SDG 14: Life Below Water

A review of research needs

Annex to the Formas report *Forskning för Agenda 2030: Översikt av forskningsbehov och vägar framåt*

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Summary

This literature review forms part of the project Formas Agenda 2030, which aims to identify research needs related to the 17 Sustainable Development Goals (SDGs) and to explore options for making structural changes in research policy and funding to foster progress on the SDGs. The project involves literature reviews and exploratory workshops focusing on three SDGs as examples: SDG 12 Responsible consumption and production, SDG 14 Life below water and SDG 17 Partnerships for the goals.

This review presents preliminary findings on research needs for SDG 14 Life below water. It focuses on three thematic areas closely linked to all seven targets under SDG 14, namely a) marine pollution, b) ocean and climate, and c) sustainable use of marine and ocean resources. The analysis identifies research gaps in the three thematic areas but also cross-cutting research gaps and potentials. Furthermore, the analysis considers cross-cutting issues such as linkages to other SDG targets and the challenges (and opportunities) of balancing social, economic and environmental dimensions of sustainable development, issues which are all closely interlinked to SDG 14.

Overview of the goal and targets

Table 1 lists the targets and means of implementation under SDG 14. This review does not consider the means of implementation. We cluster the seven targets under three themes and focus our review on those themes, which are: marine pollution (target 14.1), ocean and climate (target 14.2, 14.3 and 14.5) and the sustainable use of marine and ocean resources (target 14.7, 14.4 and 14.6).

Table 1. Overview of SDG 14. Targets in focus are in bold.

SDG 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development	
14.1	**By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution**
14.2	**By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans**
14.3	**Minimise and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels**
14.4	**By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics**
14.5	**By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information**

14.6	**By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation**
14.7	**By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism**
14a	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries
14b	Provide access for small-scale artisanal fishers to marine resources and markets
14c	Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want

Summary of findings: research needs

Cross-cutting issues and research needs

- **Balance competing social, economic and environmental demands for ocean resources**. The formulation of the SDG 14 and its targets aims to balance social, economic and environmental demands for ocean and marine resources. Although all three dimensions of sustainable development in the long-term would mutually benefit from a balanced approach, there is risk for trade-offs to occur in the short-term, e.g. between the environmental protection of marine resources and the economic use of the same resources.
- **Balance of timely policy measures and more research-informed policies**. By addressing the significant knowledge gaps on marine and ocean issues the research community could contribute to the formulation of more effective, efficient and sustainable policies. However, climate research often requires long-term observations which creates a mismatch with the shorter time perspective of national policy-making but also of Agenda 2030. The remaining 12 years until 2030 is challenging for developing new research projects, securing robust results, communicating these to policy, and securing political agreement on policy measures.
- **Local, regional and global perspective**. Despite differences in ecosystem characteristics and socio-economic context, many of the world's oceans and seas are facing similar challenges related to climate change. There is potential for Swedish national and regional research projects, e.g. acidification, to contribute to achieving progress of SDG 14 on a global level.
- **Need for improved models**. Uncertainty in modelling and predictions particularly affects Arctic research, partly because there is limited ability to conduct observations. Improved ocean models would contribute to better overall climate change predictions.

- **Need for forward-looking research**. Research in support of Agenda2030 needs to be forward-looking and identify issues which are not included in current goals and targets but which in the medium and long-term risk becoming important challenges for marine life. An important role for science is thus horizon scanning and identifying the next generation of sustainability challenges, not necessarily identified already in Agenda 2030.
- **Prospects and challenges of multi-disciplinary research**. Multi-disciplinary research has the potential to bridge existing knowledge gaps by bringing different disciplinary knowledge together, but is often constrained by structural challenges, including research funding structures not favourable to building more sustainable multi-stakeholder networks.
- **Science to fill knowledge gaps; but solutions rely on political will**. Although additional research efforts could contribute to providing a better understanding of climate change impacts on oceans, effective mitigating measures primarily depend on political will.

Thematic issues and knowledge gaps

Theme 1: Marine pollution

Marine litter

- By contributing systematic assessments of intervention options the research community could contribute to the design and development of policies and coordinated action across sectors and scale.
- Case studies and comparative studies of different policy measures on marine litter could contribute to policy-making by providing a better understanding of factors that explain why some policies succeed and others risk failing.

Microplastics

- Research gaps on the pathways of microplastics particles to the sea but also on the impact of microplastics on individual organisms and populations, as well as on humans.
- In Sweden, further research is needed to support policy-making processes and the design of additional preventive measures aimed at the main sources of microplastic emissions to the environment.
- On a regional and global level a standardised global monitoring programme for microplastics in freshwater and marine ecosystems would provide a understanding of the occurrence of microplastics and contribute to the design of better management strategies.

Eutrophication

- More research is needed to assess the effectiveness of existing and new mitigation activities for nutrition pollution and eutrophication, including for the Baltic Sea.
- The research community has a potential role to play in the development of platforms fostering collective action between stakeholders involved in the production and consumption chain of nutrition products.

Brownification

- More research is needed to identify the underlying causes of brownification, as well as for creating platforms promoting joint preventive measures with cross-sector stakeholders, including the forest industry.
- Knowledge gaps on the impacts on marine ecosystems.
- In Sweden more research on the links between dissolved organic carbon (DOC) and acidification is needed to improve acidification assessments in Swedish lakes and streams.

Theme 2: Ocean and climate

Ocean warming

- Large uncertainty and knowledge gaps persist for estimating the longer-term impact of ocean warming on the Arctic and its ecosystem services.
- Because of logistical and financial constraints for long-term observation, research projects in the Arctic are highly reliant on models. There is a need for a Pan-Arctic research action plan for observation systems and the development of specific Arctic system models.

Ocean acidification

- Increased research efforts are needed to develop coordinated and standardised methods of monitoring that can improve the reliability of projections of impacts on marine ecosystems, especially for the Arctic.
- The research community could contribute to bridge research gaps through interdisciplinary studies and increased cooperation between research communities and marine resource end-users. Research institutes could also help to provide more long-term platforms for stakeholder networks.

Protected areas

- There are considerable knowledge gaps on the Baltic Sea, and how its biodiversity is affected by human pressures, e.g. pollution, over-fertilisation, fishing pressure and climate change.
- Addressing the knowledge gaps on marine issues, which contributes to the uncertainty on the impacts of climate change projections, would benefit climate change research at large.
- The research community could further contribute to the design of policy strategies by providing more information on policy needs on the local level, and gathering interdisciplinary research contributions.

Theme 3: Sustainable use of oceans and marine resources

Blue economy and sustainable management of marine resources

- More research is needed to develop concepts related to sustainable marine development, including the “blue economy”, so that these concepts can serve as platforms for advancing a broader set of objectives and governance practices.

- To foster progress on ocean sustainability the research community could contribute to setting up frameworks and mechanisms bringing a range of stakeholders together – e.g. researchers, private sector and policy-makers – to promote joint action.
- Researchers could play an important role in bridging policy gaps for the high seas by researching different governance and sustainable management regimes.

Overfishing and fishery subsidies

- There is a need for more coherent reporting methods on trade and consumption of fish in Sweden to promote responsible seafood and fish consumption.
- The science community could further contribute to the protection of oceans, including addressing illegal fishing in the high seas by providing technological and innovative solutions, such as innovative satellite monitoring tools.
- The use and implementation of management plans of sustainable fishery would benefit from increased research efforts, e.g. developing tools for decision-making that can analyse trade-offs across sectors.

1 Introduction

This literature review forms part of the project Formas Agenda 2030, which aims to identify research needs related to the 17 Sustainable Development Goals (SDGs) and to explore options for making structural changes in research policy and funding to foster progress on the SDGs. The project involves literature reviews and exploratory workshops focusing on three SDGs as examples: Goal 12: Responsible Consumption and Production; Goal 14: Life Below Water; and Goal 17: Partnerships for the Goals.

This review presents preliminary findings on research needs for Goal 14: Life Below Water. It focuses on three thematic areas closely linked to all seven targets under SDG 14, namely a) marine pollution, b) ocean and climate and c) sustainable use of marine and ocean resources. The analysis identifies research gaps in the three thematic areas but also cross-cutting issues such as links to other SDG targets and the challenges (and opportunities) of balancing social, economic and environmental dimensions of sustainable development, issues which are all closely interlinked to SDG 14.

In the context of the SDGs, three distinct roles for science, technology and innovation have been defined by Nilsson (Nilsson 2016).
1. characterising the challenges
2. providing the solutions, and
3. strengthening public institutions and society.

