MISTRA

The Swedish Foundation for Strategic Environmental Research

Background paper

Ecosystem approach to enhance resilience in Swedish offshore marine areas and contribute to a sustainable blue economy

August 2021

Authors:

Björn Dahlbäck, Senior advisor, independent (chair)

Meinhard Doelle, Dalhousie University

Cathy Hill, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas)

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The contents of this background paper are the responsibility of the authors.

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Contents

Summary

Mistra appointed an expert group to prepare a background report on the current state of knowledge, and the priority research needs for enhancing the resilience of ecosystems in Swedish marine areas while contributing to a sustainable blue economy. The focus of this background report is on marine areas beyond the coastal zone and on Mistra's priority to fund research most critical for finding solutions to important environmental problems and for ensuring development is sustainable.

The report discusses the range of interests and stakeholders involved in Swedish marine areas, including present commercial interests such as shipping, fisheries and energy extraction, as well as potential future interests such as aquaculture and seabed mining. Existing environmental pressures resulting from human activities are identified and briefly discussed.

The clear need for effective governance of marine areas at different scales (global, regional, national, subnational) is a key conclusion of the report. The report more specifically argues for an ecosystem-based approach for understanding, managing and governing the range of existing and potential future human activities and how they interact with each other and with natural systems.

It is expected that a focus of future research should be to improve knowledge needed for an effective ecosystem-based management and governance approach that resolves conflicts between different activities/sectors and enhances synergies between them. The research proposals should pay particular attention to cross-cutting issues such as climate change and biodiversity.

Research proposals should use a regional case-study approach. The rationale for the proposed regional case-study approach is that problems and solutions for effective ocean governance and management are context specific. They depend on local ecological conditions and the needs, priorities and values of those affected. A regional approach moves the analysis and considerations of the challenges and solutions from the generic to the specific. A regional approach is critical to ensuring that the research program will deliver specific and practical solutions toward the goal of enhanced ecosystem resilience and improved social, cultural and economic benefits derived from Swedish marine areas. The research program should be sensitive to the equitable distribution of the benefits derived from Swedish marine areas.

When designing a regional case study approach, applicants should be clear on how they intend to organize the research project to consider all relevant stakeholder and how to support their effective and fair engagement in all phases, including problem identification, knowledge gap analysis, and governance and management solutions.

Preamble

The world faces major challenges associated with the environment, human use of natural resources and our impact on our surroundings. The Swedish Foundation for Strategic Environmental Research (Mistra) plays an active part in meeting these challenges by investing in research that helps to bring about sustainable development of society. This is done by setting up research programmes in which researchers, stakeholders and end users make joint contributions to solving key environmental problems. According to the statutes, Mistra "promotes the development of strong research environments of the highest international class with importance for Sweden's future competitiveness. The research shall be of importance for finding solutions to important environmental problems and for a sustainable development of society. Opportunities for achieving industrial applications shall be taken advantage of."

The board of Mistra has decided that one of the forthcoming research programmes should focus on the marine environment. This is in line with the start of the new UN Decade of Ocean Sciences for Sustainable Development (2021-2030)[1]. A tentative budget for the programme is MSEK 40-50 for a four-year period, followed by the possibility of a second four-year phase depending on a positive midterm review.

A scoping study was commissioned by the Mistra secretariat, to provide a background for initiating a new call for a research programme focused on Swedish offshore marine areas (Johansson 2021[2]). The scoping study included an overview of the challenges and the opportunities that face Swedish marine areas beyond the coastal zone, as well as other major research initiatives in the field.

1 Ocean Decade: *https://oceandecade.org/*

2 Johansson S. (2021): On Research in Swedish Offshore Marine Areas. Scoping report for Mistra.

Overall aim of the future Mistra programme

We propose that the aim of the programme should be to create a knowledge base to enhance resilience in Swedish marine areas beyond the coastal zone, move towards a sustainable blue economy, and promote an integrated implementation of the global Sustainable Development Goals. We believe that this can be achieved by using science-based ecosystem management in cooperation with relevant stakeholders, and by using a well-defined case-study approach.

Our starting point is the scoping study commissioned by Mistra (Johansson 2021) which focuses on Swedish marine areas that lie outside the coastal zone (the coastal zone stretches from land out to one nautical mile off the shoreline). There is no sharp border between the coastal zone and the offshore marine area, due to physical and biological exchange between coastal waters and the open sea. Moreover, human activities on land and in coastal waters affect the environmental status of offshore marine areas.

Many different sectors have an interest in using, managing and protecting Swedish marine areas beyond the coastal zone. These sectors include nature conservation (protection of biodiversity), scientific research, environmental monitoring, cultural heritage, recreation and tourism, regional development, fisheries, aquaculture, shipping, energy production (the oil and gas industry, wind energy, wave energy), seabed mining, geoengineering and military activities.

The scoping report lists a number of stakeholders (Appendix 2 in Johansson 2021). International stakeholders include international authorities, international conventions (CBD, UNFCCC, UNCLOS), and international science-policy panels (IPBES, IPCC), regional conventions,(HELCOM, OSPAR), regional fisheries management organisations (NEAFC/ North East Atlantic Fisheries Commission, BALTFISH), intergovernmental marine science organizations (ICES) and the European Union (Common Fisheries Policy, Habitats Directive, Birds Directive, Maritime Spatial Planning Directive, Marine Strategy Directive, Water Framework Directive and EU regulation on Invasive Alien Species).

National stakeholders include Swedish national authorities, regional stakeholders, coastal municipalities and public marine sectors (environment, fisheries, maritime spatial planning, research, defence). Private stakeholders include industries such as seafood, offshore energy, transportation, tourism and recreation, manufacturing and construction, and seabed mining.

The scoping study recommended that the aim of the proposed research programme should be to apply an ecosystem approach to the management of Swedish marine areas beyond the coastal zone, in order to achieve Blue Growth. Blue Growth is a strategy to support sustainable development in the marine and maritime sectors, based on ecosystem-based management of the marine environment. The European Commission's *Blue Growth Strategy* aims to develop the potential of Europe's oceans, seas and coasts, and highlights the need for the blue economy to be sustainable and respect potential environmental concerns, given the fragile nature of the marine environment (European Parliament 2020[3]). The strategy focuses on five Blue Growth sectors: renewable energy, biotechnology, coastal and maritime tourism, aquaculture and marine mineral resources. Other key maritime sectors are ship building and repair, transport, fisheries, and offshore oil and gas.

Much marine research has been focused on coastal waters which are close to shore, but less is known about offshore marine environments, which are harder to access. Offshore areas have their own unique ecosystems and environmental challenges compared to coastal areas and are of interest to international stakeholders (UN Environment 2018[4]).

The scoping study (Johansson 2021) provided an overview of current gaps in knowledge about ecosystem-based management of Swedish offshore marine areas and identified three sectors that particularly affect these areas: shipping, fisheries and wind energy. In this background report, we identify further activities that are important in Swedish marine areas beyond the coastal zone and may become important in the future e.g. aquaculture, seabed mining and marine geoengineering.

The scoping study (Johansson 2021) stressed that there is a need to develop instruments for sustainable management of activities in Swedish offshore marine areas and for protection of ecosystem services and biodiversity. For Swedish coastal waters, there are well-tested methods and governance tools for sustainable coastal zone management in cooperation with regional stakeholders such as Integrated Coastal Zone Management, ICZM (Ackefors & Grip 1995[5], Ambio 2005[6]). MISTRA has previously funded the SUCOZOMA research programme on "Sustainable Coastal Zone Management" (Carlberg et al 2005[7]).

For Swedish marine areas beyond the coastal zone, we identify a number of governance tools apart from those mentioned in the scoping study e.g. maritime spatial planning. Maritime spatial planning is a relatively new governance instrument required by the EU Maritime Spatial Planning Directive (Directive 2014/89/EU[8]). The Swedish Agency for Marine and Water Management (SWAM) has delivered draft marine spatial plans for Sweden's territorial waters and exclusive economic zone (SWAM 2019a[9]) that are pending approval from the Swedish government. An important question is whether the Swedish marine spatial plans are sufficiently well developed to enable ecosystem-based management of offshore marine areas. Research teams are encouraged to critically assess the state of marine spatial planning in Swedish marine areas beyond the coastal zone and suggest how governance and management can be improved.

In this background report we recommend a regional approach to research on ecosystem-based management of Swedish marine areas beyond the coastal zone in cooperation with relevant stakeholders, similar to the multisectoral approach used in Integrated Coastal Zone Management. The goal is the effective governance and management of the region selected. Research teams need to identify the region,

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3 European Parliament (2020): The blue economy. Overview and EU policy framework: *https://www.europarl.europa.eu/RegData/etudes/IDAN/2020/646152/EPRS_IDA(2020)646152_EN.pdf*

4 UN Environment (2018). The Contributions of Marine and Coastal Area-Based Management Approaches to Sustainable Development Goals and Targets. UN Regional Seas Reports and Studies No. 205: *https://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/539/original/A2_Ocean_SDG_Technical_Report_Aug18_FINAL%281.2%29.pdf?1534861934*

5 Ackefors H. & Grip K. The Swedish Modeö for Coastal Zone management. Swedish EPA Report 4455.

6 Ambio (2005) Special Issue Sustainable Coastal Zone Management: *https://www.jstor.org/stable/i399671*

7 Carlberg A., Bruckmeier K., Elmgren R., Neuman E. & Sterner H. (eds.) (2005): Kustmiljöns framtid. Erfarenheter från forskningsprogrammet SUCOZOMA. Länsstyrelsen i Stockholms län, Rapport 2005:09. Länsstyrelsen i Västra Götalands län, Rapport 2005:10.

8 Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning: *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.257.01.0135.01.ENG%20*

9 SWAM 2019a: Havsplaner för Bottniska viken, Östersjön och Västerhavet. Förslag till regeringen 2019-12-16: *https://www.havochvatten.se/download/18.4705beb516f0bcf57ce1b184/1604327609565/forslag-till-havsplaner.pdf*

based on ecological considerations rather than political boundaries, and suggest effective methods for governing that (specific) region.

One of the key elements that are important for good governance is the issue of scale (global, regional, national, subnational). Another key element is an ecosystem-based approach to understanding the current state of the area from an ecological perspective and how the range of existing and potential future human activities interact with natural systems. This includes understanding the full range of human activities that need to be considered, and how they interact with each other and with natural systems. It also means considering the full range of actors that should be included in the governance and management of the region, and their respective roles. Finally, it includes consideration of the potential roles of various governance tools.

The research programme should be characterized by transformative change where positive development results are achieved and sustained over time. The results should provide decision makers with options to enhance resilience in Swedish offshore marine areas, move towards a sustainable blue economy, and contribute to the Sustainable Development Goals.

For the coming Mistra call on Swedish offshore marine areas we recommend the following:

1. Focus on avoiding/solving conflicts between different activities/sectors and increasing synergies between them.
2. Research proposals should be based on ecosystem-based management.
3. Research proposals should use a regional case-study approach.
4. The research proposals should also consider the cross-cutting issues of climate change and biodiversity.

