Blue Economy, and C. Human Wellbeing, all aiming to support and enable the ecosystem-based management in the BANOS region. In addition, three attributes defining the scope of the future BANOS Programme are (i) relevance to ecosystem with biodiversity as its principal component, (ii) dependence on climate impact and (iii) geographic relevance to the Baltic Sea and the North Sea.

Ecosystem Approach to Management

The future BANOS Programme is aiming to support and enable the ecosystem-based management in the BANOS region. The Ecosystem Approach (EA) to Management (EAM) is a planning procedure that integrates the management of human activities and their institutions with the knowledge of the functioning of ecosystems. Ultimately it is an integrated management approach that can be applied across coastal and marine areas and their natural resources, promoting conservation and sustainable use of the whole ecosystem. Key aspects of EA relevant to the governance of marine ecosystems include i) a broader, system-wide perspective taking in account both ecosystem interactions along the aquatic continuum from land to sea 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.

While using the whole policy mix in their work, the Regional Sea Conventions (RSC) are regarded as an intergovernmental effort on a regional level that aim to implement the directives and the underlying EA, e.g. HELCOM BSAP and OSPAR NEAES. The EA was formally adopted by HELCOM and OSPAR in "The Bremen Statement" in 2003. Thus, the European environmental policies can be regarded as an effort for the implementation of the UN SDG 14. In addition, many environmental management strategies and directives dealing with aquatic environmental issues are based on the concepts of resilience and ecosystem health and can be used to implement the EA, e.g. WFD, MSFD, MSPD and CFP. Further, also strategies addressing environmental issues on land that have implications for aquatic resources are part of the EA. The EU CEAP and more recently also the Plastic Directive (EU) 2019/904 are crucial in the EA to manage human activities in relation to the marine environment. This is particularly the case when considering the management of marine microplastics, but also other hazardous waste and nutrients from agriculture. Likewise, the Common Agricultural Policy (CAP) is part of the EA for management of coastal water bodies in the catchment but also adjacent coastal water bodies. Finally, the strategies and regulation of atmospheric pollution (UN ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) and in the EU NEC Directive) are part of the EA.

Main strategies are already in place to support the implementation of the EA in management and governance of human activities in the marine environment. However, to action it across different fields in the BANOS region, an urgent need still exists to boost transdisciplinary research and develop transition pathways (instead of fulfilling path dependencies) in policy implementation and management. Also, studies are needed to plan and experiment with ideas to develop and test solutions for sustainable economic transition that would deliver both human wellbeing and ecosystem health, and that are equitable and socially just. This requires systematic analyses, how the management of uses of the sea is dependent and impacted by societal systems, such as food system, energy system, transport system etc.

Strategic Objective A. Healthy Seas and Coasts

Healthy seas and coasts are resilient and high in biodiversity. They are a prerequisite for a healthy planet as well as for human wellbeing. They provide an amplitude of ecosystem services, ranging from food provision to production of oxygen and climate regulation. However, seas and coasts everywhere, including the BANOS region, are under an increasing amount of pressure leading to deterioration of the marine environment and its biodiversity. This is caused by pollution with an increased range of contaminants, eutrophication and deoxygenation as well as new threats that are emerging in response to economic development at the seas and in response to climate change. This all has negative consequences on marine ecosystem functioning, resulting in, for example, decline in biodiversity and possible changes in the 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. This should be accompanied by approaches on how to minimise ecosystem deterioration and avoid reaching critical ecosystem thresholds, so called tipping points. Importantly, new nature-based solutions (NbS)[2] on how to successfully restore and vitalise already degraded habitats are critically needed. Healthy seas and coasts and their sediments also play an important role in reaching climate neutrality due to their capacity to store organic carbon naturally. Thus, in order to maximise the carbon sequestration into natural coastal habitats, more understanding of marine ecosystems functioning is needed, e.g. which types of northern latitude habitats are most impactful in this respect. To ensure that the future uses of the seas are managed and governed sustainably, and to overcome the existing and future challenges and to reach a good environmental status (GES) in the BANOS region, new adaptive measures and monitoring approaches that support and enable EA are required.

The strategic objective A. Healthy Seas and Coasts consists of four specific objectives:

- A.1: A Resilient Marine Ecosystem
- A.2: Seamless Governance Linking Land, Coast and Sea
- A.3: Digital Ocean – Competent Ecosystem Modelling, Assessments and Forecasting
- A.4: Efficient Techniques and Approaches for Environmental Monitoring and Assessment

Together the 16 R&I themes and their outputs listed under these specific objectives will enhance the capabilities to protect the Baltic Sea and North Sea ecosystems while enabling more sustainable use of marine space and its resources. This specific objective is closely associated to many regional, European and global policies, supporting among others the implementation of HELCOM BSAP, OSPAR NEAES, EGD, MSFD, SDGs and many more (Fig. 3).

Strategic Objective B. Sustainable Blue Economy

Blue economy offers multiple possibilities and solutions to support the Europe's green transition, from food production to supply of renewable energy.

The role of the coastal seas as providers of healthy food is likely to increase in the future, creating opportunities for the seafood sector to develop new sustainable approaches and practices with a minimal environmental impact. Especially the production of healthy marine resources of protein, with relatively low carbon footprint, and new opportunities to seaweed and algal production are expected to emerge. In addition, marine biomass offers new innovative possibilities for many other sectors including, but not limited to, pharmaceutical and materials' industry. The circular approaches should be promoted and adapted, leading to less waste and lower demand on existing, limited resources. All in all, the use of the marine commons should be carried out following the principles of EAM.

The establishment of the renewable energy sector will play a pivotal role in Europe's ambition of reaching carbon neutrality. The offshore wind sector, which is already prominent in the North Sea but also expected to rapidly increase in the Baltic Sea during the coming decades, is playing a key role here. However, development of other renewable energy sectors should not be overlooked as all solutions are likely to be needed to reach the targets. The expansion of the energy sector is, however, putting more pressure on the already very crowded regional seas. Solutions to accommodate the expansion while minimising its impacts are needed

2 Following the definition by the International Union for Conservation of Nature (IUCN) NbS are "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".

providing opportunities to enhance the biodiversity locally and regenerate the marine ecosystems. In addition, as many sectors have vested interest in the coastal seas, also competition for marine space is rapidly increasing. The expansion and coexistence of new sectors need to be resolved in a sustainable manner with adequate space reserved for marine protected areas (MPAs). Here, new strategies and tools are needed to align and, where possible, combine new activities with existing industries, including fisheries and aquaculture sector, and marine transport. The impact of the emerging sectors on the ecosystem functioning must also be assessed and understood. Importantly the spatial planning needs to be done in a coordinated manner and, where possible, different sectors should combine the use of infrastructure and space. While the EU countries are expected to deliver their maritime spatial plans in 2021, many challenges and unsolved questions remain. Those will have to be answered while implementing and further updating these plans.

The strategic objective B. Sustainable Blue Economy consists of two specific objectives:

- B.1: Sustainable Resource Management of Marine Commons
- B.2: Sustainable, Smart and Circular Solutions for Blue Economy

Together the eight R&I themes listed under these specific objectives aim to enable the sustainable development of the blue economy sector in the BANOS region aligned with the principles of the EAM. The outputs will provide innovative tools and practices for comprehensive planning and management of maritime activities, mitigating the trade-offs among different user while supporting the development of new, sustainable and circular innovation in the region.

This specific objective is closely associated with a number of regional, European and global policies, supporting among other the EGD, the BGS to be updated with the Commission's forthcoming new strategy for a sustainable blue economy, CFP, MSPD and more (Fig. 3).

Strategic Objective C. Human Wellbeing

Human wellbeing[3] (HWB) is intrinsically connected to and impacted by the sea and its ecosystem services.

3 In the BANOS SRIA the human wellbeing is based on the concept that healthy marine ecosystems support the ability of humans to survive and thrive, and that understanding the interactions between HWB and ecosystem health are critical to promoting a healthy planet. As such the definition is based on a holistic understanding of multiple factors, including the following eight domains: 1. Economic living standards, 2. Material living standards, 3. Health, 4. Education, 5. Social relations, 6. Security and safety Governance, 7. Subjective wellbeing, 8. Culture and spirituality, and 9. Freedom of choice and action (after McKinnon, M.C., Cheng, S.H., Dupre, S. et al. 2016).

The coastal areas are heavily populated with almost half of the EU population living less than 50 km from the sea and with the seaside being Europe's most popular holiday destination. Much of the food consumed is produced in the local regional seas; with safety and availability of it relying on healthy marine ecosystem and sustainable consumption and harvesting processes. The food should be safe to eat as regards to contaminants and pathogens, produced ethically while its production also managed following principles of EA.

There is also increasing evidence demonstrating a link between human wellbeing and access to coastal environments for relaxation, exercise and recreation, i.e. the so called blue-gym effect. These benefits should become available and accessible for everyone. Engagement of citizens with the marine environment and associated awareness of marine related challenges will also enhance ocean literacy and appreciation of marine environment among the citizens, thus also its protection.

Climate change and associated challenges, e.g. sea level rise, increase in extreme weather events and higher temperatures, are posing new threats on human wellbeing. Coastal defence and protection need to be considered and locally adapted to the needs of the specific regions. Where possible solutions enhancing local biodiversity and marine resilience should be developed and favoured. Such developments may also provide new opportunities for ecotourism and recreation, increasing the value of the environment and creating new jobs for the local communities. In addition, these could be considered for optimal development of the MPAs.

An evident link also exists between human wellbeing (or health specifically) and sustainable blue economy sector associated with pharmaceuticals and the health care industry (namely included in the BANOS specific objective B.2).

Finally, healthy, productive and resilient ecosystems are a prerequisite for the provision of a multitude of ecosystem goods and services in support of human wellbeing. The concept of ecosystem services, and their value, can be made operational in a manner that enables quantitative projections as a response to changes in ecosystem state, pressures, societal trends and policies. Such projections and associated cost-benefit analyses can provide important information to decision makers and industry alike in respect to consequences of investments, abatement measures and policy instruments, and, importantly, support the sustainable use of these services. The value of ecosystem services must be further defined, including both their monetary and non-monetary aspects, to assist the marine management and governance, and to support awareness of the true value of the marine ecosystem services to the society as a whole.

The strategic objective C. Human Wellbeing consists of three specific objectives:

- C.1: Safe Food and Feed
- C.2: Safe and Accessible Coast
- C.3: Understanding the Benefits of Ecosystem Goods and Services as Sources of Human Wellbeing

Together the eight R&I themes listed under these specific objectives aim to provide a new knowledge base and solutions that support human wellbeing and emotional connection to the sea, as well as to promote the understanding of the value of ecosystem services in management and decision-making. The themes encourage strong interdisciplinary research approaches, connecting natural sciences and humanities, which is critically needed to tackle the existing challenges and to provide solutions in support of sustainable future.

This specific objective is closely associated to numbers of regional, European and global policies, supporting among other the EGD, BGS, MSFD and many more policy frameworks (Fig. 3).

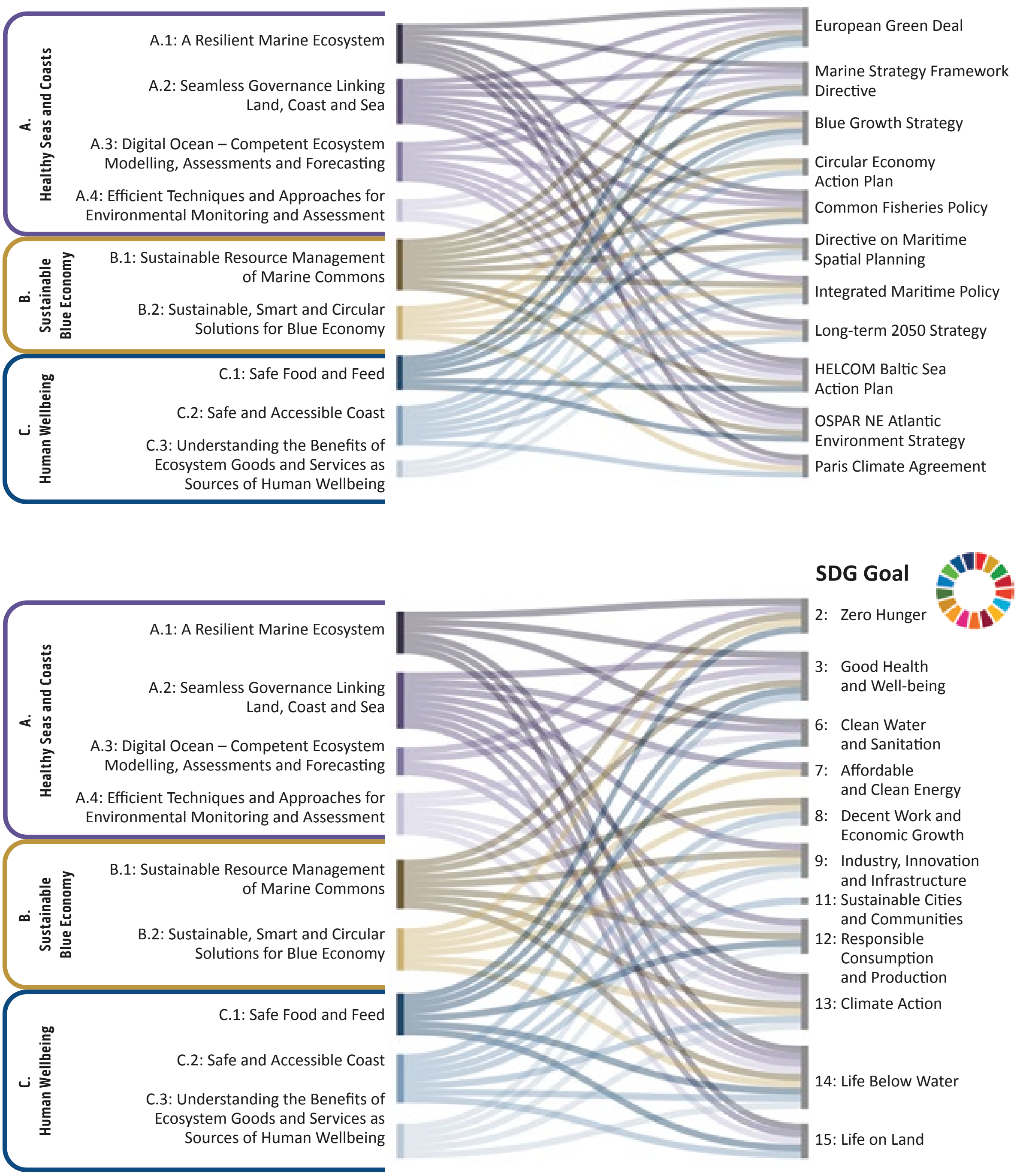

Figure 3. Top: The links between BANOS strategic and specific objectives and selected key regional, European and global policy frameworks. Below: Detailed links between the BANOS objectives and United Nations Sustainable Developments Goals.

4.1 Specific Objective A.1: A Resilient Marine Ecosystem

Overall rationale

A resilient ecosystem is healthy, diverse and robust. It can resist perturbations and recover from them quickly. If a perturbation is extensive and goes beyond the capacity of the ecosystem to respond to it, this may lead to an ecosystem shift into a qualitatively different state or regime. Such regime shifts as a response to climate drivers, have been demonstrated in the Baltic Sea and the North Sea, i.e. the BANOS region, in the past. However, the role of compounding drivers, such as eutrophication, contaminants, fisheries and physical operations in regime shifts are still debated. Especially the combined influence of climate drivers and compounding drivers remain unknown and need to be urgently quantified.

Ecosystems are complex; they include multiple trophic levels that are tightly connected and cannot function independently in an optimal way. Due to external pressures and the openness of the environment, ecosystems are also continuously evolving and responding to external factors. These ecosystem characteristics challenge the normative regulation of the environment, which traditionally address and compare only a single or a few components of an ecosystem at a time, focusing on common drivers of change such as non-functioning regulating services (e.g. nutrient cycling, carbon storage and oxygen production), loss in biodiversity and productivity of higher trophic levels (fish, shellfish). However, as the resilience deals with the capacity of the whole ecosystem to self-organise, a more comprehensive management approach is required. Ultimately, widening our understanding of the resilience of marine ecosystems in the BANOS region is pivotal in enabling EAM and safeguarding biodiversity and ecosystem functions and services in a changing world.

State of the art and knowledge gaps

Whereas major human drivers of marine ecosystem state have been identified and their independent impact on the ecosystems and their resilience is relatively well understood, their combined effects remain poorly known. In addition, holistic management measures, which consider multiple drivers of change, are urgently needed to operationalise the EA. More specifically, critical components of marine ecosystem resilience, i.e. the role of habitat forming species, foundation species (common species of any trophic level) or keystone species (top predators), need to be understood. What happens to the ecosystem resilience if one of these species' groups disappear/ is substituted? Much of the understanding on how marine organisms may 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. This knowledge is just on the brink of delivering critical insights in environmental management and needs to be broadened. However, given that many stressors cannot be prevented, and new ones are likely to emerge, for example in response to expansion of blue economy sector, there is a need to develop quantitative understanding of cumulative effects of multiple stressors on marine ecosystem resilience, including the links among them, and to consider adaptation to ecosystem changes while ensuring that the systems maintain their ecological structure, biodiversity, and function.

Therefore, the R&I agenda put forward here focusses on the targets, thresholds and trigger values with consideration of the shifting baselines in response to climate change.

Impact and linkages

The R&I put forward under the specific objective A.1 deliver policy-relevant and research-based knowledge on the state, functioning and vulnerabilities of marine ecosystems and their biodiversity. The outcomes will form the basis for implementing EAM across sectors exploiting marine ecosystem services and achieving the GES of the northern European regional seas. In addition to European polices, such as the EU's MSFD, EGD and BdS, the outcomes are also closely associated with the SDG 14, which explicitly expresses the need to understand 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".

The R&I outcomes addressing the themes under the strategic objective A.1 provide essential conceptual and process knowledge of marine ecosystem functioning as needed in A.3 (modelling and forecasting) and A.4. (monitoring and assessment), and as required for a seamless governance of the uses of the marine environment (A.2). In addition, the role and functionality of blue carbon ecosystems as NbS for sustainable management, that also contribute to climate change mitigation and biodiversity hot spots, will be elucidated and closely linked to the themes in B.2 (circular and bio-based blue solutions) and C.3 (ecosystem goods and services)

Whereas the EAM is an overarching and binding concept through the BANOS strategic objectives A, B and C, an effort will be put forward under A.1 to create case studies, which provide practical management solutions for specific sectors. Hence, a lot will be learned from these and other cases where new indicators for the BANOS region will be developed, linking human resource use, ecosystem services, opportunities for industries and environmental legislation.

A.1.1
Understanding Marine Food Web Interactions and Their Services

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 lower trophic level 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 climate and direct human induced pressures. 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 into the dynamics of mesozooplankton and its important linking function to fish. The role of benthos (both biogeochemical processes and animals) has often been overlooked. The link between fish and their food and predators remains unresolved in most fisheries studies. There is also limited insight into how food web dynamics affect 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 the North Sea to the adjacent ocean as well as burial of organic matter in sediments, are climate drivers at long time scales but are extremely difficult to measure. There is a lack of directly observed rates: observations of food webs are typically on states, not on processes (probably apart from primary production, where rates can be measured but this is only occasionally done as part of research projects). New molecular and biogeochemical techniques have a great potential to contribute novel insights into food web processes as they facilitate the direct observation of critical rates and allow to resolve food sources in very specific ways.

Modelling plays an essential role in the analysis of food webs and in understanding causality, such as the relation between measures and their effects. 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 an 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 environmental change and human induced pressures.

Model development should be tightly coupled to field observations and process studies, as models are dependent on solid observational basis for proper process representation and for validation. The interplay between both approaches enrich the study of food webs to the best possible extent.

Comparing the Baltic Sea and the North Sea with respect to functioning of the food web and response to human induced pressures and climate change is particularly relevant. Despite the differences in the physical settings of the seas and complexity of the food webs, comparison of 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 North Sea 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 improved understanding of the functioning and structure of marine food webs (incl. all trophic levels) in response to changes in environmental and human induced pressures, including but not limited to eutrophication, fishing pressure (e.g. protection of top predators), aquaculture deployment and habitat changes (e.g. in response to wind farm development), sand extraction, marine infrastructure.
- An improved understanding of the dependence of food web structure and functioning (incl. all trophic levels) on ocean acidification and climate change, e.g. temperature increase, changes in carbonate chemistry, changes in meteorological patterns, migration of species.
- New information on the marine food web fluxes to provide a better observational basis on which to conceptualise and model marine food webs in the Baltic Sea and the North Sea.
- Identification of food web indicators and related baseline and threshold values for assessing the state of marine ecosystems, e.g. in the context of MSFD, OSPAR and HELCOM, and options for efficient monitoring of these indicators.
- An improved understanding of expected changes in the functioning and structure of marine food webs due to changes in marine management practices, accompanied by novel statistical and mechanistic modelling to predictively link management measures to effects in the food web.

A.1.2
Understanding Critical Components of Marine Ecosystem Resilience and Drivers of Change

State of the art and knowledge gaps

Multiple drivers (climate change, fishing, pollution, shipping, physical exploitation) affect the Baltic Sea and the North Sea marine ecosystems. Knowledge on how these drivers and interactions among them act on key species functions and distributions, including range shifts, is urgently needed to enhance our understanding of ecosystem dynamics and resilience.