In this review, we focus primarily on research needs in relation to the first and second roles, whereas the main report elaborate on the third role as well.

As an extension of this review, analysis could be made of the comparative potential of Swedish research to fill knowledge gaps at regional and global levels. Furthermore, good examples of Swedish research projects and collaborations could be identified. However, this goes beyond the current scope of the review.

1.1 Overview of the goals and targets

For this review, our point of departure has been the goal and its seven targets. Table 1 lists the targets and means of implementation under SDG 14. This review does not consider the means of implementation.

Table 2. Overview of Sustainable Development Goal 14. Targets in focus are in bold.

Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development	
14.1	**By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution**

14.2	**By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans**
14.3	**Minimise and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels**
14.4	**By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics**
14.5	**By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information**
14.6	**By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognising that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation**
14.7	**By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism**
14a	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries
14b	Provide access for small-scale artisanal fishers to marine resources and markets
14c	Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want

We focus our review on three themes as means of grouping the SDG targets: marine pollution (target 14.1), ocean and climate (target 14.2, 14.3 and 14.5) and the sustainable use of marine and ocean resources (target 14.4, 14.6 and 14.7).

1.2 Method and approach

SDG 14 was selected as one of three SDGs for which we test this review approach. This review should therefore be seen as a first attempt to identify research needs. The scope of this study did not allow for an exhaustive or in-depth assessment of the state of knowledge.

The first step was to **identify key themes** among the SDG 14 targets to find broader knowledge areas that relate to several targets and as means of grouping the targets. The criteria and approach for selecting these key themes are described below.

The second step was to conduct a **literature review**, to identify research needs explicitly or implicitly defined in existing literature. A key challenge was that the breadth of the SDG and

its targets means that there is a very wide scope of scientific and grey literature to cover. For this reason, the review primarily searched scientific assessments and synthesis reports. Based on these broader assessments and syntheses, more in-depth knowledge and analysis was gathered through searches for specific peer-reviewed journal articles. In addition to web-based searches, relevant literature was identified through contacts with experts and "snowballing" (using the reference list of a paper or the citations to the paper to identify additional papers).

The third step was to organise an **expert workshop**, held on 3 May 2018 in Stockholm. The workshop included 25 experts from science, policy and practice. The task of the workshop was to identify high-priority research needs, based on but not limited to preliminary findings of the literature review. Results from the workshop are incorporated in this review: research gaps, suggestions and input from workshop participants are referred to directly in the theme sections. Academic references and literature shared by workshop participants has also been added to the literature review.

A number of **challenges and limitations** should be noted on the method and approach of the literature review. First, as mentioned, the SDG targets are very broad and cover vast areas of knowledge, and exhaustive reviews are inevitably difficult. Second, despite their breadth, the SDG targets are a result of international negotiation, which means they may not always reflect local or national sustainable development priorities and problems, and there may thus still be gaps from local and national perspectives.

A third challenge was to ensure that the text is relevant and accessible to different target groups. We have tried to strike a balance between ensuring plain language and avoiding technical terms so that the analysis is accessible to policy-makers, and ensuring there is enough scientific substance for the analysis to be of interest for researchers in the field. Finally, if a systematic literature review was done in relation to SDG 14, it seems highly plausible that it could be subject to publication bias, data availability bias and reviewer selection bias. While we do not claim to provide a full systematic literature review, these common types of bias remind us that two key limitations must be emphasised when considering the results: a) only a limited part of the relevant literature has been reviewed; and b) when considering research gaps, we report on "known unknowns" rather than "unknown unknowns".

1.3 Identifying key themes

For all three SDGs reviewed in this project, the same set of four criteria were applied to identify key themes among targets. These criteria are as follows:

- Targets where lack of knowledge or research is not a critical barrier were excluded (e.g., targets for implementing a international political agreement).
- Targets which address similar issues and share a knowledge domain were clustered together.
- In some cases, our identified themes interpret or expand on the stated targets, namely to a) adapt targets to a Swedish context, and b) look at the more general sustainability issues implied by the goal but not necessarily reflected by the targets.
- In some cases, a smaller selection of targets were prioritised due to the limited scope of and resources for our study.

In addition, the following considerations informed the selection of key themes:

- Relevance: Themes should be of relevance for multiple governance levels and different regions: e.g. national (Sweden), regional (Nordic, Baltic Sea) and global.
- Links: Themes should be closely linked to SDG 14 targets but also linked to other SDGs (and ideally progress on the theme would have implications for Agenda 2030 more broadly).
- Topical: Themes should relate to timely and "topical" issues highlighted in research platforms.

For the last criterion on topical and timely themes, strategic guidance has been drawn from discourse in the international community on SDG 14, including the thematic categorisation applied by research institutes in background documents, or policy briefings, or declarations prepared for or delivered at the 2017 UN Ocean Conference in New York and the review of the SDGs at the High-level Political Forum on Sustainable Development. For example, background briefings and declarations made by the Government of Sweden at the Ocean Conference highlighted three "critical areas": marine litter, ocean and climate change, and sustainable blue economy.

Following the criteria mentioned above the following three themes have been selected for this analysis.

- Marine pollution
- Ocean and climate
- Sustainable use of marine and ocean resources

Table 3 shows how the SDG 14 targets can be grouped according to the three key themes.

Table 3. Targets included under each identified key theme

Marine pollution	Ocean and climate	Sustainable use of marine and ocean resources
14.1	14.2	14.4
	14.3	14.6
	14.5	14.7

2 Research challenges

2.1 Oceans: everyone's problem, no one's responsibility

Covering more than 70% of the world's surface the economic, social, and environmental importance of the oceans and seas cannot be overestimated. The market value of marine and coastal resources and industries is estimated at US$ 3 trillion per year, or about 5% of global GDP (UN 2017a; CBD 2016). Key economic services derived from oceans include transportation of goods, fisheries and tourism but also potential new uses such as the

generation of renewable energy and mining of materials (ICSU 2017). Furthermore, oceans are essential for human wellbeing both as a source of food and livelihood. More than three billion people depend on the oceans as their primary source of protein, and marine fisheries directly or indirectly employ over 200 million people (UN 2017a). Furthermore, oceans and coastal areas are estimated to partially support about 75% of the global population, residing in the wider coastal margins. Furthermore, oceans also host the largest connected ecosystem which provides services such as climate stability, oxygen generation, nutrient cycling and food production. Oceans play a vital role in climate change mitigation, absorbing about a third of carbon dioxide produced by humans (ICSU and ISSC 2015).

Pressures such as climate change and other changes brought about by humans, such as pollution, are putting the wellbeing of the oceans and thus the provision of its services at risk. In recent years research has helped to improve awareness of the importance of the ecosystem services and resources of the oceans to all countries worldwide. Yet oceans and seas have for a long time not been prioritised in international forums or on national agendas. A central challenge is the transboundary nature of marine resources and human pressure on oceans. Collective and coordinated action by governments at sub-regional and global level is needed to address issues such as marine pollution (IASS 2017). In the absence of coordinated and enforced regulations, unsustainable use of ocean resources risk resulting in a “tragedy of the commons”. The term, first introduced by Garrett Hardin (1968), refers to situations where it is difficult and costly to exclude potential users from common-pool resources. As a consequence the finite resources will be exhausted by rational, utility-maximising individuals rather than conserved for the benefit of all (Ostrom 2008).

Another factor likely to contribute to the lack of prioritisation is that oceans have for a long time been considered an expert area primarily discussed by scientists who are disconnected to the high-level arenas of policy-making. Furthermore, a fragmented institutional system for regulating the management of marine natural resources under the United Nations Convention on the Law of the Sea (UNCLOS) has contributed to a lack of coherent follow-up on national and global ocean commitments (IASS 2017). In recent years an increased focus on oceans has been noted in high-level processes such as Agenda 2030, the development of an ocean-specific SDG, the 2017 UN Ocean Conference on SDG 14, and in the oceans reports of the Intergovernmental Panel on Climate Change (IPCC). This shift was noted by the Swedish minister Isabella Lövin at the opening of the Ocean Conference:

> “For the first time, the full range of ocean issues was raised at the UN General Assembly. It has moved from being an area for marine and fisheries experts to one that concerns everyone's survival…. The silo mentality that has been the curse of the oceans is finally beginning to erode.”(GOS 2017).

The increased interest in oceans is also reflected in increased investment in ocean research, which has resulted in improved data coverage and in an increase in the number of marine scientists and research and education bodies (ECESA 2017).

