Sustainability in an Arctic context: Resilience of the Arctic marine environment

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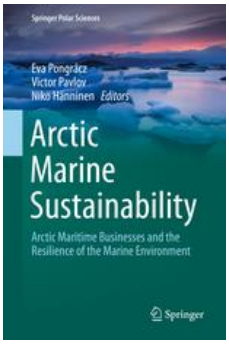

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Abstract

This chapter provides the theoretical basis of the book by outlining the framework of sustainability in an Arctic marine context. The chapter presents the sustainable development goals, especially goal 14 on conserving and sustainably use the oceans, seas, and marine resources, as well as Arctic states commitments to goal 14. The chapter explains the sustainability framework conditions and the concept of resilience, in the context of the Arctic marine environment. The chapter further discusses the concerns of cumulative impacts to the Arctic marine environment from multiple and concurrent natural and human perturbations, and the consequent weakening of the resilience of Arctic marine environment. Finally, the chapter summarizes the status of processes that influence the resilience of Arctic marine ecosystems.

1.1 Introduction

Since the introduction of the sustainability concept in 1987 (United Nations General Assembly), humans have struggled to comprehend the notion of sustainability. Even though the concept has moved to the forefront of consciousness to the degree of almost being passé, the understanding of what sustainability actually means still eludes many. The purpose of this chapter is to provide the theoretical basis of the book by providing the sustainability framework for main themes of the book.

Sustainable development defined as “development that meets the needs of the present without compromising the ability of future generations to meet their needs” (United Nations General Assembly, 1987) speaks of the process. The report, ‘*Our Common Future*’, highlighted that satisfying human needs is a major aspiration and does not set limits to economic growth, but indicates that natural resources are to be exploited within the limits of their regenerative capability. It concludes that sustainable development is a process of change in which resource use, technological development and institutional change are in balance. The Millennium Development Goals, later replaced by the Sustainable Development Goals (United Nations, 2016), give goals to meet. The end-result, sustainability, could then be argued to be human-ecosystem equilibrium state (Shaker 2015). This ideal is viewed unattainable by many, pointing out the inherent unsustainability of unlimited growth in a closed system.

The United Nations 2030 Agenda for Sustainable Development emphasized the need to strengthen resilience across human and natural systems, with special emphasis on the sustainable management of marine ecosystems to avoid significant adverse impact and strengthening their resilience. Understanding and moderating human impacts on marine ecosystems is in the forefront of ecology research and new paradigms are surfacing. A cumulative assessment framework needs to be adopted, in order to respond to the diversity of cumulative impacts in the Arctic environment.

1.2 The Arctic

The Arctic may be considered a single region, but it can be defined and bordered in many different ways. First, I would like to introduce the different ways the Arctic can be and has been defined by different scholars and organizations.

1.2.1 Defining the Arctic

The Arctic is most typical defined by the Arctic Circle, 66° 33’ 44’’ North, which is the Northernmost latitude at which the sun can remain continuously above or below the horizon for 24 hours. Another view is the Arctic tree line boundary: the northernmost latitude in the Northern hemisphere where trees can grow. Further north, it is too cold all year round to sustain trees. The low average temperature is an important indicator of the Arctic as well. The third definition is the 10°C July isotherm, which is the area where the average temperature for the warmest month is below 10°C and is often used by biologists as a definitional boundary of the Arctic. There are also other definitions, or more like areas of interest defined by different working groups of the Arctic Council. Figure 1.1 by the Arctic Portal illustrates some of these boundaries.