In the BANOS region, extensive monitoring generates time series data that are important but so far untapped sources of information to understand the dynamics of the marine systems. Combined with modelling, these data can be used to address effects of single external drivers and of the complex effects of multiple drivers.

Earlier research has shown for example that fishing is a main driver in many systems, leading to depleted fish stocks but also to changed ecological dynamics with loss of biogenic structures, changed dynamics of seagrass meadows and seaweed forests, and shifts in benthos and plankton communities. However, the interaction between fishing and climate change needs to be understood.

Integration of empirical data into modelling of scenarios will be needed to address the combined effects of drivers of ecosystem change. Such change may include extinctions and introductions of species, but also range contractions and expansions of species. It is important that we understand both short-term (ecological) and long-term (evolutionary) effects of these changes.

There is currently insufficient understanding of which factors support ecosystem resilience along both the ecological and the evolutionary axes. For example, what are the roles of foundation species in ecosystem resilience, and what processes challenge these roles? How will interactions among multiple drivers of change shape the main components of marine ecosystems? What direct and what indirect effects of various drivers will play roles in redistributing key actors of the ecosystems?

Expected outcomes

- A better understanding of factors that support resilience of a marine ecosystem and of mechanisms that drive ecosystems away from resilience.
- Improved understanding of direct and indirect effects of climate change and ocean acidification on ecosystem key species, including range expansions and contractions and how these affect other species of the ecosystem.
- Improved understanding of the effects caused by actions and interactions of multiple drivers, e.g. climate, pollution, fish harvesting, wind farms, in the ecological dynamics of the Baltic Sea and the North Sea.
- Improved understanding by use of biophysical and other models that describe both short-term and long-term effects of single and combined drivers on coastal ecosystems, parameterised by time-series data from research and monitoring in the BANOS region.

A.1.3
Understanding the Potential of Marine Organisms and Ecosystems to Adapt to Environmental Changes

State of the art and knowledge gaps

Changes in temperature, salinity and eutrophication in the BANOS region are much more rapid than in the open ocean due to their relatively shallow water column and enclosed (Baltic) locations. With warmer waters, these ecosystems also receive increasing numbers of new 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 impact on the seabed and underwater constructions causes increased fragmentation of benthic habitats or provide stepping-stones 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 going locally extinct.

One urgent research question is whether populations of key species are now adapting to global and local environmental changes, or whether there is an extinction risk. On the one hand, examples show populations of species that can cope well with rapid evolution of new adaptations as a response to a shift in the environment, including adaptation to decreased salinity, increased temperature, and even increased levels of toxins. On the other hand, 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 BANOS region is largely a marine transition zone, characterised by a salinity gradient which in some areas is very steep. Most species that have been genetically characterised have established locally adapted populations along this gradient, including establishment of even new endemic species. For some populations the gene flow has been heavily reduced, while this is less so for others. For a relevant ecosystem-based management, we need basic information on the genomic landscape of key marine species in the BANOS region. Based on this knowledge, we need to find out what will happen to all these locally adapted populations or new species when both temperature clines and salinity clines rapidly shift away from their current positions, and how negative effects of this can be mitigated. We need to understand better what will be the effect of more frequent and extreme climate events, e.g. heat waves. 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 BANOS region, local populations of commercial fish species and habitat-forming species, such as eelgrass, seaweeds or flat oyster, are already lost in many 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

- A model-based framework (combining genetic and biophysical data) 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 of restoration of marine populations, including opportunities and risks using re-location of organisms and assisted evolution.
- Empirical and model-based scenarios to estimate and predict impacts of ocean acidification and climate induced changes in selection pressures, e.g. temperature increase and changes in carbonate chemistry, on local marine populations and identification of measures that can support adaption.
- Measured and predicted ecological and genetic effects of climate-induced migration of species, including the roles on ecosystem/food web functioning, replacement of foundation and key species, e.g. by non-indigenous species.

A.1.4
Operationalisation and Assessments for the Implementation of the Ecosystem Approach

State of the art and knowledge gaps

While the principles of EA are generally acknowledged by decision makers and environmental management practitioners, putting the EA into practice has only been partly achieved to date. The operationalisation of the EA and its concepts in the BANOS region still require integration and transfer of scientific knowledge into the daily management practices. In addition, an optimum approach serving both administrative bodies and all relevant stakeholders need still to be developed.

The EA is ultimately related to resilience and ecosystem health that is assessed by means of numerical models or semi-empirical-statistical approaches. 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. The management of marine environments and resources as driven by administrative bodies and agencies (EU and regional sea bodies) follows consecutive workflows, e.g., the cyclic workflows originating from the Drivers – Pressure – State – Impact – Response (DPSIR) approach. However, response times of the various ecosystem components have different 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. As such, there is a huge need for an integrated approach linking the various models and statistical approaches used for decision-making purposes. Further, such integrated approach should have clear linkages to human activities and/or industries using marine resources. However, the current models which combine scientific and socio-economic approaches are highly complex and uncertain due to model error progression as well as lack of data and relevant indicators. Also, the resulting scenarios are often long-term and too generic to be of practical help in decision-making. Hence, there is a need to develop new comprehensive assessment practices which include human use of resources and opportunities, the four types of ecosystem services (i.e., provisioning, regulatory, cultural and supporting ecosystem services) and environmental legislation to address ongoing goal conflicts in assessments supporting the EA. Overall, socio-economic indicators need to be adjusted to ecosystem indicators.

Here, specific case studies aiming at operationalisation of EA must generate tangible products including a robust management plan guaranteeing a sustainable use of the marine resources while simultaneously protecting ecosystem integrity and functionality. Further, the opportunities for industries and other users of sea to support the development of sustainable blue economy need to be considered. Cases, with starting points in actual management challenges where an EA is promising to address urgent environmental problems, are needed to fill in the existing knowledge gaps. By collaborative work between scientists, managers and stakeholders, such projects are expected to identify tools and methods for adaptive management. Furthermore, contributions to societal learning and assistance in identifying good examples and practices are expected of the projects in efforts to overcome current implementation obstacles of EA in the BANOS region.

Expected outcomes

- Formulation of an operationalised EAM concept for the BANOS region including the development of a practical implementation model, which addresses both environmental risks and opportunities relevant for case studies in question. Establishing new learning and collaboration processes that are based on concrete cases and use integrative tools and methods for adaptive management of environmental and social interactions.
- Identification of indicators and related targets, threshold and trigger values for the assessment of the 11 descriptors of the MSFD, supporting the developments in the regional seas conventions and the Common Implementation Strategy.
- Identification of indicators addressing human resource use and goal conflicts across sectors, ecosystem services, social costs, economic opportunities and environmental legislation.
- Short-term predictions of climate variables and related impacts to living resources in combination with long-term integrated strategies including risk and vulnerability assessments towards climate resilience.
- New strategies to support restoration of collapsed and unstable components of marine ecosystems.

A.1.5
Coastal and Marine Ecosystems as Nature-based Solutions

State of the art and knowledge gaps

Healthy marine and coastal ecosystems provide fundamental societal services including climate regulation, nutrient cycling, stimulation of biodiversity and food provisioning. However, many marine species, habitats and ecosystems have suffered catastrophic declines due to human pressures such as eutrophication, overfishing and mechanical impact, and climate change is further undermining ocean productivity and biodiversity. Protection, restoration and sustainable use of the marine ecosystems is critically needed to maximise its functionality as NbS for global challenges such as climate change, eutrophication, loss of biodiversity and resource limitation.

Seagrass meadows, saltmarshes, mangroves, kelp forests and reefs are key components of coastal ecosystems distributed in shallow waters along the world's coastlines where light reaches the seafloor. Through their high productivity, they take up and store vast amounts of CO_2 as 'blue carbon'. These habitats also constitute an important component of the coastal filter, slowing down nutrient cycling and promoting nutrient removal and clear water, and potentially suppressing sediment production of greenhouse gases (GHGs) such as methane and nitrous oxide. Therefore, increased area and functionality of these blue carbon ecosystems contribute to mitigating climate change and eutrophication. At the same time, these ecosystems contribute to climate change adaptation by constituting natural coastal protection, as well as zones of increased pH and elevated seafloor. The ecosystems also underpin marine biodiversity by providing habitat and recruitment area for a wide range of species including economically important fishes. Sustainable management of these ecosystems, which are among the most threatened on the globe, is, therefore, increasingly acknowledged internationally as 'win-win', 'no-regret' NbS to environmental challenges and share close links with the "building with nature" concept. The NbS include strategies for conservation (e.g. MPAs), for restoration (e.g. by ensuring suitable habitat conditions are supplemented with seeding/transplantation of new populations) and for sustainable harvest/cultivation of e.g. seaweed resources.

To date, the field of blue carbon ecosystems and their role as NbS has, however, received limited attention in the BANOS region. This even though the long and convoluted coastline of the Baltic Sea and the North Sea with extensive shallow areas subjected to multiple stressors, suggests a vast potential for effective

NbS to stimulate the expansion of these ecosystems and their functionality. There is a need for quantification of the potential of NbS for climate change mitigation and adaptation and co-benefits in this region and for tailoring NbS to the characteristics of the region and to expected impacts of climate change. This requires scientific insight on distribution areas of blue carbon ecosystems and their connectivity, and trends in distribution areas. Also insights are needed to quantification of functionality, including carbon and nutrient fluxes, and the potential for coastal protection, resilience and feedbacks between functionality and stressors, including impacts of climate change. Optimisation of climate-ready strategies also involves predictions for various stress- and management scenarios through ecosystem modelling.

Relevant tools in this context include novel remote sensing technologies, which support improved quantification of distribution areas of shallow vegetated habitats, and tracing techniques for blue carbon, including fingerprinting of sediment and logger systems for GHG fluxes. Furthermore, needed are ecosystem modelling developed based on existing data and projected for future scenarios, along with climate-smart design of marine protected areas as well as new technologies for farming of low trophic level marine organisms. In the BANOS region, there is also a need for knowledge-transfer through international collaboration and coordination of experience from the region and elsewhere to strengthen scientific research and management strategies in the field of NbS. The main goals of these efforts are to enable maintenance and stimulation of the region's natural ocean carbon sinks, nature-based coastal protection, and marine biodiversity in a changing coastal setting.

Expected outcomes

- First-order estimate of the significance of potential carbon sinks and sequestration rates provided by the Baltic Sea and the North Sea marine ecosystems in the coastal zone and via export to sinks in deeper areas. The estimate requires quantification of the distribution area and functionality of the northern seas blue carbon ecosystems in terms of their carbon sinks and fluxes. The estimate should be accompanied by evaluation of which sinks offer best prospects as NbS in the area and where these sinks are located. The estimate should also be related to the overall understanding of the carbon cycle of the region as well as to findings from other temperate/northern regions.
- Quantification of nutrient removal and retention rates in NbS, including the role of biodiversity enhancing the efficiency of the coastal filter in the BANOS region.
- Assessment of GHG production in different habitats and how keystone organisms and biodiversity modulate these rates.
- First-order assessment of the potential of NbS for coastal protection and stimulation of biodiversity in the BANOS region.
- Assessment of resilience and feedbacks of blue carbon ecosystems in the BANOS region to multiple stressors including climate change.
- Optimised NbS strategies for maintenance and stimulation of carbon sinks while also supporting the capacity for climate change adaptation and the biodiversity of coastal and marine ecosystems in the BANOS region.
- Quantification of the climate change mitigation and adaptation potential of NbS, targeting the conservation, restoration and sustainable harvest/cultivation of key coastal habitats based on knowledge of threats and loss rates.

4.2 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 institutional structures. Furthermore, it 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 the more recent policies is EA; the integrated management approach across coastal and marine areas and their natural resources that promotes conservation and sustainable use of the whole ecosystem.

The HELCOM BSAP and the OSPAR NEAES form the basis for common actions within the respective convention areas, while for EU Member States, the marine environment is protected by measures taken under multiple directives, including the MSFD, WFD, Habitats Directive (HD) and Birds Directive. In addition, EU directives aimed at specific pressures and sectors, such as the Nitrates Directive, CFP, and CAP 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/environmental status', 'good water status' and 'favourable conservation status', however, need to be defined and put into practice to regularly assess the state of the sea.

To reach the desired state, the defined objectives need to be operationalised into measures and management responses. Programmes of measures (PoMs) and action plans are therefore developed nationally under several EU directives and regional policies. Many 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.

Due to overlaps and inconsistencies in environmental policies and their objectives, there is a need for cross-sectoral governance, good combinations of policy instruments that complement each other and harmonisation of their practical implementation.

State of the art and knowledge gaps

Many EU directives and regional strategies are lagging in implementation. There are also gaps between current policies and governance to enable the introduction and implementation of an ecosystem approach, circular economy, sustainable blue economy as well as other objectives such as a more inclusive and fairer EU.

The practical implementation of policies, including the formulation of coherent indicators and threshold values to reach GES, is still hampered by knowledge gaps, especially on quantitative relationships between human induced pressures and marine organisms and habitats. Both OSPAR and HELCOM have developed agendas specifying their respective science needs. These highlight priority areas for research to the further development of indicators and associated threshold values, understanding of cumulative effects on the ecosystem, development of mitigation and protection measures and the assessment of effectiveness of measures to reduce pressures.

Another challenge is coherence of implementation of policies between countries and between marine 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. While the EU is a party to the regional sea conventions in the BANOS region and synergies are sought, there is a risk of divergence and loss of effectiveness in the operational implementation of marine policies.

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 recreation. Here, science can help to improve organisational aspects of these short-term management cycles.

The projected changes in climate and ocean chemistry will have a profound influence on the state and management of the regional seas within this century, i.a. in the adaptation of policies, review of threshold values and reduction targets, and development of mitigation measures. Consequences of climate change need to be intrinsically addressed in all themes addressed under this specific objective.

Impact and linkages

The R&I put forward in this part of the BANOS SRIA is intended to provide knowledge and solutions to 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 A.2 is highly dependent of the outputs of several other SRIA themes: e.g. understanding resilience and function of ecosystems (A.1) is fundamental for the management of uses of the marine environment with a view to reach a good environmental status. New techniques for ecosystem modelling, assessments and forecasting that provide evidence-based decision support (A.3 and A.4) can be integrated in a governance system as addressed here in R&I themes A.2.3 and A.2.4. Studies on the linkages between the ecological and social-economic systems, addressed in C.3, will provide complementary information for developing more efficient policies.

The outputs of this specific objective are expected to contribute vital information for other R&I themes of the BANOS SRIA. Understanding how the governance system and single policy instruments should be designed to work optimally and which management tools can promote sustainable harvesting of both new and underutilised marine resources are highly relevant for specific objectives and R&I themes within B.1 and B.2. In addition, as the reduction targets for pressures need to be aligned with sustainable use, the evaluation of synergies and conflicts of environmental policies and targets (A.2.3) is highly interlinked to sustainable resource management of marine commons. Demonstrating pathways to a governance system that promotes improvement of the capacity to sustainably extract, produce and process marine resources contributes to increasing the region's food and feed security while adapting to a changing climate and thereby reducing risks and optimising opportunities for human wellbeing (C.1 and C.2).

A.2.1
Understanding the Impact of Land-derived Pollution on the Status of the Marine Environment and Ecosystem Services

State of the art and knowledge gaps

Due to the different water residence time in the Baltic Sea and the 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 understanding of how nutrients impact 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 constitute a major fraction of the total riverine nutrient loads. They are also foreseen to increase with climate change, at least in the boreal area, thus they can potentially have a profound impact on composition of phytoplankton communities, which in turn translates to changes in the food web.

Coastal ecosystems maintain the highest marine biodiversity and support various ecosystem services, such as nutrient retention and carbon sequestration (often called 'the coastal filter'), which are especially impacted by land-derived pollution whereas eutrophication is often regarded as the most important factor causing ecosystem degradation. Thus, there is a need to distinguish between impact from land and internal processes, feedbacks and legacy pools to derive a quantitative understanding of role of nutrients in ecosystem degradation. Further, effects of land-derived pollution on benthic biomass, biodiversity patterns and ecosystem functions are not quantitatively understood, nor are potential paths and timescales for ecosystem recovery. A more detailed knowledge about the relative role of the various land-derived pollution pressures on the ecosystem status help to define reduction targets for pressures by putting forward quantitative impact estimates of these compounding factors from which a list of priority actions can be developed.

In the BANOS region, contaminant levels in organisms are generally higher in the Baltic Sea, although some contaminants are enriched in marine organisms, notably top predators, also in the North Sea. However, knowledge on the effects of contaminants on marine species is limited. While the effects of marine litter and microplastics are currently being actively investigated, reviews on this subject are not yet comprehensive. It remains of crucial importance to understand sources and pathways of contaminants and marine litter into the marine environment in order to continue designing appropriate measures.

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 in the past. Yet, although concentrations of the 'classic' POPs and heavy metals are generally decreasing in the marine environment, due to actions taken to reduce their emissions, the legacy pools of these persistent contaminants, e.g. in marine sediments, still pose certain challenges. Today, many point sources have been regulated and sources of contaminants 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. There is still a huge knowledge gap in the understanding of the magnitude of diffuse vs. point sources for many contaminants. The current focus in management, such as in the WFD, 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 focusses on a minor part 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 required.

Expected outcomes

- Understanding of nutrient retention processes and nutrient legacy pools; their time scales, in both coastal environments and the open sea. This knowledge is vital for a more realistic estimate in which time scales eutrophication targets can be achieved.
- Understanding the dynamics and fate of terrestrial organic matter under the changing climate, including consequences on adaptation and evolution of key phytoplankton functional groups and their lifecycle strategies. Knowledge about key primary producers feeding fish and benthic communities is essential for future management plans.
- Knowledge on feedback loops between land-derived nutrient loads, benthic biodiversity, carbon sequestration and carbon air sea-exchange across coastal seascapes, i.e. their impact on blue carbon.

- Understanding of time scales and mechanisms for ecosystem/biodiversity recovery after decades of increased land-derived nutrient loads and related degradation. This knowledge is vital for a more realistic estimate in which time scales eutrophication targets can be achieved.
- Indicators for and tools to identify emerging contaminants, including their sources (diffuse versus point source), transformation products, and forms of litter including microplastic and associated contaminants. This includes the advancement of non-target and suspect screening methods.
- 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.
- Knowledge on how the land-based pollutants are affecting the biodiversity hotspots, e.g. Natura 2000 areas in the BANOS region.
- Identification of reduction targets with new knowledge on understanding of composition, sources and pathways of pollutants to enable design of impactful and appropriate measures.

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 PoMs is a requirement under several EU directives and is also an ambition for HELCOM and OSPAR. Due to the time-lag in the recovery of ecosystems, marine environmental policy evaluation is difficult. For instance, it is rarely suitable to use data from coastal and offshore monitoring programmes to assess the progress, since it may take decades (e.g. 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 additional 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 the state of the environment need to be projected by use of models. Estimates on the costs of measures are furthermore crucial for determining how to achieve the environmental targets most cost-efficiently, i.e. resulting in cost savings to society and smart use of resources.

Knowledge on the effectiveness and costs of existing and potential new measures in the BANOS region is, however, often limited. This concerns measures directed at both land-based and sea-based sources and a broad range of topics, such as measures to reduce the input of litter and noise, restoration of coastal and marine habitats, effects of marine protected areas, and areas closed for specific activities such as fishing. For the land-based input of hazardous substances and nutrients, the knowledge is somewhat better since these topics are covered by the WFD. Also, in evaluating the progress on implementation of the WFD PoMs the effect of measures to reduce nutrients and chemicals in catchment areas has been at least partly assessed. However, in the case that information exists, it is often of local character and potential effects are rarely available for larger areas, e.g. entire marine regions. With regard to cost estimates, they are frequently based on expert evaluation and qualitative, instead of monetary estimates based on measurements or models.

Thus, there is an overall need for collecting information on and evaluating the effects and costs of marine environmental protection and mitigation measures. There is a need to develop also 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 uncertainties and spatial and temporal variation associated with 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.

In HELCOM, more information on knowledge gaps will be provided in late 2021 when the results of initial analyses on the effects, costs and sufficiency of measures in the Baltic Sea region will become available, and in 2023 when ongoing work aimed at improving the information base on the effects and costs of measures will be completed. 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

- Quantitative evaluation of effectiveness, monetary costs and cost-effectiveness of existing and potential new measures, e.g. measures planned or proposed in PoMs under EU directives and under RSCs.
- Approaches and models for evaluating effectiveness and cost-effectiveness of measures at the level of regional seas.
- Improved understanding about the (a) magnitude of uncertainty and (b) spatial and temporal patterns associated with the effects and cost-effectiveness of potentially most promising mitigation measures.

The information can be described in terms of e.g. probability distributions.
- Analyses of synergies across the most promising mitigation measures in mitigating given pressures and measures that contribute to the mitigation of several pressures.
- Methods to design monitoring strategies that support identification and monitoring of effective measures, e.g. close to source of the particular pressure and with sufficient temporal and spatial resolution to distinguish the effect of measures from natural variability.

A.2.3 Evaluation of Synergies and Conflicts in Relation to Targets of Different Environmental Policies

State of the art and knowledge gaps

Marine environmental policy evolves and has become more comprehensive and holistic over time, even when the scientific tools for evaluating its implementation have not always been available. Newer legislative objectives on the same subject have sometimes resulted in discrepancies with an earlier legal situation. While the 'more stringent' evaluation conditions should guide policy implementation, the 'imperfections of this tapestry' and the resultant confusion for stakeholders may nevertheless hamper a coherent and balanced implementation of concurrently valid policy instruments.