2.2 SDG 14 and its targets: background and formulation

SDG 14 aims to "Conserve and sustainably use the oceans, seas and marine resources for sustainable development". Progress on SDG 14 and achieving sustainable use and development of oceans and marine resources is closely linked to the underlying challenge of Agenda 2030, that is, balancing the social, economic and environmental dimensions of sustainable development. More specifically, SDG 14 concerns how to balance competing uses of water resources in an equitable manner while maintaining water quality and ensuring healthy and diverse ecosystems (Berggren and Lymer 2016).

Over-exploitation of oceans and marine resources risks negative impacts on ecosystems in other areas and jeopardise their ability to meet social, environmental and economic demands (ICSU 2017). All three dimensions of sustainable development would thus in the long-term gain from more regulated sustainable management of oceans and their resources. Yet in the short-run, sustainable management risks substantial trade-offs. For example, conservation measures may in some cases limit options for economic growth. Progress on SDG 14 thus requires well-adapted managements plans for marine resources, at international, national and local levels, which mitigate tensions and build on synergies between environmental protection and social and economic uses of resources.

Different stakeholders and forums tend to emphasise different aspects of SDG 14, which shifts the balance between the economic, social and environmental dimensions. For example environmental dimensions of SDG 14 (e.g. protection and marine pollution but also sustainable management and development of fisheries) were emphasised in the Government of Sweden's reporting to the High-level Political Forum on Sustainable Development (HLPF) in 2017 (GOS 2017). On the other hand, many developing countries emphasise the cross-cutting relationships between the three dimensions, including small island developing states, where oceans and marine resources tend to play a more fundamental role in financial, social and environmental wellbeing (ECESA 2017). At the HLPF in 2017, SDG 14 was reviewed under the theme of poverty reduction and prosperity promotion, together with goals on hunger, health, gender equality, industry, innovation and infrastructure. This grouping suggests an emphasis on oceans as a source of income rather than on conservation and environmental protection (Berggren and Lymer 2016). If SDG 14 had been reviewed together with SDGs on ecosystems and climate change it would have indicated a stronger focus on the environmental and protection dimensions of SDG 14.

2.3 The SDG 14 targets: relevance and measurability

SDG 14 and its seven targets broadly address human interaction with, and the environmental, sustainable economic use of, oceans, seas and marine resources. Coastal zones are included, as are conservation and protection of resources and social and institutional dimensions of ocean governance (ICSU 2017; ECESA 2017).

The goal and targets are understood to cover dominant ocean industries such as fisheries and resource extraction) which are key in promoting sustainable development of the ocean (ICSU 2017). Targets 14.1 (marine pollution), 14.2 (conservation) and 14.4 (overfishing) are judged to have the strongest scientific foundation and to be the most important of the seven targets (ICSU 2017). Furthermore, one constraint of the targets is that while they focus on existing industries and "challenges", they do not anticipate future challenges and issues that may

emerge following new potential uses of ocean resources. For example, there are few references to new technologies such as blue carbon and bioprospecting, which are intended to be used to explore oceans to develop new products for market. Such technologies imply large risks (ICSU 2017). Some of the targets would also benefit from clearer wording and better quantification; for instance goals on equity or fair access, marine spatial planning efforts and improved governance/institutions (ICSU 2017). In addition, to foster the spirit of an indivisible idea of Agenda 2030, a stronger use of ocean indicators in other SDGs would have been desirable (ICSU 2017).

An important constraint on the measurability and follow-up of SDG targets on a global and regional level is the absence of standardised monitoring approaches. For example, measuring and comparing marine pollution of microplastic between regions is difficult without a standardised measure. Limited ability to compare developments between regions constrains global efforts to keep track of progress towards SDG 14 (ICSU 2017). The thematic review of SDG 14 for the 2017 HLPF identified an important need for increased international collaboration and networks for ocean monitoring. The monitoring and information gaps are particular important for target 14.3 on acidification and climate change (ECESA 2017).

Statistics Sweden (SCB) found that most of the SDG 14 targets are relevant for Sweden (SCB 2017). Sweden has already met several of the targets. The global target to conserve at least 10% of coastal and marine areas by 2020 was met by the Swedish Government in 2017 (GOS 2017). SCB stresses the value of and potential to develop longer-term indicators for SDG 14, albeit without providing any concrete suggestions (SCB 2017).

A possible reason why Sweden is well positioned to deliver on SDG 14 could be that marine life and ocean issues are mainstreamed to a substantial extent in national environment priorities. For example, the 16 environmental quality objectives which Sweden adopted in 1999 include a balanced marine environment and zero eutrophication. A mapping exercise of the environmental quality objectives and the SDGs finds a strong connection between five of the objectives and three of the SDG 14 targets (Helker Lundström 2017).

2.4 SDG 14 interactions with other goals and targets

SDG 14 is recognised as having a cross-cutting role in Agenda 2030. Conservation and sustainable use of the ocean is expected to have positive (largely indivisible, reinforcing and enabling) interactions with other SDG goals (ECESA 2017). The nature and strength of these interactions are dynamic and context-specific and can range from synergistic to opposed interdependencies. A better understanding of these interactions would help in exploring synergies and developing methods for mitigating negative impacts (Weitz et al. 2017; ICSU 2017). Below is a brief overview of some key interactions between targets, identified on a global level.

SDGs 6, 7 and 11

SDG 6 on water and sanitation is strongly linked to SDG 14 on issues such as water quality and water resources management. More specifically, water uses and developments upstream on land and along rivers risk impacting on ecosystems downstream in coastal zones and marine environments (Berggren and Lymer 2016). Other goals which risk implying significant

downstream effects include access to energy (SDG 7) and promoting sustainable urban and industrial development (SDG 11).

SDGs 1, 2, 8 and 12

Because of the huge economic and social value of healthy oceans, both as a source of food and income, progress on SDG 14 is expected to contribute to poverty alleviation (SDG 1), hunger (SDG 2) and economic growth (SDG 8). At the same time, there are risks that progress on measures for protecting marine areas could constrain access to resources that are important for poverty alleviation and economic growth (ICSU 2017; ECESA 2017). Furthermore, efforts to achieve SDG 2 (e.g. doubling of incomes for small-scale producers), risk putting additional pressure on the wellbeing of ocean ecosystems and increase downstream effects of land use on marine ecosystems (ICSU 2017). Progress on sustainable consumption (SDG 12) is vital for addressing key challenges for SDG 14, such as marine pollution.

SDGs 13 and 15

Work on combating climate change (SDG 13) and protecting ecosystems (SDG 15) needs to be integrated with SDG 14. Progress on these goals would be mutually reinforcing, because progress in restoring and protecting the health of oceans and marine resources would contribute to stronger resilience and greater capacity to adapt to climate change (ICSU 2017; ECESA 2017).

SDG 16

Efficient management of ocean and marine resources relies on effective, accountable institutions and participatory decision-making, which implies strong links between SDG 16 and SDG 14. More specifically, progress on the conservation and sustainable use of ocean resources is strongly linked to progress on efforts to enforce and strengthen regulatory frameworks, for example by tackling illegal, unregulated and unreported fisheries and the reduction of corruption and bribery (ICSU 2017).

In the SEI Formas workshop on SDG 14 participants highlighted that in addition to considering trade-offs between goals it is important to recognise that stakeholders are affected by progress on the SDGs in different ways. Uneven power balances on an international level, for example between developed countries and small island developing states, affect states' ability to influence global policy-making linked to Agenda 2030. Furthermore, there is a risk that uneven power relations on national and sector levels between stakeholders with competing interests and demands for marine resources, such as between industrial fishing companies and small-scale fishers, will lead to SDG goals and targets being pursued primarily in line with the priorities of stronger interest groups. There is a need for more comprehensive and inclusive socio-economic, political and environmental assessments to deepen understanding of potential trade-offs, and instead promote equity between stakeholders with contradictory demands on marine resources and the implementation of the SDGs. More information on one potential tool to support such assessments – ecosystem services mapping – is provided in section 5.1 on sustainable management of marine resources.

3 Key theme 1: marine pollution

Marine pollution is a complex environmental problem. The pathway of litter to the sea involves polluting activities in many sectors based on land and sea. Addressing marine pollution is thus closely linked to achievements in waste and litter management across sectors as well as progress in other SDGs (SwAM 2017). Target 14.1 and associated indicators stress in particular the problem of plastic debris and nutrition pollution, linked to eutrophication. An issue which is not mentioned under SDG 14 but could become a more pressing issue in the medium term is brownification, which currently primarily affects the quality of freshwater but which is also linked to oceans' wellbeing. Under the marine pollution theme, the analysis will focus on the following four areas:

- Marine litter
- Microplastics
- Eutrophication
- Brownification.