Sectors/activities that use Swedish marine areas beyond the coastal zone and ongoing/potential conflicts and synergies

The draft marine spatial plans for Sweden's territorial waters and exclusive economic zone (SWAM 2019a[10]) consider the conflicts and synergies between the different activities, sectors and stakeholders in the three Swedish marine plan areas. The spatial plans specify ten uses: energy extraction, defence, general use, culture, nature, recreation, sand extraction, maritime shipping, investigation area maritime shipping, and commercial fishing. The draft plans include a Strategic Environmental Assessment (2019b[11], 2019c[12]) and an evaluation of their economic, ecological and social sustainability (SWAM 2019d[13]). The evaluation includes potential economic effects, impacts on ecosystem services, impacts on the marine environment and climate, and social aspects such as employment, accessibility, health and cultural heritage. The evaluation also shows how the draft marine spatial plans contribute to the Global Sustainability Goals and the Swedish Maritime Strategy.

The Swedish work on maritime spatial planning shows that many sectors and activities operate concurrently in certain marine areas beyond the coastal zone, for example the offshore banks in the Baltic Sea and the Kattegat (SWAM 2016[14], 2017[15]). The offshore banks have high natural values, are close to heavily trafficked shipping routes, are productive areas for commercial fisheries, and are proposed sites for wind energy production.

The strategic environmental assessment of the Swedish draft marine spatial plans includes measures that aim to prevent, halt, mitigate or remedy significant negative environmental effects. The assessment recommended sector-specific

10 SWAM 2019a: Marine spatial plans for the Gulf of Bothnia, the Baltic Sea and Skagerrak/Kattegat. National planning in Sweden's territorial waters and exclusive economic zone (EEZ): *https://www.havochvatten.se/download/18.56d79bf516b232e9db573cab/1560164109554/proposal-marine-spatial-plans-sweden-revieiw.pdf*

11 SWAM 2019b: Miljökonsekvensbeskrivning av havsplaner för Bottniska viken, Östersjön och Västerhavet. Underlag till regeringen. Dnr 3628-2019: *https://www.havochvatten.se/download/18.4705beb516f0bcf57cee066/1604327317531/miljokonsekvensbeskrivning-av-havsplaner.pdf*

12 SWAM 2019c Strategic Environmental Assessment of the marine spatial plan proposals for the Gulf of Bothnia, the Baltic Sea and the Skagerrak and Kattegat. ENGLISH SUMMARY: *https://www.havochvatten.se/download/18.4b6151c116b836ca6982fa03/1561470379481/summary-sea-swedish-msp-review-stage.pdf*

13 SWAM 2019d: Hållbarhetsbeskrivning av havsplaner för Bottniska viken, Östersjön och Västerhavet. Underlag till regeringen. Dnr 3628-2019: *https://www.havochvatten.se/download/18.4705beb516f0bcf57cee381/1604327412334/hallbarhetsbeskrivning.pdf*

14 SWAM 2016: Sjöfart och naturvärden vid utsjöbankar i centrala Östersjön. Report 2016:24: *https://www.havochvatten.se/download/18.16c4dbac15817a9551e46077/1478095712777/hav-rapport-2016-24-sjofart-naturvarden-utsjobankar.pdf*

15 SWAM 2017: Omdirigeringsanalys av sjöfart kring Hoburgs bank och Midsjöbankarna. Report 2017:11: *https://www.havochvatten.se/download/18.4ed9ddf715b4ec1c8fc5554c/1491806972643/omdirigeringsanalys-av-sjofart-kring-hoburgs-bank-och-midsjobankarna-hav-rapport-2017-11.pdf*

measures to evaluate and deal with potential environmental effects, mainly during licensing evaluations, including Natura 2000 appraisals. The assessment also identified the need for further analyses, e.g. of the cumulative effects of offshore wind power on seabirds, the occurrence and migration patterns of bats at sea and the impact of wind power, alternative geographical areas for offshore energy production, area-specific measures in areas with high natural values and cultural landscape values, the possibility of redirecting shipping in the South Bothnian Sea, and spatial data on ecosystem services (SWAM 2019[16]).

16 SWAM (2019): Strategic Environmental Assessment of the marine spatial plan proposals for the Gulf of Bothnia, the Baltic Sea and the Skagerrak and Kattegat: *https://www.havochvatten.se/download/18.4b6151c116b836ca6982fa03/1561470379481/summary-sea-swedish-msp-review-stage.pdf*

Proposed orientation of the research programme

We recommend that this research programme should use an ecosystem-based approach for understanding, managing and governing the range of existing and potential future human activities in Swedish marine areas beyond the coastal zone. Research proposals should use a regional case-study approach, as the problems and solutions for effective ocean governance and management are context specific. The research proposals should pay particular attention to cross-cutting issues such as climate change and biodiversity.

Ecosystem-based management

The scoping study (Johansson 2021) presents several definitions of the ecosystem approach and ecosystem-based management, which are often used interchangeably (see Appendix 4 "Ecosystem Approach"). These include the CBD principles, the Malawi principles, and UNEP (2011[17]) on "Taking Steps toward Marine and Coastal Ecosystem-Based Management". See **Appendix 1** for more detailed descriptions of some of these definitions.

According to UNEP, ecosystem-based management *"involves two changes in how management is practiced: (1) each human activity is managed in the context of ALL the ways it interacts with marine and coastal ecosystems, and (2) multiple activities are being managed for a common outcome"*.

The HELCOM guideline for the ecosystem-based approach for maritime spatial planning in the Baltic Sea is based on the definition adopted jointly by HELCOM and OSPAR in 2003: "*the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity*."

According to ICES the aim of ecosystem-based management is "*long-term sustainable use of marine resources with a resilient ecosystem. The health and productivity of the ecosystem should be maintained while allowing appropriate human uses for the benefit of current and future generations*".

The proposed regional case-study approach

The call on Swedish marine areas beyond the coastal zone builds om the Mistra strategy to support research programmes in which researchers, stakeholders and end users make joint contributions to solving key environmental problems. The programme should be based on the ecosystem approach and a regional case-study approach, in order to deliver specific and practical solutions toward the goal of

17 UNEP (2011): Taking Steps toward Marine and Coastal Ecosystem-Based Management – An Introductory Guide: *https://www.unep.org/resources/report/taking-steps-toward-marine-and-coastal-ecosystem-based-management-introductory*

enhanced ecosystem resilience and improved social, cultural and economic benefits derived from Swedish marine areas.

The selected case studies should include all past and current activities within an area and anticipate activities that might occur in the future. They should provide knowledge needed for an effective ecosystem-based management and use a governance approach that resolves conflicts between different activities/sectors and enhances synergies between them.

The regional approach was chosen in part to enable an integrated approach to understanding the challenges facing the area and the solutions that hold the most promise. Problems and solutions for effective ocean governance are context specific. A regional approach moves the analysis and consideration of the challenges and solutions from the generic to the specific.

A regional approach also helps to identify appropriate and specific stakeholders and ensure that they are involved in the research and in the implementation of the results. The regional approach will ensure that the work takes place on a manageable scale, and that the proposed solutions will be meaningful. These solutions can hopefully be modified for use in other marine contexts. When applying a regional case-study approach, research teams have to be very clear about how they intend to organize the research project to consider all relevant stakeholders and how to support their effective and fair participation in all phases of the research, including problem identification, knowledge gap analysis, and governance and management solutions.

For the regional case-study approach in Swedish marine areas beyond the coastal zone, research teams need to select a region that includes significant marine areas beyond the Swedish territorial sea but could include the territorial sea and internal (coastal) waters as appropriate. For instance, on the Swedish west coast (the Skagerrak and the Kattegat) large parts of the territorial border are almost aligned with the EEZ border. The region selected needs to be defined on ecological rather than political grounds. The research team needs to offer a clear ecological rationale for the proposed boundaries of the region. At the same time, the geo-political complexity associated with the selected region needs to be addressed in the proposal and in the implementation.

The research teams need to consider all human activities, past, present and potential future, inside the region and beyond, that are important for the effective governance of the region as defined. The research teams need to consider all impacts of human activities, past, present and future, on the region selected. The research should produce adequate scenarios that can be used for planning the management of the region.

Cross-cutting issues: Climate change and biodiversity

Climate change is an urgent cross-cutting issue, and there is a need for scientific knowledge to plan for and tackle the challenges that climate change presents to the ecosystem-based management of Swedish marine areas beyond the coastal zone. The environmental problems of the Baltic Sea (e.g. eutrophication, hazardous substances, overfishing, habitat destruction, climate change) are still managed separately, due to a lack of ecological knowledge and a lack of governance tools for ecosystem-based management (Elmgren et al. in Ambio 2015[18]). Successful ecosystem-based management in the Baltic Sea requires better modelling of multi-scale ecosystem processes, geographical and cross-sectoral collaboration between stakeholders, innovative tools and methods that integrate both ecological and socioeco-

18 Ambio (2015): Special Issue: Baltic Sea ecosystem-based management under climate change: *https://link.springer.com/journal/13280/volumes-and-issues/44-3/supplement*

nomic aspects (e.g. Integrated Ecosystem Assessment, IEA) and local and regional case studies (Blenckner et al. and Elmgren et al. in (Ambio 2015[19]).

An interesting initiative is the newly launched multidisciplinary project "*Marine Spatial Planning Addressing Climate Effects*" (MSPACE[20]) which aims to develop, design and implement climate-smart marine spatial plans in the EEZ of the UK. The project will model scenarios of climate change for the marine environment, species and habitats by using spatial meta-analysis (Queiros et al. 2016[21]). MSPACE will collaborate with UK policymakers and industries, is based on a number of case studies and will deliver specific recommendations that support sustainable co-uses of the marine environment, marine conservation, preservation of natural capital and resource exploitation[22].

The Swedish maritime spatial planning process has considered how to incorporate climate change into the management of Swedish offshore marine areas. A review commissioned by SWAM concluded that climate change has already affected Swedish seas and that the effects will increase in coming decades (SWAM 2017a[23]). There are likely to be significant shifts in the biodiversity of Swedish marine ecosystems, including direct effects on single species and cascading effects on interactions between species, especially in the Baltic Sea. The review identified scientific methods for integrating climate change into Swedish marine spatial planning and suggested that a spatial meta-analysis like that of Queiros et al. (2016[24]) would be very useful in the Baltic Sea, where there are relatively few key species.

Biodiversity loss is another urgent cross-cutting issue, and the Swedish maritime spatial planning process stresses the importance of protecting biodiversity to increase the resilience of marine ecosystems and maintain ecosystem services under ongoing climate change. The draft marine plans consider measures that focus on key species, biodiversity, connectivity, and "climate refuges" (areas in which climate change is slow relative to surrounding areas, which may aid the survival of species that live close to the limits of their environmental tolerances). The draft marine spatial plans proposed twelve climate refuges to protect key species (SWAM 2019e[25]). Five of the climate refuges are in areas that are designated as high priority for protection of natural values. However, the other seven climate refuges are in areas that lack protection, and more scientific knowledge is needed to ensure that they can function as climate havens. The location of the climate refuges in the Baltic Sea was based on models of ecological and hydrographic factors under two different climate scenarios, and predictions of consequent changes in the geographical distribution of some important marine species (SWAM 2017b[26]).