To meet the requirement of different policies, the EU Member States and RSCs are further developing indicators and associated threshold values for 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 land-based and sea-based pressures can be expected in the future due to requirements 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 one, some EU directives provide guidance for how to assess environmental status that do not always concur with assessment methods used under RSCs – which often do not carry legally binding weight in these matters – or, indeed, under other EU directives. For example, the HD requires 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 do not consider national borders. This can result in dissimilar assessment results using the same data as shown by HELCOM evaluation for the Baltic Sea.

A further complication is the inconsistency in terminology used in the different directives and RSCs. Key concepts such as 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.

While the development of indicators and targets within the marine regions are science-based, their development is not always coordinated. For instance, threshold values are not necessarily compatible, i.e. it has not been tested if it is possible to reach all threshold values included in the status assessments for all variables concurrently. 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 the 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.

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 it is the assessed status that establishes whether countries are required to take measures.

The outcomes of the R&I will contribute to providing 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, within and between regions, contributing to streamlining of implementation of marine policies.

Expected outcomes

- An evaluation of the functions and legal effect of concepts linked to environmental objectives and standards and how to develop a more consistent terminology.
- Methods and recommendations on how the implementation of different marine policies can be rationalised to improve coherency and accuracy in assessments of environmental status and definition on reductions targets for pressures within marine regions, including across coastal and offshore waters. This could be based on the evaluation, e.g. through modelling of the compatibility or conflicts of i) thresholds values for state variables across descriptors/topics, ii) threshold values for state variables and associated targets for pressures, iii) threshold values for state variables and targets for pressures across policies, where not done before.
- Comparative analysis of approaches for setting threshold values and pressure targets in the Baltic Sea and the North Sea regions 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 dissimilarities.

A.2.4 Alternative Policy Instruments and New Governance Structures to Solve Current and Future Sustainability Challenges

State of the art and knowledge gaps

The marine governance system is expected to mitigate conflicts over allocation of space and rights of access to marine resources and ecosystem services and at the same time support social welfare and ecological sustainability. Policies and objectives like the ones stated in the EU Agenda 2030, WFD, MSFD, HELCOM BSAP, OSPAR 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 analysing 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 holistic level, the bottlenecks, gaps or unnecessary overlaps as well as links between different policies and policy instruments. There is also a clear lack of integration between different policies both horizontally (among different environmental problems) and vertically (globally, regionally, nationally), creating inefficiencies and conflicts in relation to the key objectives of these policies. Thus, the required analysis should cover different sectoral and environmental policies in a critical systems perspective and address also processes such as Marine Spatial Planning (MSP) or Integrated Coastal Zone Management (ICZM) that aim to coordinate various policies.

In addition to lack of policy coordination and mainstreaming, reasons for the implementation gaps may stem from social and economic implications of marine and maritime policies, lower priority or an unclear cost/benefit ratio. As such, the research should shed light on how policies and policy-mixes impact distribution of ecosystem service benefits, existing human rights regimes and livelihoods, how participation is enacted in formulation and implementation of policies, how such processes vary in different institutional contexts, and whether possibilities exist for foregrounding concerns such as inclusion and equity.

As a reaction to the perceived failure of formal institutions to deliver sufficient change, numerous examples exist on how businesses, NGOs and the general public take their 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.

To find pathways and approaches that are successful in driving the sustainability transformation, it is important to understand the difference regarding the successful use of policy instruments and mix of such instruments, between the two regional seas and between the individual countries in the sea region, and to explain the reasons for such differences, which often are context dependent. However, in order to understand which approaches and mixes of policy instruments have higher potential to drive long-term transformation of societies towards achieving the key objectives, the insufficiencies of the existing marine governance system including single policy instruments and measures, causing critical gaps in effectiveness in the implementation of decided objectives, need to be further understood also from a general perspective. Drawing from such understanding, there is also a need for (co-) creating alternative policy instruments and new governance structures.

Expected outcomes

- Evaluation of the strengths, weaknesses, drivers and obstacles within the existing governance frameworks and also within proposed frameworks, to deliver transformation towards implementation of the specific objectives of the WFD, MSFD, MSPD, HELCOM BSAP, OSPAR 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 available policy instruments' and policy mixes' success for delivering on the jointly agreed goals - generally, in relation to specific coastal and ocean areas and by comparisons across marine regions.
- Analysis of the interplay between different policies and policy instruments, particularly in order to unveil potential synergies and underpin coordination in implementation of measures and implementation of policies.
- Better understanding of social implication of policies and policy development: distributional outcomes, impacts on existing human rights regimes, livelihoods, communities, how participation is enacted in marine governance.
- Evaluation of new governance mechanisms and initiatives that make use of voluntary action of civil society and/or enterprises (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.
- Recommendations on how to integrate relevant policy areas, sectors, and administration levels necessary to organise a rapidly transforming sustainable use of the ocean (taking into account all SDGs) as well as how to use different sets of policy instruments and design institutions.

A.2.5 Fast Feedback Mechanisms from Maritime Observation

State of the art and knowledge gaps

Fast feedback mechanisms to respond to and process real time marine observations are needed to protect the marine environment and humans from incidental hazards and accidents at sea or other events that require a rapid response and up-to-date environmental information. The only way countries can manage these effectively is through monitoring, swift and adequate analysis of information, efficient management cycles and good, often international, collaboration. In many cases the operational collaboration is established through agreements between countries or EU legislation. For instance, through the Bonn Agreement in the North Sea and Helsinki Commission (HELCOM) in the Baltic Sea, countries have agreed to help each other to carry out surveillance and to clean up after maritime disasters and pollution offences. The North Sea countries also collaborate under the Political Declaration on energy cooperation, including aspects of offshore windfarms and sharing best practices in their building and operation. In addition, the European Bathing Water Directive requires systems for early detection of microbial pollution that threaten the health of bathers. Control of mariculture sanitary risks is also regulated.

Storm surge forecasting is a good example of well-organised collaboration between countries and institutions, and integration of data sources and modelling that are capable of issuing early warnings for potentially dangerous situations. In general, these systems are well-established and running smoothly. However, fast feedback and response mechanisms and management practices to many other evolving and new hazards and risks, such as combating sea and air pollution from ships and offshore installations (including enforcement of regulations) and managing risks to marine life from wind farms and to humans from microbial pollution, e.g. pathogens in bathing water, are often still lacking.

In respect to maritime safety and shipping, knowledge needs related to the Bonn Agreement and HELCOM include improvement of response technologies, equipment and other operational means. Examples are integrated surveillance sensors, technology to respond to accidents at night and in bad visibility, under bad weather and ice 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 generation shipping fuels. Degradation and behaviour of these new fuels under various conditions are largely unknown and current clean up techniques are likely to be inefficient.

Also, research to improve enforcement of licenses for the construction and operation of wind farms and ocean energy installations in relation to preventing effects of underwater noise on sensitive sea life (e.g. harbour porpoise) 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.

Expected outcomes

- Understanding governance aspects of collaboration between operators in short-term management cycles and developing tools to improve these workflows. More specifically, how to organise an operational government service responsible for such risk aversion, what systems are currently operational and for which purpose, how are data collection and management (internationally) coordinated and how can these be improved (following FAIR principles). How to deliver feedback from experience to organisation and roll out best practices from the North Sea to the Baltic Sea and vice versa. Example related to the Bonn Agreement is a region-wide strategic analysis of surveillance needs, or region-wide risk assessment studies, and development of risk assessment tools.
- Investigation of novel routine measurement techniques and their ability to support fast feedback mechanisms in response to e.g. pollution events, including oil spills and lost containers, microbial pollution events or other acute environmental health hazards, loud impulsive or episodic noise events, occurrence of sensitive marine mammals, birds and bats near various potentially harmful operations.
- Development of an information system of what fuels and hazardous cargoes specific ships carry.
- Investigations of properties and behaviour of new generation ship fuels under various conditions at sea, as well as understanding of properties and behaviour of harmful substances other than oil i.e. hazardous noxious substances (HNS).
- Investigation of response techniques and decision-support tools to minimise environmental impacts from spills of new generation fuels and HNS. This should include development of technology to respond to accidents at night and in bad visibility, under bad weather and ice conditions.
- Development of methods to analyse 'big data' and integrate observations and modelling in (automated) fast feedback decision-making systems, e.g. using artificial intelligence (pattern recognition, decision trees).
- Assimilation of modelling results and novel in-situ monitoring data in, e.g. automated assessment tools, risk assessment tools and/or online data visualisation tools, and integrated life feed from online monitoring devices, e.g. SeaTrackWeb.

4.3 Specific Objective A.3: Digital Ocean – Competent Ecosystem Modelling, Assessments and Forecasting

Driven by the rapid growth of digital technologies in computing power, data collection and storage capabilities, combined with development of artificial intelligence, entirely new opportunities are currently emerging for advanced modelling, assessment and forecasting. These new modelling approaches are critically needed to understand and provide management solutions to traditional and new, emerging human induced pressures at seas and the ocean. In addition, advanced modelling and forecasting is likely to play a pivotal role in the development of the Digital Twin of the Ocean, the powerful tool aiming to integrate a wide range of data sources, to transform data into knowledge and to connect, engage, and empower citizens, governments and industries by providing them with the capacity to inform their decisions.

State of the art and knowledge gaps

The possibilities for advancing data-driven approaches to problems of understanding and managing uses of marine ecosystems have exploded in the past decade. New artificial intelligence techniques are conquering more and more fields of society and hold a large promise for application in marine ecosystem understanding and prediction. However, few solid examples of these applications exist to date, partly because of the difficulty to simultaneously observe and measure all essential components of ecosystems, bridge different time scales and ensure consistency of the data analysis. It is expected that artificial intelligence techniques will find many useful applications in resolving processes and phenomena that are difficult to represent in mechanistic models. For instance, assessing with AI the evolving composition of phytoplankton communities and the development of harmful algal blooms (HABs) during the growth season would enhance our current capabilities. 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 repositories of data 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. Data on bathymetry, geology, ocean physics, biogeochemistry and ecology need to be combined in user-friendly ways with interactive elements and possibility to easily update the system based on user feedback and requests.

The non-linearity of natural system dynamics is known to provoke unexpected shifts in ecosystem structure and function, generally indicated as tipping points and, for example, often related to cascade effects in food webs. The rationale behind tipping points is gradually being incorporated into the conceptual framework of social-ecological system thinking; however, we lack practical implementation of such holistic approach. Facing large and possibly non-linear changes, the dynamics of social-ecological system need to be understood better as a foundation for the future development of knowledge, management and governance.

Impact and linkages

This specific objective will contribute to development of predictive modelling capabilities by exploring and identifying new possibilities that better integrate current digital developments into the study and management of marine systems. More specifically, outputs of R&I focusing on this specific objective will provide concrete case studies which include both methodological and conceptual model developments with immediate applicability in the BANOS region.

As such the outputs are closely associated to the MSFD and achieving the GES in the BANOS region, as well as, operationalising the EAM in the region.

The work carried out under this specific objective is closely associated with the specific objectives on resilient marine ecosystems (A.1) and sustainable management of marine commons (B.1), in respect to understanding of ecosystem functioning and food web dynamics, as well as data acquisition; Seamless governance linking land coast and seas (A.2) and efficient techniques and approaches for environmental monitoring and assessment proving new solutions for ecosystem monitoring, management and governance (A.4); and to safe food and feed providing new solutions for understanding the development and tracking of toxic algal blooms and pathogens (C.1).

A.3.1
Development of Artificial Intelligence for Marine Ecosystem Data Analysis and Models

State of the art and knowledge gaps

Machine learning is often considered a subfield of artificial intelligence and consists of methods for learning patterns and performing predictions based on data. In the past decade, machine learning methods have shown remarkable performance in many new areas. In particular for supervised learning of regular data types, new deep learning methods have revolutionised automated analysis of many kinds of data. These methods are now making inroads into new fields and are beginning to see adoption in marine science and management.

Currently, machine learning methods are most mature for supervised learning, i.e. predicting a value or label for new data points, when the model has been trained with large training data sets with ground truth. Unsupervised methods finding structures in the data (e.g. learning a probability density function over the data) are also developing. The field is in rapid development with advances being made in model architectures, learning schemes and regularisation as the methods are brought to new fields and data sets.

Ecosystems are complex, with a multitude of relationships and interactions that are nonlinear. They operate on very different spatial and temporal scales, and where the parameters are often not known with a high degree of accuracy. Recent advances in sensor and sensor platform technologies have made it possible to collect orders of magnitude more data at rapidly decreasing cost. For certain parameters, like physical and chemical properties and plankton, this has greatly improved the resolution in time and space with which ecosystems can be viewed and allowed new analyses in spatial ecology. However, for higher trophic levels, e.g. fish, birds and mammals, unfortunately this is less the case yet. New approaches, such as environmental DNA (eDNA), show promise for delivering the data needed for more comprehensive analysis of spatial ecology in future.

Ecosystem models are currently often mechanistic, using causal interactions with fixed parameters to predict the ecosystem responses. These parameters are often assumed to follow mathematical functions such as linear or sigmoid relationships. Machine learning models, and in particular deep learning models, on the other hand, excel at finding even highly nonlinear relationships. However, operating with a high number of parameters requires large amounts of data. The mechanistic models and deep learning-based models can be seen as presenting two ends of a continuum i.e. rigid and possibly simplified, but human-understandable models, and flexible, potentially highly complex, and difficult or impossible to understand models.

Currently, the most promising applications of machine learning in the context of marine ecosystem modelling are in solving operational problems, like short-time forecasts 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, causality-based model concepts (e.g. mass balance, transportation and mixing pathways) can be combined with rich data sources on the ecological processes.

Since the application of artificial intelligence in marine ecosystem modelling and forecasting is only at its infancy, there is a need for well devised examples of this approach for advancing the field in the BANOS region. Both "black box" and causality-based approaches are welcome as well as their hybrids. The chosen applications should have a high affinity to solving marine management issues.

Expected outcomes

- Exploration of possibilities and limitations of machine learning and artificial intelligence methods in the understanding, forecasting and management of the Baltic Sea and the North Sea marine ecosystems, including the estimation of forecasting uncertainty.
- A demonstration of the usefulness and limitations of deep learning models and other complex, data-based model types for ecosystems as an alternative/ supplement to mechanistic/physical models.
- An application of artificial intelligence techniques to resolve important ecological processes (e.g. species or functional group composition of plankton) that cannot be easily resolved in mechanistic models, while maintaining classical model constraints (e.g. mass balance considerations).
- Applications of artificial intelligence methods in decision support systems at short- to medium-term (see also A.2.5).

A.3.2 Ecologically Relevant Modelling of Underwater Landscapes

State of the art and knowledge gaps

Over the past decades, considerable efforts have led to a substantial improvement of the underwater landscape's detailed mapping in the Baltic Sea and the North Sea. Currently bathymetric maps with relatively high (100 m scale) resolution are readily available, 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 many other parameters have been extensively monitored. Also the existing datasets have been compiled, e.g. in the framework of EMODNET. In addition, maps of human activities, such as fisheries pressure, offshore constructions, mineral extractions, transport routes etc., have been charted and the information made available at high resolution. Extensive compilations of marine biological data on the occurrence, biomass and numerical density of many biological populations can also be found at the EMODNET Biology Portal. These compilations are being made available increasingly as species distribution maps. In future, new technological developments, such as acoustic methods and automatic monitoring devices, will facilitate synoptic data collection. This will lead to refinement of available maps as well as inclusion of temporal dynamics in spatial data that are often static today.

In addition to the above, 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.

Increasing the understanding and modelling of underwater landscapes, including its pelagic and benthic components, is especially relevant in respect to spatial planning of increasingly extensive human and economic activities in the BANOS region. 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 increasing quality and quantity of spatial data and models, the increasing awareness of the importance of spatial variability in the structure of the seascape as well as the increasing need for spatially well-tuned activity planning, opens up perspectives 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 need to be assessed and understood. The combination of datasets and models yielding qualitatively diverse data as a background for improvements of spatial decisions is a major scientific challenge that needs to be tackled and solved.

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

Expected outcomes

- Formulation of a synoptic approach to the characterisation of the abiotic environment in marine landscapes, taking into account the vast availability of data as compiled by EMODNET, COPERNICUS and other data sources, and using this diversity to provide mean fields and estimates of uncertainty.
- Development of statistical and, where applicable, conceptual and mechanistic models revealing the correlation structure between the available data sets and classifying landscapes at different spatial scales of resolution; and incorporating Machine Learning methods (link to A.3.1) where appropriate.
- A method to relate 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.
- A case study to investigate 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 an approach for optimising spatial use patterns of the marine landscape, with respect to the preservation and/or strengthening of natural ecosystem services, such as biodiversity values and functional services.
- Identification methods for optimising the sustainability of marine activities in view of the inherent landscape properties of the Baltic Sea and the North Sea and the preservation of ecosystem health.

A.3.3
Models to Predict Tipping Points or Cascade Effects in Biological Systems

State of the art and knowledge gaps

Complex dynamic ecosystems may exhibit tipping point behaviour as a result of self-reinforcing biological or biophysical interactions. Theoretical studies show that in these cases the ecosystem is resilient to pressure up to a certain level. However, if the capacity of the ecosystem to tolerate stress or pressure is exceeded, it may ‘tip over’, i.e. shift into a different new state, leading to reorganisation of ecosystem composition and functioning. Such changes can have a detrimental impact on marine ecosystem services and reversing a passed tipping point can be considered very costly if even possible.

For an ecosystem to recover or to bring it back into an earlier stable state often requires considerably stronger efforts and big pressure reductions below those present just before the tipping point. In spatial dynamics, the existence of alternative stable states may result in patterned and highly spatially organised systems that respond differently to the overall physical drivers. To date, the concept of tipping points 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 for example in response to increase in temperature or of the fishing pressure, usually in the top of the food web.

Empirical studies in the Baltic Sea and the North Sea have led to the description of regime shifts. 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 due to the phenomenon described above.

From a marine management perspective, early action to prevent the occurrence of tipping points and to preserve the ecosystem resilience is likely to be more practical, affordable, and effective than late action to halt or reverse the crossing of a tipping point. 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. The 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 GES.

Being 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 destabilise a community’s ability to prevent, e.g. a coastal bay, from entering an undesirable state, the recognition of the non-linearity of the problem and the importance of feedbacks and time lags is an essential step to improve system management.

Expected outcomes

- An analysis of cascades and other causes of tipping point behaviour in marine systems, and the application of the concept in the design of social-ecological management systems.
- An understanding of the likelihood of the occurrence and the consequences of tipping point behaviour in shallow shelf seas, making use of the contrasting characteristics of the Baltic Sea and the North Sea. Preferably a limited study system will be identified, investigated for (potential) tipping point behaviour and compared across both seas.
- An investigation on how society can react to systems exhibiting tipping point behaviour. This involves the delineation of clear signs of approaching tipping points or consistent recovery trajectories, methods of detection and communication, and response systems to the behaviour of the natural systems. It includes non-linear behaviour and considers the coupled system dynamics.
- Identification of data needs and monitoring/modelling approaches that support detection of (changes in) causal relationships and integration of results and that allow societies to cope with non-linear behaviour of natural systems.
- An approach (based on particular examples) how tipping point behaviour can be incorporated into ecosystem-based management approaches and determine the need for such evolution. Contribution to studies on the operationalisation of the ecosystem approach (e.g. specific objective A.1) with essential insight on the consequences of tipping point behaviour.

4.4 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. The assessments should be based on adequate and legitimate data, including both spatial and temporal dimensions, and derived from standardised monitoring practices, which provide us with a comprehensive understanding of the state and functioning of the marine ecosystem. The social needs are formulated in many policy documents at the global, European and regional level, such as the SDG 14 "Life below water", EU MSFD, WFD, HD, etc., and regional conventions of marine environmental protection in the BANOS region. The observational programmes that gather data for the required assessments have been, with varying degrees of coverage, in place in European marine areas for decades. However, both our knowledge about the functioning of marine ecosystems and observational technologies are continuously advancing, and new threats and pressures for the marine environment are continuously emerging such as micro-litter, underwater noise and pharmaceuticals. Thus, the approaches for monitoring and assessment should evolve accordingly and include the current challenges, for example, related to the expected expansion of Blue Economy sectors. Furthermore, the constraints in available resources call for cost-efficiency and better coordination of the efforts at the regional and national level.

The knowledge gaps to be solved to design more cost-effective and scientifically sound marine environmental monitoring and assessment approaches in the Baltic Sea and the North Sea are very similar in nature. The primary questions are related to the joint organisation of monitoring, systems and methods for data handling and analysis, taking into account the above dynamics and increasing amounts of data within an Open Science context. Although the species and habitats may differ in the Baltic Sea and the North Sea there are common principles and technologies which should be applicable for both. Moreover, cooperative efforts that avoid duplication will speed up advancement in all areas of the BANOS region.

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. Some of these weaknesses may be remedied by better regional and institutional coordination, more strategic development of the observational programmes as regarding the themes (e.g. as in MSFD Descriptors), as well as faster inclusion of the state-of-the-art cost-effective methods and technologies into the programmes. Also addressing gaps in knowledge on characteristics and impacts of less studied pressures, such as litter, underwater noise and pharmaceuticals, can help raise the effectiveness of respective parts of monitoring.

Biological monitoring of the marine environment is very costly today (ship time, sample treatment), and this restricts our current knowledge of marine ecosystem functioning especially in respect to its 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, there are many open questions which should 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 earth observation (EO) and ferrybox data, there is a need to demystify the satellite data and ensure the reliability of automated observations and applicability of model results for status assessments. Joint actions covering both sea areas should lead to, for example, a better understanding of the impacts of marine litter, underwater noise and micropollutants as well as suggestions of cost-effective monitoring techniques for these themes of high societal interest.