3.1 Marine litter

Marine litter (also called marine debris) is defined as waste discharged by humans into coastal or marine environments, resulting from activities on land or at sea. Marine litter is recognised as a cross-sectoral and transboundary problem. Sources and pathways of marine litter are diverse which makes it difficult to estimate exact quantities and routes. In general, around 80% of marine litter worldwide is estimated to originate from land-based sources while the remaining 20% come from sea-based sources (Eunomia 2016). The lion's share of marine litter consists of plastics, which is due to the large-scale use of plastics and their durability and persistence in the environment (Ryan et al. 2009)(Ryan et al 2009).

The quantities of plastic litter emitted to the oceans are particularly high for **developing countries**. More specifically, 83% of the 4.8–12.7 million tons of land-based plastic waste which ends up in the oceans originates from 20 developing countries, with China, Indonesia and the Philippines emitting the most. A key characteristic of the largest marine polluters is the lack of a functioning waste management system (Löhr et al. 2017; Jambeck et al. 2015). Coastal and marine litter also affects developed countries. For **the EU** the potential cost of cleaning coasts and beaches of marine and coastal litter was assessed at almost € 630 million per year. The cost of marine litter to the fishing industry has been estimated at € 60 million per year, representing 1% of total revenues of the EU fishing fleet in 2010. The quick accumulation and dissemination of marine litter makes it one of the fastest growing threats to the wellbeing of the world's oceans (EC 2018).

In Sweden the northern parts of the west coast are particularly affected by marine litter and identified as one of the worst affected areas in Europe. Research on marine litter highlights the environmental challenges but also the large economic costs of inefficient uses of material and waste (SwAM 2017). On a regional level marine litter is a rather new area of research, but an increased amount of work is ongoing within the two Regional Sea Conventions, OSPAR for the North-East Atlantic and HELCOM (The Baltic Marine Environment Protection Commission) for the Baltic, as well as in the EU and the Marine Strategy Framework Directive.

Progress on the SDG target on marine litter is closely linked to progress on other SDG targets, more specifically to untreated wastewater (SDG 6), waste management in sustainable cities (SDG 11), reduction as well as recycling and reuse of water waste (SDG 12). Progress on these targets however requires collective actions among a large and diverse set of actors representing different interests across sectors and scales (Löhr et al. 2017).

Research gaps

The scientific understanding of the problem of marine litter and the range of effective solutions has significantly increased in recent years. Yet many knowledge gaps remain on the sources, pathways and effects of marine litter on the environment (Löhr et al. 2017; SwAM 2017). In addition to further research efforts in assessing these links, the research community could also more systematically assess possible interventions to contribute to the design and development of policies and coordinated action across sectors and scales. Furthermore, because effective, efficient and legitimate actions require a thorough understanding of the local governance context, academia could also contribute by producing more case studies and comparative studies. Specifically, these studies could contribute to a better understanding of the underlying and contextual factors that explain why certain policies and legal institutions aiming to prevent marine pollution are more successful in one context than in another (Löhr et al. 2017).

Participants at the SEI Formas workshop highlighted that the problem of chemical pollution must be addressed if progress on healthy oceans is to be made. Chemicals and waste management are linked to other SDG targets under health and wellbeing targets (3.9) and sustainable consumption (12.4) but not specifically mentioned under SDG 14. Yet workshop participants identified important research needs on pharmaceutical residues impact on marine organisms and humans, not the least of endocrine disruptors. The combined effect of these substances and other human-induced stress factors on marine organisms and ecosystems is another area of limited knowledge. Workshop participants also stressed the need for more systematic review of global use, release and dispersion of chemicals and dangerous substances to oceans and seas.

Workshop experts also highlighted the need to address the cross-sectoral aspects of marine litter by applying transdisciplinary research approaches. Marine science can on its own not solve the problem of marine litter, especially plastics, instead strong collaboration is needed with key polluting sectors, such as food manufacturing and processing systems.

3.2 Microplastics

Plastics are lightweight, durable and cheap, yet plastic is a most widely used product. Yet derived primarily from petrochemicals and composed of non-biodegradable material, plastics constitutes at the same time a significant environmental threat (Ryan et al. 2009). The global production of plastic has increased rapidly in the past 50 years. Between 2004 and 2014 the total production of plastic increased by 28% to a total of 300 million metric tons per year (Worldwatch Institute 2015). Plastic litter enters the sea in different shapes and sizes but is gradually broken down into smaller pieces. In scientific literature marine litter and plastic is

divided into four different size classes: micro-, meso-, macro- and mega-debris (Moora and Piirsalu 2016; Löhr et al. 2017).

The problem of microplastics in the marine environment is increasingly recognised, both by policy-makers and the research community, as well as the general public. The number of peer-reviewed articles on microplastics more than doubled between 2012 and 2016. A search on "microplastic" and "effects" on Web of Science generated total 180 published articles between 1985 and 2015 (Kärrman et al. 2016). Research has contributed to a better understanding of the process of how plastics, due to exposure to ultra violet light as well as currents and waves at sea, degrade over time into smaller particles. The particles act as magnets, attracting and carrying bacteria and various contaminants which negatively affect organisms and bringing a risk that these will move up the food chain to humans. The annual dietary exposure for European shellfish consumers is estimated to 11 000 microplastic fragments per year. However, due to the complexity of estimating microplastic toxicity it is currently not possible to estimate the risks this exposure implies for human health (Van Cauwenberghe and Janssen 2014). Improved awareness of the potential risks of microplastics has resulted in an increased demand for mitigating measures. Policy-makers in Sweden and Europe, and also the US and other parts of the world, have recently brought into force, or are in the process of designing, policies aiming to ban products that contain microplastics, such as some types of cosmetics (Östersjöcentrum 2015). Studies in Denmark and Germany however estimate that only a minor share – 0.1–0.3%, which equates to 66 tons per year – of emissions of microplastics originates from cosmetic products (KEMI 2016). By far the largest source of emissions from Sweden is road wear and abrasions of vehicle tyres, with emissions estimated at 8190 tons per year (IVL 2016).

Research gaps

A number of research gaps on microplastics persist. For example, in order to develop efficient policies, more information is needed on the pathways of microplastics particles to the sea. This information is needed to bridge the gap between the amounts of microplastics estimated on the basis of emission source and actual levels found in the sea in field data (IVL 2016). More research is also needed on the impact of microplastics on individual organisms and populations of organisms, as well as on humans (Kärrman et al. 2016). However, bridging either of these research gaps is challenging, not least due to the difficulty of designing experiments which can distinguish plastic-specific impacts from impacts caused by other particles (Ogonowskia et al. 2018).

In Sweden there is strong demand for more knowledge on microplastics as input to developing policies and measures to tackle the issue. Yet the complexity of conducting research on microplastics makes it difficult for the research community to respond to timebound policy-making processes. This is illustrated by the ban on personal hygiene products containing plastic microbeads, which will enter into force on 1 July 2018 in Sweden. The Swedish Chemicals Agency (KEMI) argued that although more research is needed on the origins and pathways of microplastics entering the sea, the existing research knowledge was sufficient for implementing the suggested ban. The cost of waiting for further scientific information in terms of delayed policy implementation was considered too high. More research was however recommended before additional measures addressing other sources of microplastics is developed (KEMI 2016).

In a more recent study by KEMI on microplastics in products not covered by the upcoming ban, research gaps were identified for the smallest microplastic particles and the effects of their possible transmission through waste water collection and treatment plants to the ocean as well as to cropland through the application of sludge for fertiliser (KEMI 2018). Furthermore, currently there is no internationally agreed definition of microplastics in terms of sizes, and characteristics such as solubility and degradability. The lack of a joint, clear and precise definition constrains the development of regulations, not the least for sectors and companies working in international markets. KEMI identifies a need for Swedish involvement at the EU or global level in a joint definition of microplastics (KEMI 2018).

On **regional and global levels** the prospects for designing measures and management strategies on microplastics is constrained by the lack of a standardised global monitoring programme. Standardised methods for sampling and analysing marine microplastics for monitoring purposes is thus identified as a strategic area for further research at national, regional and global levels (Kärrman et al. 2016; SwAM 2017).