19 Ambio (2015): Special Issue: Baltic Sea ecosystem-based management under climate change: *https://link.springer.com/journal/13280/volumes-and-issues/44-3/supplement*

20 MSPACE project "Marine Spatial Planning Addressing Climate Effects": *https://pml.ac.uk/News_and_media/News/Climate_ready_spatial_management_of_UK_marine_habitats_and_resources*

21 Queirós AM, Huebert KB, Keyl F et al. (2016) Solutions for ecosystem-level protection of ocean systems under climate change. Global Change Biology, 22, 3927-3936.

22 MSPACE project: *https://www.smmr.org.uk/funded-projects/marine-spatial-planning-addressing-climate-effects-mspace/*

23 SWAM (2017a): Havsplanering med hänsyn till klimatförändringar. An Assessment of the Theoretical Basis, and Practical Options, for Incorporating the Effects of Projected Climate Change in Marine Spatial Planning of Swedish Waters: *https://www.havochvatten.se/download/18.52b25cb615f1927bbd9f077f/1508402546736/havsplanering-med-hansyn-till-klimatforandringar.pdf*

24 Queirós AM, Huebert KB, Keyl F et al. (2016) Solutions for ecosystem-level protection of ocean systems under climate change. Global Change Biology, 22, 3927-3936.

25 SWAM (2019e): Natur i havsplaneringen. En fördjupning om utgångspunkter och underlag för natur och klimat i havsplaner för Bottniska viken, Östersjön och Västerhavet. Underlag till regeringen. Dnr 3628-2019: *https://www.havochvatten.se/download/18.4705beb516f0bcf57cee5f7/1604327472099/natur-i-havsplanering.pdf*

26 SWAM (2017b): Möjliga klimatrefugier i Östersjön baserat på två olika scenarier. Kunskapsunderlag för havsplanering: *https://www.havochvatten.se/download/18.5114cf181604c603d487fbf3/1513839698982/rapport-2017-37-underlag-for-klimatrefugier-i-havsplaneringen-2017.pdf*

International perspective

Swedish offshore marine areas are of interest to many international stakeholders, and Sweden needs to protect and manage its marine areas according to its international commitments (Johansson 2021[27]).

For instance, the first draft of the Global Biodiversity Framework proposes a target of 30% protection of marine areas by 2030 (CBD 2021[28]). This level of protection for marine areas is already an obligation under the EU Biodiversity Strategy for 2030, which includes the strict protection of 10% of the terrestrial and marine areas (European Commission[29]). About 14% of Sweden's total marine area, including the EEZ, is currently protected by MPAs (Miljömålsberedningen 2020[30]). This means that Sweden has to protect additional marine areas, and that the area under strict protection e.g. from fisheries, has to increase.

We envisage that this research programme is inspired by and will contribute to the 2030 Agenda and the global Sustainable Development Goals (SDGs), in particular the following:

- SDG 12 **Responsible consumption and production:** Ensure sustainable consumption and production patterns
- SDG 13 **Climate action:** Take urgent action to combat climate change and its impacts
- SDG 14 **Life below water:** Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- SDG 17 **Partnerships for the goals:** Strengthen the means of implementation and revitalize the global partnership for sustainable development

27 Johansson S. (2021): On research in Swedish Offshore marine Areas. Scoping report for Mistra.

28 CBD (2021): Convention on Biodiversity. First Draft of the Post-2020 Global Biodiversity Framework: *https://www.cbd.int/doc/c/d605/21e2/2110159110d84290e1afca98/wg2020-03-03-en.pdf*

29 European Commission: Biodiversity Strategy for 2030: Title: *https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en#:~:text=Biodiversity%20strategy%20for%202030%20The%202030%20EU%20Biodiversity,by%202030%2C%20and%20contains%20specific%20actions%20and%20commitments* and *https://op.europa.eu/en/publication-detail/-/publication/31e4609f-b91e-11eb-8aca-01aa75ed71a1*

30 Miljömålsberedningen (2020): Havet och människan. Delbetänkande av Miljömålsberedningen. SOU 2020:83: *https://www.regeringen.se/48e643/contentassets/491f58ce6d5c42a8958dad0b446a743d/havet-och-manniskan-sou-202083-volym-2.pdf*

Challenges that need a science-based and solution-driven approach

Sweden is surrounded by the Baltic Sea to the east and south and the Kattegat and the Skagerrak, adjacent to the North Sea, to the west. While the North Sea is clearly connected to the Atlantic Ocean and shares most properties with the ocean, the Baltic Sea is an almost entirely enclosed brackish-water sea with limited water exchange. Both marine areas are important from an economical perspective and both areas face serious environmental disturbances and challenges due to human activities (Snoeijs-Leijonmalm et al 2017[31]).

The scoping study (Johansson 2021) identified a number of challenges and potential challenges to Swedish offshore marine areas, that can be approached from different angles, here sorted into three categories:

A. Human activities,

B. Impacts from human activities and

C. Governance tools

It should be stressed that human industrial activities at sea have the potential to play important roles in developing a sustainable blue economy, if they are planned and performed in a sustainable way.

A. Human activities

The scoping report (Johansson 2021) identifies three main sectors with direct impacts on Swedish offshore marine areas: shipping, fisheries and offshore energy production (wind farms).

Shipping

The Baltic Sea is one of the world's most heavily trafficked seas, mostly due to transport of goods to and from Russia and to other countries around the Baltic (SWAM 2016e). According to Helcom more than 61 000 vessels passed Skagen's Odde (where the Skagerrak meets the Kattegat at the entrance to the Baltic Sea) in 2012. Nearly 20 000 vessels trafficked the "marine highway" west of the island of Gotland, and more than 34 000 vessels trafficked the "highway" east of Gotland (Helcom 2014[32]).

The International Maritime Organization (IMO) is the global regulator of shipping, and IMO also has specific regional regulations. Regional implementation of these regulations and initiatives on clean and safe shipping in the Baltic Sea are discussed within the Helcom MARITIME group. The Baltic Sea area has been des-

31 Snoeijs-Leijonmalm P., Schubert H. & Radziejewska T. (eds.) (2017): Biological Oceanography of the Baltic Sea: *https://link.springer.com/book/10.1007/978-94-007-0668-2?page=1#toc*

32 HELCOM (2014), Annual report on shipping accidents in the Baltic Sea area during 2012. 43 pp.

ignated as a special area in accordance with the International Convention for the Prevention of Pollution from Ships (MARPOL) Annexes I (oil), IV (sewage), V (garbage), and VI (Sulphur). This means there are strict IMO restrictions on discharges of oil or oily mixtures, sewage from passenger ships and garbage.

Shipping has many environmental impacts (Helcom[33]) including pollution (oil, sewage, toxic substances, SO2, NOx, CO2), oil spills that constitute a considerable threat to several species of seabird that overwinter in the Baltic Sea (Nordic Council of Ministers 2011[34]) and underwater noise that is harmful to marine animals such as the harbour porpoise (HELCOM 2016[35]).

The OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic also deals with the environmental effects of shipping, including pollution with oil and other hazardous substances, the introduction of alien invasive species via ballast water, air pollution emissions, toxic substances from anti-fouling paints, and marine litter. A study on non-indigenous species published by the European Environment Agency in 2019 reported that 256 non-indigenous species were recorded in the North-East Atlantic Ocean between 1949 and 2017 (OSPAR[36]). Some of the main routes for these unintended introductions are through the discharge of ballast water.

Shipping is the main vector for the spread of Alien Invasive Species (AIS) which are transported via ballast water and on ship hulls, and about 100 AIS are found in the Baltic Sea (HELCOM 2016[37]). The invasive comb jelly *Mnemiopsis leydi* presents a threat to Baltic cod (Haslob et al., 2007 in SWAM 2017). The introduction and spread of this comb jelly in the Black Sea had catastrophic effects on plankton and fish communities and led to the collapse of commercial fisheries (GRID Arendal[38]).

Climate change is expected to increase the spread of Alien Invasive Species in Swedish seas (SWAM 2017)[39]. Climate-induced melting of sea ice and the opening up of shipping routes in the Arctic Ocean will increase the transport of AIS between the North Pacific and the North Atlantic and consequently their spread to the Skagerrak, the Kattegat and the Baltic Sea (SWAM 2017)[40]. Less sea ice in winter in the Baltic Sea may also extend the shipping season and increase the spread of AIS.

The Convention on Biodiversity has proposed a target for the management of Invasive Alien Species (IAS) in the First Draft of the Post 2020 Global Biodiversity Framework[41]: "Target 6. Manage pathways for the introduction of invasive alien species, preventing, or reducing their rate of introduction and establishment by at least 50 per cent, and control or eradicate invasive alien species to eliminate or reduce their impacts, focusing on priority species and priority sites."

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33 HELCOM Action Areas. Shipping: *https://helcom.fi/action-areas/shipping/*

34 Nordic Council of Ministers (2011): Waterbird Populations and Pressures in the Baltic Sea. TemaNord 2011:550: *http://norden.diva-portal.org/smash/get/diva2:701707/FULLTEXT01.pdf*

35 HELCOM (2016): State of the Baltic Sea: *http://stateofthebalticsea.helcom.fi/pressures-and-their-status/underwater-sound/*

36 OSPAR Work Areas. Shipping: *https://www.ospar.org/work-areas/eiha/shipping#:~:text=A%20study%20on%20non-indigenous%20species%20published%20by%20the,that%20it%20carries%29%20and%20fouling%20on%20ships%E2%80%99%20hulls*.

37 HELCOM (2016): State of the Baltic Sea: *http://stateofthebalticsea.helcom.fi/pressures-and-their-status/non-indigenous-species/*

38 GRID Arendal: Comb jelly (Mnemiopsis leidyi) is spreading in the European seas: *https://www.grida.no/resources/5730*

39 SWAM (2017): Havsplanering med hänsyn till klimatförändringar. An Assessment of the Theoretical Basis, and Practical Options, for Incorporating the Effects of Projected Climate Change in Marine Spatial Planning of Swedish Waters: *https://www.havochvatten.se/download/18.52b25cb615f1927bbd9f077f/1508402546736/havsplanering-med-hansyn-till-klimatforandringar.pdf*

40 SWAM (2017): Havsplanering med hänsyn till klimatförändringar. An Assessment of the Theoretical Basis, and Practical Options, for Incorporating the Effects of Projected Climate Change in Marine Spatial Planning of Swedish Waters: *https://www.havochvatten.se/download/18.52b25cb615f1927bbd9f077f/1508402546736/havsplanering-med-hansyn-till-klimatforandringar.pdf*

41 *https://www.cbd.int/meetings/WG2020-03*

Fisheries

The scoping study (Johansson 2021) identified fisheries as one of the most important human activities in Swedish offshore marine areas. Fisheries affect not only commercially important fish stocks but also non-target species (due to bycatches), the seabed (trawling damages benthic communities) and top predators, which leads to cascading effects in the entire ecosystem. The scoping study called for more knowledge about interactions between species and ecosystem effects in order to promote sustainable fisheries and ecosystem-based management. All decisions about the management of fisheries and their environmental impact need to be assessed according to the ecosystem approach and based on all three dimensions of sustainable development.