Impact and linkages

The R&I put forward in this part of the BANOS SRIA will contribute directly towards achieving the GES in the BANOS region, in addition to better understanding of the functioning of ecosystems leading to better governance of marine environment and its natural resources. As such the outputs are closely associated to the implementation of policies, such as MSFD and WFD, which promote ecosystem-based management and require comprehensive monitoring and assessment of the status of the marine environment. In more general terms, the development of environmental monitoring programmes will contribute to the other needs of the society for ocean information and data as outlined in the UN Ocean Decade and the EOOS initiative.

The outputs of this specific objective are closely associated with BANOS SRIA specific objectives on ensuring resilient marine ecosystem (A.1) and focusing on issues of marine governance (A.2). In addition, the monitoring and assessments will be relevant for the sustainable resource management (B.1) as well as the expansion of the sustainable blue economy sectors (B.2).

A.4.1
Application of Powerful DNA Approaches to Monitor Ecosystem Resilience and Changes

State of the art and knowledge gaps

DNA and RNA sequencing technologies are developing rapidly, and what is not possible today, might be possible tomorrow. The current high cost of biological monitoring restricts our current level of information in an ecosystem with extensive spatial and temporal dynamics. A combination of automatic sampling with eDNA will open big new possibilities for monitoring the fauna and flora of coastal ecosystems. However, much research is needed before the eDNA technology can serve such a purpose for large-scale marine biological monitoring. Also, other sequencing approaches, such as metagenomics of pooled samples of fish egg and larvae, phytoplankton and zooplankton, would potentially become powerful tools in biological monitoring, as will the analyses of expressed genes through environmental RNA sequencing (eRNA).

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. Environmental RNA might be an alternative as RNA degrades more rapidly and eRNA samples will target only those genes that are currently active, that is, genes in live organisms.

One issue to address in research and development of eDNA and eRNA 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 and volume of functional pathways. A DNA signal in an enclosed coastal bay, for example, will tell us that 'species A' is present there 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? Many open questions remain also in respect to harmonisation and optimisation of methods used. 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 the important marine species commonly targeted in monitoring of pelagic and benthic habitats.
- Understanding of the sensitivity and precision of eDNA/eRNA methods, for example, by producing mesoscale empirical data 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/eRNA signal and how the signal can be interpreted.
- Models to support the interpretation of sequencing signals. For example, models taking into account hydrodynamic and topographic conditions of coastal waters and how the signals are affected.
- Research illustrating the potential to extract quantitative or semiquantitative information from eDNA/eRNA signals.

- The joint development, e.g. with the participation of academic, environmental agent and industry representatives, of standard eDNA and eRNA methods in relation to the topic of interest, e.g. estimation of biodiversity, tracking of invasive species
- Strategies to use metagenomics in pooled samples of, e.g. groups of plankton, including descriptions of bioinformatic pipelines for filtering of data and down-stream analyses.

A.4.2
Novel Remote Sensing and Automated Techniques and Approaches in Monitoring and Assessment for Sustainable Ecosystem Management

State of the art and knowledge gaps

Remote sensing and high-frequency automated observations have a high potential to become an essential and powerful component of the observation and monitoring systems in the ocean and regional seas, including the BANOS region. These cost-effective techniques could potentially lead to significant increase in data coverage, both spatially and temporally, advancing the confidence of assessments. However, several outstanding questions remain in a way of using these techniques to their full potential.

Pelagic and coastal environments are known to be highly dynamic. Ship-based monitoring alone cannot resolve the temporal and spatial variability as the required resolution would make it prohibitively costly. There is scope to increase the confidence in status assessments in relation to how the environmental status is affected by natural variability and changes in hydrographic conditions. Such improved understanding from assessments will also improve confidence in evaluation of the effectiveness of measures.

To date, several EU-wide and/regional actions and projects have been set up to coordinate the development and provision of operational marine environmental data and information services (COPERNICUS, EuroGOOS, EOOS, JERICO projects, AtlantOS, EuroSea, etc.). The operational station network in the Baltic Sea and the North Sea at present consists of a large number of coastal tide gauges and offshore fixed platforms, including Smart Buoys and national 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 analysers, pCO_2, pH, and CH_4 sensors, imaging flow cytometry, spectral fluorescence and absorption methods, etc. have been tested. However, currently these data streams are not fully employed for environmental assessments. The outstanding questions are related to the availability and reliability of sensors, the quality of data and the comparability of results with the conventional methods.

Targeted actions are needed to integrate these sensors, platforms and analysis techniques into the monitoring and assessment systems. A major aim should be to enhance significantly cross-disciplinary and regional cooperation. Furthermore, to optimise a marine monitoring platform, other marine data needs, such as operational oceanography and climate change related research, should be considered to ensure the platforms can cater for all interested parties. Cost-efficiency of observations is achieved when the measurements meet the requirements of multiple programmes, 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. Monitoring platforms should be able to follow the common guidelines and quality standards for the regional environmental monitoring programme as well as quality standards for the different other systems or programmes to which they contribute.

High resolution data are also collected by recreational seagoers with boat being equipped with high quality equipment and sensors. In addition, data are collected by industry continuously. Approaches to utilise these data to the maximum benefit of assessments and environmental protection should be explored and identified.

Expected outcomes

- Demonstration of how new technologies can be integrated into the marine environmental monitoring and assessment systems. The demonstration should focus on increased cost-efficiency of the monitoring programmes and higher confidence of indicator-based assessments as well as maximising knowledge increase of pressures and impacts.
- Approach on how to include EOs and numerical modelling, in combination with high-frequency in-situ monitoring in the environmental status assessments. Such an approach should lead 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 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.

- Evaluation how to make best use of data collected by recreational seagoers and industry in respect to environmental monitoring and protection.
- 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, as well as increasing their technology readiness level (TRL).

A.4.3 Monitoring and Long-term Solutions for Micro- and Macro-litter in Aquatic Environments

State of the art and knowledge gaps

Marine litter[4] is widespread and common in all marine environments across the globe. Plastic is the most common type of marine litter and in the BANOS region it makes up between 70 % to 90 % of the beach litter and around 70 % of all litter found on the seafloor.

It is estimated that during the next decades the global plastic input to our seas and ocean will only increase, accompanied by a dramatic increase the concentrations of microplastic particles[5]. Therefore, urgent actions are needed to combat the plastic litter, both from entering the ocean but also to clean up the existing litter. As majority of the marine litter that enters the sea eventually ends up on the seafloor, innovative clean-up approaches are also needed to address the seabed litter. However, technological clean-up solutions alone are not sufficient to solve marine plastic pollution problems. Instead a triple helix approach (involving actors from science, industry and governance) in combination with multiple strategies (including removal and prevention) are needed to eliminate ocean's and seas' plastic contamination in the long-term. Therefore, collaborative efforts that encourage innovation together with new prevention/clean-up strategies of marine litter should be promoted.

The education and involvement of citizens should be prioritised. Clean-up activities by citizens are already widespread throughout Europe and contribute towards increased awareness of marine environmental problems. The next step should involve systematic and rigorous research to understand better human behaviour and perceptions in order to develop effective communications and to tackle the inflow of plastic litter from its source. Furthermore, remediation policy can be strengthened by the integration of social science, humanities research, and socio-economic studies, which can evaluate the impact of the measures concerning the reduction of litter.

Preparing and launching an extensive long-term monitoring programme for litter (including plastics) in the marine environment is required to collect the necessary data to provide information on the sources, presence, behaviour and effects of litter and microplastics on marine ecosystems. As such, standardisation and quantification of plastic flux and stock from land to ocean must be improved and documented. Focus points are the introduction of innovative techniques into the existing marine litter monitoring and standardised cost-efficient microplastic monitoring. Especially for micro/nano-plastic monitoring, there is an urgent need to progress in development of understanding of impact pathways and related biotic indicators and simple, cost-effective detection techniques. Moreover, improvements are needed related to the automated characterisation of microplastic and litter, e.g. multi platforms with sensors and remote sensing approaches.

Besides the need to work on establishing thresholds, i.a. impact-relevant environmental assessment criteria, background assessment criteria, for micro-litter assessments, more knowledge is needed on the ecosystem effects of plastic particles. This includes the impact of associated substances of concern, e.g. additive chemicals, pollutants or potential pathogens, to determine safe limits coupled with spatial variability of marine micro-litter in the environment. New techniques and models to quantitatively assess the risks of plastic particles to humans and the environment are indispensable to establish a global risk assessment framework.

Expected outcomes

- Development of a critical knowledge base needed for comprehensive long-term observations of micro- and macro-litter in the marine environment to complete the obligations for regional assessments at HELCOM, OSPAR and MSFD levels.
- Full-scale model of sources and fluxes of micro- and macro-litter from land to the sea, validated with observations in rivers to support policy measures and actions tackling litter.
- Full-scale 3D model to illustrate movement of plastics in the ocean, contributing to understanding of distribution of marine plastic litter in the seas and the ocean. This model should include both inputs of litter from land and from operations at sea.
- Satellite assisted detection of plastic accumulation in the Baltic Sea and the North Sea.

4 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.

5 A distinct fraction of the marine litter is made of microplastic litter, typically known as pieces of plastic smaller than five millimeters, although some scientists prefer a definition of smaller than one millimeter.

- 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.
- Assessment of human behaviour and perceptions to develop and deploy effective prevention measures.
- Reduction and prevention of plastic inflow due to technological and industrial innovation, combined with socio-economic analysis and involvement of citizens.
- Methods to remove large concentrations of macro-litter from accumulation hot spots.
- Better understanding of effects of plastic litter, and associated substances of concern, to marine ecosystems and human health underpinning relevant and cost-effective monitoring and assessment approaches.

4.5 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 EGD'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 effective international collaboration. To emphasise 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 highlighting 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 is therefore the cooperation within and 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 sustainably unlock the full potential of the BANOS region'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, substantial scientific work is still needed to cover the full potential related to improving the capacity to extract, produce and process many marine resources sustainably. 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 the ocean finds as "already observed on habitat area and biodiversity, as well as ecosystem functioning and services" in coastal ecosystems. Adapting management and value chains which are projected to "transition to unprecedented conditions" over the 21st century, thus require 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

The R&I supporting this Specific Objective will deliver novel 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 EGD. In addition, the outputs will support the achievement of multiple UN SDG targets (e.g., 2, 12, 13, 14) in the BANOS region.

To deliver the above, key outputs from the other parts of the BANOS SRIA are needed, including, e.g. improved understanding of the sea basins' resilience, as well as our capacity to monitor, assess and forecast their dynamics, general ecosystem service characteristics and options for seamless governance (A.1-A.4). The work towards achieving this specific objective will contribute to understanding of the value of ecosystem goods and services (C.3) and ultimately to development of sustainable circular and bio-based blue solutions (B.2). It has obvious linkages to production of safe food and feed (C.1) and coastal economic development (C.2).

B.1.1 Sustainable Harvesting, Extraction and Use of Marine Living and Mineral Resources

State of the art and knowledge gaps

In marine ecosystems, the biotic and abiotic components are inextricably linked. As such, the sustainability issues raised by the harvest of living and mineral resources (including sand and gravel) should be considered in the same evaluation framework. Harvesting of marine resources by fishing and extraction/mining have both immediate and long-term effects on the renewal of the resources and the structure of the whole ecosystem in which these resources are embedded. Sustainability of fishing and resource extraction relies on environmental conservation and management as well as mitigation of any impacts these processes may cause to the marine environment. As significant increases in demand of both living and non-living marine resources are expected in the coming years, efforts are needed to ensure that sustainable and safe practices are followed.

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 these products keep increasing. Of the limited worldwide catch of wild marine fish about 20 % is currently processed to fishmeal and fish oil that is subsequently used in marine aquaculture, a sector that is projected to expand linearly in the next 10 years with a resulting growing demand for fish feed. With no additional raw material expected from capture fisheries, any increase in fishmeal production will need to come from using fish by-products or alternative resources. Many scientists are seeking alternative sources of PUFAs. As an example, zooplankton could be utilised to alleviate the pressure on traditional forage fish used to feed farmed fish. Zooplankton could also be used as a 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. 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 at the same time, generate potentially high conservation risks.

Sand and gravel extraction, which constitutes an important part of the extracted mineral resources in the BANOS region, has experienced a steep increase in consumption (a world-wide threefold increase over the last two decades). The demand in these resources is expected to rise even further in the future, i.a. to cope with the infrastructural challenges posed by sea level rise and the need for land reclamation. There are only a few alternatives to sand and aggregates extraction to meet that demand, although using dredged material from maintenance or capital dredging could also be considered in the future. The economic opportunities brought about by intensification in gravel and sand extraction would need to be balanced with related environmental challenges, e.g. alteration of coastline, habitats and of various ecological functions. Non-living resources are, however, not limited to sand and gravel: recent research has shown that the ferromanganese nodules in the Baltic Sea are more widespread than originally thought and experimental extraction has already taken place. Technological progress and the increasing demand for these resources may bring operational exploitation closer. The knowledge about the spatial extent, ecological importance of the nodule field and environmental impact of extraction needs to be further deepened before commercial exploitation can take place.

Without the basic knowledge of the environmental, socio-economic and ecological effects, harvest marine living and non-living resources at an existing, let alone an increased level, is unlikely to be sustainable in the long-term. To achieve this will require fostering 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 environmental threats the exploitation of marine resources could create, and balance these with the benefits their utilisation could provide in a circular economy context. This is particularly true for untapped resources, for which knowledge is generally poor. The sustainable exploitation of marine resources encompasses therefore 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 traditional marine resources, the R&I projects will develop R&I in anticipation of impacting economic development and political decisions. The projects will encompass multi-disciplinary 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 BANOS region, which offer contrasted marine resources, environments, ecosystems and human activities.

Expected outcomes

- Evaluation tools for assessing the extent, volume and quality of the available resources in the BANOS region, such as maps of non-indigenous/newly discovered species with exploitation potential and innovative geophysical approaches to measure and model the extent of sub seafloor sand, aggregate and mineral resources, including also case studies highlighting innovative projects from the BANOS region.

- Improved knowledge of biotic and abiotic marine processes including life cycles and distribution of living resources and their resilience to current and emerging pressures.
- Development of supportive instruments, such as 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 harvesting and extraction of marine resources.
- Improved knowledge base and strategy, including case studies from the BANOS region, on the ecosystem and socio-economic effects of exploiting traditional and new marine living and mineral resources, including a substantiated framework to assess the most efficient use of available resources in a circular economy context.
- 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.

B.1.2
Sustainable, Efficient and Waste-free Seafood Value Chains

State of the art and knowledge gaps

To unlock the full potential of the BANOS region's 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 recognised 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. Hence, changes to current practices would not only lead to more efficient use of marine resources but also generally lower the environmental footprint of the industry.

The demand for R&I 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 region'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 and landing obligations, 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 e.g. DNA-based methodologies have been explored. Similarly, advancements of blockchain technology have 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 to mitigate negative impacts. Range shifts are, however, not only a problem, as it might also provide the BANOS region with new fisheries opportunities related to an inflow of new species.

The potential in cross-cutting technological solutions to the adaptation challenge is broadly recognised, with several examples of known gaps. For example, the extraction of omega 3 fatty acids from fish waste, e.g. fish livers, and bycatch, e.g. starfish, are still problematic. Also several types of cultivation of marine organisms, including macroalgae, are 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. Finally, dioxin removal from the Baltic Sea herring also presents a relevant challenge with respect to increasing the value of the biomass.

Innovation to overcome technological bottlenecks experienced by the industry related to biological valorisation, 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 region's fisheries and aquaculture industries.
- Value chains with enhanced ability to scale-up production of low trophic level organisms, including seaweed, mussels, etc. from the BANOS region.
- New potential products based on current discards and waste, including processing water from the BANOS region's seafood value chains.
- Identified and advanced possibilities of present fisheries and aquaculture value chains in the BANOS region to deliver high quality products with long shelf-life, through innovation in, e.g. storage and sorting tools, and selective gear in order to reduce waste at both the producer and consumer level.
- R&I illustrating the potential for creating new local value chains based on sustainable aquaculture in the BANOS region.
- New traceability opportunities for marine resources from the BANOS region 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 region's stakeholders, e.g. environmental agencies, fisheries, aquaculture, feed and food industries, and exploring options for viable solutions.

B.1.3
Knowledge-based Multifactorial Marine Spatial Planning Tools

State of the art and knowledge gaps

According to the MSPD, the EU Member States were expected to prepare maritime spatial plans by March 2021. With it, a unique situation is now approaching in which all EU waters are spatially planned, including Exclusive Economic Zones where such are claimed. In the Baltic Sea region, this will be a major change in the governance landscape as this is the first round of MSP for most of the countries. In the North Sea region, national-level MSP has longer history with some countries being already in their third planning cycle.

At the completion of the plans, focus shifts from the preparation of plans to their implementation, consequently, to monitoring, evaluating and updating of the existing plans. The tools and information used during the first planning cycle will have to be adapted to respond to the changes in the use of marine space, and climate change, but also taking into account the reviews, comments and progressive insight gained during the previous planning rounds. Changed demands for the sea space are driven, for instance, 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 offshore wind farms at an unprecedented large scale. The scale of the anticipated developments leads to the expectation that MSP development will have to extend beyond national borders for both data collection and the effective development of the plans.

As a first step, stocktaking of the consequences of MSP in Europe is required 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 a potential of becoming one of the approaches to reform ocean governance. However, while introducing MSP legislation and planning systems, the EU countries have not replaced any of the existing frameworks. 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 plans in the UK, France and Estonia. The MSP practices have also been criticised for maintaining the agendas of dominant actors, while stakeholder involvement does not guarantee them sufficient power to really influence the process and decisions made. Stocktaking of the gained experience will serve as a basis for further development of MSP practices, tools and even the MSP theory.

Potential additional knowledge gaps and bottle necks within MSP will have to be identified and studied. For example, protection of cultural heritage will have to be considered within the planning process as well as the recently launched EU Biodiversity Strategy 2030, which is potentially a game changer also for the future MSP. The target of protecting 30 % of the EU sea areas, of which one third in strict protection, need to be taken into account in the next planning cycles. Here, MSP is an opportunity to preserve areas of high nature value to comply with the targets of the EU Biodiversity Strategy. The socioeconomic aspects of MSP, e.g. charting how the impacts – both positive and negative – are distributed among different groups of actors and how the planning decisions affect the coastal communities, will need to be considered and evaluated. Extensive research and collaboration on cumulative effects on marine ecosystems 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.

MSP should become a common platform that is usable by governments, industry, academia and civil society alike. Development of MSP methodology shall be supported by social and political science analyses. Research on processes of plan preparation as well as on consequences of MSP on marine governance, maritime sectors and coastal communities can substantially improve the knowledge base for further development of MSP. A part of the future perspective may also lie in taking into account the temporal dimension of using space and as such enabling and facilitating simultaneous multi-use and consecutive co-use, based on the specifics of different ecosystems and activities.

In order to achieve these objectives, a thorough knowledge of the natural, social and economic environment within which they operate is required, underpinned by the necessary (spatial) data on ecosystems and human activities. Definition of data streams, considering the combination of data from different sources, will be based on the existing and new challenges within MSP. Data deficiencies should be identified and addressed on a supra-national, European scale. Knowledge and tools, such as GIS methodologies and Decision Support Tools (DST) should be further developed to support the creation of future-proof platforms. These tools should also work transnationally and be transferable in practice (easy and cost-effective to use, able to handle different types of data, etc.). By working directly with the relevant planning tools authorities will work towards ensuring their appropriate development.

Expected outcomes

- A comprehensive overview of the situation post-2021, based on 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 processes.
- Improving the knowledge basis of MSP systems, starting from a 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 MSP, including the existing and new methods for including and assessing MSP's role in achieving GES and cumulative effects of MSP, with attention on the inclusion of socio-economic aspects (such as equity of processes and distribution of benefits) and the cross-border coherence of the plans and with indication of the knowledge gaps.
- Development of data flows, tools and knowledge for MSP to assess current and future development in the use of the sea areas and anticipated effects of the plans on them. The improved MSP data systems and tools facilitate inclusion of ecosystem services and takes into account climate change and cross-border perspectives.

B.1.4
Predicting and Managing Ecosystem-scale Effects of Renewable Energy Installations

State of the art and knowledge gaps

The EU strives to become the first climate-neutral continent by 2050, as emphasised in the EGD. The continued growth of the offshore renewable energy (ORE) sector (wind, wave, tidal and solar energy) plays a crucial role in reaching this ambitious goal. To support ORE development, on 19 November 2020 the Commission published the EU ORE Strategy. In this strategy, the Commission anticipates that today's installed offshore wind capacity of 12 GW should grow to an installed capacity of at least 60 GW of offshore wind and at least 1 GW of ocean energy by 2030, and that by 2050, respectively, 300 GW and 40 GW of installed capacity is realistic and achievable. The combined national ambitions of the countries bordering the BANOS region, namely several hundred GW of installed capacity offshore, mirror this EU ambition, making the further development of ORE arguably the most influential and challenging near future development for these seas. A major challenge lies in the ORE Strategy underlining the protection of the environment and biodiversity (with an ambition of 30 % of the total surface area with a protection status and up to 10 % even with a strictly protected status, according to the new EU Biodiversity Strategy) as most of the impact mechanisms related to ORE that undermine marine habitats and wildlife populations are not yet fully understood.