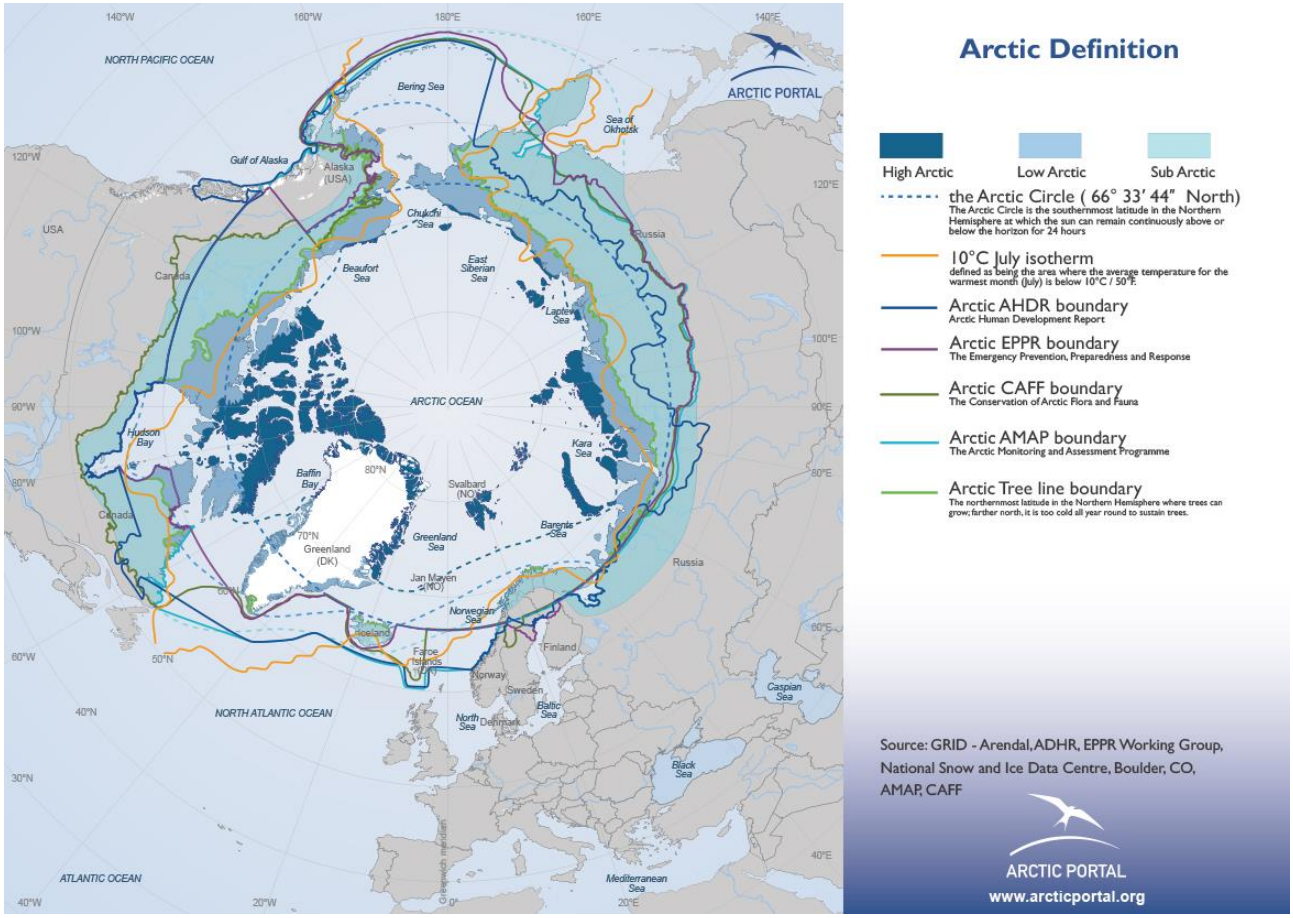

Figure 1.1 The boundary of the Arctic by different definitions

1.2.2 The changing Arctic

The ever-accelerated pace of change in the Arctic is a concern most scientists share. The issue is both the speed of change and the variety of changes, both ecological and societal. Climate change is the strongest driver of change, worsened by widespread pollution of seas, and the unprecedented interest in the Arctic, both in terms of natural resources and ecosystem services. These changes threaten the integrity of both ecological and human systems in the Arctic. Understanding Arctic change requires a systemic perspective that integrates human and natural dynamics. (Arctic Council 2016). Studies at open ocean and coastal sites

around the world show that current levels of marine acidity have increased by about 26 per cent on average since the start of the Industrial Revolution. Moreover, marine life is being exposed to conditions outside previously experienced natural variability. Global trends point to continued deterioration of coastal waters due to pollution and eutrophication. Without concerted efforts, coastal eutrophication is expected to increase in 20 per cent of large marine ecosystems by 2050. These concerns call for the investigation of sustainability in an Arctic context, and examining the role of Arctic business in weakening the resilience of the marine environment.

The Arctic Council *(this part to be a box)*

The Ottawa Declaration lists the following countries as Members of the Arctic Council: Canada, the Kingdom of Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States. In order to ensure sustainable development in the Arctic region, work is carried out in six Working Groups:

- **ACAP:** Arctic Contaminants Action Program is encouraging national actions to reduce emissions and other releases of pollutants (acap.arctic-council.org)
- **AMAP:** Arctic Monitoring and Assessment Programme monitors the Arctic environment, ecosystems and human populations, and provides scientific advice to support governments as they tackle pollution and adverse effects of climate change (www.amap.no)
- **CAFF:** Conservation of Arctic Flora and Fauna Working Group addresses the conservation of Arctic biodiversity, working to ensure the sustainability of the Arctic's living resources (www.caff.is)
- **EPPR:** Emergency Prevention, Preparedness and Response Working Group works to protect the Arctic environment from the threat or impact of an accidental release of pollutants or radionuclides (eppr.arctic-council.org)
- **PAME:** Protection of the Arctic Marine Environment Working Group is the focal point of the Arctic Council's activities related to the protection and sustainable use of the Arctic marine environment (www.pame.is)
- **SDWG:** Sustainable Development Working Group works to advance sustainable development in the Arctic and to improve the conditions of Arctic communities as a whole (www.sdwg.org)

1.3 The United Nation's Sustainable Development Goals

As a starting point, the sustainable development goals of the United Nations General Assembly are introduces, which were intended to change societal values (UNGE 2015). The United Nations adopted the 17 new Sustainable Development Goals (SDGs, Figure 1.2) and their 169 targets in September 2015. The primary objectives are to end poverty, protect the planet, reduce inequality and, generally, improve the well-being of everyone in the world. The 2030 Agenda outlines an ambitious action plan for people, planet and prosperity, to strengthen peace and freedom.