The Swedish fishing fleet in the Baltic Sea consists of about 20 large offshore vessels and 550 small coastal vessels (ICES 2020[42]). The offshore fleet mainly targets herring and sprat in the main basin of the Baltic Sea and cod in the southern Baltic Sea. Coastal fisheries catch flatfish, cod, herring, freshwater fish, whitefish and salmon. It is suspected that large-scale offshore fisheries on herring have depleted local coastal populations and spawning stocks, as herring migrate from offshore areas to coastal areas to spawn (SLU 2021[43]).

The eastern stock of Baltic cod is currently at historically low levels due to a combination of overfishing, poor oxygen conditions in the spawning areas, the availability and distribution of prey (herring, sprat, invertebrates) and expanding seal populations (predation and parasites) (Johansson 2021). The collapse of the cod population has had cascading effects on its main prey (sprat) and consequently on zooplankton and phytoplankton communities, which means that a food-web perspective is needed for management of the Baltic fish stocks (Casini et al. 2008[44], Casini et al. 2009[45]). Traditional fisheries management is not sufficient to rebuild the Eastern cod stock in the Baltic Sea, and more scientific knowledge is needed to guide management decisions in an ecosystem context, including the effects of climate change (Eero et al. 2020[46]).

Fish stocks in the Baltic and the North Sea have traditionally been managed by using single-species models based on scientific advice from ICES (the International Council for the Exploration of the Sea). Today, ICES sees ecosystem-based management as the primary way to manage fisheries and other sectors that affect marine ecosystems in the European ICES area. ICES is developing methods and tools to make the ecosystem approach operational by including ecosystem trend analyses, by developing methods to qualify, quantify, and prioritize regional anthropogenic pressures, and by including the impact of climate change on marine ecosystems in their ecosystem assessments (ICES 2020[47]). Baltic Sea fisheries are a good candidate for ecosystem-based models, due to the small number of fish species compared to the Kattegat and the Skagerrak.

The Swedish fishing fleet in the Greater North Sea consists of more than 400 vessels, most of which operate in the Skagerrak and the Kattegat (ICES 2020a[48]). Most of them (270 vessels) mainly use passive gear to catch Norway lobster, lobster

42 ICES (2020): ICES Fisheries Overviews. Baltic Sea ecoregion: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/FisheriesOverviews_BalticSea_2020.pdf*

43 SLU (2021): The Herring stock in the Baltic Proper is being fished too hard: *https://www.slu.se/ew-nyheter/2021/5/sillbestandet-i-egentliga-ostersjon-fiskas-for-hart/*

44 Casini M. et al. (2008): Multi-level trophic cascades in a heavily exploited open marine ecosystem. Proc. R. Soc. B (2008) 275, 1793-1801.

45 Casini, M. et al. 2009): Trophic cascades promote threshold-like shifts in pelagic marine ecosystems. PNAS (2009) 106 (1), 197-202: *https://www.pnas.org/content/pnas/106/1/197.full.pdf*

46 Eero M., Cardinale M. & Storr-Paulsen, M. 2020: Emerging challenges for resource management under ecosystem change: Example of cod in the Baltic Sea. Coastal and Ocean Management 198 (2020) 105314: *https://doi.org/10.1016/j.ocecoaman.2020.105314*

47 ICES 2020: ICES and Ecosystem-based management. 5 pp. *http://doi.org/10.17895/ices.pub.5466*

48 ICES (2020a): ICES Fisheries Overviews. Greater North Sea ecoregion: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/FisheriesOverview_GreaterNorthSea_2020.pdf*

and edible crab, while about 130 vessels trawl for demersal species such as Norway lobster, northern shrimp, cod, witch, flounder and saithe. The pelagic fleet consists of ten vessels that use active gear to fish herring and sprat in the Skagerrak and the Kattegat. The fish stocks and the food webs are influenced not only by fisheries, but also by predation by other fish, seabirds, and marine mammals. Changes in fishing pressure on the main species of predatory fish influence the abundance and yield of other fish stocks.

Although fishing efforts in the North Sea have declined since the reform of the EU Common Fisheries Policy in 2002, its marine ecosystems are still in a perturbed state and there has been a shift from pelagic to benthic production (Johansson 2021). Fisheries still impact the marine ecosystems due to bycatches of protected, endangered, and threatened species such as sharks, skates, rays and harbour porpoises (ICES 2020b[49]). Bottom trawling causes physical disturbance and destroys habitats on the seabed. ICES estimated that in 2018, about 73.1 % of the area of the Greater North Sea was trawled by commercial fishing vessels larger than 12 m (ICES 2020b).

The scoping study (Johansson 2021) stressed that we need more knowledge about how fish are affected by climate change, in order to promote sustainable and healthy fish stocks in the Baltic Sea, the Kattegat and the Skagerrak. A review commissioned by SWAM (2017)[50] stated that shifts in temperature, salinity and oxygen conditions already affect the distributions of some key species in Swedish marine areas, for instance cod, herring and their prey in the Baltic Sea. The review concluded that it is vital for Swedish maritime spatial planning to identify the locations, ranges, and magnitudes of such climate-induced shifts.

Atlantic cod is an apex predator and also a cold-water species that is sensitive to climate-induced changes in temperature, salinity, ocean currents and oxygen exchange, which affect spawning success, larval recruitment, prey availability, growth, age/size structure, survival as well as fishing pressure (ICES 1994[51]). Climate change affects the carrying capacity of marine ecosystems, so there is a need to revise fisheries management models that are based on historically observed variables, such as spawning-stock biomass (ICES 1994).

Climate change and warmer waters have led to northerly shifts in the distribution of fish that are usually found at lower latitudes, and Northern Blue Fin Tuna now occurs in the cooler waters of the Kattegat and the Skagerrak. There is interest in developing a commercial Swedish fishery on this species (which is listed as "Endangered" on the IUCN Red List).

Offshore wind energy

The EU climate goals require a 55% reduction in emissions of CO2 by 2030, and there is a rapid expansion of offshore wind. EU parliamentarians have recently (7 July 2021) expressed concern about the future construction of offshore windfarms in EU seas due to potential negative impacts on marine life and fisheries:

> ***"More than 85 % of all offshore wind capacity in EU-27 waters is concentrated in the Northern Seas (North Sea, Baltic Sea and North-East Atlantic). According to European Commission's estimate, 30% of the EU's electricity demand in 2050 will be met by offshore wind, corresponding to an increase from the current 12 GW offshore wind capacity in the EU-27 to a target of 300 GW in 2050. The European marine space already counts 110 offshore wind farms with more***

49 ICES (2020b): ICES Ecosystem Overviews. Greater North Sea Ecoregion: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/EcosystemOverview_GreaterNorthSea_2020.pdf*

50 SWAM (2017): Havsplanering med hänsyn till klimatförändringar. An Assessment of the Theoretical Basis, and Practical Options, for Incorporating the Effects of Projected Climate Change in Marine Spatial Planning of Swedish Waters: *https://www.havochvatten.se/download/18.52b25cb615f1927bbd9f077f/1508402546736/havsplanering-med-hansyn-till-klimatforandringar.pdf*

51 ICES 1994: Cod and Climate Change. ICES mar. Sci. Symp., 198:2.

than 5 000 wind turbines. To reach the 2050 offshore wind energy capacity targets it would be necessary 15 times more marine space than what is used now with the current capacity"[52].

According to the Swedish Energy Agency the Swedish marine spatial plans should aim to enable around 50 TWh of offshore wind power to achieve the goals of the Swedish energy agreement, which is to produce 80–120 TWh of renewable energy in Sweden by 2040–2045 (SWAM 2019a[53]). The draft Swedish marine spatial plans have considered the environmental effects of offshore energy production (SWAM 2019b[54]).

There is ongoing rapid expansion of offshore wind-energy production in Swedish marine areas, with a focus on establishing wind farms on the relatively shallow offshore banks. The offshore banks are geographical areas where there are major conflicts between wind-energy production, nature conservation, shipping and fisheries, e.g. *Hoburgs Bank* and *Midsjöbankarna* in the Baltic Sea (south of the island of Gotland) and *Stora Middelgrund* in the Kattegat (SWAM 2019b). Technical advances mean that floating wind power is expected to be commercially viable by 2030 (SWAM & RISE 2019[55]) and floating wind farms may provide alternative locations for production of offshore energy away from the vulnerable offshore banks.

One of the emerging environmental pressures in the Baltic Sea and the Greater North Sea is death or injury to seabirds due to collisions with turbine blades on offshore wind farms (ICES 2020[56]). In the draft marine spatial plan for the Gulf of Bothnia, it is expected that energy production in the Southern Bothnian Sea (the Finngrunden banks) will likely have negative effects on wintering seabirds (SWAM 2019b).

In the draft plan for the Baltic Sea, the development of offshore wind power is expected to have negative effects of international significance on migrating and wintering seabirds. The draft plan for the Baltic Sea includes specific measures to address the negative environmental effects, including relocating the shipping routes around the island of Gotland to minimise the impact of oil spills on seabirds, harbour porpoise and benthic ecosystems near Hoburgs Bank and the Northern and Southern Midsjöbanks. There will also be an assessment of the effects of offshore wind power installations on seabirds on the entire Southern Midsjöbank, including Polish waters (SWAM 2019b).

In the draft marine spatial plan for the Skagerrak and the Kattegat, the designation of areas for offshore energy production in the Kattegat will likely have a negative effect on the landscape. One of the proposed measures is to designate additional areas for offshore wind energy production between the offshore banks in the Kattegat (SWAM 2019b).

Activities on the seabed

Constructions such as offshore wind farms, harbours, underwater cables and pipelines cause a local but permanent loss of habitat in marine ecosystems. In addition, disturbance to the seabed may occur during the period of construction and instal-

52 *https://www.europarl.europa.eu/cmsdata/237894/Trawler%20June%20July%202021.pdf*

53 SWAM (2019a): Marine spatial plans for the Gulf of Bothnia, the Baltic Sea and Skagerrak/Kattegat. National planning in Sweden's territorial waters and exclusive economic zone (EEZ): *https://www.havochvatten.se/download/18.56d79bf516b232e9db573cab/1560164109554/proposal-marine-spatial-plans-sweden-revieiw.pdf*

54 SWAM (2019b): Swedish Agency for Marine and Water Management: Strategic Environmental Assessment of the marine spatial plan proposals for the Gulf of Bothnia, the Baltic Sea and the Skagerrak and Kattegat: *https://www.havochvatten.se/download/18.4b6151c116b836ca6982fa03/1561470379481/summary-sea-swedish-msp-review-stage.pdf*

55 SWAM & RISE (2019): Baltic LINes. Coherent Linear Infrastructures in Baltic Maritime Spatial Plans. 2030 and 2050 Baltic Sea Energy Scenarios: *https://vasab.org/wp-content/uploads/2019/05/Baltic-LINes-2030-and-2050-Baltic-Sea-Energy-Scenarios.pdf*

56 ICES (2020): ICES Ecosystem Overviews. Greater North Sea Ecoregion: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/EcosystemOverview_GreaterNorthSea_2020.pdf*

lation (HELCOM 2016[57]). There has been much debate about the environmental impacts of a submarine pipeline on the seabed of the Baltic Sea to transport natural gas from Russia to Germany (Lidskog & Elander 2011[58]).