The main immediate concerns for marine wildlife related to ORE are displacement due to loss of habitat, barrier effects (as installations may create obstacles) and collisions with wind and tidal turbines. These impact mechanisms are currently the main focus of national research programmes in countries that are working on the development of offshore wind farms (OWF) and to a lesser extent wave, tidal and solar installations. A relatively new area of focus is the ecosystem-scale effects related to large-scale development of ORE (mostly OWF). When significant parts of the North and Baltic Sea basins are occupied by ORE (mostly OWF), effects on wind, wave, current, sediment and water quality properties will occur, ultimately resulting in knock-on effects on ecosystem functioning at sea basin scale. Furthermore, ORE provides additional hard substrate (scour protection, piles and jackets, additional infrastructure) to now mostly sandy habitats, which likely results in a significant increase in filter feeders on the seabed and in the upper layers of the water column in ORE farms. This would have potentially far-reaching ecological consequences, such as changes to the total amount and the timing of primary production, food availability for higher trophic levels, and habitat suitability for many species. Finally, large-scale ORE development can facilitate introduction and dispersion of invasive non-native species. While some of these ecosystem changes are being studied at a local scale, there is an urgent need to accurately predict the physical and ecological (knock-on) effects of the expected large-scale development of ORE at the appropriate scale to allow for strategic MSP of the BANOS region.

Expected outcomes

- Identification of knowledge gaps impeding accurate assessments of impacts caused by expected ORE development and drafting of an internationally coordinated research programme focused on addressing these knowledge gaps.
- A conceptual model of the functioning of the marine ecosystem in relation to effects of ORE (of which predominantly OWF) allowing better insights into the likely pathways and magnitudes of ecosystem-scale effects of planned developments.
- Improved cost-efficiency and regional coordination of ORE environmental monitoring efforts.
- Development of a robust vulnerability analysis under different scenarios of ORE (of which predominantly OWF) development for those bird populations migrating between the Baltic and North Sea basins.
- Contribution to strategic MSP in the form of climate-proofed vulnerability maps for ORE development taking into account vulnerable species and habitats as well as cumulative ecosystem changes.
- Review of potential mitigation or even compensation measures (including technologies and practices), with their applicability and limitations.
- Assessment of the consequences of changes in marine ecosystem functioning resulting from ORE development on the descriptors and indicators of the MSFD as well as on habitats and species specifically protected by the EU Birds and Habitats Directives.

4.6 Specific Objective B.2: Sustainable, Smart and Circular Solutions for Blue Economy

Overall rationale

To reach the ambitious goals of the EGD, including the climate neutrality by 2050 and reversion of the global biodiversity loss, the future economic development must happen within the environmental boundaries while simultaneously supporting resilience and restoration of the natural habitats. Meanwhile, the population of the world is increasing and, with it, the demand for food, goods and energy. New solutions using nascent technologies, e.g. big data, Internet of Things (IoT), artificial intelligence and other smart technology, are critically needed to enable the "green arm" of the blue transition. The process must be supported by development of carbon-neutral, renewable forms of energy that are available to all. Furthermore, natural resources should be properly valued and exploited only using sustainable practices. Circular economy development will enable the efficient use of natural resources, leading to minimum waste and sustainable levels of demand, thus putting less pressure on the environment. In addition, development of novel bio-based products will provide new environmentally friendly solutions, e.g. replacing plastics, ultimately leading to reduction of pollution in marine and coastal environments. In addition, smart solutions will lead to improved sustainability of the blue economy through reduction in operational costs, for example of offshore activities in respect to monitoring and aquafarm operations.

State of the art and knowledge gaps

The blue economy offers multiple possibilities and solutions to support the green transition. The offshore wind sector in the BANOS region is already leading globally in terms of its extent and functionality and further regional development of offshore wind farms continues. The development and commercialisation of other forms of emerging renewable ocean energy sectors, however, should not be overlooked as providers of green energy. This especially as a combination of approaches is likely to be the best solution to provide sufficient green energy for the BANOS region. The expansion of the marine renewable energy industry, however, will put even more pressure on the space in the seas that are already very crowded. Hence, there is a need to explore and develop practices that support recycling of existing infrastructure and multi-use of space, including ways to simultaneously enhance local biodiversity, resilience of marine ecosystems and provide opportunities for natural carbon capture. To enable this development, barriers between sectors traditionally not working together must be understood and crossed. Also, new legislation and regional governance models to support the development of multi-use in general, as well as reuse of existing offshore structures, need to be developed.

Digitalisation is a crucial trigger for smart solutions. With a large number of reliable, new sensors for monitoring, surveillance and inspection, more data can be collected and semi-automatically analysed with means of artificial intelligence. Big data is in many cases the key enabler of smart solutions for improved monitoring, efficiency and soundness of operation and product development, while supporting sustainability through a reduction of the environmental footprint and the optimal use of energy and resources. Digital transformation also offers new opportunities to create more sustainable business models and services. It creates new possibilities to connect and communicate with the general public, raise awareness about environmental issues faced by the coastal and marine environments and helps to promote the sustainable consumption of natural resources.

Marine bioresources provide numerous new opportunities for industry to develop novel products, processes and value chains. However, the key is to ensure that the harvesting and processing is done sustainably with a minimal environmental footprint.

New bio-based and/or biodegradable products can replace existing materials that, for example, degrade poorly in the environment and pollute our seas. For long lifetime applications, a transition towards biobased materials, e.g. composites, may be more appropriate whereas for other applications easily degradable materials are needed, e.g. for building artificial reefs or replacing plastics.

Impact and linkages

The R&I put forward in this part of the BANOS SRIA will provide new sustainable and recyclable solutions that lead to a viable blue economy in the BANOS region while simultaneously supporting marine ecosystem resilience and its biodiversity. The R&I activities here are closely linked to multiple other themes outlined in the SRIA, including the development of new governance models (A.2) that can support and lead the way for development of new industries and offshore solutions with minimal environmental footprint. In addition, development of artificial intelligence applications and ocean modelling (A.3) as well as development of novel sensors and monitoring approaches (A.4) are closely linked to digitalisation of the seas, leading the way for smart solutions. The development and harvesting of new bio-based products and materials must be carried out sustainably, hence there is a close link to sustainable harvesting (B.1) but also spatial planning together with coastal development (C.2).

B.2.1
Secure, Clean and Efficient Renewable Energy

State of the art and knowledge gaps

The EGD sets ambitious targets for Europe to become carbon neutral by 2050 and already by 2030 the greenhouse gas emissions should be reduced by at least 55 % compared to 1990.

The seas and ocean can contribute significantly towards reaching these targets with the offshore renewable energy sector able to provide secure, clean and ample energy for demands of future societies. Currently, the sector of offshore wind energy is most developed producing some 12 GW energy in the EU. However, the scale up to at least 60 GW by 2030 and at least to 300 GW by 2050 is needed to support the policy goals. Especially in the North Sea region, which is already a leader in the field, the offshore wind sector is likely to increase dramatically with a capacity up to 212 GW, but current estimates also suggest that the Baltic Sea region is having a potential to contribute up to 93 GW.

Other forms of emerging renewable ocean energy sectors should not be overlooked as they are expected to complement the offshore wind sector and contribute some additional 40 GW of energy by 2050. These sectors include but are not limited to floating and airborne wind, solar, thermal, wave and tidal energy. Also, a combination of such solutions is likely. Additional research and development of testbeds to ‘reach competitive cost levels’ for these emerging sectors are needed, including solutions for energy storage and concepts for power-to-X (X as a placeholder for hydrogen, ammonia, liquid fuel etc.). Also, extensive demonstrations of ocean energy devices in real sea conditions are required to provide valuable information on their functionality and ability to withstand a wide range of natural, sometime very harsh, conditions as well as identify optimal conditions in terms of performance.

The expansion of ocean energy should be done sustainably, and other users of the sea need to be considered in the process. The net benefit to the surrounding environment (both positive and negative) of offshore activities should be considered, assessed and explored. As the environmental impact assessment, licensing and regulations are quite diverse in the different parts of the Baltic Sea and the North Sea, new guidelines and rules are needed, which also consider local processes. Where possible, existing infrastructure and multi-use of space should be preferred. In case of new structures, emerging concepts such as building with nature, smart materials or ‘Internet of Things’ offer a potential to increase not only the robustness but significantly improve the efficiency, sustainability, availability and safety of the installations. The current legislation is not always well adapted for the blue economy to support the installation and use of new technologies and smart ideas, hence new procedures are needed to allow flexibility for update of new innovations at sea.

The spatial planning of the offshore sector, including the infrastructure, should take a futurity approach to prepare for both upscaling and production efficiency, while taking into account issues related to the installation and maintenance of large infrastructure. Here, R&I efforts should focus on new solutions to support this process most sustainably, e.g. via robotisation and development of end-of-live and multi-use practices.

Expected outcomes

- R&I contribution to the development of prototypes of emerging ocean energy generators with robustness and high efficiency that generate minimal impact to the environment.
- R&I contribution to the development of an overarching network of offshore testbeds to enable efficient research, testing and demonstration of innovative energy solutions (including concepts of multi-use) taking into account the different natural and weather conditions as well as ecologic impact in the Baltic Sea and the North Sea.
- New sustainable solutions to increase the lifespan of offshore installations, including predictive maintenance to reduce failure, as well as concepts of recycling of materials in case of decommissioning.
- New methods for maintenance, including robot-based repair and refurbishment, to reduce risks and expand the life span of offshore structures.
- R&I contribution to the development of pilots of decentralised small offshore energy installations and demonstration of their application in selected use cases.
- R&I contribution to the development of 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, including:
  - solutions to issues related to interconnectivity of energy networks across wind parks and country borders.
  - solutions to monitor interactions between energy installations and the marine environment and how to mitigate negative impacts.
- New concepts for planning approval procedures that offer flexibility for innovation. A focus should be on novel concepts for environmental impact assessment and compensation measures such as adaptive and dynamic ocean management.
- Holistic assessment of possibilities of multi-use of offshore energy installations in the Baltic Sea and the North Sea including aspects of multi-use with nature protection, building with nature and integration of other activities such as aquaculture.

B.2.2
Sustainability of Marine Infrastructures

State of the art and knowledge gaps

Maritime infrastructure includes a broad spectrum of technical structures, including bridges, ocean energy devices, coastal protection, oil and gas pipelines, mariculture, energy and communication cables and ports etc. The future expansion of the blue economy is going to lead to development of new infrastructures in the BANOS region which is already very crowded. Any new infrastructure should be built and designed with sustainability as a guiding principle. As such there is a need to develop novel, durable and environmentally friendly materials. Any new materials should have a minimal environmental impact, easy and environmentally friendly maintenance properties, and broad application in marine infrastructures. In addition, new innovative solutions based on nature friendly foundations and concepts of building with nature should be explored in respect to the development of new installations at sea or on the coast. There is also a need to understand the environmental impact and trade-offs with the surrounding marine environment.

Where feasible, approaches should be developed to reuse, recycle, and refurbish existing infrastructure for its new purpose as any new installation built at sea or on the coast will always have an impact on the existing ecosystem. This, however, requires updated regulations that need to be flexible and allow the development of new concepts and innovations related to upcycling of existing infrastructure, and innovative materials with better recycling properties. The life span of infrastructure should be maximised without increasing any risks. This can be achieved by the development of efficient maintenance and structural monitoring approaches using digital technology, including novel sensors.

Possibilities of multi-use of infrastructure and offshore platforms should be further evaluated since such approaches would not only save space but also lead to maximum and complementary utilisation of expensive structures. Possibilities include, for example, combinations of different forms of ocean energy as well as aquaculture. In addition, platforms could be used and developed for environmental monitoring purposes or for having a secondary semi-natural function to support surrounding ecosystem services. However, real demonstrations, including cost-effectiveness, of such combinations in natural conditions are still scarce. Also many challenges related to technology and design as well as operational challenges for integration of multiple functions, such as anchoring, mooring, hydrodynamic behaviour, safety, maintenance, etc., remain to be solved before multi-use can become a new norm. In addition, socioeconomic studies are needed to overcome the silos of various sectors involved, e.g. ocean energy, aquaculture and shipping, that do not normally work together. Collaboration between industrial sectors could be stimulated by the development of methodologies and procedures that bring together these parties and open up dialogues to explore multi-use concepts. In addition, studies are needed to understand social perception of multi-use and, in general, the expansion of infrastructure at sea. Currently, the development of multi-use of infrastructure is also limited by governance and regulatory frameworks, involving a substantial number of governing bodies. Clear definitions on administrative and legal procedures related to the implementation of offshore projects need to be formulated at regional and/or sea basin level to guide the development of multi-use of infrastructure.

Expected outcomes

- New concepts and tools for the design of new offshore infrastructure, including life-cycle assessments, recycling, logistics of decommissioning, materials and redesign of different existing offshore infrastructures and their components, evaluated in the light of both relative and absolute sustainability criteria.
- Novel feasibility studies as well as demonstration of multi-use of infrastructure at sea in natural conditions, which take into account different environmental conditions in the BANOS region.
- Governance regulatory framework solutions to allow construction and development of offshore multi-use infrastructure.
- Understanding of social perception of multi-use and, in general, the expansion of infrastructure at sea. Solution how to overcome the silos of various sectors involved in the development of multi-use that do not normally work together.
- Demonstration of novel technologies and approaches in a real-world setting in the Baltic Sea or the North Sea to jointly monitor the state, efficiency, maintenance needs and environmental impact of offshore infrastructures.
- R&I contribution to development of pilot installations demonstrating how present and future offshore and coastal infrastructure could be engineered to add secondary value to support the restoration of biodiversity, ecosystem services and resilience in marine and coastal ecosystems in support of ecosystem-based management.
- Evaluation of trade-offs between functionality and ecology in respect to novel materials in marine infrastructure, including novel and environmentally friendly materials for sustainable applications in marine infrastructures in the BANOS region.

B.2.3
Enhancing the Sustainability of the Blue Economy with Smart Solutions

State of the art and knowledge gaps

Given the availability of huge amounts of new sensors, big data, novel ways of 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 forms of maritime economy. Smart solutions that use nascent technologies, including big data, Internet of Things (IoT), AI and other smart technology do not only have the potential to improve performance, productivity and economic competitiveness but also lead the way to more sustainable practices. Here, the intention is to open the minds and induce some blue skies research with high impact. It should open the door for transformation research and disruptive ideas by broadening the scope of sustainable maritime activities, by application of AI and robotics, observation and measuring techniques, big data and connectivity, the digital ocean twin, and for blue bioeconomy also in combination with recent molecular and veterinary approaches.

For the blue bioeconomy, high global growth rates are expected for many sectors, including but not limited to aquaculture. Many of the maritime sectors, however, are still in their infancy, and lagging behind, e.g. in the knowledge level and technology available compared to similar practices on land. Closing this gap through technological innovation (e.g. expanding use of sensors and AI) and providing new cost-efficient and environmentally friendly solutions to manufacturing of goods (and making the value chains more efficient) will lead to more efficient use of natural resources and a lower environmental footprint of products and processes.

After successful examples of digital value chains in materialising the Industry 4.0 vision and their application in energy sector, it is now time to focus on development of the digital blue economy. The enhanced availability of data in the marine sector, including from ocean models and simulations to understand the marine ecosystems, in combination with open access and automatic data analytics using AI provide new opportunities for business to develop digital competitiveness (including digital twins), more sustainable business models and consumer services. To support this development current regulatory obstacles must be overcome.

Digitalisation and smart solutions also offer novel opportunities for development and implementation of sustainable marine spatial planning across the BANOS region, 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 multi-use of areas.

Open and FAIR[6] data and digitalisation also provide new opportunities to engage with citizens, understand consumer behaviour and also provide educational opportunities to guide citizen towards more sustainable and environmentally friendly products and services. Such practices and application should be developed and encouraged across maritime sector without neglecting the personal data security.

Expected outcomes

- Novel smart solutions to enhance sustainability and productivity of Blue Economy sectors in the BANOS region. The solutions can be applicable to single or range of maritime sectors ranging from aquaculture to shipping and ports to offshore platforms and beyond.
- New smart solutions that can guide citizens about their consumer choices, educating them about the environmental impact of their choices and allowing them to choose more sustainable products and services.
- Smart solutions to optimise value chains of blue bioresources leading to a reduced environmental footprint of products and more sustainable and cost-efficient practices.
- Novel solutions to support the development of the marine digital economy, including ways to exploit "digital bycatch", to create new products, business models and services leading to more sustainable and efficient practices of existing and emerging blue economy sectors, including:
  - identification of possibilities of data mining of marine datasets and development of new data products.
  - solutions for data transfer, connectivity and energy provisioning of sensor, dataloggers, etc. in remote offshore areas.
  - examples of R&I developments that explore applications of digital twins.

6 The BANOS data strategy (BANOS CSA D4.7) aims to fulfill the minimal requirements for FAIR and open data set by the Open Data Directive and Horizon Europe. As such data should be "as open as possible, as closed as necessary", meaning that data should be open by default, yet allowing for data to be closed when there are valid reasons relating to publisher requirements, moratorium periods, privacy and security issues, etc. In light of this, the use of standard open licenses is recommended to indicate the status of the data. FAIR data are data which meet principles of findability, accessibility, interoperability, and reusability.

B.2.4
Recyclable and Sustainable Biobased Products from Marine Resources

State of the art and knowledge gaps

The use and uptake of new technology is widely recognised 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 BANOS region. A range of marine resources have, however, not been extracted earlier nor necessarily explored to any significant degree for their potential uses. This includes, in particular, biomasses from many low trophic organisms and most marine micro-organisms where a 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. Continued exploration, identification and characterisation of marine organisms is thus a key to ongoing innovation, given their very different adaptations compared to their terrestrial counterparts, yielding different chemical scaffolds, carbon sources, etc.

From a biomass utilisation 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 is increasingly being tested and used in, e.g. agriculture, as health management tools. Such novel products would indirectly promote the marine health and sustainability by leading to reduction in use of antibiotics or other pharmaceuticals, common in traditional practice. Similarly, new ingredients from, e.g. algae, are increasingly identified and recognised for the ability to prolong the shelf-life of certain food products, reducing wastage. Chitin and its modified polymer chitosan from marine animals with shells and fish skin can now be used in textile production.

For the food industry, significant development is 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 just some of the examples of ongoing approaches being piloted.

In order to harvest, produce, process or extract compounds of interest at a scale that is commercially viable, refining, automated handling and other supporting logistics must necessarily be developed further alongside the actual product innovation. As the diversity of viable businesses is still low, these demands in the BANOS region translate into a need to seek opportunities for innovation and solutions related to future commercial production of products derived from macroalgae, bivalves and fish species. The systemic sustainability of these emerging value chains is not a given. Aspects of environment, nature and climate should be considered, and therefore be guided by, e.g. different life cycle assessments, to avoid the risk of burden shifting or benchmark against present alternatives.

Expected outcomes

- Identification/discovery of new types of materials and natural fabrics based on marine resources of the BANOS region, which can be produced, used, recycled and upcycled in ways which are 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, including assessment of lifecycle impact.
- Knowledge 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 region.
- New extraction technologies and opportunities for marine biomasses harvested or produced in the BANOS region, 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 region to produce either new or more sustainable food, feed, fabrics and other bio-based products.

4.7 Specific Objective C.1: Safe Food and Feed

Overall rationale

The Farm to Fork Strategy can be considered one of the corner stones of the EGD, tackling the current and future challenges of sustainable food systems while taking into account the inextricable links between healthy people, healthy societies and a healthy planet. It provides new opportunities for recovery from the COVID-19 crises, including the development of environmentally focused practices, and robust and resilient food systems, while ensuring a just transition which considers the livelihood of primary producers.

To deliver on the policy goals, the aquatic food supplies from the BANOS region need to become *sufficient*, *safe*, *sustainable*, *shock-proof* and *sound*. In this context, 'sufficient' means that the food supply is able 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, including environmental practices.

State of the art and knowledge gaps

Any moves towards improving the security and safety of future aquatic food supply in the BANOS region will need to take into account the climate-driven changes in the marine environment. Climate change is projected to lead to substantial changes in the spatial distribution and productivity of wild fish stocks, with a general northward shift in the distribution forecast. While there may be some compensation in terms of increased availability of new species, this would have implications for selling the catch in a market accustomed for more traditional species. Furthermore, future projections of the productivity of wild fish stocks in the Baltic Sea and the North Sea indicate that they are likely to be adversely affected by climate change. This may, however, open new opportunities for aquaculture, including the further development of lower trophic level aquaculture with a reduced carbon footprint, as the growing conditions have been estimated to improve with scenarios of warming. Such shifts in supply require an integrated, sea-basin-level risk assessments for aquatic food production in the Baltic Sea and the North Sea, and for the development of a flexible, portfolio-based approach for managing aquatic food sources. The assessment should include analyses of trade-offs between different scenarios, considering the environmental impacts, as well as understanding consumer behaviour.

The presence of contaminants and pollutants in aquatic food and feed needs to be re-evaluated and current guidelines updated accordingly, including the emerging contaminants and mixtures of pollutants and their physiological effects. For instance, a possible risk which previously may have been largely overlooked relates to the differences in profiles of hazardous substances in fish meal as well as the physiological specifics of farm animals and how this may modulate hazardous substances in animal products for human consumption. In addition, 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 persistent bio-accumulative toxic (PBT) substances. However, these guidance documents need to be integrated and interpreted from the regional long-term perspective. Interdisciplinary expertise would be required from scientists across the BANOS region to review and update food and feed safety guidance with state-of-the-art knowledge and consideration of emerging and novel food technologies.