Figure 1.2 The Sustainable Development Goals of Agenda 2030 (United Nations, 2016)

SDG14 aims toward the conservation and sustainable use of oceans, seas and marine resource for sustainable development. Advancing the sustainable use and conservation of the oceans continues to require effective strategies and management to combat the adverse effects of overfishing, growing ocean acidification and worsening coastal eutrophication. The expansion of protected areas for marine biodiversity, intensification of research capacity and increases in ocean science funding remain critically important to preserve marine resources. Table 1.1 summarized the targets and indicators of SDG14.

Table 1.1 Sustainable development goal 14: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development. Targets and indicators (UN 2016)

Targets		**Indicators**
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	Index of coastal eutrophication and floating plastic debris density
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	Proportion of national exclusive economic zones managed using ecosystem-based approaches
14.3	Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	Average marine acidity (pH) measured at agreed suite of representative sampling stations
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	Proportion of fish stocks within biologically sustainable levels
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	Coverage of protected areas in relation to marine areas

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	Progress by countries in the degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing
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	Sustainable fisheries as a percentage of GDP in small island developing States, least developed countries and all countries
14.A	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	Proportion of total research budget allocated to research in the field of marine technology
14.B	Provide access for small-scale artisanal fishers to marine resources and markets	Progress by countries in the degree of application of a legal, regulatory, policy, institutional framework which recognizes and protects access rights for small-scale fisheries
14.C	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	Number of countries making progress in ratifying, accepting and implementing through legal, policy and institutional frameworks, ocean-related instruments that implement international law, as reflected in the United Nation Convention on the Law of the Sea, for the conservation and sustainable use of the oceans and their resources

The high-level United Nations Conference to Support the Implementation SDG14 (The Ocean Conference) was convened at United Nations Headquarters in New York in June 2017. The Conference adopted the "Our Ocean, Our Future: Call for Action" to support the implementation of SDG14. At the Conference, close to 1400 voluntary commitments for concrete action to advance implementation of SDG 14 were made by governments, the United Nations, civil society organizations, the scientific community, and the private sector.

The nine Communities of Ocean Action are:

1. Coral reefs
2. Implementation of the United Nations Convention on the Law of the Sea
3. Mangroves
4. Marine and coastal ecosystems management
5. Marine pollution
6. Ocean acidification
7. Scientific knowledge, research capacity development and transfer of marine technology
8. Sustainable blue economy
9. Sustainable fisheries

Currently, there are over 1500 voluntary commitments. Some of those made by Arctic nations and organizations are (https://oceanconference.un.org/commitments/):

- OceanAction16721 Iceland commits to reduce marine litter
- OceanAction16733 Addressing acidification by Iceland
- OceanAction18373: Study on Marine Litter including Microplastics in the Arctic by Sweden, Norway, Iceland
- OceanAction18818: Ban plastic microbeads in cosmetics by Sweden
- OceanAction18424: Adoption of Fisheries Management Plans with long term precautionary Harvest Control Rules for commercially harvested fish stocks in Icelandic waters
- OceanAction19375: Measures to reduce marine pollution and microplastics in Norway by targeting their sources
- OceanAction19509 Industry and research driven development and introduction of selective and low impact fishing gears by Sweden
- OceanAction18382: Identification of Ecologically or Biologically Significant Marine Areas in the Baltic Sea by HELCOM
- OceanAction17174: Strengthening the implementation of the HELCOM Baltic Sea Action Plan to support ocean-related SDGs (HELCOM)
- OceanAction 20500: Reducing marine litter

There is significant attention on pollution prevention, with marine plastics on top of the list. Actions also concern sustainable fishing, as well as ecosystem-based management approaches.