Dredging and dumping operations in the Greater North Sea dump between 80 and 130 million tonnes of sediment (dry weight) on the seabed each year (ICES 2020[59]), and most of the sediment comes from the expansion of ports and deepening of navigation channels to major seaports. Cable laying activities have increased in the Greater North Sea and are projected to continue to increase due to the development of offshore wind farms.

Seabed mining is ongoing in the Baltic Sea and the Greater North Sea. According to a 2010 report from OSPAR, 50 to 60 million m3 of marine mineral deposits were extracted from the seabed and sediments each year, and about 80% of the total volume was extracted from the Greater North Sea (ICES 2020). The marine sand and gravel were extracted mainly for the construction industry, for landfill, or for replacing sand on eroded beaches.

In the Baltic Sea, seabed loss is caused by sand extraction, dredging and deposit of dredged material, harbours and marinas, and to a lesser extent by offshore installations and mariculture (HELCOM 2016[60]). Seabed infrastructure is also being developed for energy transmission in the Baltic Sea, the Kattegat and the Skagerrak (SWAM, RISE 2019[61]). There is limited information about the effects of these activities on benthic habitats, and HELCOM plans to address this issue in future environmental assessments.

According to the environmental assessment of the draft Swedish marine spatial plans (SWAM 2019a[62]) proposed sand extraction in the Bothnian Bay and the southern and southwestern Baltic Sea will have negative environmental effects.

Seabed mining is expected to increase in the future and there is global concern about the environmental effects. Many of the regions identified for future seabed mining are already recognized as vulnerable marine ecosystems (VMEs). Deep-sea mining causes the loss of biodiversity on a local scale (Miller et al. 2018[63]), but the total area affected by mining will depend on factors such as the type of impact (for example, sediment plumes or noise), the type of mining and the ecosystem. Thus, biodiversity could be affected across a much wider area ranging from tens to thousands of square kilometers per operation per year (*Wedding et al., 2015*). Mining activities will result in the direct mortality and removal of organisms, removal and fragmentation of substrate habitat, and degradation of the water column and seabed by sediment plumes (*Van Dover et al., 2017*).

The total effects of deep-sea mining are difficult to predict, given that there have been no large-scale trials. Impacts on the marine environment outside the area mined include drifting sediment plumes and low frequency noise, which could alter species distributions, ecosystem functioning or even processes such as carbon cycling (*Le et al., 2017*).

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57 HELCOM (2016): State of the Baltic Sea. Second Holistic Assessment 2011-2016: *http://stateofthebaltic-sea.helcom.fi/pressures-and-their-status/seabed-loss-and-disturbance/#construction-and-installations*

58 Lidskog R. & Elander I. (2011): Sweden and the Baltic Sea pipeline: Between ecology and economy: *https://www.sciencedirect.com/science/article/abs/pii/S0308597X11001084?via%3Dihub*

59 ICES (2020): ICES Ecosystem Overviews. Greater North Sea Ecoregion: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/EcosystemOverview_GreaterNorthSea_2020.pdf*

60 HELCOM (2016): State of the Baltic Sea. Second Holistic Assessment 2011-2016: *http://stateofthebaltic-sea.helcom.fi/pressures-and-their-status/seabed-loss-and-disturbance/*

61 SWAM, RISE (2019): Baltic LINes. Coherent Linear Infrastructures in Baltic Maritime Spatial Plans. 2030 and 2050 Baltic Sea Energy Scenarios: *https://vasab.org/wp-content/uploads/2019/05/Baltic-LINes-2030-and-2050-Baltic-Sea-Energy-Scenarios.pdf*

62 SWAM (2019b): Swedish Agency for Marine and Water Management: Strategic Environmental Assessment of the marine spatial plan proposals for the Gulf of Bothnia, the Baltic Sea and the Skagerrak and Kattegat: *https://www.havochvatten.se/download/18.4b6151c116b836ca6982fa03/1561470379481/summary-sea-swedish-msp-review-stage.pdf*

63 Miller K.A, et al. (2018): An Overview of Seabed Mining Including the Current State of Development, Environmental Impacts, and Knowledge Gaps: *https://www.frontiersin.org/articles/10.3389/fmars.2017.00418/full*

The potential for benthic communities to recover is likely to vary substantially between locations and ecosystems but has shown to be slow. For example the extraction of manganese nodules removes the habitat for nodule-dwelling organisms, making recovery of these communities almost impossible given the long time periods required for nodule formation. A meta-analysis of 11 test studies (*Jones et al. (2017)* found that the effects of nodule mining are immediate and severe. Although signs of recovery were observed at most sites after one year, there was a significant reduction in the number of recolonizing species, even after two decades.

Military and civil defence activities

Sweden's total defence consists of military activities (military defence) and civil activities (civil defence). The Swedish Armed Forces require marine areas for military exercises offshore and in the coastal zone, without disruptions caused by physical or technical obstacles. Civil defence requires a functioning supply of goods and services. Sea lanes to strategic ports need to be kept clear, and subsea cables for power supply and communications need to be maintained (SWAM 2019b[64]).

The Swedish maritime spatial planning process identified potential conflicts between military and defence activities and offshore energy production, in particular in the Baltic Sea planning area (SWAM 2019). It is difficult to combine defence interests and energy production in many offshore marine areas, as wind farms can have a considerable impact on the facilities needed by the Swedish Armed Forces. Sweden's total defence has extensive interests in the Baltic Sea and wind farms were deemed to be inappropriate in several areas due to these interests.

Military activities produce underwater noise (e.g. underwater explosions, seismic booms) that can disturb, damage and kill marine organisms such as marine mammals, birds, fish and invertebrates (HELCOM 2016[65].). One way of decreasing the environmental impact of military activities is to adjust the location and timing of activities to minimise damage to marine organisms (SWAM 2019) for instance by avoiding military exercises in certain areas that are important during certain periods (e.g. spawning and reproductive areas, nursery areas, overwintering areas). The Swedish Armed Forces have developed a marine biological calendar that contains information on which geographical areas are sensitive to underwater noise at different times of the year (SWAM 2019b).

Other environmental pressures

Other emerging environmental pressures in the Baltic Sea and the Greater North Sea include marine litter and underwater noise (ICES 2020[66]). Marine litter, which mainly consists of plastic waste from discarded and/or lost fishing gear, household waste and waste generated by recreation or tourism is a major global environmental problem. It is also a problem in the Baltic Sea (HELCOM[67]) and Helcom has a Marine Litter Action Plan for the Baltic Sea[68]. There is a need to increase circularity and increase public awareness to prevent plastics, microplastics and other debris from accumulating in the ocean (e.g. the MARLIN project "Baltic Marine Litter"[69]).

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64 SWAM (2019b): Marine spatial plans for the Gulf of Bothnia, the Baltic Sea and Skagerrak/Kattegat. National planning in Sweden's territorial waters and exclusive economic zone (EEZ): *https://www.havochvatten.se/download/18.56d79bf516b232e9db573cab/1560164109554/proposal-marine-spatial-plans-sweden-revieiw.pdf*

65 HELCOM (2016): State of the Baltic Sea. Second Holistic Assessment 2011-2016: *http://stateofthebalticsea.helcom.fi/pressures-and-their-status/underwater-sound/*

66 ICES (2020): ICES Ecosystem Overviews. Greater North Sea Ecoregion: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/EcosystemOverview_GreaterNorthSea_2020.pdf*

67 HELCOM (2016): STATE OF THE BALTIC SEA – Second HELCOM holistic assessment 2011–2016: *http://stateofthebalticsea.helcom.fi/pressures-and-their-status/marine-litter/*

68 HELCOM Marine Litter Action Plan: *https://helcom.fi/action-areas/marine-litter-and-noise/marine-litter/marine-litter-action-plan/*

69 MARLIN project "Baltic Marine Litter": *http://projects.centralbaltic.eu/project/447-marlin*

Underwater noise caused by human activities can harm marine animals and impair their ability to communicate, survive, breed and rear their young (European Commission[70]). Underwater noise is produced by shipping, oil exploration, wind farms and underwater construction work, and also by the use of echo-sounders, sonars and seismic airguns. In the Baltic Sea, sound levels are particularly high along the major shipping routes, especially in the southernmost areas (HELCOM 2016[71]). The impulsive noise produced by piling, underwater explosions or airgun signals used in seismic investigations can displace animals such as fish and marine mammals and scare them away from areas that are important for feeding, breeding and social interactions, and cause temporary or permanent hearing loss.

Offshore energy production

In addition to offshore wind farms, potential future activities in Swedish marine areas beyond the coastal zone include wave energy production (Chatzigiannakou et al. 2019[72]) and floating solar energy parks (Utrecht University 2020[73]).

Offshore aquaculture

In a report to the European Commission on how the oceans can help satisfy the global demand for food, SAPEA (Science Advice for Policy by European Academies) found that mariculture was the primary means of obtaining significantly more food and biomass from the ocean and maximising the benefits for future generations. Options included mariculture of seafood from lower trophic levels in the food chain e.g. seaweed and mussels, and integrated multi-trophic aquaculture (IMTA) (SAPEA 2017[74]).

Sweden maintained a trade deficit of EUR 672 million in fish and fish products in 2016 (Research4Committees 2019[75]) and aquaculture is the best way to provide local seafood and decrease this deficit. There is potential to develop aquaculture facilities for algae, shellfish and fish (e.g. cod) in Swedish offshore marine areas.

There are strong conflicts over the use of space in coastal areas, so aquaculture is exploring ways to use the offshore space (Buck et al. 2018[76]). This is challenging for management, for protection from storms and for security, but new technologies are being developed in the international arena to enable the expansion of aquaculture and Integrated multi-trophic aquaculture (IMTA) to offshore areas.