3.3 Eutrophication

Nutrition pollution, especially from nutrients such as nitrogen and phosphorus, entering oceans and seas is a widespread and growing problem. Nutrient over-enrichment causes eutrophication, which is a process that causes structural changes to ecosystems, including elevated levels of algal blooms, deterioration of water quality, oxygen depletion and changes in species composition. The main sources of nutrition pollution are agriculture, wastewater and fossil fuels. The main pathways of nutrients to the seas include atmospheric deposition of nitrogen and direct waterborne discharges, either from coastal activities or ships (HELCOM 2014; UN 2017b).

Sweden is highly affected by eutrophication in the Baltic Sea, both on a **national and regional level**. In 2013 the entire open Baltic Sea was assessed as being affected by eutrophication (HELCOM 2014). This indicates that measures taken to reduce external inputs of nitrogen and phosphorus to the sea have not yet had the desired impact on eutrophication.

Research gaps

Compared with other related issues there are comparatively few evaluations of measures taken to reduce flows of nitrogen and phosphorus into seas and oceans. Not only is there a strong need for more research to review the effectiveness of existing measures, but also to explore new mitigation activities (Grimvall et al. 2017). A survey of the current state of scientific knowledge on the Baltic Sea identified research gaps in the biogeochemical cycles of the eutrophication process. More specifically, big research gaps were identified for assessing the effectiveness of potential mitigation measures of nutrition pollution from agriculture and other land-based activities, as well as on the capacity of the coastal zone to serve as a natural “filter”, by retaining nutrients through sedimentation (Rolff and Nekoro 2013).

Another potential role for the research community is to contribute to the development of tools and platforms which can facilitate collaboration between stakeholders involved in the production and consumption chain of nutrient products. To foster collective action, a greater effort is needed to identify common goals and joint interests in reducing marine eutrophication, for example by techniques for nutrient recycling that have commercial value (Grimvall et al. 2017).

3.4 Brownification/browning

Lakes and rivers in the Northern Hemisphere have the last 50 years experienced problems of the water getting darker. The phenomena is called browning or brownification and is linked to increases in concentrations of dissolved organic carbon (DOC) (Sonesten 2010). Browning has a negative impact on waters' ecosystem services. Research efforts have so far primarily focused on freshwater, but more recent research warns of growing pressure on marine environments as brownified fresh water joins ocean and sea water. More specifically, studies establish a connection between increased amounts of DOC and humic substances and increases in nutrition pollution from phosphorous and other minerals (Sonesten 2010).

A recent report identified increased use of land in the forestry industry, especially for fir tree plantation, and changes in acidification levels possibly linked to liming of lakes, as key contributing factors to increased levels of DOC in the Baltic Sea and in coastal and marine ecosystems. Furthermore, the report points to uncertainty about the impact of brownification on marine ecosystems. Results, however, suggest that increases of DOC in marine ecosystems do not only affect the quality of water but also nutrient turnover and species composition (Svedäng et al. 2018).

Research gaps

The design of measures to prevent brownification is constrained by limited knowledge on its underlying causes (Monteith et al. 2007; Sonesten 2010). In order to identify preventive measures, more research is needed on polluting factors, as well platforms for stakeholder consultations, involving the forest industry, local and regional authorities (länsstyrelsen), water agencies and universities (Svedäng et al. 2018). More research is also needed on assessing the impacts on marine ecosystems for example impacts on plankton and the food chain, for example links to thiamine deficiency.

A recent comprehensive **review of Swedish studies** on brownification by the Swedish Environmental Research Institute (IVL) investigates changes in the amount of DOC using data from the past 30 years. The report highlights a need for more research into the links between DOC content and acidification in order to improve acidification assessments of Swedish lakes and streams (Stadmark, et al. 2017).

3.5 Summary of identified research gaps for marine pollution

Marine litter

- The research community could contribute to the design and development of policies and coordinated action across sectors and scales through systematic assessments of potential interventions.
- Case studies and comparative studies of different policy measures on marine litter can contribute to policy-making by providing a better understanding of factors explaining why some policies succeed and others do not.

Microplastics

- There are significant research gaps on the pathways of microplastics particles to the sea, as well as on the impact of microplastics on individual organisms, populations of organisms, and on humans.
- In Sweden, policy-making processes and design of additional preventive measures addressing the main sources of microplastics emission to the environment needs to be supported by further research.
- At regional and global levels, a standardised global monitoring programme for microplastics in freshwater and marine ecosystems is needed.

Eutrophication

- More research is needed to assess the effectiveness of existing measures, and to explore new mitigation activities for nutrition pollution and eutrophication, including for the Baltic Sea.
- The research community can have a role to play in developing platforms to support collective action between stakeholders involved in the production and consumption chain of nutrition products.

Brownification

- More research is needed to identify the underlying causes of brownification, and for creating platforms that promote preventive measures developed jointly by stakeholders across sectors, including the forestry industry.
- There are knowledge gaps on the impacts of brownification on marine ecosystems, for example on plankton and the food chain (e.g. links between brownification and thiamine deficiency).
- In Sweden, more research on the links between dissolved organic carbon (DOC) content and acidification is needed to improve assessments of acidification in Swedish lakes and streams.

4 Key theme 2: ocean and climate

Researchers and policy-makers have been aware of climate change and global warming for more than 60 years. However, the role and impact of the oceans in climate change has long been neglected (Laffoley and Baxter 2016). In recent years the scientific community has given more attention to issues related to oceans and climate change, such as ocean acidification and ocean warming. This research has increased awareness of how climate change and other human-induced stresses factors are putting the ecosystem services of oceans at risk. The consequences of disrupted ocean ecosystems would not only have significant consequences on marine organisms, it would also severely impact countries and humans on local and global level. (Laffoley and Baxter 2016). Furthermore, in an attempt to put an economic value of the ecosystem services provided by oceans, coastal and marine resources are estimated to contribute US$ 28 trillion annually to the global economy (ESC UN 2017).

This review of research gaps on ocean and climate focuses on the following three issues:

- ocean warming
- acidification
- marine protection.

4.1 Ocean warming

Ocean warming has been referred to as possibly "the greatest hidden challenge of our generation" (Laffoley and Baxter 2016). Despite the key role oceans play in providing ecosystem services such as mitigating global warming, ocean warming has not been a prioritised research area.

Oceans are highly affected by global warming: the speed of warming in the ocean is estimated to happen between 1.5 and 5 times faster than on land. More than 93% of the warming since the 1970s caused by human activities has been absorbed by the ocean, and data suggest a worrying accelerating upward trend in ocean warming. It is predicted that ocean warming will bring irreversible changes with significant impacts on ecosystems (Laffoley and Baxter 2016). Oceans and seas in different regions are reacting differently to global warming. For example, an average global increase of 2 ˚C is expected to imply a 3.5 to 5˚C increase in the Arctic (Laffoley and Baxter 2016; Schlosser et al. 2016).

Ocean warming, but also ocean acidification, is strongly linked to climate change. This means that addressing and mitigating their negative impacts is strongly tied to progress on the implementation of international climate agreements (Laffoley and Baxter 2016). Although more research can improve knowledge and help make better climate change projections, progress on these international agreements is primarily a question of political will.

Research gaps

The Arctic has been called "a desert as far as research is concerned" (Gascard 2018). There is increased knowledge on the global services provided by the Arctic, such as reflectivity of solar radiation, storage of carbon in permafrost, or storage of glacial ice (which prevents sea level rise). Yet there are substantial uncertainty and knowledge gaps in estimating the longer-term impact of a significant temperature increase in the Arctic, not only in the Arctic itself, but also at regional and global scales (Laffoley and Baxter 2016). A recent report on the Arctic identifies the need for a pan-Arctic research action plan for observation systems and the development of specific Arctic system models, including an early warning system (Schlosser et al. 2016). Greater capacity in modelling to enable continuous re-estimates of the increased risks connected to ocean warming and other stressors is another area where more research is needed (Laffoley and Baxter 2016).

Arctic research is also particularly affected by issues in modelling and accuracy in predictions. Due to logistical challenges or high costs of conducting water observations, Arctic research is even more dependent on robust model projections. Another constraint highlighted by researchers is weak information-sharing between observation projects (Isaksen 2018; Mayer 2017). Researchers are also experiencing difficulties in securing government funding for long-term observation research projects, which is needed to separate semi-seasonal fluctuations from variations caused by climate change change. In addition, there is a disincentive for researchers to engage in more long-term research projects because of academic pressure to continuously produce articles (Mayer 2017).

At the **global level**, a comprehensive literature review on ocean global warming by the International Union for Conservation of Nature (IUCN) underlines that research often focuses on the impacts on specific species, whereas few studies provide an overview of impacts across species and ecosystem (Laffoley and Baxter 2016).