1.4 Arctic nations' commitment to the Agenda 2030 and SDG14

Nordic environment and climate ministers are urging firmer action to combat plastic and microplastic pollution in seas and oceans. At their meeting on 10 April 2019, they signed a declaration of 11 key commitments. In it, the ministers ask the Nordic Council of Ministers to prepare a study to consider which specific elements should be included in a global agreement to combat microplastics and plastic waste in the marine environment. (Nordic Council of Ministers for the Environment and Climate, 2019)

1.4.1 Norway

As a nation reliant on resources from the sea, Norway has taken a leading to combat marine litter. The latest status report on eutrophication (2016) classifies Norwegian offshore and outer coastal areas as non-problem areas. Norway monitors and records marine litter including plastic and micro plastic in our three oceans. More susceptible to ocean acidification than temperate waters, the pH surface layer of the Norwegian Sea has decreased by 0.13 pH units the past 30 years, compared to the global average of 0.1 pH units. Norway keep on monitoring ocean acidification and increase knowledge on its effects. Plastic waste in the oceans is a pressing global concern. Put forward by Norway, in December 2017 the UN Environment Assembly agreed on a vision for zero release of plastics into the ocean. Norway has also allocated NOK 150 million to combatting marine litter and microplastics in the oceans of developing countries. A High-Level Panel on Building a Sustainable Ocean Economy was also established, to increase global awareness of the relationship between clean and healthy oceans, sustainable use of ocean resources and economic growth and development. (Norwegian Ministry of Finance and Norwegian Ministry of Foreign Affairs, 2018)

1.4.2 Sweden

Sweden's 2030 agenda (2018) put forward an action for the conservation and sustainable use of the seas and marine resources. Sweden has introduced a ban on microplastics in certain cosmetic products and is working on reducing the amount plastic waste ending up in the sea and lakes. Action has also been taken to reduce pollution and eutrophication. The Marine and Water Authority draws up proposals based on the ecosystem approach. There is great emphasis on international cooperation on the implementation of

SDG14. The Government's global strategy for the environment, climate and the sea and sustainable use of natural resources 2018–2022 is central to this work. Sweden is also working to establish an ambitious implementation agreement for the UN Convention on the Law of the Sea for the Protection of Biodiversity in Areas beyond National Jurisdictions. In its resolution 69/292 of 19 June 2015, the General Assembly decided to develop an international legally binding instrument under the United Nations Convention on the Law of the Sea (UNCLOS) on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. (Regeringskansliet 2018)

1.4.3 Finland

Finland was one of the first countries reporting their 2030 agenda. It mentions Food security, access to water and energy, and the sustainable use of natural resource as one of the priority areas, but SDG 14 is not mentioned as one of the focus areas. The report, however, has assessed that, as a starting level, the progress of Finland in terms of SDG14 goals has been moderate. The Ocean Health Index was labelled green; however, percentage of marine sites important to biodiversity that are completely protected was marked red. At this time Finland put focus on SDGs 8 and 13. (Prime Minister's Office, Finland, 2016)

1.4.4 Iceland

The Iceland 2020 – governmental policy statement for the economy and community (Iceland Prime Minister's Office, 2011) contains visions and measurable objectives targeted at improving welfare, knowledge and sustainability. In the preparation phase for Agenda 2030, Iceland actively promoted key areas such as sustainable management of oceans at home and abroad and stated that utilizing marine resources in a responsible manner based on scientific advice plays a vital role in ensuring food security and prosperity.

1.4.5 Denmark

The Danish government has formulated an Action Plan (The Danish Government, 2017) to adapt the 2030 targets to national circumstances. The Action Plan is centered on the 5 P's: Prosperity, People, Planet, Peace and Partnerships. The government has formulated 37 targets. They reflect the government's wish to prioritize building on existing positions of strength as well as on areas where improvement is needed. Each target has one or two national indicators, which are in large part measurable and quantifiable.

1.4.6 Canada

Many of the Government of Canada's priorities and programs, both domestically and internationally, are already well aligned with the 2030 Agenda. Canada's 2016-2019 Federal Sustainable Development Strategy, which sets out Canada's sustainable development priorities, is linked to many SDGs, including SDG 14. Furthermore, in Budget 2018, the Government of Canada announced that it would provide $49.4 million over 13 years to establish an SDG unit and fund monitoring and reporting activities by Statistics Canada (Government of Canada, 2018)

1.4.7 USA

Bertelsmann Stiftung and the Sustainable Development Solutions Network have been following the progress of all 193 countries in achieving the SDGs since 2016. Their report (2018) focusing on the G20 countries survey to gauge how strongly the SDGs were integrated into institutions and policy. In their evaluation, the United States ranked right at the bottom.

1.4.8 Russia

Bobylev and Solovyeva (2018) analyzed the compliance of the SDGs with the development goals of Russia and found that SDGs 12–15 are not reflected in the areas of activity outlined in Strategy 2020. Attention currently focuses on social and economic SDGs.