Natural toxins originating from harmful algal blooms (HABs) also pose risks to the human health and wellbeing and are a concern for the aquaculture industry. Furthermore, the occurrences of toxic blooms are likely to increase in future due to the impact of climate change. Innovative solutions are needed to predict and understand the formation and composition of HABs and how to minimise their effect on the seafood industry and human health.

Impact and linkages

The research and innovation put forward in this part of the BANOS SRIA will support the development of sustainable and safe food and feed supply in the BANOS region, and the outputs are associated with objectives of the Farm to Fork Strategy and EGD.

The safe food and feed availability, however, will depend on the multitude of factors and therefore the R&I themes here are closely linked and dependent upon other BANOS specific objectives and their outputs. In particular, understanding the marine ecosystem dynamics in the two seas and their resilience to external pressures, as well as links to possible regime shifts and associated tipping points (A.1, A.3), can be considered as prerequisites of food and feed safety. Furthermore, sustainable resource management of marine commons (B.1) is a key element of ensuing future aquatic food security and availability. To ensure that the future food and feed are safe to consumers and animals, new guidelines which include impact of mixtures and emerging contaminants are needed, linking this specific objective to marine governance (A.2), including a link to land-derived pollutants.

The balanced food and feed production between aquaculture, capture fisheries and terrestrial sources, and understanding economic, social and environmental impacts and trade-offs of different scenarios as well as the sea-basin-level risks for aquatic production are also closely linked to R&I outputs to development of off-shore industry and its infrastructure (B.2), including aspects of MSP (B.1.4).

Finally, development of AI and advanced modelling (A.3) together with risk prevention and fast feedback mechanisms (A.2.5), are likely to provide new solutions to ensure food safety in future, e.g. minimising the consequences of toxin impacts on seafood.

C.1.1
Aquatic Food Security in a Changing Environment

State of the art and knowledge gaps

To ensure food security in future, the aquatic supply must be sufficient, safe, sustainable, shock-proof and sound[7], and also take into account the 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. A broader context of obtaining 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. The research areas needed to provide the evidence base for policy decisions in this context 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 pandemic 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 ensuring that all aspects of the food production process

7 Components of food security are explained in the rationale of specific objective C.1.

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.

The likely climate-driven changes in the marine environment and their consequences for food species and the ecosystems that support them will likely have negative impacts on food security, e.g. through leading to changes in the abundance and distribution of currently commercially important fish species or pathogenic organisms. Contemporary frameworks to address these issues, e.g. the ecosystem approach, are multi-disciplinary and multi-sectoral. The One Health approach is of particular relevance in this respect as it explicitly requires "the collaborative efforts of multiple disciplines working locally, nationally, and globally, to attain optimal health for people, animals and our environment". It is anticipated that any research undertaken within this BANOS R&I theme would reflect such an integrated approach, e.g. drawing on expertise in natural and social sciences, industry, public health and other disciplines as required. 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 it would be optimally addressed at a sea-basin, or regional scale.

Expected outcomes

- Evaluation of the balance of food production between aquaculture and capture fishery sources, and also between aquatic and terrestrial sources; including any trade-offs and understanding of 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 BANOS region likely to impact food supply and the incidence of pathogens.
- Improved national and basin-level risk assessments for aquatic food production in the BANOS 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
Reduction of Health Risks from Toxic Substances in Regional Sea Food and Feed Chains

State of the art and knowledge gaps

Persistent bioaccumulative and toxic (PBT) substances that end up in seafood, including algae and seaweed, present health hazards for humans not only directly as part of the diet but also as a contaminant of animal feed. Differences in fish meal hazardous substance profiles and farm animals', e.g. poultry, swine, cattle, and farmed fish, physiology, modulate hazardous substances in animal products for human consumption. Based on its assessment of contaminant levels and the associated risks, EFSA provides safety guidelines on fish consumption to protect human health. EFSA's advice concentrates on the most relevant potentially toxic elements (PTEs) and persistent organic pollutants (POPs), namely (methyl)mercury, dioxins and dioxin-like PCBs. This advice does not extend, however, to fish by-products fed to farmed animals. Animals (especially farmed fish) that are fed fish meal and fish oil can extensively bioconcentrate hazardous contaminants in protein matrices and fat, which can then be passed on in the components of derived foods.

The 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 BANOS region. Interdisciplinary expertise would be required from scientists across the Baltic Sea and the North Sea regions in order to review and update food and feed safety guidance with state-of-the-art knowledge, while taking into account also emerging and novel food technologies and contaminants, including influence of micro/nano-plastics and associated contaminants. An important knowledge gap is also related to the health risk posed by exposure to mixtures of contaminants from marine food and feed. Such update would require expertise in chemical analysis, dietary exposure assessment, food and feed processing, human and veterinary toxicology and animal nutrition.

The goal is to form the scientific basis for drafting a roadmap on how to increase the Baltic Sea and North Sea food and feed safety by 2030. This entails proposing enhancement of the relevant governance and management across the BANOS 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 contaminants in the food chain including fish meal indicate that food safety objectives should be applied with the consideration of the impact of regionally derived fish meal on human health.

Expected outcomes

- Review of potential and updated guidelines on toxic substances, with reference to the MSFD descriptors (e.g. descriptor 9 on contaminants and 10 on plastics), in aquatic food and feed with highest potential adverse impact on human health and wellbeing. This should include PTEs (e.g. (methyl) mercury, lead, cadmium, inorganic arsenic), POPs, 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'.
- Evaluation of exposure levels and health risk assessment among population, including mixtures of contaminants, micro/nano-plastics and potential antagonistic or synergistic effects.
- Strategies for reduction of the health impacts for the sensitive population groups.
- Updated risk assessment framework and the necessary techniques/ models to quantitatively assess the health risks for humans and the environment.

C.1.3 Mitigating the Risks Caused by Marine Toxins

State of the art and knowledge gaps

Marine toxins originating from harmful algae or cyanobacteria may accumulate in seafood and cause different health risks. The frequency, intensity and distribution of harmful algal blooms (HABs) resulting in toxic events in the Baltic Sea and the North Sea is changing. In the Baltic Sea, cyanobacterial blooms are a particular concern. The presence of aquatic toxins necessitates constant monitoring of aquaculture facilities. Exceeding regulatory limits of concentrations in seafood results in the closure of aquaculture production 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 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 to fill this knowledge gap and provide better detection of a wide range of marine toxins. Little is known on the effects on seafood and human consumers of combined exposures to different marine toxins and other pollutants. Research on this aspect of multiple stressors, evaluating synergies and antagonisms can support impact reducing measures.

Efforts are made on a global scale to monitor the occurrence of HAB events. However, many HABs 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 either earlier or later, or by providing 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, which is now often lacking. 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 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, responsible harvesting strategies or smart choices for the location of aquaculture facilities. Although generally it is clear that nutrients and temperature play a role in the formation of certain HABs, for many algal species exact knowledge on the factors leading to the formation of HABs in the Baltic Sea and the North Sea basins is lacking. New blue economy developments may induce such factors, e.g. nutrients released by aquaculture facilities.

Seawater temperature, pH and nutrient content are affected by climate change and ocean acidification. These changed conditions may alter the formation of HABs, also by affecting species-specific life cycle characteristics such as cyst formation and emergence dynamics or phenology. 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 competitive advantages in comparison with non-HAB species. New experimental and field data need to be fed into models predicting the formation of HABs and the occurrence of marine 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. Modelling HAB formation is still very challenging at present, due to the many factors involved and complex phenomena such as mixotrophy in many species. Interdisciplinary research including physiology, biochemistry, systems biology and ecological modelling can fill related knowledge gaps and assist management action.

The response of HABs to changes in nutrient availability and climate forcing is likely to differ between the Baltic Sea and the North Sea. As such, the BANOS region can serve as a model system to study the effect of nutrient and climate change drivers on future HABs. Such studies should include ecophysiological mechanisms involving other microbial communities and biota.

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, including research on potential non-target effects. Methods exist for physically separating cultured fish from harmful algae and these can be optimised through R&I. An interesting innovation avenue for shellfish aquaculture could be shortening toxin depuration times 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 abiotic factors under the changing climate that impact formation and spatial distribution of HABs, taking into account the whole range of environmental conditions prevailing in the BANOS region.
- Novel solutions and innovations to predict and detect the development, movement and quiescence of HABs, including the detection of early stages of HAB development and of the toxicity of HAB species near real time.
- 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.
- 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.
- New methods incorporated in rapid test kits to evaluate a wide range of toxins in water and seafood.
- Improved analytical methodologies and innovative in vitro toxicity assays to detect emerging toxins and their metabolites in seafood.
- Novel mitigation measures preventing or minimising the consequences of toxin impacts on seafood.
- Screening method for the vulnerability of potential new aquaculture sites for HABs.

4.8 Specific Objective C.2: Safe and Accessible Coast

Overall rationale

The proximity of the sea supports human wellbeing in many ways. The view of the sea, recreation on or by the sea, as well as enjoying seafood directly promotes our health and wellbeing. Indirectly the wealth and wellbeing of coastal communities is promoted by economic activities near the coast. Traditionally the economies on marine coasts have been driven by industries related to harbours and fisheries, in some areas also recreation. More recently, tourism, aquaculture and businesses related to marine renewable energy have become increasingly important to 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 events in combination with increasing coastal populations and economic development lead to a strong increase of risks to humans and economies. Reducing these risks and optimising 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 could serve for additional recreational purposes or enhance local biodiversity. Changes in sea levels may affect the accessibility of harbours in the future and new residential and economic developments should avoid 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. The benefits of coastal areas to human wellbeing may be difficult to express in economic values. Still, their importance needs to be measured and evaluated to enable balancing these interests with other uses of the coast. Therefore, the effects of different types of coastal landscapes on the wellbeing of residents and tourists need to be better understood. This will enable coastal economies to adapt to a changing world in a way that benefits overall human wellbeing.

State of the art and knowledge gaps

Although access to the seaside has been shown to have benefits to the human wellbeing, the evidence of coastal environments to human physical and mental health and wellbeing in Europe, including the BANOS region, is still incomplete as was identified by the Horizon 2020 funded SOPHIE[8] project. Specifically, research is needed to clarify interactions through which coastal environments improve human health or increase various health risks. This will include assessments of increased human use of coastal areas and their impacts on the ecosystems and biodiversity in order to ensure that these interactions can be optimised for environmental sustainability as well as human wellbeing.

Coastal areas are known to be highly vulnerable to climate change and future sea levels, however, flood risks and erosion rates remain uncertain. As such, there is a need to develop coastal climate adaptation strategies that can support environmental resilience, deal with different scenarios of climate change and societal changes and be adjusted accordingly. The scenarios underpinning adaptation strategies should be supported by estimations of water level extremes, wave climates, sediment transport and coastal erosion. This requires a better understanding of the expected changes in terms of climate, land use and use of marine waters and how the natural system will respond to these changes. The scenario studies are expected to clarify whether the present coastal defence strategies will be effective in future or alternative strategies need to be developed. Similarly, different options for economic developments, including but not limited to tourism, aquaculture and marine renewable energy, need to be evaluated. To attract tourists to coastal areas all year round, sustainable blue tourism options need to be developed, promoting also the wellbeing of local residents.

The questions and knowledge gaps related to coastal access, development and safety, and their impact on human wellbeing, involve multiple stakeholders from local residents to representatives of traditional and emerging industries. Close involvement of the stakeholders is necessary, as is the support of transdisciplinary research, in the process of finding solutions to these questions.

Impact and linkages

The research and innovation put forward in this part of the BANOS SRIA provides scientific support for ICZM. It will enhance our abilities to plan developments and adapt local economies in coastal areas, anticipating on expected risks due to climate change and opportunities from sustainable blue economy developments, while at the same time optimising human safety and wellbeing in coastal areas. In this, way it supports the implementation of the EU Floods Directive, MSPD and the UN Sendai Framework for Disaster Risk Reduction.

Climate change adaptation strategies do not only require knowledge on changing natural conditions but also on possibilities how to adapt coastal economies optimally, taking into account the needs and demands of different sectors, health and wellbeing of local residents and the environment. This links the work focused on further development of sustainable marine industries in the BANOS region (B.2) as well as its impact on MSP (B.1.3). In addition, understanding of the value of ecosystem goods and services (C.3) and trade-offs between different options is critically needed for optimising coastal adaptation strategies.

The research on safe and accessible coasts is also strongly linked to the specific objective on resilient marine ecosystems (A.1) to enhance the understanding and the role of natural habitats in coastal defence. In addition, big data approaches, AI and advanced modelling (A.3) can all contribute to a better understanding of risks and wellbeing benefits in coastal areas particularly if they are supported by ample monitoring and surveillance data (A.4).

C.2.1
Challenge-driven Transformation of Coastal Economies in Support of Human Wellbeing and Environmental Sustainability

State of the art and knowledge gaps

Flood and erosion risks vary between different areas of the BANOS region. For example, coasts along the southern North Sea and the southern Baltic Sea suffer from coastal erosion, which is strongly affected by waves and reduced influx of sediments from rivers. Also, some areas are highly prone to the impact of sea level rise. In contrast, the rocky coasts along the northern Baltic Sea are likely to be affected by increase in storm surges and associated flooding in future since the frequency of the storms is likely to increase with climate change.

Currently, the management of the flood risks and coastal erosion varies among the BANOS countries or even within a country, depending on local environmental conditions and governance (e.g. local versus regional versus national approach). For example, in the Netherlands, where large areas are already located below sea level, the national government takes on coastal defence as a national priority. In the UK, approaches differ along the coast with some areas managed with a 'retreat' approach and in other areas a 'hold

8 H2020 SOPHIE Consortium, 2020, https://sophie2020.eu

the line' approach. In Denmark, the coastal defence is the responsibility of local governments. In addition, for many coastal cities, the challenge is to adapt the coastal defence to increasing flood risks without compromising cultural heritage and harbour activities. New innovative solutions and optimum governance models are needed to protect the coastal areas against flooding. These should optimally take into account the coastal geomorphology and characteristics, stimulate local biodiversity and ecosystem resilience and support coastal economies. For example, coastal protection measures can be combined with recreation areas or allow economic developments such as renewable energy structures or mariculture facilities. Furthermore, collaboration among different geographic areas and comparing different approaches can boost learning on promising solutions. Involvement of local stakeholders is required for the development of innovative solutions that optimally match local conditions.

Everywhere in the BANOS region, the accessibility of coasts and harbours is likely to be affected by changes in sea levels, wave climate and sediment transport. This may, in time, even lead to changes in shipping routes. Moreover, the development of new offshore industries may have yet unknown effects on wind, waves, and sediment transport and therefore indirectly affect coastal erosion rates. The effects of offshore developments must be understood and mitigated, for example, via development of predictive modelling, which can also assist in optimised MSP.

The rise of new sectors, further development of coastal tourism (including recreation) and harbours will put pressure on traditional industries, such as fisheries, while simultaneously providing opportunities for new business models and economic growth. Conflicts between the sectors must be avoided and the preparedness of local residents to change must be understood, taking into account that values and priorities may differ between different countries. Studies focusing on social perspectives and willingness to change are critically needed. In addition, citizens should be engaged in the process of coastal redevelopment to ensure their involvement and acceptance of the process. Furthermore, a framework is needed for balancing coastal management and development options for optimal human wellbeing, social equity and nature.

In addition to natural hazards, other threats to the coastal communities should be minimised, for example from historical unexploded ammunition (unexploded ordnance, UXO). Currently, there is a lack in capacity to identify UXO in challenging sediment environments. 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. Knowledge is lacking on the potential current and future risk for human health of UXO and the chemicals they may release in the BANOS region. Removal is currently often done by detonating ammunition, but this generates shockwaves over long ranges which may impose a risk for marine animals and maritime installations, and also may still cause (chemical) pollution.

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 ICZM / MSP.
- Understanding of impacts of climate change and economic development, e.g. offshore marine renewable energy sector 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.
- Demonstration and evaluation of 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. The strategies should find ways to involve all relevant stakeholders, including the general public and the public health sector.
- Mapping of hazards, including an evaluation and mitigation of risks due to ammunition dumped after the World Wars. Mapping requires novel techniques for the large-scale identification of buried ammunition, for example through chemical sensing or sub-bottom imaging. There is a need to develop novel technologies to remove or disable ammunition in a responsible way, to reduce these risks for offshore activities, fisheries and tourism.

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 BGS, representing one third of the maritime economy. While disrupted during the COVID pandemic, the tourism sector has generally grown fast, with a 7 % annual increase in turnover during the ten years prior to 2020. Various sustainability indicators for tourism exist, many of which build on indicators described by the UN World Tourism Organization. There is currently no standardised set of sustainable tourism indicators that can be used for assessing the sustainability of blue tourism development in the BANOS region. Circular economy approaches are not widely adopted in the blue tourism sector, although innovations in this field, aiming at minimising waste and maximising the reuse of materials, can provide 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. For instance, the Baltic Sea and the North Sea hide interesting information from the past, from paleo-landscapes to shipwrecks, each with their own history. These hide also an underused potential of becoming all-season tourist attractions.

The growing blue economy in the BANOS region 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 minimised, while positive impacts are maximised. In addition to increased flood risks and extreme weather events, climate change will impact blue tourism and recreation in other ways, e.g. shifting target species for recreational fisheries, changes in the frequency of harmful algal blooms, and 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.

The limited extent of the coastal zone creates 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 ICZM should consider the value of different coastal land uses, including the indirect value for recreation and tourism. Restoration and regeneration of degraded coasts may create economic opportunities going hand in hand with sustainable blue tourism developments and providing opportunities for increasing the well-being of local communities. Social science studies and co-creation with citizen involvement can give insight into the needs of low- and middle-income communities and the benefits such actions can bring.

Studies have demonstrated in some countries the positive effect of coastal proximity and/or exposure to blue spaces on human health. It is not clear yet if this is common throughout the BANOS region, to what extent this positive effect occurs in tourists and how this is related to recreational activities. If such an effect of increasing public health can be substantiated, informing coastal tourists about it may promote sustainable actions that work towards preserving the coastal environment.

Expected outcomes

- Knowledge for innovative and diversified touristic and recreational infrastructure to sustainably attract tourists to the coastal environment year-round and with a benefit for the wellbeing of local communities, 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, or restoration actions to regenerate degraded stretches of coast in the BANOS region.
- 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 for blue tourism in the BANOS region (reflecting ecology, cultural heritage and socio-economic aspects), applied to present tourism and leisure activities to scientifically underpin which forms of tourism are truly sustainable.
- Novel approaches for ICZM to reconcile the protection of natural coastal habitats with touristic development and sustainable forms of ecotourism.
- Knowledge on the public health benefits of blue tourism and recreation, recommendations to improve such health benefits by promoting relevant activities and appropriately managing marine environments.
- Novel applications and innovations of circular economy in blue tourism, e.g. in material use for leisure boating or in the hospitality sector, resulting in more sustainable tourism.
- Insight into the socio-economic groups that contribute to coastal tourism in the BANOS region, 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 responsible travellers.

4.9 Specific Objective C.3: Understanding the Benefits of Ecosystem Goods and Services as Sources of Human Wellbeing

Overall rationale

Popularised as part of the Millennium Ecosystem Assessment in the early 2000s and further developed in research projects and by international efforts, the concept of ecosystem services now offers widely applied and accepted approach for identifying and communicating the impacts of nature on human wellbeing. Implementation of international and European policy frameworks (such as SDGs, MSFD, 2020 Biodiversity Strategy) assume that the concept of ecosystem services, and their value, is operationalised 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, MSFD and MSPD) require explicit linking of ecological and social systems. The ocean economy is defined by the Organisation for Economic Co-operation and Development (OECD) as the sum of the economic activities of ocean-based industries, together with the assets, goods and services provided by marine ecosystems. These two pillars are interdependent, in that much activity associated with ocean-based industry is derived from marine ecosystems, while industrial activity often impacts marine ecosystems.[9]

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. This is the case also in regard to 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 broad 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 visualisations 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 the goods and benefits from 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 the North Sea. However, approaches that synthesise 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

The R&I put forward in this part of the BANOS SRIA enables linking the ecological and social systems, supporting the implementation of the ecosystem-based approach, a premise of many marine policies. It will provide information of the linkages between the ecosystem and human wellbeing at different levels and perspectives. More specifically the themes lead to (i) understanding the whole chain of interactions describing how the marine environment and human wellbeing are connected, which is important information when assessing the effectiveness of measures and policy alternatives, (ii) spatially and temporally detailed information that serves more detailed assessments of ecosystem services and benefits and their distribution, as well as policy frameworks such as MSP, (iii) further development of existing or new knowledge on ecosystem services for the purposes of ecosystem accounting at national and international levels to improve the comparability and inclusion of ecosystem values into decision-making.

The outputs from R&I themes under this specific objective are set up to support each other, and combined, aim to put theory into practice and to contribute the implementation of the regional programmes both in the Baltic Sea and the North Sea (HELCOM BSAP and OSPAR NEAES), several EU policies and strategies such as BGS, CFP, MSPD, EGD, EUSBSR, and current UN initiatives i.e. SDGs and Ocean Decade. It also supports the EU Member States' contribution to

9 www.oecd.org/ocean/topics/ocean-economy

ongoing Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) work. Together with outcomes of sustainable, smart and circular solutions for blue economy (B.2) and sustainable resource management (B.1), this objective provides overall understanding and creates new knowledge about the prospects for sustained utilisation of goods and services from marine environments.