According to a review commissioned by SWAM (2017)[77] marine aquaculture in Sweden is largely limited to mussels and rainbow trout, but techniques are being developed for farming other marine species such as wolffish, lobsters, native oysters (*Ostrea*) and macroalgae. There is interest in farming invasive Pacific oysters

70 European Commission (2013): Science Communication Unit, University of the West of England, Bristol (2012). Science for Environment Policy Future Brief: Underwater Noise. Report produced for the European Commission DG Environment, June 2013: *https://ec.europa.eu/environment/integration/research/newsalert/pdf/FB7_en.pdf*

71 HELCOM (2016): State of the Baltic Sea. Second Holistic Assessment 2011-2016: *http://stateofthebaltic-sea.helcom.fi/pressures-and-their-status/underwater-sound/*

72 Chatzigiannakou, M.A., Ulvgård, L., Temiz, I. et al. Offshore deployments of wave energy converters by Uppsala University, Sweden. Mar Syst Ocean Technol 14, 67–74 (2019). *https://doi.org/10.1007/s40868-019-00055-2*

73 Utrecht University 2(020): Floating solar panels at sea: higher yields, better for the landscape: *https://www.uu.nl/en/news/floating-solar-panels-at-sea-higher-yields-better-for-landscape*

74 SAPEA (2017): Food from the oceans: how can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits? Berlin: SAPEA. doi:10.26356/foodfromtheoceans: *https://www.sapea.info/wp-content/uploads/FFOFINALREPORT-1.pdf*

75 Research4Committees (2019): *https://research4committees.blog/2019/12/31/sweden/*

76 Buck et al. (2018): State of the Art and Challenges for Offshore Integrated Multi-Trophic Aquaculture (IMTA): *https://www.frontiersin.org/articles/10.3389/fmars.2018.00165/full*

77 SWAM (2017): Havsplanering med hänsyn till klimatförändringar. An Assessment of the Theoretical Basis, and Practical Options, for Incorporating the Effects of Projected Climate Change in Marine Spatial Planning of Swedish Waters: *https://www.havochvatten.se/download/18.52b25cb615f1927bbd9f077f/1508402546736/havsplanering-med-hansyn-till-klimatforandringar.pdf*

(*Magallana gigas*)[78] and Baltic cod[79], and in cultivating them at greater depths where the seawater is cooler. The Swedish Board of Agriculture and the Swedish Agency for Marine and Water Management (SWAM) have recently launched a new strategy for Swedish fisheries and aquaculture 2021-2026 and an action plan for the development of aquaculture[80].

Aquaculture (especially when it is based on artificial feed) is responsible for many environmental impacts. In Swedish marine areas, these impacts include pollution due to releases of excess nutrients (nitrogen and phosphorus) and chemicals (e.g. antibiotics) from fish farms (Olsson & Nellbring 1996[81]). Other impacts are negative effects on genetic diversity (e.g. due to overharvesting of wild broodstocks, inbreeding of cultivated populations and the escape of farmed organisms), the spread of parasites and invasive alien species, and the environmental impact of producing fish meal (which often comes from offshore fisheries).

In Sweden there is growing interest in establishing land-based aquaculture facilities where recirculating systems can decrease the release of pollutants and escapees, and in Integrated Multi-Trophic Aquaculture, where filter-feeders and macroalgae are farmed alongside fish and mussels, to reduce the environmental impact.

Aquaculture is the second most important vector for the spread of Invasive Alien Species. In the Kattegat and the Skagerrak, the European lobster (*Homarus vulgaris*) is threatened by introduction of the American lobster (*Homarus americanus*) (Katsanevakis et al., 2014 in SWAM 2017). The spread of AIS may be exacerbated by the expansion of offshore aquaculture where organisms can escape into the open sea. Climate change is predicted to increase the spread of AIS in the Baltic Sea (Holopainen et al (2016) in SWAM 2017).

Climate change is expected to affect the biotic and physical conditions for aquaculture in Swedish marine areas, due to factors such as changes in the abundance of species used to produce fish feed, lower salinity due to greater freshwater runoff, increased storm activity and increased pathogens and parasitic loads (SWAM 2017[82]). Climate change and higher sea temperatures may have negative impacts on the planned large-scale production of cold-water marine species such as wolffish, lobsters, and macroalgae.

Marine geoengineering

Marine geoengineering is defined as "a deliberate intervention in the marine environment to manipulate natural processes, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to result in deleterious effects, especially where those effects may be widespread, long-lasting or severe" (IMO[83]). Marine geoengineering includes techniques such as ocean fertilization, the sequestration of carbon dioxide in sub-seabed geological formations (Ginski 2018[84]) and the re-oxygenation of "dead zones" in the ocean.

Ocean fertilization proposes seeding the oceans with iron to stimulate the growth of phytoplankton and increase the uptake of carbon dioxide from the atmo-

78 *https://www.ivl.se/vart-erbjudande/forskning/vatten/teknikutveckling-for-odling-av-stillhavsostron.html#:~:text=Stillahavsostronet%2C%20%C3%A4ven%20kallat%20japanskt%20j%C3%A4tteostron%20%28Magallana%20gigas%29%20%C3%A4r,spreds%20hit%20som%20larver%20med%20str%C3%B6mmar%20fr%C3%A5n%20Danmark*.

79 ReCod project: *https://balticwaters2030.org/project/recod-utsattning-av-smatorsk-i-ostersjon*

80 Swedish Board of Agriculture (2021): Action plan for the development of Swedish aquaculture 2021–2026: *https://www2.jordbruksverket.se/download/18.3258773a179c55014dd4457a/1622622688851/ovr596.pdf*

81 Olsson I & Nellbring S (1996) Fiske och vattenbruk. Ekologiska effekter. Naturvårdsverket Rapport 4247.

82 SWAM (2017): Havsplanering med hänsyn till klimatförändringar. An Assessment of the Theoretical Basis, and Practical Options, for Incorporating the Effects of Projected Climate Change in Marine Spatial Planning of Swedish Waters: *https://www.havochvatten.se/download/18.52b25cb615f1927bbd9f077f/1508402546736/havsplanering-med-hansyn-till-klimatforandringar.pdf*

83 International Maritime Organization, IMO: Marine geoengineering: *https://www.imo.org/en/OurWork/Environment/Pages/geoengineering-Default.aspx*

84 Ginzky H. (2018) Marine Geo-Engineering. In: Salomon M., Markus T. (eds) Handbook on Marine Environment Protection. Springer, Cham. *https://doi.org/10.1007/978-3-319-60156-4_53*

sphere, but research suggests that fertilization with iron may not have a significant impact on phytoplankton growth on a global scale (Lauderdale et al. 2020[85]).

Carbon capture and storage on the seabed or in deep offshore waters is another geoengineering solution to counteract the release of carbon dioxide into the environment. In the ocean, dead marine organisms normally sink to the seabed and sequester carbon, but this process is counteracted by fisheries. Fisheries remove fish that would otherwise sink to the bottom, and trawling releases carbon dioxide from the seabed by disturbing sediments (Mariani et al. 2020[86]).

Carbon Capture and Storage (CCS) is a method for reducing concentrations of carbon dioxide (CO2) by capturing CO2 from industrial or fossil-fuel sources and storing it underground or in the ocean at great depth. The process involves capture, compression/liquefaction, transport (piping and shipping) and injection of CO2 into the ocean or ocean bed. The addition of CO2 can harm marine organisms, so there are fears that CCS may have a negative impact on deep-sea organisms and ecosystems (IPCC 2018)[87]. There are no CCS operations in Sweden at present, but geological surveys indicate that two marine areas are suitable for carbon dioxide capture and storage: The Faludden storage facility in the Borgholm formation in the southeast Baltic Sea, and the Arnager storage facility in the Arnagergrönsanden aquifer off southwestern Skåne (SWAM 2019[88]).

Oxygen conditions in the Baltic Sea have deteriorated mainly due to eutrophication (inputs of excess nutrients) but also due to rising water temperatures caused by climate change (Carstensen et al. 2014[89]). This has created an enormous "dead zone" of oxygen-deficient waters that covered about 28% of the area and 22% of the volume of the central Baltic and the Gulf of Finland in 2017 (ICES 2020b[90]).

A number of large-scale geo-engineering solutions have been proposed to counteract oxygen depletion in deep waters of the Baltic Sea e.g. pumping oxygen-rich surface water to greater depths (Conley 2012[91]). Although these geo-engineering schemes are unrealistic, extremely expensive and have undesirable side-effects (Conley 2012) some pilot studies have been carried out in the Baltic Sea and on the Swedish west coast. Maritime spatial planning needs to consider the ecosystem effects of such geo-engineering projects if they were to be carried out in Swedish offshore marine areas.

B. Impacts from human activities

Eutrophication

One of the best-known and well-studied anthropogenic impacts on Swedish seas, including offshore areas, is eutrophication (Andersen et al. 2015[92]). Nutrient enrichment due to inputs of nitrogen and phosphorus from land-based sources and

85 JM Lauderdale, R Braakman, G Forget, S Dutkiewicz, MJ Follows (2020): Microbial feedbacks optimize ocean iron availability. Proceedings of the National Academies of Sciences USA 117, 4842-4849: *https://www.pnas.org/content/117/9/4842*

86 Mariani et al. (2020). Let more big fish sink: Fisheries prevent blue carbon sequestration—half in unprofitable areas . *https://advances.sciencemag.org/content/advances/6/44/eabb4848.full.pdf*

87 PCC (2018): IPCC Special Report on Carbon dioxide Capture and Storage. 6. Ocean Storage: *https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_chapter6-1.pdf*

88 WAM (2019b): Swedish Agency for Marine and Water Management: Strategic Environmental Assessment of the marine spatial plan proposals for the Gulf of Bothnia, the Baltic Sea and the Skagerrak and Kattegat: *https://www.havochvatten.se/download/18.4b6151c116b836ca6982fa03/1561470379481/summary-sea-swedish-msp-review-stage.pdf*

89 Carstensen J., Andersen J.H., Gustafsson B.G. & Conley D.J. (2014). Deoxygenation of the Baltic Sea during the last century: *https://www.pnas.org/content/111/15/5628*

90 ICES 2020b: ICES Ecosystem Overviews. Baltic Sea Ecoregion. Published 10 December 2020: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/EcosystemOverview_BalticSea_2020.pdf*

91 Conley D.J. 2012: Save the Baltic Sea. Geoengineering efforts to bring oxygen into the deep Baltic should be abandoned. Nature 486(7404): 463-464.

92 Andersen J.H. et al. (2015): Long-term temporal and spatial trends in eutrophication status of the Baltic Sea. Biological Reviews: *https://onlinelibrary.wiley.com/doi/full/10.1111/brv.12221*

atmospheric deposition has caused shifts in species composition, extensive algal blooms and oxygen depletion (Carstensen et al. 2014[93], ICES 2020[94]). The Helsinki Commission's (HELCOM) Baltic Sea Action Plan includes efforts to combat eutrophication in the Baltic Sea (HELCOM[95]). The OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic has developed the OSPAR Eutrophication Strategy to combat eutrophication in the OSPAR maritime area (OSPAR[96]). MISTRA financed the MARE research programme (1999-2006) which successfully developed a user-friendly support system (Baltic NEST) to implement cost-effective strategies against eutrophication in the Baltic Sea[97].

Hazardous substances

Hazardous substances enter Swedish seas from land-based sources (industries, wastewater treatment plants, rivers), sea-based sources (spills of oil and toxic chemicals, dumping of hazardous waste and munitions) and atmospheric deposition (emissions from industries and shipping). These hazardous man-made substances are harmful to marine ecosystems as they are persistent, accumulate in the food web and are toxic to marine organisms.

The Baltic Sea is particularly affected by hazardous substances, as the waters of this semi-enclosed sea have a slow turnover time (about 30 years). Top predators such as seals, harbour porpoises and white-tailed sea eagles have been particularly hard hit, and hazardous substances have accumulated in the sediments of the Baltic Sea. HELCOM and OSPAR produce status reports on levels of hazardous substances in organisms and ecosystems in the Baltic Sea[98] and the North East Atlantic[99].