1.4.9 The Sustainable Development Working Group (SDWG) of the Arctic Council

The SDWG plays a lead role in addressing the human dimension of the Arctic within the Arctic Council. The goal is building self-sufficient, resilient and healthy Arctic communities for present and future generations while protecting the environment. SDWG work falls under six broad thematic areas, including sustainable economic activities and management of natural resources. During the Finnish chairmanship between 2017-2019, the SDWG was engaged in 20 projects, and reported on their outcome in May 2019. Among these were the progress report on the Arctic Resilience Action Framework; Good Practices for Environmental impact Assessment and Meaningful Engagement in the Arctic and The Arctic as a Food-Producing Region Final Report. (Arctic Council, 2019)

1.5 Sustainability framework conditions

The vast and growing array of concepts, methods and tools in the sustainability field imply a need for a structuring and coordinating framework, including a unifying and operational definition of sustainability. One attempt at such framework began over 25 years ago and is now widely known as the Framework for Strategic Sustainable Development (Missimer et al, 2017). The Framework is the result of a long-term effort of several scientist led by Karl-Henrik Robért. One of the main feature of FSSD is the four system conditions for sustainability. To become a sustainable society we must (Robért et al, 2002):

1. Eliminate our contribution to systematic increases in concentrations of substances from the Earth's crust
2. Eliminate our contribution to systematic increases in concentrations of substances produced by society
3. Eliminate our contribution to the systematic physical degradation of nature
4. Contribute as much as we can to the meeting of human needs in our society and worldwide

In terms pertinent to Arctic marine sustainability, the first could be applicable to oil and gas exploration in the Arctic. We should try to manage with more renewable resources or such that do not contribute to climate change. The second condition points to the prevention of pollution of the seas, due to human incidents such as oil and chemical spills, runoff of wastewater or dumping other wastes to the sea that do not readily degrade in the marine environment. The third would warn both about the dangers of overfishing as well as the significant alteration of the physical environment that takes away the space from biological species and weakens marine biodiversity. On the other hand, we need to maintain the wellbeing of arctic communities and ensure that they can practice their traditional livelihood.

The framework follows from principles for how a system is constituted (ecological and social principles) and contains principles for a favourable outcome for the system (sustainability), as well as principles for the process to reach this outcome (sustainable development). Broman and Robèrt (2017) have concluded that essential aspects that need to be sustained include (a) assimilation capacity, (b) purification capacity, (c) food production capacity, (d) climate regulation capacity, and (e) diversity. In terms of the Arctic marine environment, many authors of this book argue that human activities have weakened all of these capacities of the Arctic marine ecosystem. While climate change is having direct effects on Arctic ecosystems, the dynamics of pollutants within Arctic ecosystems are also being affected, enhancing pollutant mobility and effects in some cases (Gamberg 2019).

With regards to sustainability framework conditions, an essential element in the Arctic is the multiple and concurrent perturbations from anthropogenic activities, and the limited capability of Arctic ecosystems to absorb them and regenerate. This prompts the discussion about resilience of ecosystems and its limitations in the Arctic.

1.6 The concept of resilience

Resilience is a popular narrative for conservation and it implicates the possibility that ecosystems can recover and rebound from disturbances. The term resilience captures two dynamic processes: the ability of ecosystems to resist and absorb disturbance, and their ability to recover. (Darling and Côte, 2018) Resilience was originally introduced by Holling (1973) as a concept to help understand the capacity of ecosystems with alternative attractors to persist in the original state subject to perturbations. Walker et al. (2004) define resilience as the capacity of a system to absorb disturbance and reorganize in ways that retain essentially the same functions, structures, identities, and feedbacks. Interest in the concept of resilience has grown dramatically in recent years, and it is featured prominently in the Paris Agreement on climate change, the United Nations Sustainable Development Goals, and the Sendai Framework for Disaster Risk Reduction, among others (Carson and Peterson, 2016).

1.6.1 Resilience of marine ecosystems

The intensity and frequency of climate-driven disturbances are increasing in coastal marine ecosystems, driven by disturbances associated with ocean warming, acidification, sea-level rise and extreme weather events (O'Leary et al., 2017). Whether marine ecosystems resist, recover, restructure, or vanish, hinges on how extreme future climate change is (Darling & Côte, 2018). For example, in the case of coral reefs, Darling and Côte concluded that they will most likely transform beyond recognition in the coming decades. Such ecological shifts will, in turn, force people depending on marine ecosystems to change how they use and depend on ecosystem services. Similar conclusions were made in this book also by Koeningstein, for the case of the Barents Sea. The implication is that we also need to improve the resilience of people and communities to help dampen coming climate shocks. The extensive review of O'Leary et al. (2017) also concluded that whilst "bright spots" of ecological resilience exist, indicating that ecosystems can be resilient even facing long-term chronic climatic stress. There was, however, also a high frequency of reporting "local stressors", both anthropogenic and biotic, that was preventing resilience. In general, genetic diversity seems to be the most important positive, and human interaction the most serious negative factor. The authors concluded that the escalating impacts of climatic change on marine ecosystems and ecosystem services require that the conditions and processes enabling resilience are understood and supported. The results indicate that the reduction of additional local stressors and the use of marine spatial planning, may be the most effective approaches to promoting resilience. Reducing the cumulative impacts to biogenic ecosystems during climatic disturbance is essential for maintaining at least some biogenic structure and source populations that can provide for post-disturbance recruitment and regrowth. The results indicate that although marine ecosystems face growing cumulative stress from coupled human perturbations and climatic instabilities, they still harbour enormous capability for resilience. Maintaining and rebuilding this capacity should be a major focus of marine science and management. (O'Leary et al., 2017)