Quantification of ecosystem services is improved through advances in modelling and monitoring marine environments (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).

C.3.1 Integrated Analyses of the Ecosystem and Social-economic System to Support the Implementation of the Ecosystem Approach in Marine Policies

State of the art and knowledge gaps

The EA, a guiding strategy in many marine policies, e.g. MSFD, MSPD, HELCOM BSAP and OSPAR NEAES, requires consideration of 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. However, there is insufficient knowledge on the interactions between these elements, as well as impacts on economic welfare[10]. Thus far, integrated assessments of the marine environment that explore and quantify the interlinkages across different ecosystem components, sectors and activities and economic welfare have been to a large extent missing or focused on specific links, for example between two components. Decision-support frameworks and tools useful for the key stakeholders and policymakers that are based on integrated assessments are needed to (i) operationalise the ecosystem-based approach, (ii) evaluate how the marine environment affects economic welfare, and (iii) allow for improved consideration of impacts on key environmental goals, including the 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 economic welfare. There is a need for better integration of theory, methods and practical application of the ecosystem approach.

The work should be based on a strong conceptual framework for linking drivers, activities, pressures, state, ecosystem services and economic welfare, and seek to build on existing frameworks and approaches, such as the DPSIR framework and concept of ecosystem services. There is a need to move from conceptual frameworks and strategies towards operationalising 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 (economic 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 those provided by studies under the BANOS R&I theme B.2.2, as well as support the ongoing work of OSPAR and HELCOM.

The social-ecological systems (including economic interactions) are complicated and 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 and consider them throughout the analyses and outputs. 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 economic 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 economic 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 economic welfare. The knowledge base for the assessment should also include a description of potential differences in understanding of the interlinkages between the system components, e.g. across stakeholders or relevant policy documents. Additional information is also needed on the limitations of integrated assessment frameworks and possibilities of filling the gaps with existing and new research, as well as complementary approaches.

10 Economic welfare: Economic welfare is the part of human wellbeing that can be measured in money. It refers to the utility gained through material and immaterial goods and services. Economic welfare measures the level of satisfaction, prosperity and quality of living of either an individual or a group of people.

Expected outcomes

- Assessment of potential use of, and need for, integrated assessments in marine decision-making on different scales and a clear view on these needs throughout the analysis and results.
- Description of the conceptual framework, approaches and methods used for the integrated assessment of drivers, human activities, pressures, state of the environment, ecosystem services and economic welfare.
- Operationalised 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 economic welfare.
- New knowledge on limitations of the assessment framework and solutions to fill in the gaps.
- Outputs of integrated assessments informing implementation of the ecosystem-based approach to support national and international marine policies.
- Assessment of linkages between marine policies based on the framework linking drivers, activities, pressures, state, ecosystem services and economic welfare.

C.3.2
Spatial and Temporal Analysis of the Contribution of Ecosystem Services to Human Wellbeing

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 from and value of ES that is non-spatial and non-temporal, as well as research on mapping and assessment of ecosystems and their services (MAES), which has developed indicators for ES and considered integrating them into accounting. However, spatially and temporally explicit approaches, data and results are largely missing, in particular for marine environments, as well as results that can directly support marine policies. The key to success in assessing ES is good spatial data on the marine ecosystem and ecosystem services, which in most countries is limited.

There is a need to cover both monetary and non-monetary benefits from ES, as well as conduct additional research on ES that have been studied less or that are considered of a particular importance in the BANOS region. Many existing studies on the benefits from ES are case-specific with limited generalisation possibilities. Future case studies should be designed in such a way that they are representative of broader, regional geographic areas and settings, and that the results can be transferred to other contexts, especially if all relevant countries, areas and ecosystem components cannot be covered with primary studies. Innovative methods to collate spatial data from multiple sources and use it for assessing the benefits from ES need to be developed.

To improve the knowledge base on ES 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 the benefits from ES from natural and semi-natural systems under different management scenarios, including information on possible trade-offs between management measures in terms of provision of ES. To this end, spatially explicit and internationally coordinated valuation studies on the monetary and non-monetary value of (positive or negative) changes in the state of the environment and provision of ES are needed, to provide coherent information on the impacts on human wellbeing. These studies should enhance our understanding of the motivations and determinants of social and economic values provided by ecosystem services in different areas and management scenarios. It is important to assess existing and new information on ES that can be directly incorporated into marine policies and decision-making.

Expected outcomes

- Spatially explicit innovative approaches and methods to identify and value the benefits from ES.
- Data and results from representative 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 wellbeing under different scenarios.
- Approaches and results for generalising research outcomes on the benefits from ecosystem services to cover broader geographic areas and contexts.
- Understanding of reasons and factors behind spatial and temporal variation of ES demand and benefits from ES.
- Recommendations on how to incorporate the value of ecosystem goods and services as part of informed marine decision-making, e.g. MSFD, MSPD, Biodiversity Strategy, RSCs (HELCOM, OSPAR) policies.

C.3.3
Incorporation of Marine Ecosystem Goods and Services into National Accounts

State of the art and knowledge gaps

There is an increasing demand for statistics on quantitative assessment of 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. Another well-established way for measuring and tracking the progress in sustainability of nations and wellbeing of their people is offered by the World Bank's Adjusted Net Savings (ANS) approach. The OECD is working on methodologies for 'ocean economy satellite accounts'.

At the European level, three EU policy initiatives foster the development of ecosystem accounting. The Commission's Communication on the European Green Deal commits support to businesses and other stakeholders in developing standardised natural capital accounting practices within the EU and internationally. The EU Biodiversity Strategy for 2030 emphasises the business case for biodiversity stating that half of the world's GDP - some €40 trillion - depends on nature. 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 main gap of knowledge is operationalisations of the existing frameworks as part of national accounting or systems that can be included as elements of extended national accounts. To this end, reliable information is needed about the value of tangible marine 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 and sustainability appraisals.

Extended national accounts, accounting for the flows of most important of marine ecosystem services and benefits on top of flows of capital and production that make part of the gross domestic product would help the decision makers to better acknowledge the role of nature on sustained human wellbeing. Extended accounts will serve decision makers at regional, national and international levels. These will provide research-based information to properly plan investments in natural capital, infrastructure, nature protection, mitigation of pollution, and eventually to safeguard the resilience of blue environments for later generations to enjoy.

Expected outcomes

- Applications and representative case studies that build on existing approaches and relevant typologies to create meaningful operationalisations of marine ecosystem services for the extended national accounts.
- Accounting tools that help to measure progress towards the national goals and SDGs.
- Research results that are instrumental for progress towards full integration of economic-environmental accounting with the national accounts.
- Methodological developments in the analysis of uncertainties and the quality of data in accounting of marine ecosystem services. 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.

5. From Vision to Action

■ A well-designed, feasible and trustworthy implementation plan underpins a solid strategic R&I agenda. Without this, also the BANOS SRIA's far-reaching foresight and intense process of co-creation involving potential users of scientific knowledge and know-how, funders of R&I and multidisciplinary expert team would risk of transpiring into little value. The Strategic Research Agenda of the BANOS predecessor, the joint Baltic Sea Research and Development Programme – i.e. the BONUS SRA – was created, and subsequently updated as a part of an TFEU Art.185 action, and appreciated for its 'hybrid character': it set both a strategic direction for a transnational R&I effort within BONUS and, at the same time, provided a streamlined, yet flexible, implementation plan covering the programme's whole duration. This approach provided much desired medium-term predictability to both the funders and implementers of R&I as well the potential users depending on the new knowledge produced by the BONUS funded projects. This predictability of the implementation plan allowed also the R&I community ample time for preparing high quality multinational proposals in response to each BONUS call issued. As for the BONUS management team, this approach provided time and opportunity for designing an effective impact enabling strategy.

The development of the BANOS SRIA coincides with a period of exceptional dynamism in EU policy landscape (see chapter 3 for more details), including a transition to the new EU Framework Programme, HE, associated with an ambitious refurbishing of the whole EU R&I landscape in the face of today's grand challenges. This transformation is not complete at the time of publishing the BANOS SRIA. Consequently, decoupling the strategic agenda from a far-reaching implementation plan is a logical solution. In the following paragraphs we outline the recommended BANOS SRIA implementation strategy to the best of our ability to project the scenario of further development.

5.1 The Planning Cycles and Calls

The recommended BANOS implementation model would be structured into annually updated planning cycles (work plans) each covering approximately two years (Fig. 4). Each of the consecutive work plans would be prepared and approved before the beginning of the respective planning period. The work plan would comprise (i) a firm schedule of activities, e.g. calls for R&I proposals and impact enabling actions, for the first 12 months of the planning period and (ii) a tentative outline of activities envisaged to take place during the latter part of the planning period. This approach would allow combining the predictability desired by the BANOS community (R&I funders, R&I implementers, knowledge users and collaboration partners) with a flexibility allowing agile response to urgent new knowledge needs. At the same time, the proposed planning approach would support necessary synchronisation with the SBE Partnership (see next sub-chapter).

The main instrument of implementing the BANOS SRIA will be a transnational research and/or innovation project. BANOS projects will be selected in a process of centrally arranged competitive calls for proposals. The thematic composition of each of the calls will be formulated in BANOS work plans and further detailed in dedicated call announcements and guides for applicants. The whole call administration process comprising submission of proposals, evaluation and selection (two-stage submission and evaluation to be applied), project monitoring and reporting including gathering information on performance indicators will run on a web-based BANOS Electronic Programme Service System (BANOS EPSS). Although as broad as possible participation of BANOS countries in the calls is desirable, BANOS will be open for application of 'variable geometry approach' in arrangement of the calls. BANOS will seek opportunities for tying as many as possible of its calls as joint and/or mutually coordinated/informed activities with other concurrent relevant initiatives, e.g. the Interreg Programmes operating in the BANOS region, thematically relevant partnerships, European Structural and Investment Funds and others. The envisioned co-funded European Sustainable Blue Economy partnership is seen as potentially a promising platform for implementing the BANOS SRIA through embedded calls.

5.2 European Sustainable Blue Economy Partnership as the Main Implementation Vehicle

There is a consensus among the BANOS countries that the main implementing platform for the BANOS SRIA would be envisaged as the SBE Partnership intended to be funded under HE. Within a process of co-creation among the EU member and associated states the high level SBE Partnership SRIA was finalised in early 2021. The SBE Partnership SRIA is underpinned by the strategic planning documents of the European regional seas' R&I initiatives, including the BANOS SRIA. Around the time of the BANOS SRIA publishing, the parties involved in planning the SBE Partnership have entered the next phase of outlining the Partnership proposal – negotiations of its governance and management model. Majority of the BANOS participating states support a 'partnership of partnerships' model, by which the SBE Partnership serves as a platform for jointly addressing the issues demanding pan-European approach as well as for joining forces for securing strong impact of marine and maritime R&I at European and global arenas. The implementation of the BANOS SRIA within the broader Partnership should not, however, preclude BANOS from devising its own complementary set of activities to address the specific challenges faced in the BANOS region in a most efficient, fit-to-purpose way. It is generally agreed that the regional sea basins (marine eco-regions *sensu* EU MSFD) are the basic units for restoring GES and achieving lasting sustainability of marine ecosystem services to humans. Moreover, the specific geopolitical circumstances and individual maturity levels of transnational R&I cooperation around Europe's regional sea basins require much of a tailored approach.

Timewise, at the time of the BANOS SRIA publishing, the SBE Partnership scenario envisages a six or seven-year implementation period during the HE Framework Programme, probably commencing sometime during 2022 and encouraged to transition towards a self-sustaining format afterwards. During the lifetime of the SBE Partnership, its activities are expected to be outlined as part of the Partnership proposal for the entire period, planned in detail in annual increments and implemented in accordance with the rules of HE co-funded partnership. The first annual work plan would be drafted concurrently with the full SBE Partnership proposal (anticipated call on 28 October 2021 and submission deadline on 15 February).

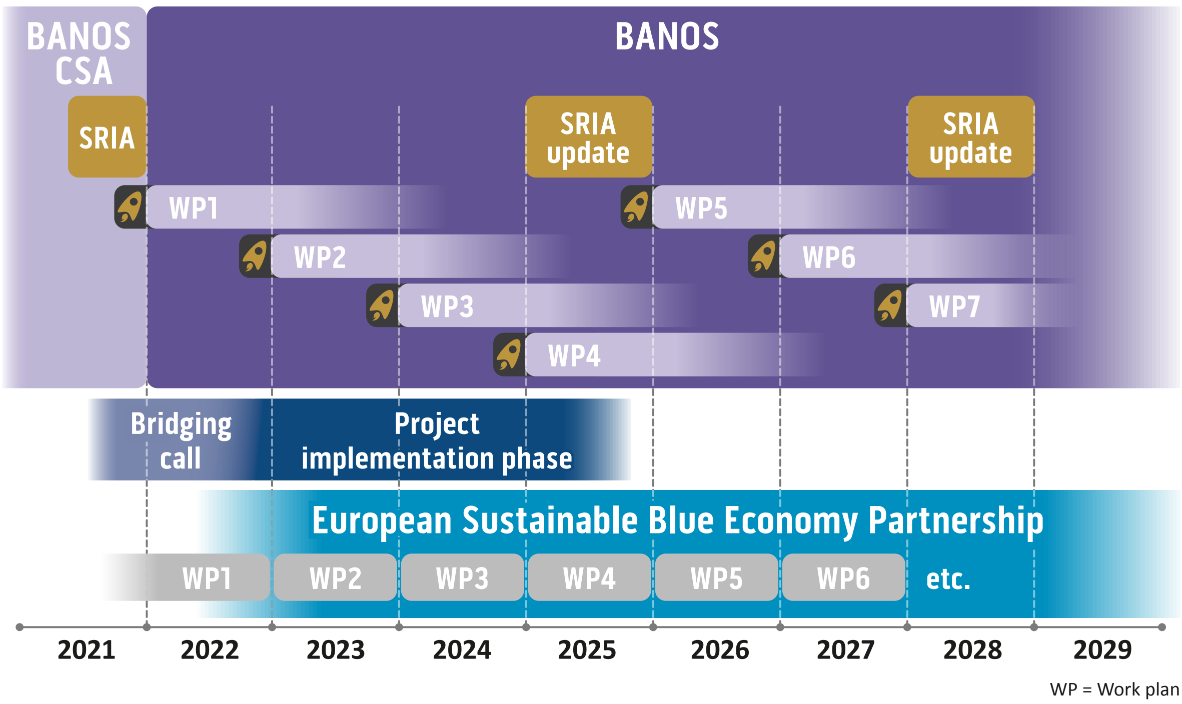

Figure 4. A possible scenario of BANOS implementation within the context of the SBE Partnership.

5.3 An Impactful Programme is More than Implementing R&I Projects

In addition to implementing high quality projects, a successful transnational, policy-driven and impactful R&I programme requires a set of dedicated tools to turn the outputs of academic and cutting-edge innovation work into practical impact. Based on the well-evidenced and praised BONUS Art. 185 experience, the BANOS CSA has developed a whole array of 'impact enablers' (see section 6), including, among other, the following:

- Promoting and organising mobility among the R&I project partners
- Facilitating infrastructure sharing
- Arranging thematic clustering of R&I projects within BANOS and beyond its remits
- Promoting open science, open data, and open innovation policies
- Enhancing citizen science and ocean literacy
- Enhancing human capacity building in the blue economy sector in line with the EU BGS
- Implementing the programme level communications, dissemination, and stakeholder engagement strategy
- Arranging R&I collaboration with international partners
- Systematic monitoring of the performance and progress towards the set values of impact indicators and arranging programme level impact assessment actions

Similarly, as for the key activity – competitive calls for R&I proposals and centralised scientific management of the selected projects – the BANOS impact enabling work would be planned within a seamless series of partly overlapping two-year periods. Responding to the development of scientific thinking and the emerging needs for new scientific knowledge and know-how, the BANOS SRIA itself would be reopened for updates within 2–3-year intervals (Fig. 4).

6. Impact Enablers

The future BANOS Programme intends to underpin and develop EU and national policies and strategies, with a particular consideration of EGD, development of the sustainable blue economy sectors in the BANOS region, and to generate strong EU added value and impact. To achieve these goals and deliver on programme's objectives, dedicated measures, so-called impact enabling strategies, have been designed (Fig. 5). These strategies include:

- R&I Impact Monitoring and Assessment
- Effective Communication of the Results of R&I
- Knowledge Synthesis as Enabler of Greater Research Impact
- Collaboration Across Marine and Maritime Funding Streams
- Human Capacity and Skills Development
- Open Science: Open Access
- Open Science: Open Data
- Open Science: Marine Citizen Science
- Stimulating Innovation Diffusion and Open Innovation
- Cooperation among Europe's Regional Seas' R&I Programmes

The ten strategies are closely interlinked and should not be considered in silos. The highest level of impact is expected when they are implemented jointly. For example, communication is essential to all. It is needed to ensure high level of stakeholder engagement of various sectors, and to enable collaboration. Collaboration

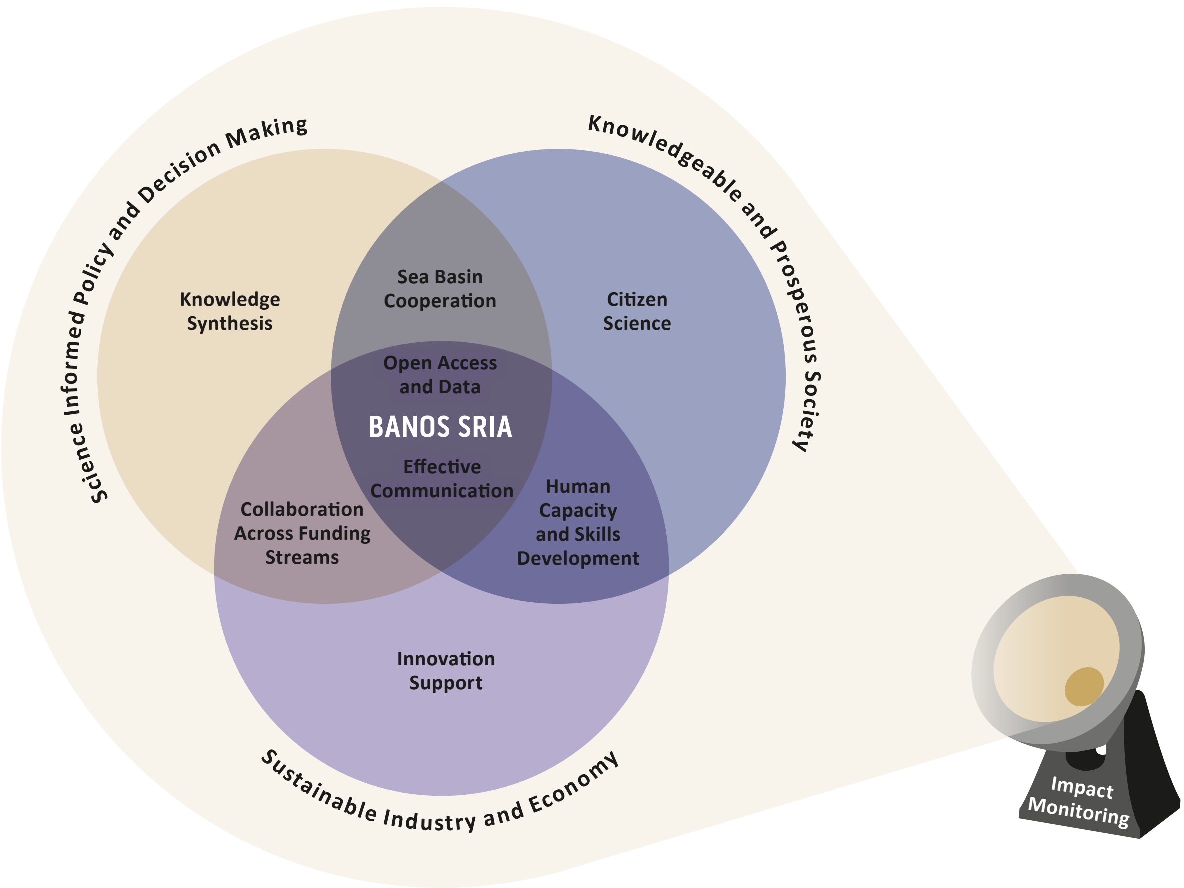

Figure 5. The framework of mutually interlinked BANOS impact enabling strategies supporting BANOS and its SRIA's aims and objectives. The BANOS funded R&I in its core, the impact enablers collectively work towards building science informed policy and decision making as well as sustainable innovation and economy, leading ultimately to a knowledgeable society that supports citizens' wellbeing.

across geographical areas and among the various funding streams is needed to align the R&I investments and to achieve financial and administrative impact. For this to be evaluated, an impact monitoring and assessment are critically needed to ensure that progress towards the goals of BANOS can be measured and future investments aligned with, for example, R&I approaches that are likely to be most impactful and beneficial to society at large. Here, adequate research and knowledge synthesis is also critically needed, which is enhanced through open science. Open access and open data also speed up the science and innovation process and are also closely linked to human capacity building and skills development. These in turn are needed to ensure that the upcoming young professionals are well equipped to take on the future challenges. Here the wider engagement with the society, for example through activities of citizen science, is critically needed to enhance the ocean literacy and the feeling of connectedness to our regional seas and the ocean. The following section contains short overviews of the ten impact enabling strategies[11].