Climate change

The sixth assessment report[100] from the Intergovernmental Panel for Climate Change (IPCC) recently presented the effects of climate change due to human-caused emissions of CO2, which include warming of the global upper ocean (0–700 m), global acidification (decrease in pH) of the surface open ocean, lower oxygen levels in many upper ocean regions and an increase in global mean sea level. Many changes due to past and future emissions of greenhouse gases are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level. Past emissions of greenhouse gases have committed the global ocean to future warming, greater stratification of the upper ocean, acidification and deoxygenation.

Climate change is predicted to affect Swedish marine areas in several ways, e.g. higher water temperatures, changes in salinity in the Baltic Sea, deoxygenation, acidification and sea-level rise. In the North Sea, temperature trends are linked to ecosystem changes and so-called regime shifts, i.e. episodic changes in the productivity of key components of the ecosystem (phytoplankton, zooplankton, benthic

93 Carstensen J., Andersen J.H., Gustafsson B.G. & Conley D.J. (2014): Deoxygenation of the Baltic Sea during the last century: *https://www.pnas.org/content/111/15/5628*

94 ICES (2020): ICES Ecosystem Overviews. Baltic Sea Ecoregion: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/EcosystemOverview_BalticSea_2020.pdf*

95 HELCOM Baltic Sea Action Plan: *https://helcom.fi/baltic-sea-action-plan/#:~:text=Baltic%20Sea%20Action%20Plan%20Reaching%20Good%20Environmental%20Status,measures%20and%20action%20for%20a%20healthy%20marine%20environment*.

96 OSPAR Eutrophication Strategy: *https://www.ospar.org/work-areas/hasec/eutrophication#:~:text=The%20OSPAR%20Eutrophication%20Strategy%20sets%20the%20objective%20to,marine%20environment%20where%20anthropogenic%20eutrophication%20does%20not%20occur*.

97 Ambio (2007) Special Issue Science and Governance of the Baltic Sea: *https://www.jstor.org/stable/i399786*

98 HELCOM (2018) The sixth pollution load compilation (PLC-6): *https://helcom.fi/wp-content/uploads/2019/10/PLC-6-Executive-Summary-1.pdf*

99 OSPAR Quality Status Report 2010: *https://qsr2010.ospar.org/en/ch05.html*

100 IPPC Sixth Assessment Report: AR6 Climate Change 2021: The Physical Science Basis: *https://www.ipcc.ch/report/ar6/wg1/*

fish and pelagic fish) (ICES 2020a[101]). The temperature cycle of the North Atlantic (the Atlantic Multidecadal Oscillation, AMO) affects the ecosystems of the North Sea, but the mechanisms behind this link are not clear.

Climate change has already affected the Baltic Sea ecosystem (ICES 2020b[102]) as seen by an increase in the annual mean temperature of its surface waters and milder ice conditions in winter. It is expected that there will be large-scale alterations in the hydrography, biogeochemistry and physical properties of the Baltic Sea during this century, including long-term changes in temperature (Kniebusch et al. 2019a[103]), ice cover, salinity (Kniebusch et al. 2019b[104]), pH (acidity), oxygen, nutrient concentrations and primary production. This will likely result in direct and indirect effects on plankton communities, animal communities on the seabed, fish, seabirds, and habitats ICES 2020b).

Offshore marine areas have become more acidic as oceans absorb carbon dioxide from the atmosphere, and acidification of the Baltic Sea is likely to be exacerbated by decreases in salinity due to greater runoff of freshwater from land (Gustafsson & Gustafsson 2020[105]). Continuing acidification of the Baltic Sea will lead to changes in species composition and influence ecosystem function (Gustafsson et al. 2020[106]).

A special issue of Ambio on ecosystem-based management of the Baltic Sea under climate change[107] compiled research on the socio-economic system of the Baltic Sea and interactions between environmental problems such as nutrient enrichment, contaminant loads, overfishing, invasive species and climate change. In the Baltic Sea, climate change is expected to affect temperature, ice conditions, salinity, pH and oxygen conditions, which will in turn affect all the interacting environmental problems (Ambio 2015[108]).

Threats to biodiversity

The brackish Baltic Sea is home to several endemic species/populations that are under threat. These include the Eastern Baltic cod (large genetic differences show that it is a separate species from Atlantic cod) and the Baltic population of Harbour porpoise, which is genetically distinct from the Kattegat population. The Baltic population of Harbour Porpoise is classed as critically endangered (CR) on the IUCN Red List, and there are only about 500 individuals left according to inventories by the SAMBAH project (Carlström & Carlén 2016[109]). The Baltic harbour porpoise is threatened by fisheries (bycatches), underwater noise (shipping, pipelines) and hazardous substances (ASCOBANS 2020[110]).

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101 ICES 2020a. ICES Ecosystem Overviews. Greater North Sea Ecoregion. Published 10 December 2020: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/EcosystemOverview_GreaterNorthSea_2020.pdf*

102 ICES 2020b: ICES Ecosystem Overviews. Baltic Sea Ecoregion. Published 10 December 2020: *https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/EcosystemOverview_BalticSea_2020.pdf*

103 Kniebusch, M., Meier, H. E. M., Neumann, T., & Börgel, F. (2019a). Temperature variability of the Baltic Sea since 1850 and attribution to atmospheric forcing variables. Journal of Geophysical Research: Oceans, 124, 4168–4187: *https://doi.org/10.1029/2018JC013948*

104 Kniebusch M. et al. (2019b): Changing Salinity Gradients in the Baltic Sea As a Consequence of Altered Freshwater Budgets. Geophysical Research Letters: *https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019GL083902*

105 Gustafsson E. & Gustafsson B.G. 2020: Future acidification of the Baltic Sea – A sensitivity study. Journal of Marine Systems 211: *https://www.sciencedirect.com/science/article/pii/S0924796320300932*

106 Gustafsson E. et al. (2021): Science in brief: OMAI – Assessing acidification in the Baltic Sea: Monitoring and scientific basis. Nordic Council of Ministers: *https://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A1536613&dswid=-128*

107 Ambio (2015) Special Issue: Baltic Sea ecosystem-based management under climate change: *https://link.springer.com/journal/13280/volumes-and-issues/44-3/supplement*

108 mbio (2015): Special Issue: Baltic Sea ecosystem-based management under climate change: *https://link.springer.com/journal/13280/volumes-and-issues/44-3/supplement*

109 Carlström J & Carlén I. (2016): Skyddsvärda områden för tumlare i svenska vatten. AquaBiota Report 2016:04 (in Swedish): *https://www.aquabiota.se/wp-content/uploads/abwr_report2016-04_skyddsvarda_omraden_for_tumlare_i_svenska_vatten.pdf*

110 Ascobans (2020): Baltic Proper Harbour Porpoise in Focus: *https://www.ascobans.org/en/news/baltic-proper-harbour-porpoise-focus*

Offshore banks in the Baltic Sea and the Kattegat have high natural values (unique habitats with hard-bottom communities of plants and animals, seabirds, marine mammals). Threats include offshore wind farms, shipping (oil spills, underwater noise), fisheries (bycatches) and extraction of marine sediments. Many of the offshore banks are part of the EU Natura 2000 network of protected areas.

The offshore banks provide habitats for overwintering seabirds, and many are classified as Important Bird Areas (IBA) according to BirdLife International. In the Baltic Sea, *Hoburgs Bank* and *Northern Midsjöbank* south of Gotland are classed as Sites of EU importance and Congregations of Global importance for overwintering Long-tailed Duck and Black Guillemot (Skov et al. 2000[111]). Populations of Long-tailed Duck on these offshore banks declined drastically (by 64%) from over one million in 1993 to about 361 000 in 2009 (Nordic Council of Ministers 2011[112]). In the Kattegat, *Lilla Middelgrund* has the largest concentrations of overwintering fish-eating seabirds (Kittiwake, Razorbill, Guillemot) in the Baltic Sea and is classed as a site of EU importance with Congregations of Global importance (Skov et al. 2000).

Offshore banks are important geographical areas for Harbour porpoise in the Baltic Sea. In 2016 the Swedish government approved a large Natura 2000 area that includes *Hoburgs bank* and *Norra Midsjöbanken* to protect Baltic Harbour porpoises. Offshore banks are also important geographical areas for populations of Harbour porpoise in the Kattegat (*Fladen*, *Lilla Middelgrund*, *Stora Middelgrund*). The busy shipping lane near the northern tip of the Danish island of Jylland where the Kattegat meets the Skagerrak (61 000 vessels pass this area yearly) is also an important geographical area for Harbour porpoises. Harbour porpoise populations in the Kattegat and Skagerrak are red-listed as “vulnerable”.

C. Governance tools

This research programme needs to develop governance tools, principles, and concepts for governance of Swedish marine areas beyond the coastal zone, and explore their strength and limitations in the context in which they would be applied here. Research teams need to consider the following governance issues:

- International law context (what are the international law obligations that are relevant, what are the international law principles that are helpful to encourage effective cooperation and effective governance of the region)
- Integrated planning
- Area-based planning, including marine spatial planning and marine protected areas (MPAs)
- Tiered impact assessments
- Ecosystem-based approaches
- Resilience
- Protection of ecosystem services
- Precaution (precautionary principle)
- Transformational change
- Just Transition

111 Skov H. et al. 2000: Inventory of coastal and marine Important Bird Areas in the Baltic Sea. BirdLife International, Cambridge.

112 Nordic Council of Ministers (2011): Waterbird Populations and Pressures in the Baltic Sea. TemaNord 2011:550: *http://norden.diva-portal.org/smash/get/diva2:701707/FULLTEXT01.pdf*

It is also important to consider which issues should be included when deciding which tools or which combinations of tools will be most effective. Such issues are the distribution of power and influence, the distribution of capacity and resources, the equitable distribution of impacts and benefits of activities, and the distribution of risk and uncertainty. The research programme also needs to make integrated progress on achieving the Sustainable Development Goals (SDGs). Ideally this would mean progress on all of the SDGs, or at least progress on some without regression on others, while avoiding trade-offs between the SDGs.

The project applications need to demonstrate an understanding of the governance challenges associated with the effective governance of the offshore region they have chosen. First, this includes understanding the various jurisdictions involved in the governance of the region from the EU level down to municipal governments, including the various maritime zones in the region, and which national and subnational jurisdictions are involved in their governance.

Secondly, it includes identifying and understanding the perspectives, values and priorities of the key sectors and the interested members of the public that have a stake in the effective governance of the region.

Thirdly, it involves understanding the various governance and management tools available to contribute to the effective governance of the region, their individual strength and limitations, and the contribution each could make to the effective governance of the region.

Finally, it involves understanding the information needed for effective governance, the current state of knowledge, and the uncertainties associated with the current state of knowledge.

Potential governance elements

The following governance dimensions are relevant for the protection and sustainable use of offshore marine areas:

- Power & Influence (how does the governance approach address imbalances of power and influence among those with a legitimate interest in the outcome?)
- Institutions (formal, informal, who is involved, how does it contribute to an effective, efficient, and fair outcome)
- Tools (regulatory tools, economic instruments, voluntary measures, participatory governance tools, area-based planning, tiered impact assessment processes, etc) What combination of tools is needed for an effective, efficient, and fair outcome? Whose behaviours need to change, what is motivating the current behaviour, how can the behaviours be changed in the most effective, efficient, and fair manner?
- Who has rights, who has a stake, who has an interest, who should be involved and how?