1.6.2 Resilience in an Arctic context

The Arctic Resilience Interim Report (2013) defines resilience as a "systems' capacity to cope with disturbances and recover in such a way that they maintain their core function and identity". It also relates to the capacity to learn from and adapt to changing conditions and, when necessary, to transform. The Arctic Resilience Action Framework (ARAF), was approved in 2017. The final report of the ARAF implementation project (Arctic Council SDWG 2019) highlights that the Arctic is warming twice as fast at the rest of the planet (Overland et al 2018), and many researchers call the Arctic as the indicator of climate change. Substantial social, environmental, and economic changes have also taken place. There are 4 million people who call the Arctic their home (Larsen and Fondahl, 2014), many of them Indigenous peoples who have lived in the Arctic for centuries and have a long history of navigating environmental changes.

However, the current rate of change and the potential for surprises and shocks creates unprecedented challenges for Arctic residents.

The Arctic Climate Impact Assessment of 2014 was an eyeopener in highlighting the rapid changes occurring in the Arctic. Since then, the Arctic Council has continued to study the physical, ecological, and social changes that are impacting the people and the natural systems of the Arctic. During the Swedish Chairmanship of the Arctic Council (2011-2013), the Arctic Council, deeply concerned about climate impacts and other transformations happening in the region, initiated the Arctic Resilience Report (ARR) project. Its final report (Carson and Peterson, 2016), concludes that rapid change is the norm in the Arctic and that the main drivers of this change are largely outside the Arctic. Climate change caused by greenhouse gas emissions plays a particularly large role, but migration, resource extraction, tourism, and shifting political relationships are also reshaping the Arctic in significant way. The report also identified "regime shifts", or large, abrupt changes in social-ecological systems, and evaluated characteristics of resilient Arctic communities. Resilience, as the capacity to buffer and adapt to stress and shocks, and thus navigate the large and rapid changes occurring in the Arctic, is immensely relevant to the people of the Arctic, its ecosystems, and the management and governance of the region's natural resources.

The Arctic Council plays an important role in building a collective understanding of Arctic change and resilience, promoting dialogue, and providing information, especially in connection with climate-related risks in the Arctic region (SDWG, 2019). The Adaptation Actions for a Changing Arctic (AACA) project projected potential adaptation responses in three regions and complemented the work of the ARR project.

The first Arctic Resilience Forum in Rovaniemi in 2018 (Halonen et al. 2018) noted the multiple risks to Arctic livelihood, due to climate risks on ecosystem service. The report suggests that the changes in some cases are so dramatic and unavoidable that transformation of livelihoods remains the sole option.

1.7 Cumulative impacts assessment

Reports on Arctic resilience point to the multiple impacts from human activities, which calls for cumulative impact assessment. Cumulative impacts have been defined as impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project (Walker and Johnston, 1999). Examples listed were: (a) incremental impact from a number of separate developments; (b) combined effect of different impacts on the same receptor; (c) several individually insignificant impacts which together have a cumulative effect. It is required by legislation that, when conducting Environmental Impact Assessment, cumulative impacts and impact interactions should be included. It is because the environmental impacts resulting from cumulative impacts, and impact interactions can be significant. Cumulative assessment methods have been used to assess the accumulation of ecological impacts (Frank et al., 2010) as well as social sustainability benefits (Fedorova and Pongrácz, 2019) within a region. The indication from the literature in resilience is that cumulative impacts from several stressors are inhibiting the ability of ecosystems to resist and recover. As an illustration, Table 1.2 presents some of the most critical disturbances to Arctic marine ecosystems (marine pollution, ocean acidification, perturbance to genetic diversity and disturbance to habitats) and some of the chief causes (coastal activities, fishing, transportation, oil and gas exploration, tourism). Further, Table 1.3 attempts to illustrate the severity of these impacts.

Table 1.2 Cumulative impacts to Arctic marine ecosystems and impact categories

	Coastal activities	**Fishing**	**Transportation**	**Oil and gas exploration**	**Tourism**
Marine pollution	Runoff spills, wastewater nutrients, plastics	Lost fishing lines	Waste from ships, oil spill	Seepage and spills	Waste from ships, potential spills
Ocean acidification	CO_2 emissions from human activities	Emissions from fishing fleet	Emissions from cargo ships	Burning fossil fuels	Emissions from cruise ships
Perturbance in genetic diversity	Fishfarming	Preference of commercial fish species	Invasive species from ballast water		
Disturbance to habitats	Stress to coastal ecosystems	Potential overfishing	Disruption due to ship traffic	Pollution and physical disruption	Diving and recreational activities