6.1 R&I Impact Monitoring and Assessment

WHY: To enable strong and the most desirable public presence, active stakeholder engagement and effective, multi-flow knowledge and eco-innovation dissemination have a role to play in efforts aiming to increase impact of BANOS. A strong, strategic communications approach ultimately transpires to having an ample number of key stakeholders applying to calls, participating in projects as well as end-users of knowledge and eco-technological advances implementing the results generated in support of the long-term sustainability action.

WHAT: The development and implementation of a tailored communications and stakeholder engagement strategy addresses the brand, engagement tools, activities and tailored plans that provide opportunities for BANOS to grow and engage purposefully in the BANOS region and wider. 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 realisation of communications and dissemination efforts according to target audiences, as well as deep understanding of BANOS 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 for systematic and reciprocal stakeholder consultation and other engagement in support of the BANOS Programme and its delivery.

6.2 Effective Communication of the Results of R&I

WHY: Globally there is a growing demand to understand the impacts of R&I projects as well as funding programmes. 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 maximise the returns and public benefits.

WHAT: A systematic approach, which builds on the BONUS experience and the best practices identified among research funders and in literature, is developed to ensure a successful impact assessment of the BANOS Programme and its funded projects in the future. The strategy encompasses: (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 to materialise.

HOW: The project impact assessment will be carried out periodically, primarily as part of the project reporting as well as ex-post. The assessment will be based on a set of performance indicators following the concepts of the Research Impact Pathway as well as open self-assessment questions. Mandatory stakeholder engagement plans are designed already at the proposal phase and followed throughout the lifespan of the projects to ensure impact. The programme level impact assessment is based the BONUS experience and an independent panel assessment is favoured here. Additional, bibliometric analyses may be chosen for impact analyses of specific research areas.

11 The ten impact enabling strategies are amongst the 32 BANOS CSA deliverables listed in full in Annex 2 – all directly or indirectly supporting the realisation and implementation of the BANOS SRIA.

6.3 Knowledge Synthesis as Enabler of Greater Research Impact

WHY: As BANOS aims to give clear and scientifically robust answers to practical questions faced by policy makers, managers, industries and every citizen aspiring to healthy marine environment and sustainable blue economy, critical review and synthesis of scientific knowledge is important. Taking a stock of "what is known and what not known" is also a crucial step in updating of the BANOS SRIA.

WHAT: BANOS sees knowledge synthesis as a mandatory step in a seamless process of translating research results into societal benefits. Firstly, the primary research outputs within the defined scope are collected, assessed, and synthesised in a transparent and evidence-based process. If and where appropriate, applying systematic review approach is advisable. Synthesis shall be based upon a wider survey of the respective scientific field(s), including but not limited to BANOS funded projects. Secondly, the outputs from syntheses shall be communicated to a wide range of stakeholders. With an underlined link to the overall BANOS communication strategy, this includes identification of target groups, further tailoring of syntheses to target audiences and delivery of syntheses' results using appropriate strategies and channels. As both actions are complementary, they should proceed in parallel.

HOW: Selecting the most appropriate knowledge synthesis tool shall be achieved by employing the best available practice, including lessons-learned from the BONUS synthesis projects. Thematic scoping of knowledge synthesis would greatly relay on broad and inclusive stakeholder consultation and codesign. A wide variety of knowledge synthesis instruments can be exploited as best fit to each specific case, e.g. dedicated calls for knowledge synthesis projects, mandating thematic project clusters, arranging dedicated ad hoc panels, solicitating expert consultancy etc. While disseminating the synthesis outputs, advanced methods of stakeholder engagement, tailored communication strategies and channels shall be applied.

6.4 Collaboration Across Marine and Maritime Funding Streams

WHY: Alignment of R&I activities tackling marine and maritime issues which one country cannot solve on its own has been on the European agenda for a long time. However, concrete measures to achieve this are still lacking, including cooperation and collaboration between HE, European Structural and Investment Funds (ESIF) and other transnational initiatives and funding streams. First steps to allow such an alignment of funds on EU legislative level has now been made as the members states can now use the ESIF funds as part of their cash contribution towards HE. Yet, in practice the collaboration among these funding streams to support the development of sustainable blue economy is still to materialise.

WHAT: The future BANOS Programme 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 possible synergies in R&I funding among relevant funding programmes have been identified, enabling the enhanced synergies and alignment between funding streams as well as utilisation and further development of project results. Once BANOS is operationalised, collaborations are formalised to allow sharing of knowledge and best practice with the other initiatives. This can take place via joint regular activities, such as participation in advisory board meetings, hosting joint education activities and policy related working group meeting etc. In addition, possibilities of combining of R&I funds from various initiatives to achieve a joint target, e.g. R&I outputs, are sought as appropriate.

6.5 Human Capacity and Skills Development

WHY: There is a disconnect between marine graduate training and the needs of non-academic employers. The EU BGS identified the need for an appropriately skilled workforce to unlock innovation in the EU sustainable blue economy. The 'Blue Careers in Europe' addresses this mismatch between the traditional educational path and the job market in the maritime sectors. In the Rome Declaration, the European marine science community calls for 'innovation in (post)graduate training and enhancing skill sets and career pathways for marine professionals'. There is broad agreement on the need to tackle this 'skills gap' in the marine and maritime sectors, and to do this in an EU-wide approach.

WHAT: The BANOS Human Capacity and Skills Development (HCSD) strategy includes discipline-specific skills as well as transferable skills, and covers formal degrees, short-term, vocational educational training, lifelong-learning and continuous professional development. It aims for appropriate academic and soft skills for the next generation of marine researchers.

HOW: The strategy builds on existing experiences and best practices at global, regional and EU level, and needs assessments at national and sea basin scale. It proposes innovative approaches in training and education (MOOCs, webinars, internships, e-learning, summer schools…) and aims for transdisciplinarity, internationalisation, and collaboration between science-policy-industry. The HCSD strategy aligns with needs as identified through the SRIA, with special attention for capacity and skills in other, crosscutting BANOS science-impact enablers. It articulates at the level of: thematic/disciplines, as identified by the SRIA; skills required in the context of R&I impact enablers; and transferable skills. The strategy targets: the broader policy level (global/EU/sea basin); the BANOS Programme level; and the project level. At project level, HCSD plans provide guidance for practical implementation of HCSD and serve as instruments to ensure the uptake of the strategic objectives of the HCSD Strategy.

6.6 Open Science: Open Access

WHY: Open science improves quality, efficiency, and responsiveness of research, helping to diffuse the latest knowledge to all relevant parties, ranging beyond academia to society, policymakers and manages and innovators. It is high on the political agenda and in the new EU R&I Framework Programme, HE, and as stipulated by the Open Science Policy, all published peer-reviewed journal articles must be free of charge and publicly available.

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 aiming to make science and its outputs more accessible and impactful.

HOW: Aligned with the EU Open Science Policy, BANOS will require full and immediate Open Access to peer-reviewed scholarly articles from research funded by it. In addition, the BANOS Open Access requirements should align with the requirements of Plan S[12]. The costs for publishing in immediate open access are covered either by the funding agency or by transformative agreements with publishers, i.e. the costs for publications are prepaid by the higher education institutions to which the researcher belong or by other organisations. In respect to any project receiving funds from the HE; open access publications are also possible free of charge via the new EU platform, Open Research Europe.

Separate BANOS strategies are developed to ensure that the other aspects of open science, including open data, open innovation and citizen science are addressed (see below for more details on the relevant strategies).

6.7 Open Science: Open Data

WHY: Broad access to data enhances multiple aspects of the R&I 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: The Open Data Directive will be compulsory for all EU Member States from 17 July 2021 onwards, and BANOS is set to follow this directive and fulfil its minimum requirements.

HOW: The BANOS rules of participation and/or grant agreement will include participant requirements for R&I data management and sharing. Fulfilment of

12 Initiative of Open Access supported by cOAlition S, an international consortium of research funding and performing organisations. It requires that from 2021 all scientific publications that result from research funded by public grants must be published in compliant Open Access journals or platforms. For more information: https://www.coalition-s.org/.

these obligations are to be monitored through periodic project reporting in the form of a mandatory Data Management Plan (DMP). A DMP template is provided to all BANOS projects' participants to aid them in setting up their plans.

6.8 Open Science: Marine Citizen Science

WHY: Citizen Science (CS) has emerged as a powerful new concept to enable individuals representing the general public to become involved in scientific research in different shapes and forms. While CS increasingly demonstrates its potential to enhance, e.g. scientific data collection, it equally provides an avenue to strengthen ocean literate and engaged society, emphasising more and more the role society can have in science and vice versa.

WHAT: By considering recent marine CS developments, linking with the wider European CS movement and embedding the most appropriate approaches into the BANOS SRIA, the CS framework can act as a fit-for-purpose support tool in the BANOS Programme. More specifically, its utilisation can help in realising some BANOS SRIA aims and objectives and add value to the BANOS Programme as a whole.

HOW: A set of recommendations is issued to act as a basis of a fit-for-purpose CS strategy. The BANOS definition of CS recognises civil society as a potentially valuable asset contributing to BANOS and implementation of its SRIA. Consideration of CS approaches where applicable and for reaching future projects' specific objectives, is recommended while at the same time it is recognised that not all BANOS funded projects will necessarily be suitable for CS approaches. Also inclusion of CS among BANOS projects' performance indicators is encouraged. Recognition of the value in all levels of CS related participation from crowdsourcing to involving citizens throughout the project cycle is made, as is consideration of citizens involvement in the widest sense, incl. marginal communities, ethnic and other minorities. Furthermore, BANOS is encouraged to explore new ways for knowledge transfer and possibilities to use new technologies as well as support compulsory data management plans for all future BANOS projects, including aspects of data ownership and openness. Contributing to the international development of marine CS and collaboration with CS experts is necessary as is support to efforts towards creation of a joint, marine and coastal CS database for the BANOS region.

6.9 Stimulating Innovation Diffusion and Open Innovation

WHY: New solutions and innovation are critically needed to enable the green transition of the sustainable blue economy in the BANOS region. The goal is to stimulate and provide innovative, transformative as well as optimized products and services for society in support of the European Green Deal and Sustainable Development Goals. This policy-driven transition needs to be supported by innovation that is open, responsible, and brings benefits to everyone. Here, a change from a traditional way of working in silos towards an 'innovation ecosystems' mindset, building on the Quadruple Helix principle, embracing academia, government, industry and civil society as equally important players, is critical.

WHAT: Calls for competitive transnational project proposals are seen as the core activity of future BANOS Programme. Diversified grants should be tailored towards funding of cutting-edge innovation with practical impact for the benefit of the society and to enhance the sustainability of practices in the Blue Economy. In addition, BANOS recognises the importance of accompanying measures in promoting the development and concepts of an open innovation ecosystem. Such measures could include but not be limited to, support to incubators and accelerators as well as promoting sharing of the infrastructure needed for demonstration and prototyping to enhance the collaboration between academia and early-stage innovation. Professional development of starting-up entrepreneurs and spin-off enterprises is also considered important to take the innovation capacity in the BANOS region to the next level.

HOW: BANOS will aim at fast and simple application procedures that will enable easy participation of SMEs, start-ups and early-stage entrepreneurs in the Programme's activities. Further, the evaluation process will be tailored to be as quick and agile as possible. Adequate feedback to applicants will be provided to develop the innovation concepts and ideas further. A vision of BANOS Programme is to eventually create a community of regional R&I funders, business support, entrepreneurs, and alumni to support the development of sustainable blue economy in the region. BANOS recognises the value of additional business readiness assistance measures and will seek novel efficient ways of advancing the innovative capacity in the region, strengthened by policy that will drive and incentivise the sustainability of business. To this end, BANOS is open for systematic and ad hoc joining forces with relevant public and private initiatives at different geographic scales.

6.10 Cooperation among Europe's Regional Seas' R&I Programmes

WHY: Recent years have seen a rapid development of the joint R&I initiatives and networks in all Europe's regional sea basins. The BANOS CSA in the Baltic Sea and North Sea region is based on the oldest, profound BONUS R&I implementation experience and legacy of over 10 years in the Baltic Sea region. The other programmes include: BLUEMED Initiative CSA in the Mediterranean, AORA CSA and AANCHOR CSA in the Atlantic, and as the newest addition, the Black Sea CONNECT CSA. Through these initiatives, rich and diverse R&I effort is growing within EU and wider, as is the need for sharing this experience in a systemic way. Also, while individual sea basins are the basic units for restoring GES and achieving true sustainability of ecosystem services, many of the issues requiring more knowledge and innovative solutions are global. Therefore, cooperative and consolidating R&I effort could bring better and more cost-efficient results and elevate the pan-EU impact to a higher level.

WHAT: BANOS is open for systematic and diverse cooperation and will proactively seek opportunities to network with the existing regional seas' initiatives. It strongly supports the establishment of the European partnership 'Climate-neutral, sustainable and productive blue economy' as an umbrella of cooperation in marine and maritime R&I across Europe. Its high-level partnership SRIA is largely based on the sea basins' SRIAs. In our vision a 'partnership of partnerships' model, if applied, would allow the partnership to materialise to its fullness.

HOW: We see the candidate SBE Partnership not only as a key implementation mechanism of the BANOS SRIA, but also as an invaluable platform for mutual alignment and collaboration in marine and maritime R&I across Europe's sea basins and continuator of the cooperation effort initiated by BANOS CSA[13]. The collaborative actions could be various, ranging from joint and/or complementary calls for R&I proposals to establishing multi-sea-basin clusters of projects, to full spectrum of various impact enabling activities including, but not limited to those presented in this chapter. These will be specified in the periodic work plans by BANOS and the SBE Partnership.

13 In 2019, a workshop 'Towards stronger cross-basin R&I collaboration' was held at EMD in Lisbon jointly with AANcHOR, AORA, BLUEMED, Black Sea, leading to *Lisbon Agreement* which was drafted on the needs and interest of organisations to collaborate and present a common strategy for coordination. Also JPI Oceans joined later the updated *Lisbon Agreement*.

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Glossary

AANCHOR CSA	All Atlantic Ocean Research Alliance Coordination and Support Action
AI	Artificial intelligence
ANS	World Bank's Adjusted Net Savings
AORA CSA	Atlantic Ocean Research Alliance Coordination and Support Action
AtlantOS	Atlantic Ocean Observing System
BANOS	Baltic Sea and North Sea Research and Innovation Programme
BANOS CSA	Baltic and North Sea Coordination and Support Action
BANOS region	The Baltic Sea and the Greater North Sea region
BANOS SRIA	The Baltic and North Sea Strategic Research and Innovation Agenda
BdS	EU Biodiversity Strategy
BGS	EU Blue Growth Strategy
Black Sea CONNECT CSA	Black Sea Blue Growth Initiative and Coordination and Support Action
BLUEMED Initiative CSA	Research and Innovation for Blue Jobs and Growth in the Mediterranean Area
CAP	EU Common Agricultural Policy
CBD	Convention on Biological Diversity
CDOM	Colored Dissolved Organic Matter
CEAP	EU Circular Economy Action Plan
CFP	EU Common Fisheries Policy
COPERNICUS	European Union's Earth observation programme
CS	Citizen science
CSA	Coordination and Support Action
DMP	Data Management Plan
DPSIR	Drivers – Pressures – State – Impact – Responses
EA	Ecosystem approach
EAM	Ecosystem approach to management
eDNA	Environmental DNA
EFSA	European Food Safety Agency
EGD	European Green Deal
EMODNET	European Marine Observation and Data Network
EO	Earth observation
EOOS	European Ocean Observing System
EPSS	BANOS Electronic Programme Service System
ES	Ecosystem services
ESIF	European Structural and Investment Funds
EU NEC Directive	National Emission Reduction Commitments Directive
EU	European Union
EuroGOOS	European Global Ocean Observing System
EuroSea	Improving and integrating the European Ocean Observing and Forecasting System
EUSBSR	EU Strategy for the Baltic Sea Region
FAIR data	Data which meet principles of findability, accessibility, interoperability, and reusability
GES	Good environmental status
GHGs	Greenhouse gases
HABs	Harmful algal blooms
HCSD	Human Capacity and Skills Development
HD	EU Habitats Directive
HE	Horizon Europe
HELCOM	Baltic Sea Environment Protection Commission, also known as Helsinki Commission
HELCOM BSAP	HELCOM Baltic Sea Action Plan
HNS	Hazardous noxious substances
HWB	Human wellbeing
ICES	International Council for the Exploration of the Sea
ICM	Integrated coastal management
ICZM	Integrated coastal zone management
IMP	EU Integrated Maritime Policy

IoT	Internet of Things
IPBES	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
JERICO	Joint European Research Infrastructure of Coastal Observatories: Science, Service, Sustainability
JPI Oceans	Joint Programming Initiative Healthy and Productive Seas and Oceans
MAES	Mapping and Assessment of Ecosystems and their Services
MARNET	Marine Environmental Monitoring Network
MFF	EU Multiannual Financial Framework
MOOCs	Massive Open Online Courses
MPAs	Marine protected areas
MSFD	EU Marine Strategy Framework Directive
MSP	Marine spatial planning
MSPD	EU Maritime Spatial Planning Directive
NbS	Nature-based solutions
Ocean Decade	United Nations Decade of the Ocean Science for Sustainable Development (2021–2030)
OECD	Organisation for Economic Co-operation and Development
ORE	Offshore renewable energy
ORE Strategy	EU Offshore Renewable Energy Strategy
OSPAR (convention)	Convention for the Protection of the Marine Environment of the North-East Atlantic
OSPAR NEAES	OSPAR North East Atlantic Environment Strategy
OWF	Offshore wind farms
PBT	Persistent bioaccumulative toxic
PCA	Paris Climate Agreement
PoMs	Programmes of measures
POPs	Persistent organic pollutants
PTEs	Potentially toxic elements
PUFA	Polyunsaturated fatty acid
R&I	Research and innovation
RSCs	Regional Sea Conventions
SBE Partnership	Sustainable Blue Economy Partnership
SDG	United Nations Sustainable Development Goal
SEEA	United Nations System of Environmental Economic Accounting
SOPHIE	The Seas, Oceans and Public Health in Europe project
SRA	Strategic research agenda
SRIA	Strategic research and innovation agenda
TFEU Art.185	Article 185 of the Treaty on the Functioning of the European Union
TRL	Technology readiness level
UN ECE	United Nations Economic Commission for Europe
UNFCC	United Nations Framework Convention on Climate Change
UXO	Unexploded ordnance
WFD	EU Water Framework Directive

Annex 1: BANOS CSA work packages and deliverables. All deliverables are completed by October 2021 unless indicated otherwise.

WP1: Strategic research and innovation agenda

D1.1 Report defining scope of the future programme. (June 2019)
D1.2 Overview of existing priorities, status and capacity in relevant fields of research and innovation in the Baltic Sea and the North Sea regions. (June 2019)
D1.3 Preliminary draft text of the proposed new joint Baltic Sea and North Sea research and innovation programme SRIA as an input document to the SOW. (February 2020)
D1.4 The SOW report. (May 2020)
D1.5 Final draft of the proposed new joint Baltic Sea and North Sea research and innovation programme SRIA.

WP2: Implementation modalities

D2.1 Analysis of options for implementation structure (IS) for BANOS Programme.
D2.2 Report on national funding landscape and modalities. (June 2019)
D2.3 Outline of BANOS Programme's implementation. (December 2020)
D2.4 Package of draft legal documentation.
D2.5 Options for appropriate programme funding principles including in-kind contributions provided free of charge. (April 2021)
D2.6 Package of draft internal regulations.
D2.7 Set of model agreements proposed for implementation of the future joint Baltic Sea and North Sea research and innovation programme.
D2.8 Report on new forms of cooperation and co-funding mechanisms with initiatives financed by ESIF and other sources.
D2.9 Set of guidelines proposed for the future joint Baltic Sea and North Sea research and innovation programme implementation.
D2.10 BONUS EPSS 2.0.
D2.11 Report on measures of maintaining UK collaboration after Brexit.

WP3: Communications, dissemination and stakeholder engagement

D3.1 Proposal for the new programme's brand and its implementation guidelines. (February 2019)
D3.2 A holistic map of programme's stakeholders. (October 2019)
D3.3 Report mapping the relevant cross-border initiatives, analysing the cooperation potentials and proposing the cooperation mechanisms with the BS/NS research and innovation programme. (April 2020)
D3.4 Concept paper proposing future programme's stakeholder platform.
D3.5 Communications strategy. (December 2019)
D3.6 Website development and launch.

WP4: Specific measures reinforcing future programme's lasting impact

D4.1 Report proposing impact indicators and programme-level impact monitoring mechanism (April 2020)
D4.2 Guidelines for Applicants on integrating practical Impact Indicators in project design.
D4.3 Report proposing implementing a systematic approach to research synthesis and scalable knowledge transfer in the new programme.
D4.4 Report proposing strategies in support of human capacity building and skill's development (May 2021)
D4.5 Report proposing programme-level strategies supporting firm establishing of 'open science'. (May 2021)
D4.6. Report (incl. recommendations) on strategies and instruments to support responsible and sustainable innovation in the Baltic and North Sea region.
D4.7 Report proposing new programme's data strategy and mechanisms for its implementation. (Nov 2020)
D4.8 Report proposing measures stimulating 'citizen science' by the new programme.
D4.9 Report of European regional seas research and innovation conference.

WP5: Governance and management

D 5.1 First Project Monitoring Report. (Oct 2019)
D 5.2 Second Project Monitoring Report.
D 5.3 Set of BANOS CSA Advisory Board meeting minutes.
D 5.4 Final Management Report to the European Commission.

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