4.2 Ocean acidification

Ocean acidification has in recent years gained increased attention in the research community. The number of scientific papers increased by 35% per year between 2000 and 2013 compared to an increase of 4.8% per year for all scientific fields (Laffoley and Baxter 2016). Ocean acidification refers to a reduction in the pH of the ocean over an extended period. The process is caused primarily by uptake of carbon dioxide from the atmosphere (IPCC 2014). Observations suggests that acidification affects individual species and ecosystems, including their provision of ecosystem services. As seawater pH drops, the availability of calcium carbonate declines which makes it difficult for organisms to fix their shells, a phenomena which is already affecting coral reefs (Gattuso et al. 2014). Changes in pH are also expected to affect oceans' ability to absorb CO_2, which is a key ecosystem service for mitigating climate change. Oceans are estimated to absorb up to 30% of CO_2 emissions in the atmosphere (IPCC 2014). Furthermore, as CO_2 dissolves more in colder water, ocean acidification is expected to progress more rapidly in the Arctic and Antarctic (AMAP 2013). Ocean acidification is also predicted to severely affect the Baltic Sea due to the low buffering capacity of the system (Hjalmarsson et al. 2008).

In **Sweden** substantial resources have been devoted to research and policy measures on acidification in fresh water. The connection between fossil-fuel emissions and acidic rains causing acidification in lakes were proven in 1960s. The low limestone "concentration" in Scandinavian geology limits the ability of lakes to neutralise acid rain. At the peak of the problem in 1990, 17% of Sweden's lakes (16 000) were affected by acidification (HaV 2015). Since 1970 lime has been added to Swedish lakes. Reviews of this large-scale environment protection measure are positive. After 13 to 16 years of liming, the fish stock in treated lakes has gone up to normal levels (HaV 2015).

Research gaps

On a **global level** the evidence base is considered strong enough for scientists to draw some preliminary conclusions on ocean acidification with various levels of confidence. At the same time considerable research gaps on ocean acidification remain (IGBP et al. 2013). To improve the capacity of making reliable projections of the impacts on marine ecosystems, including their ability to adapt to acidification, increased research efforts are needed to develop coordinated and standardised methods of monitoring. The research community could also play an enhanced role in fostering coordinated global networks of marine experimental, observation and modelling research (IGBP et al. 2013).

Participants at the SEI Formas workshop highlighted a need for a more comprehensive understanding of oceans' ability to absorb CO_2 and serve as a carbon sink.

As one of the least researched regions of the world most of the assumptions about the **Arctic's** ecosystem are drawn from research findings from other ocean systems. This suggests that research gaps on acidification are a particular concern in the region, particularly in terms of its impacts on Arctic species and ecosystems, and its effects when it combines with other environmental stressors (AMAP 2013). The Arctic Monitoring and Assessment Programme proposed filling this knowledge gaps through interdisciplinary studies on ocean acidification and increased cooperation between research communities and marine resource end-users,

including fishers and indigenous peoples (AMAP 2013). Increased interaction between researchers and other stakeholders is expected to help make better links between scientific environmental findings and social and economic issues (Schlosser et al. 2016). In addition, more research is needed to address challenges to multi-stakeholder collaboration, not only to overcome physical distance but also to address communication barriers between stakeholders as well as among researchers of different disciplines (Gascard et al. 2017). Research institutes could also help to provide more long-term platforms for stakeholder networks, and thus avoid networks being disrupted at the end of a project cycle (Gascard 2018).

Multi-disciplinary research, as well as helping to fill existing knowledge gaps more systematically by integrating existing knowledge, could also provide guidance on what research gaps different disciplines could focus on to generate benefits for other research fields (Gascard et al. 2017). At the same time challenges to transdisciplinary research need to be acknowledged and addressed. For example, without an integrated system for collecting data, socio-economic and biogeophysical data is often not compatible. Furthermore, research calls are rarely adapted to inter-disciplinary research projects in terms of budgets, timelines and in the assessment process (Crépin et al. 2017; Crépin 2018). Researchers also identify weak academic incentives as a constraint on multi-disciplinary research projects. As researchers are primarily assessed by their productivity in terms of published articles, it is often more strategic for researchers to stay within their area of expertise instead of investing time and efforts in interacting with other disciplines (Ekman 2018).

Polar research is highlighted in the Swedish research policy bill, which will guide research priorities for the coming ten years (Utbildningsdepartementet 2016). Sweden is considered to have comparative advantages for research in the polar region because of its membership in the Arctic Council, the quality of Swedish research, and because it is viewed as a neutral actor without any territorial claims in either the Arctic or Antarctic (Björck 2018).

4.3 Protected areas

Biodiversity and conservation were for a long time an mainly the preserve of environmental experts. However, in recent years the connection between marine life protection and the broader development and environmental agenda has gained greater attention both in the research community and among policy-makers, not least in the context of Agenda 2030. For example, climate change is regarded as one of the key drivers of biodiversity loss. Based on more than 50 000 occurrences capturing the geographic ranges of 457 parasite species, a recent comprehensive study states that climate change could eradicate 30% of all parasite species on earth (Carlson et al. 2017). At the same time biodiversity and its ecosystem services are key for both climate change mitigation and adaptation. As such, they are a means of addressing climate change issues, which will further protect biodiversity.[1] According to the IUCN Red List of Threatened Species, more than 79 800 species are red listed and more than 23 000 are threatened with extinction, including 33% of reef building corals.

[1] See the Convention on Biological Diversity Secretariat: https://www.cbd.int/climate/intro.shtml

In the **Swedish context** the issue of biodiversity is particularly problematic in the Baltic Sea. Over 60 species and 16 habitats are classified as threatened and/or declining in the Baltic Sea (Rolff and Nekoro 2013).

In recent years important progress in the global community has been made on reaching particular targets of global treaties and conventions on conservation. For example, the world appears on track to achieve the SDG target 14.5 on protecting 10% of the oceans by 2020. Sweden recently achieved the target on a national level.[2] However, a review of progress towards SDG 14 by the UN High-level Political Forum on Sustainable Development identifies significant challenges in the management of protected areas (ECESA 2017).

Research gaps

There are considerable knowledge gaps on biodiversity in the **Baltic Sea**, including functional diversity and non-indigenous species. For example, it is still unclear how the cumulative and synergistic effects caused by human pressures (e.g. pollution, over fertilisation, fishing pressure, climate change) will affect Baltic Sea biodiversity (Rolff and Nekoro 2013).

On a global level the documentation of the large threats to biodiversity in marine life and oceans has increased in recent years but significant knowledge gaps remain. IUCN and its sub-organ on marine species assessment is working on assessing the extinction risk of 20 000 marine species for inclusion on the IUCN Red List of Threatened Species. Bridging this research gap is also expected to contribute to better informed national and international marine conservation policies.[3] Improved knowledge is also needed on interactions between different ecosystems, for example between coastal productivity ecosystems. The knowledge gaps on marine issues contributes to the uncertainty on the impacts of climate change projections. Addressing these gaps would thus be beneficial for climate change research at large (CBD 2017).

The research community is also ascribed a potential role in contributing to more efficient policy-making on conservation and biodiversity, for example by providing more information on policy needs on local level. Biodiversity policy-making is also expected to benefit from interdisciplinary research projects that gather the contributions of a range of social and natural sciences (CBD 2017).

Participants at the SEI Formas workshop stressed the need for complementing quantitative measures of protected marine areas with qualitative research that considers the dynamic characteristics of marine environments. Participants at the workshop also indicated the need for networks for information and knowledge exchange on protected areas.

4.4 Summary: identified research gaps for ocean and climate

Ocean warming

[2] See the Swedish Agency for Marine and Water Management (Havs- och vatten myndigheten) https://www.havochvatten.se/hav/fiske--fritid/skyddade-omraden.html

[3] See ICUN http://www.iucnredlist.org/initiatives/marine, and Global Marine Species Assessment (GMSA) https://sites.wp.odu.edu/GMSA/about/

- Large incertitude and knowledge gaps persist for estimating the longer-term impact of ocean warming on the Arctic and its ecosystem services.
- Due to logistical and financial constraints for long-term observation research projects the Arctic is highly reliant on models. There is need for a pan-Arctic research action plan for observation system and the development of specific Arctic system models.

Ocean acidification

- Increased research efforts are needed on developing coordinated and standardised methods of monitoring to improve the reliability of projections of the impacts of acidification on marine ecosystems, especially for the Arctic.
- The research community could help bridge research gaps by fostering interdisciplinary studies and increased cooperation between researcher communities and marine resource end-users. Research institutes could also help to provide more long-term platforms for stakeholder networks.