Table 1.3 The severity of disturbances to Arctic marine ecosystems

	Coastal activities	**Fishing**	**Transportation**	**Oil and gas exploration**	**Tourism**
Marine pollution	↑↑↑↑	↑	↑↑	↑↑↑	↑
Ocean acidification	↑↑↑	↑	↑↑↑	↑↑↑↑	↑↑
Perturbance in genetic diversity	↑	↑↑↑	↑		
Disturbance to habitats	↑↑↑↑	↑↑↑	↑	↑↑↑	↑

Legend:	↑↑↑↑	↑↑↑	↑↑	↑	
	Highest impact	High impact	Moderate impact	Low impact	No or minor impact

This method of visualization in Table 1.3 is to be considered only indicative and the scaling intuitive, the purpose being merely illustrative. The idea presented here is that although some of the activities may have currently moderate or no impact, the cumulative impact of multiple disturbances is significant. In most cases there are also activities that generate high or even very high impact. It is also to be noted that, due to increased global interest in the Arctic, in terms of tourist destination, shipping route, and source of fossil fuels, their impact is expected to increase and potentially aggravate the already stressed Arctic marine environment – thus weakening their resilience.

1.8 Planetary boundaries and the Arctic

As a final notion to be introduced, the concept of planetary boundaries is presented. This was proposed by scientists lead by Johan Rockström from the Stockholm Resilience Centre and Will Steffer from the Australian national University. The idea (illustrated in Figure 1.3) has been presented in a special feature of Nature (Rockström and Steffen et al., 2009).

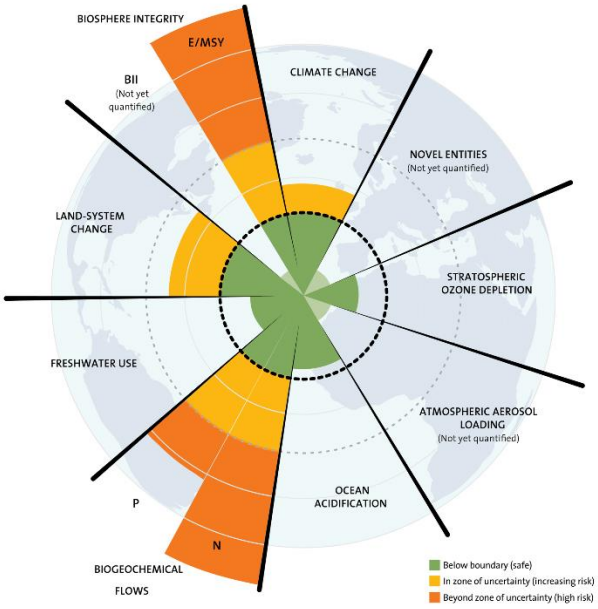

Figure 1.3 The planetary boundaries concept (Pharand-Deschênes, 2015, based on Rockström et al., 2009)

The planetary boundaries concept presents a set of nine planetary boundaries within which humanity can continue to develop and thrive for generations to come. These boundaries define the safe operating space for humanity with respect to the Earth system and are associated with the planet's biophysical subsystems or processes (Rockström et al. 2009). The scientists attempted to quantify the biophysical boundaries outside which, they believe, the Earth risks moving into a different system state. The purpose of identifying critical planetary boundaries was to inform society's decisions about sustainability and be potentially used in the societal decisionmaking process.

The wedges represent an estimate of the position for each variable, with green shading indicating safe operating space. The boundaries in three systems: rate of biodiversity loss, climate change and human interference with the nitrogen cycle, the planetary boundaries have already been exceeded (Rockström et al., 2009).

Based on this concept, and inspired by Nash et al. (2017), Figure 1.4 provides a suggestion on the status of these aspect in the Arctic marine context.