Other important elements are stakeholder engagement and polycentric governance during key stages of the work

- Who should be involved in identifying the problem(s) to be solved? How should they be engaged?
- Who should be involved in identifying the information gaps that need to be filled to improve governance to solve the problem(s)? How should they be engaged?
- Who should be involved in the design of an effective governance approach to address the problem(s) you have identified? How should they be engaged?
- Who should be involved in implementing the governance approach? How should they be involved?

Generic issues

Apart from governance tools, there are some other issues that need to be addressed for planning, protection and sustainable management of Swedish marine areas beyond the coastal zone. For instance, we need databases and maps to compile scientific information on Swedish marine biodiversity and ecosystems (Nellbring 2000[113]). This is particularly important for offshore marine environments which are less accessible and less studied than coastal marine areas.

An important challenge is how to communicate information about the marine environment and raise awareness in key decision makers and stakeholders. This can be a difficult task, as life below the surface of the sea is not easily visible (Cederqvist et al. 2019[114]). Changes in environmental conditions on land are more easily seen with the naked eye, compared to underwater environments. A striking example of this is when highly visible blooms of cyanobacteria cover the surface of the Baltic Sea, which leads to public concern and debate about the causes of these algal blooms (Funkey et al. 2014[115], Karhu et al. 2020[116]).

There is a need to develop priorities for the protection of 30% of Swedish marine areas according to international commitments, e.g. which areas should be protected and why, to reach the Global Biodiversity Framework's proposed target of 30% protection of marine areas by 2030. The Swedish Environmental Protection Agency previously commissioned a scientific study on criteria for the selection of marine protected areas (Nilsson 1998[117]) and this analysis needs updating, in the light of the new Global and EU targets for marine biodiversity.

The Swedish Agency for Marine and Water Management (SWAM) has recently presented draft maritime spatial plans for the territorial waters and Exclusive Economic Zone in Sweden's three maritime spatial planning areas (SWAM 2019[118]). SWAM developed the planning tool *Symphony* for ecosystem-based spatial planning[119] to evaluate the cumulative environmental impact of various sectors/activities within the three maritime planning areas. However, the *Symphony* tool is not detailed enough to be used as a basis for specific Environmental Impact Assessments, e.g when planning for offshore wind farms. The *Symphony* model also contains a lot of uncertainty, in particular for offshore areas where there is a lack of data compared to coastal areas.

113 Nellbring S. (2000): Gaining an overview of data on biodiversity in Swedish seas: needs and prerequisites. Swedish EPA Report 5060 (in Swedish with English summary).

114 Cederqvist J., Lidström S., Sörlin S. & Svedäng H. (2019): Swedish environmental history of the Baltic Sea, Scandinavian Journal of History: *https://www.tandfonline.com/doi/full/10.1080/03468755.2019.1692067*

115 Funkey C.P. et al. (2014): Hypoxia Sustains Cyanobacteria Blooms in the Baltic Sea. Environ. Sci. Technol. 2014, 48, 5, 2598–2602: *https://pubs.acs.org/doi/10.1021/es404395a*

116 Karhu M. et al. (2020): Cyanobacterial blooms in the Baltic Sea: Correlations with environmental factors: *http://www.wimsoft.com/mati/2020_Kahru_et_al_Cynobacteria_correlations_HA.pdf*

117 Nilsson, P. 1998: Criterria for the selection of marine protected areas – an analysis. Swedish EPA Report 4834.

118 SWAM (2019): Marine spatial plans for the Gulf of Bothnia, the Baltic Sea and Skagerrak/Kattegat. National planning in Sweden's territorial waters and exclusive economic zone (EEZ): *https://www.havochvatten.se/download/18.56d79bf516b232e9db573cab/1560164109554/proposal-marine-spatial-plans-sweden-revieiw.pdf*

119 *https://www.havochvatten.se/en/eu-and-international/marine-spatial-planning/symphony---a-tool-for-ecosystem-based-marine-spatial-planning.html*

Sweden and international commitments

The scoping study (Johansson 2021) includes a comprehensive review of international commitments that are important for the protection and management of Swedish marine areas beyond the coastal zone. International organisations with special regulations for the Baltic Sea and Greater North Sea include HELCOM (the Baltic Marine Environment Protection Commission – also known as the Helsinki Commission), OSPAR (The Convention for the Protection of the Marine Environment of the North-East Atlantic), ICES (the International Council for the exploration of the Sea) and IMO (the International Maritime Organisation).

This research programme should contribute to the United Nations Decade of the Oceans[120] (2021-2031) with the vision "*The Science We Need for The Ocean We Want*". The Ocean Decade aims to build scientific capacity and generate knowledge that will directly contribute to the goals of the 2030 Agenda for Sustainable Development and other relevant global legal and policy frameworks.

This research programme should also contribute to the goals and targets of the United Nations Convention on Biological Diversity (CBD). The First Draft of the Post 2020 Global Biodiversity Framework has recently (July 2021) proposed eight targets to reduce threats to biodiversity (see Appendix 2 for a description of these targets). All of the eight targets are relevant for ecosystem-based management of Swedish marine areas beyond the coastal zone.

120 Ocean Decade: *https://oceandecade.org/*

Appendix 1 The ecosystem approach and ecosystem-based management

UNEP, the United Nations Environment Programme

UNEP (2011[121]) on "Taking Steps toward Marine and Coastal Ecosystem-Based Management" defines marine and coastal ecosystem-based management as follows:

- ***"Ecosystem-based management, or EBM, is an approach that goes beyond examining single issues, species, or ecosystem functions in isolation. Instead it recognizes ecological systems for what they are: a rich mix of elements that interact with each other in important ways. This is particularly important for oceans and coasts. A single commercially valuable fish species, for example, may depend on a range of widely separated habitats over its life, depending on whether it is young or adult, feeding, spawning, or migrating. It needs access to each habitat at the right time, as well as ample food, clean water, and shelter.***
- ***Because humans depend on an array of ocean and coastal functions for our well-being — including fish as food, for example — EBM recognizes that our welfare and the health of the environment are linked. Put another way, marine and coastal systems provide valuable natural services, or "ecosystem services", for human communities. Therefore, to protect our long-term well-being, we need to make sure marine and coastal ecosystem functions and productivity are managed sustainably. This means managing them in a way that acknowledges the complexity of marine and coastal ecosystems, the connections among them, their links with land and freshwater, and how people interact with them.***
- ***Management must be integrated, just as ecosystems are interconnected. One of the most important aspects of EBM is that it is fundamentally a place-based approach, where an ecosystem represents the place. Across an entire "place", EBM aims to manage each of the human uses at a scale that encompasses its impacts on marine and coastal ecosystem function, rather than scales defined by jurisdictional boundaries. Regional-scale management is an important practice in a range of places, including within the framework provided by regional governance mechanisms, such as the Regional Seas Conventions and Action Plans and other regional frameworks.***

121 UNEP (2011): Taking Steps toward Marine and Coastal Ecosystem-Based Management – An Introductory Guide: *https://www.unep.org/resources/report/taking-steps-toward-marine-and-coastal-ecosystem-based-management-introductory*

- ***To summarize the above, EBM involves two changes in how management is practiced: (1) each human activity is managed in the context of ALL the ways it interacts with marine and coastal ecosystems, and (2) multiple activities are being managed for a common outcome. To describe this, the terms ecosystem-based management and ecosystem approach (EA) are often used interchangeably, and they mean generally the same thing."***

HELCOM, the Helsinki Commission

The HELCOM Guideline[122] for the ecosystem-based approach for maritime spatial planning in the Baltic Sea is based on the definition that was adopted jointly by HELCOM and OSPAR in 2003:

> ***"the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity."***

ICES, the International Council for the Exploration of the Sea

ICES considers ecosystem-based management (EBM) to be the primary means of managing human activities that affect marine ecosystems[123]:

> ***"The aim of EBM is long-term sustainable use of marine resources with a resilient ecosystem. The health and productivity of the ecosystem should be maintained while allowing appropriate human uses for the benefit of current and future generations. EBM serves multiple objectives, involves strong stakeholder participation, and focuses on human behaviour as the central management dimension. ICES follows the principles laid down by the UN Convention of Biological Diversity (CBD) and UN Food and Agriculture Organisation (FAO)."***

122 HELCOM (2015): *https://helcom.fi/new-guideline-adopted-on-ecosystem-based-approach-in-maritime-spatial-planning-in-the-baltic-sea/*

123 ICES on the ecosystem approach: *https://www.ices.dk/advice/Pages/Ecosystem-approach.aspx?gmc=rjc3emSRHk&gm=231&gml=lD2xd5axcC&gmv=0*

Appendix 2 Convention on Biodiversity Action Targets

The United Nations Convention on Biological Diversity (CBD) is the international legal instrument for "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources" (United Nations[124]). The CBD First Draft of the Post 2020 Global Biodiversity Framework[125] (July 2021) has proposed the following Action targets under heading 1. "Reducing threats to biodiversity":

Target 1. Ensure that all land and sea areas globally are under *integrated biodiversity-inclusive spatial planning* addressing land- and *sea-use change*, retaining existing intact and wilderness areas.

Target 2. Ensure that at least 20 per cent of degraded freshwater, *marine* and terrestrial ecosystems are under restoration, ensuring *connectivity* among them and focusing on priority ecosystems.

Target 3. Ensure that *at least 30 per cent globally of land areas and of sea areas*, especially areas of particular importance for biodiversity and its contributions to people, are conserved through effectively and equitably managed, ecologically representative and well-*connected* systems of *protected areas and other effective area-based conservation measures* and integrated into the wider landscapes and *seascapes*.

Target 4. Ensure active management actions to enable the *recovery and conservation of species* and the *genetic diversity* of wild and domesticated species, including through ex situ conservation, and effectively manage human-wildlife interactions to avoid or reduce human-wildlife conflict.

Target 5. Ensure that the harvesting, trade and use of wild species is sustainable, legal, and safe for human health.

Target 6. Manage pathways for the introduction of *invasive alien species*, preventing, or reducing their rate of introduction and establishment by at least 50 per cent, and control or eradicate invasive alien species to eliminate or reduce their impacts, focusing on priority species and priority sites.

Target 7. Reduce pollution from all sources to levels that are not harmful to biodiversity and ecosystem functions and human health, including by reducing nutrients lost to the environment by at least half, and pesticides by at least two thirds and eliminating the discharge of plastic waste.

Target 8. Minimize the impact of climate change on biodiversity, contribute to mitigation and adaptation through *ecosystem-based approaches*, contributing at least 10 GtCO2e per year to global mitigation efforts, and *ensure that all mitigation and adaptation efforts avoid negative impacts on biodiversity*.

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124 United Nations: Convention on Biological Diversity, key international instrument for sustainable development: *https://www.un.org/en/observances/biological-diversity-day/convention*

125 *https://www.cbd.int/meetings/WG2020-03*

MISTRA
The Swedish Foundation for
Strategic Environmental Research

Sveavägen 25
SE-111 34 Stockholm, Sweden
phone: +46 8 791 10 20
mail@mistra.org www.mistra.org