Protected areas

- There are considerable knowledge gaps for the Baltic Sea and how its biodiversity is affected by human pressures (e.g. pollution, over-fertilisation, fishing pressure and climate change.)
- Addressing the knowledge gaps on marine issues, which can contribute to resolving uncertainty on the impacts of climate change projections, would benefit climate change research at large.
- The research community could further contribute to the design of policy strategies by providing more information on policy needs at the local level and gathering interdisciplinary research contributions.

5 Key theme 3: sustainable use of oceans and marine resources

Achieving sustainable use of ocean and marine resources in terms of balancing economic, social and economic needs is a core principle of SDG 14. Yet, striking the balance between stakeholders' different interests and time perspectives is not an easy task.

This section will provide a brief overview of the issues at stake and research gaps in sustainable management of resources and overfishing, including fishing subsidies. More specifically, this section will assess two areas:

- Blue economy and sustainable management of marine resources
- Overfishing and fishery subsidies.

5.1 Blue economy and sustainable management of marine resources

In recent years several concepts for marine sustainable development have emerged. For example, blue growth and blue economy have developed alongside green growth concepts which aim to more systematically understand the economic benefits generated by coasts and oceans in all aspects of economic activity (UNSCD 2014). More broadly the concept encompasses a wide range of different sectors, such as mineral extraction, tourism, energy production, aquaculture, fishing, recreation, shipping, culture, and traditional production and

processing industries (Mattson et al. 2017). A widely accepted definition of the concept of blue growth is yet to be agreed on; instead different stakeholders tend to emphasise different dimensions of the concept. For example, small island developing states have used the term to foster a specific development agenda, while other actors have used it to promote certain sets of governance mechanisms (e.g. market based) or ideologies (e.g. the "green economy"). Furthermore, the Swedish maritime strategy from 2015 sets a strong emphasis on the promotion of a sustainable, innovative and ocean-based economy with a large emphasis on multisectoral collaboration between the public and private sectors (GOS 2015).

The fishing industry is one of the key sectors in the blue economy concept. The importance of fishing is reflected in target 14.7. Fishery is an important sector in many developing countries, especially in SIDS and coastal least developed countries (LDCs). Over half of the total global fish catch is estimated to come from small-scale fisheries in developing countries and employ a large majority of the world's fisheries workforce, and are thus hardest hit as catch decreases (UN 2017a).

Sustainable management is linked to the ecosystem approach to management, which is adaptive and takes into account ecosystem knowledge and uncertainties and considers multiple external influences (Francis et al. 2007). The concept was initially resisted by those who focused on defending single species. In recent years a paradigm shift has been noted: while the constraints on single-species fisheries science and management have increasingly been recognised, the gains of a more holistic scientific approach that incorporates the ecosystem context of fisheries into management policy have gained more attention (Francis et al. 2007).

The increased interest in ecosystems is further reflected in a rapid increase in the number of papers on marine and coastal ecosystem services. From 2005 to 2015 the number of publications on ecosystem services increased from 20 to 373 (Garcia Rodrigues et al. 2017). Marine ecosystem service assessments generally focus on economic and environmental dimensions of provisioning and regulating services, while devoting limited attention to the non-material benefits to human societies of ecosystem services. Cultural Ecosystem Services (CES) is an approach that aims to complement economic and environmental assessments by including the non-material benefits of human-ecosystem relationships (Garcia Rodrigues et al. 2017). The expected gains of marine and ocean CES assessments is a more comprehensive picture of the interactions between humans and marine ecosystems.

Research gaps

To develop more balanced decision-support mechanisms and more sustainable conservation action plans, there is a need for more comprehensive ecosystem assessments and systematic inclusion of knowledge across disciplines and cultural settings, including indigenous and local knowledge. Greater emphasis on and more resources are needed for integrated valuation assessments, with interdisciplinary research teams drawing on experts in ecology and economics as well as other social sciences and humanities (Garcia Rodrigues et al. 2017).

Science-based management plans for sustainable fishery are also needed, as is clearly stated in target 14.4. For example, more work is needed on developing and implementing integrated management plans for governing ecosystems. In particular, researchers can help develop decision-support tools that can analyse trade-offs across sectors (FAO 2016).

Different stakeholders understand and use the blue economy concept in different ways, which is problematic. Research opportunities have been identified for stakeholders to further develop the term, for example by allowing it to advance a broader set of objectives and governance practices (Silver et al. 2015).

More work, both in policy and research, is needed on advanced systems thinking and improved cross-sectoral management models (Mattson et al. 2017). Another area for increased research efforts is in developing guidelines and regionally coordinated indicators and reporting processes for ocean sustainability. Progress on ocean sustainability depends on the actions and efforts of a broad spectrum of stakeholders, including academia, the private sector and policy-makers. More efforts are thus needed to set up frameworks and mechanisms to bring these stakeholders together (IASS 2017).

Policy frameworks are particularly weak for the high seas, a term which refers to open ocean that is not within any country's jurisdiction. The high seas represent 58% of the world's oceans. The high seas are regulated under several UN-led sector-specific agreements, which has led to a fragmented governance regime providing inadequate protection of the seas' resources (Silver et al. 2015; Laffoley and Baxter 2016). As underlined in the introduction of this report and the review of relevance of SDG 14, blue carbon and bioprospecting of oceans are issues of particular concern for the high seas but which are not included in SDG 14. The high seas is thus an area where researchers could play an important role in bridging policy gaps by researching different governance and sustainable management regimes (Laffoley and Baxter 2016; ICSU 2017).

At the SEI Formas workshop, participants stressed their concern over the concept of maximum sustainable yield (MSY), and stressed the need for complementary measures to be developed in species assessments, including fishing quotas. The concept of MSY is based on single-species assessments and does not consider how ecosystems interact with exploited species. To promote a more holistic approach an alternative concept of "ecological sustainable yield" has been suggested (Francis et al. 2007).

In addition, participants at the workshop highlighted that the research community has a potential role in increasing the uptake and use of more sustainable fishery management by focusing more on educational and learning materials for knowledge transfer and lessons learned on sustainable management practices.

5.2 Overfishing and fishery subsidies

The depletion of fish stocks is an increasing problem worldwide. The proportion of assessed marine fish stocks fished within biologically sustainable levels is estimated to have declined from 90% in 1974 to 68.6% in 2013. Close to a third of the assessed fish stocks are at biologically unsustainable levels (FAO 2016). The increased threat to fish stocks is linked to human-induced stress factors such as pollution and climate change, which influence biological events such as spawning and migration (Laffoley and Baxter 2016). But more importantly the decreasing fish populations are linked to poor governance and management of the oceans and their resources, and more specifically to harmful forms of fisheries subsidies together with illegal, unreported and unregulated fishing (FAO 2016). FAO estimates illicit fishing to

account for up to 26 million tons of fish per year, which would represent more than 15% of the world's total annual fisheries catch. In addition to imposing significant economic damage, illicit fishing threatens local biodiversity and food security (FAO 2016).

Fishery subsidies are on a global level estimated to be up to US$ 35 billion a year, of which close to 60% are considered to contribute to overfishing. International efforts to address fisheries have been hindered by strong national economic and political interests as well as by technical aspects related to the wide spectrum of subsidies (ECESA 2017). Subsidies in the fishing sector involve grants, low cost loans, guarantees, tax breaks, price supports as well as direct provision of goods and services. The subsidies are provided for different reasons, for example to foster economic growth, support fisheries development, ensure crew safety or introduce less harmful fishing methods. Cross-sectoral aspects of subsidies are also contributing to their complexity. For example, certain subsidies are part of broader development programmes and aiming to contribute to progress in other sectors (ECESA 2017).

The pressure on oceans from commercial fishing is significant. A study using a tracking system installed on all industrial fishing vessels estimated that industrial fishing extends over more than 55% of the ocean surface. This is equal to an area four times that covered by agriculture. The study also finds that fishing efforts depend more on social and political schedules than economic or environmental drivers (Kroodsma et al. 2018). The consequences of overfishing are already noticeable. Global catches have fallen steadily since their peak in 1996 (Pauly and Zeller 2016). The depletion of fish species is estimated to cause ocean fisheries to reduce fishing revenues by US$ 50 billion per year globally (UN 2017a). The reduced fish stock and catches threatens stakeholders relying on fish for employment and food security. Together, fisheries and aquaculture provide 4.3 billion people with about 15% of their average per capita intake of animal protein. By 2050, an additional 75 million tons of fish will be needed to meet the consumption needs of more than 9 billion people (Laffoley and Baxter 2016). FAO estimates that, provided overfished stocks are well managed, world fish capture production is projected to increase by only 1%. Ocean fishing will thus not be able to meet increasing consumption demands, which implies a larger reliance on aquaculture production (FAO 2016).