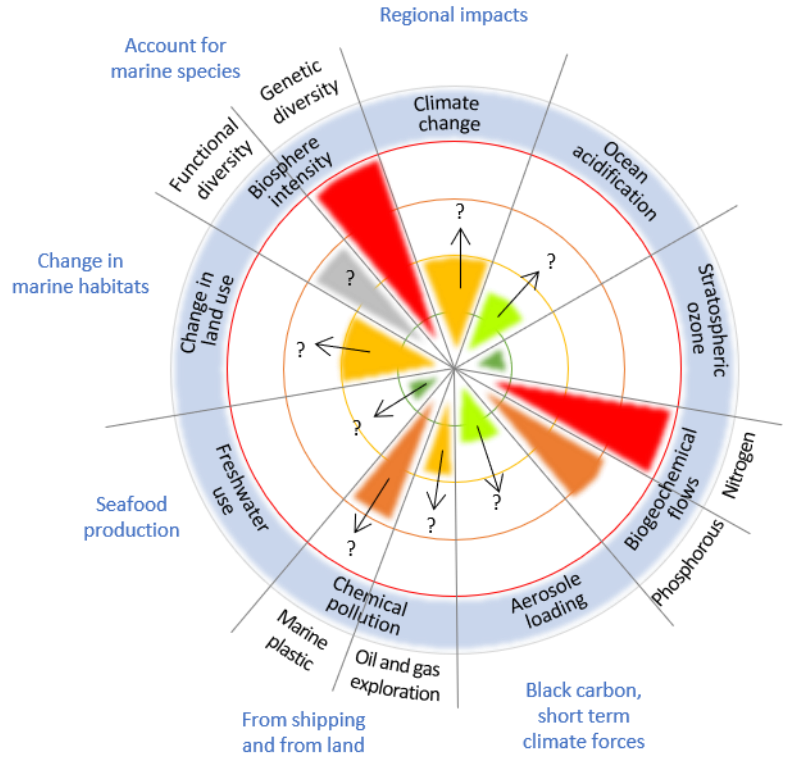

Figure 1.4 Status of processes that influence the resilience of Arctic marine environment (based on Nash et al., 2017).

Globally, genetic diversity and biogeochemical flows, especially that of nitrogen are disturbed the most by human activities. Phosphorous pollution follows closely, reaching critical levels. Functional diversity is not yet quantified. In the marine context, one of the greatest concerns of today is marine plastics (PAME 2019), closely followed by the pollution risks of oil and gas exploration, which is could be a critical pollution in Arctic seas (Pavlov, 2009). Multiple human stressors have added to the cumulation of impacts. Ocean acidification is also closing critical levels, and is closely monitored in the Arctic, the observation being that acidification levels are higher in Arctic seas than globally. While globally, aerosole loading is not yet quantified, in the Arctic seas, short term climate forcers, such as black carbon are a cause for concern (Shindell and Faluvegi, 2009). Additionally, climate change is a major stressor and it is expected that its impact may accelerate. Land-use change in the arctic marine context is interpreted here as change in marine habitats. The indication is that human activities have altered marine habitats to a significant degree and several sectors provide cumulative impacts, as seen in Table 1.2. While water use in the global context refers to freshwater use, in the Arctic marine context this could be used to identify the impact of seafood production. The impacts to date are moderate, although the expectation is that the Arctic would become also a food producing region (Natcher et al., 2019). The arrows indicate potentially increasing impact, with the question marks indicating uncertainty.

The objective of this visualization in Figure 1.4 was to indicate that, due to the cumulative impact of multiple stressors affecting the same receptor; in the Arctic, there are several aspects in which the boundaries of safe operation have been surpassed, and the indication is that the impacts are intensifying.

1.9 Conclusions

The Arctic cannot support the accelerated demand for resources and also assimilate the ecological impacts associated with these demands. Both the state of the Arctic environment as well as the use of Arctic resources indicate deepening unsustainability. We are caught in a vicious cycle of resource exploitation that leads to ecosystem damage, which will undermine livelihoods, which in turn will force Arctic communities to adapt and perhaps look for other livelihoods, leading to further exhaustion of resources, and a spiral of continuing degradation continues.

Currently, no country is on track to achieve all the Sustainable Development Goals (SDGs) by the target date of 2030, but perhaps SDG14 has been the most overlooked. The report of Bertelsmann Stiftung and the Sustainable Development Solutions Network (2018) on the progress of all 193 countries in achieving the SDGs found that the G20 countries have performed the worst in terms of failing to achieve SDG14 on protecting the marine environment. This will need to change. Most Arctic states have made efforts, focusing mainly on marine plastics, pollution prevention and sustainable fishing and blue economy. On May 9th, 2019, the general assembly of United Nations have adopted the resolution that the 2020 United Nation Conference will support the implementation of SDG14, to conserve and sustainably use the oceans, seas and marine resources for sustainable development.

The message of this chapter is also that Arctic nations should better integrate Cumulative Impact Assessment as both a tool for planning and for evaluation. It should be considered as part of a precautionary sustainability strategy, not only as a standalone solution for dealing with development-related environmental impacts (Jones 2016).

Arctic marine sustainability is a "wicked problem". This term has been introduced to describe "*ill-formulated social systems, where the information is confusing, where there are many clients and decisionmakers with conflicting values, and where the ramifications of the whole system are confusing, and solutions often turn out to be worse than the symptoms*" (Churchman, 1929). The moral of wicked problems is that it is wrong to attempt to tackle only one part of a wicked problem. Thus is the purpose of this book, to outline the many competing sectors, businesses and interests, aiming to use the Arctic, as a place to live, explore, exploit and bypass; as well as recognizing their current and potential future impacts. We need a dialogue across these sectors to avoid the cumulation of impacts, scientists to assess impact interaction and sustainable governance in Arctic States and of Arctic resources. The Arctic Council will no doubt lead the way to inform and guide, providing best practices to progress sustainable development and environmental protection in the Arctic.

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