As an EU member state **Sweden** is part of the largest single market for fish imports, estimated in 2014 at US$ 54 000 million. FAO estimates that Sweden in 2014 imported fish of a total value of US$ 4 783 million which makes it the world's eighth largest importer of fish (FAO 2016). 75% of fish consumed in Sweden is imported, with the largest share from Norway, but also from Asian countries such as Vietnam and China. Consumption patterns in countries like Sweden thus has an impact on well-being of fish-stock in other parts of the world (Ziegler and Bergman 2017). Furthermore, in Sweden overfishing and unsustainable fishing techniques are discussed in the context of a suggested ban on bottom trawling for cod in the Baltic Sea. An independent study on the impact of trawling has been commissioned by the government (Zachrisson 2018).[4]

[4] See: http://www.balticsea2020.org/english/alla-projekt/rovfisken/fishery-ongoing-projects/404-save-the-baltic-sea-cod-protect-coastal-fisheries

The growing international commitment to address overfishing and illegal fishing is well reflected in SDG 14. Target 14.4 focus on ending overfishing, illegal fishing and destructive fishing practices. The target also highlights the implementation of science-based management plans to restore fish stocks. Target 14.6 focuses on the fisheries subsidies which contribute to overcapacity and overfishing.

Research gaps

A challenge in promoting responsible seafood and fish consumption in **Sweden** is limited information on supply chains. To guide consumers towards more sustainable food consumption more information on the fish consumed in Sweden is needed. This would, for example, require more coherent reporting methods on trade and consumption of fish (Ziegler and Bergman 2017).

Participants at the SEI and Formas workshop highlighted the need for more research on consumers' and producers' attitudes and behaviour, with an emphasis on young consumers' perspectives, to be able to promote behaviour change and sustainable consumption patterns. Another suggested area of research was to map consumption patterns in relation to fish value chains to address the risk of overfishing both in small-scale and commercial fishing.

Participants also identified the need to assess future global food production systems, including the connection between ocean and land-based food production. More research is needed to help identify methods to optimise food production while respecting environmental and animal welfare requirements. Workshop participants expressed a particular interest in more research on how aquaculture on land and in the sea can contribute sustainably to meeting the rising global food demand, for example by using new fish species and fish-farming techniques. Increased research is also needed on antimicrobial resistance, because aquaculture, especially in developing countries, is considered a risk sector.

To better protect remote ocean areas, including the high seas, from overfishing and illegal fishing, there is need for innovative instruments for monitoring and policing. Research institutes and non-governmental organisations have contributed to filling this gap with innovative ways of using satellites to collect data on vessel compliance with fishing regulations. Examples of this include the work of OceanMind and Global Fishing Watch (Economist 2017).[5] The science community could further contribute to SDG 14, but also the wider implementation of Agenda2030, by providing technological and innovative solutions, such as satellite monitoring tools.

5.3 Summary: identified research gaps for sustainable use of oceans and marine resources

Blue economy and sustainable management of marine resources

- More research is needed to further develop concepts of sustainable marine development, including the blue economy, so they can serve as a platform to advance a broader set of objectives and governance practices.

[5] See Oceanmind, vessel monitoring and insights: http://www.oceanmind.global/work-initiatives/work/vessel-monitoring-and-insight

- The research community can help establish frameworks and mechanisms that can bring together a broad spectrum of stakeholders (e.g. researchers, private sector, and policy-makers) and promote joint actions.
- Researchers could play an important role in bridging policy gaps related to the high seas by researching different governance and sustainable management regimes.

Overfishing and fishery subsidies

- To promote responsible seafood and fish consumption in Sweden, more coherent reporting methods on trade and consumption of fish is needed.
- The science community could further contribute to the protection of oceans, including addressing illegal fishing in the high seas, by providing technological and innovative solutions such as innovative satellite monitoring tools.
- The use and implementation of management plans for sustainable fishery would benefit from increased research efforts on developing tools for decision-making analysing trade-offs across sectors.

6 Concluding remarks

The literature review has served to identify research needs in a broad spectrum of areas related to SDG 14: Life Below Water. In the assessment of what role science, technology and innovation can play in contributing to SDG 14, two of the three identified roles have been emphasised: characterising the challenges and providing the solutions (Nilsson 2016). Most of the research gaps identified in this report relate to the need for further clarification in research areas that already exist. This includes more basic research, for example on impacts on species and ecosystems of the combined effect of different human-induced factors. In addition to topic-specific research gaps, which are discussed under the thematic sections, the literature review also identified several cross-cutting research needs and observations for SDG 14. These are listed below.

- **Balance competing social, economic and environmental demands for ocean resources**. The formulation of the SDG 14 and its targets aims to balance social, economic and environmental demands for ocean and marine resources. Although all three dimensions of sustainable development in the long-term would mutually benefit from a balanced approach, there is risk for trade-offs to occur in the short-term, e.g. between the environmental protection of marine resources and the economic use of the same resources.
- **Balance between timely policy measures and more research-informed policies**. By addressing the significant knowledge gaps on marine and ocean issues the research community could contribute to the formulation of more effective, efficient and sustainable policies. However, climate research often requires long-term observations which creates a mismatch with the shorter time perspective of national policy-making but also of Agenda 2030. The remaining 12 years until 2030 is challenging for developing new research projects, securing robust results, communicating these to policy, and securing political agreement on policy measures.
- **A local, regional and global perspective**. Despite differences in ecosystem characteristics and socio-economic context, many of the world's oceans and seas are facing similar challenges related to climate change. There is potential for Swedish

national and regional research projects, e.g. acidification, to contribute to achieving progress of SDG 14 on a global level.

- **Need for improved models**. Uncertainty in modelling and predictions particularly affects Arctic research, partly because there is limited ability to conduct observations. Improved ocean models would contribute to better overall climate change predictions.
- **Need for forward-looking research**. Research in support of Agenda2030 needs to be forward-looking and identify issues which are not included in current goals and targets but which in the medium and longer-term risk becoming important challenges for marine life. An important role for science is thus horizon scanning and identifying the next generation of sustainability challenges, not necessarily identified already in Agenda 2030.
- **Prospects and challenges of multi-disciplinary research**. Multi-disciplinary research has the potential to bridge existing knowledge gaps by bringing different disciplinary knowledge together, but is often constrained by structural challenges, including research funding structures not favourable to building more sustainable multi-stakeholder networks.
- **Science to fill knowledge gaps; but solutions rely on political will**. Although additional research efforts could contribute to providing a better understanding of climate change impacts on oceans, effective mitigating measures primarily depend on political will.

The literature review and its assessment of research gaps was further enriched by the SEI Formas expert workshop on SDG 14 on 3 May 2018, with participants from science, policy and practice. Inputs and reflections from the experts were largely in line with the literature review's preliminary thematic findings but provided complementary and additional perspectives on research topics and needs. In addition to the experts' sector-specific suggestions, which have been incorporated into the theme sections, a number of cross-cutting observations were made during the workshop. While the cross-cutting issues are discussed in detail in the main report, a selection of key takeaways are listed below.

- **Linkages between goals**. Many of the research gaps identified by workshop experts linked to SDG 14 but were at the same time closely connected to other SDG goals and targets, for example issues on sustainable consumption and waste management. By stressing how progress on healthy oceans require efforts in several sectors and at different scales, the workshop served as an important reminder of the need to apply a cross-sector approach for SDG 14.
- **Agenda 2030: a political agenda**. SDG 14 and its targets concern already known research areas and thus do not primarily serve as a platform to guide researchers to new research areas. Experts and researchers instead mainly view the SDGs and Agenda 2030 as a political framework developed by government stakeholders. It is up to the research community to adjust to the agenda and contribute to achieving the SDGs.
- **Balance between transdisciplinary and in-depth disciplinary research**. By gathering experts and researchers from a wide range of disciplines spanning the natural and social sciences the SEI Formas workshop on SDG 14 was a good example of the value of cross-sector exchanges. Experts at the workshop highlighted the potential gains that climate research can make by drawing on arts and pedagogic research. The workshop also served as an important reminder of finding a balance between efforts and resources devoted to transdisciplinary research projects and in-depth sector-specific

research projects. This balance is key to foster synergies and allow cross-cutting research to draw on solid sector-specific research.

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