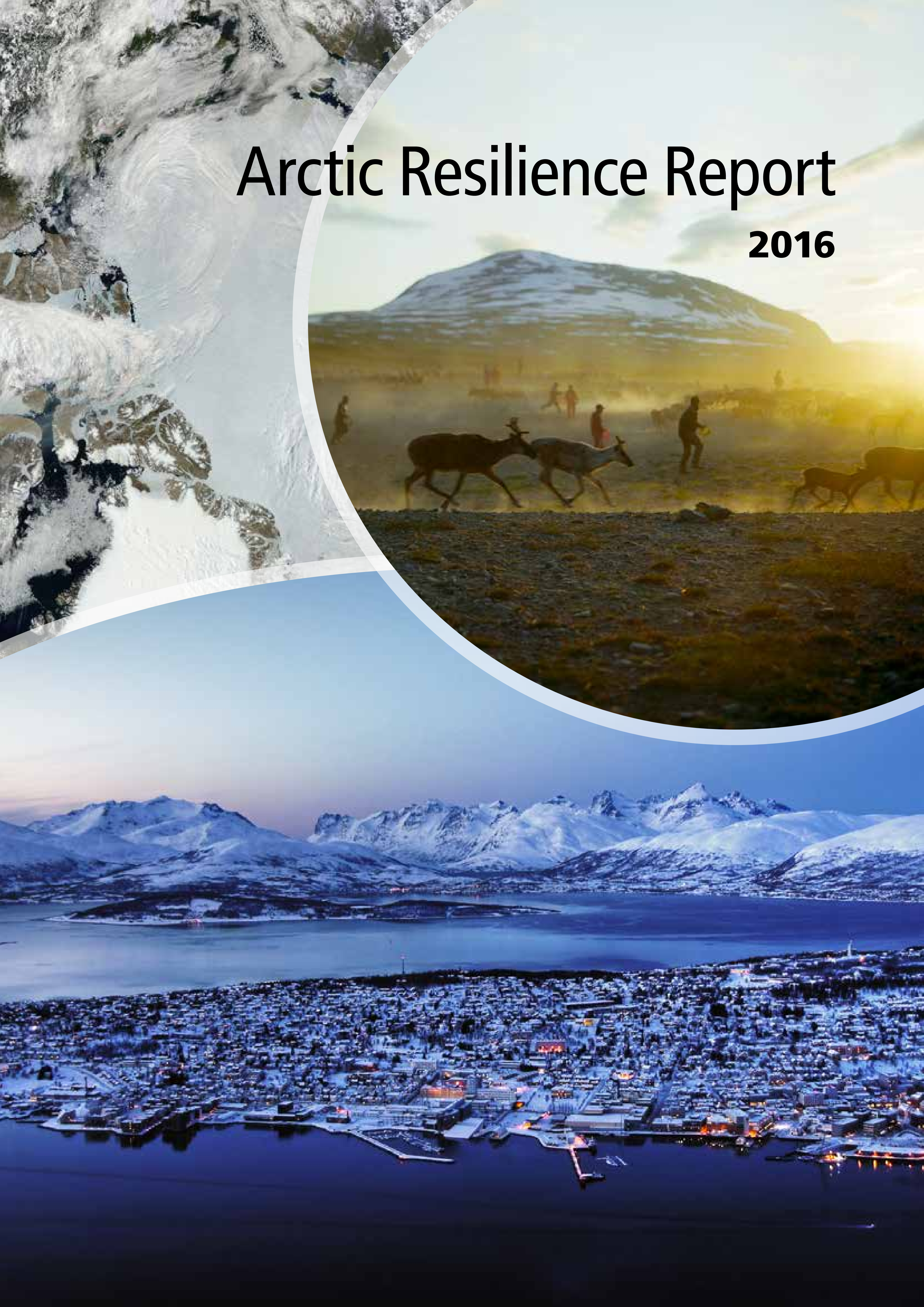
Arctic Resilience Report

2016




PACIFIC OCEAN
Bering Sea
Aleutian Islands
Petropavlovsk-Kamchatsky
Kamchatka
Sea of Okhotsk
Amur
Gulf of Alaska
Koryaks Mts.
Anadyr
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Dawson
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Chersky Range
Yakutsk
Verkhoyansk
Verkhoyansk Range
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Mackenzie Mountains
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Nunavut
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Lomonosov Ridge
Amundsen Basin
Nansen-Gakkel Ridge
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Ob River
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Qaanaaq
Nansen Basin
Franz Josef Land
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West Siberian Plain
James Bay
Ungava Peninsula
Hudson Strait
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Iqaluit
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2016

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The Arctic Resilience Assessment (ARA) is an Arctic Council project led by the Stockholm Environment Institute and the Stockholm Resilience Centre. It builds on collaboration with Arctic countries and Indigenous Peoples in the region, as well as several Arctic scientific organizations.

The ARA (previously Arctic Resilience Report) was approved as an Arctic Council project at the Senior Arctic Officials meeting in November 2011. The ARA was initiated by the Swedish Ministry of the Environment as a priority for the Swedish Chairmanship of the Arctic Council (May 2011 to May 2013) and is being delivered under the US Chairmanship of the Arctic Council.

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The ARA project is governed by a Project Steering Committee, which consists of representatives of Arctic Council Member States, Permanent Participants and Working Groups, as well as representatives of collaborating organizations. Members of the steering committee are listed below.

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Foreword

Life in the Arctic has always been defined by change and uncertainty. The seasons transform the landscape, the weather is unpredictable, and conditions can shift abruptly, sometimes dangerously. Yet the Arctic is now changing at an unprecedented pace, on multiple levels, in ways that fundamentally affect both people and ecosystems.

This report is the culmination of a five-year effort to better understand the nature of Arctic change, including critical tipping points, as well as the factors that support resilience, and the kinds of choices that strengthen adaptive capacity. Because local changes are nested in larger-scale processes, it is especially important that interactions across scales are better understood.

Resilience features prominently in three major international agreements reached in 2015: the Sustainable Development Goals, the Paris Agreement on climate change, and the Sendai Framework for Disaster Risk Reduction. The Paris Agreement alone mentions resilience six times, recognizing that climate change impacts already in the pipeline will require both humans and nature to adapt.

The changes happening in the Arctic today are driven primarily by external factors. Climate change is the most pervasive and powerful driver of change, but many other environmental changes are taking place as well, alongside rapid social and economic developments. In some contexts, factors such as resource demand, transportation needs, migration, geopolitical changes and globalization are making the greatest impact on the Arctic. Indeed, many Arctic social-ecological systems face multiple stressors at once.

Slowing Arctic change and building resilience are thus crucial for the people and ecosystems of the Arctic – but the report also highlights the stakes for the world as a whole. Arctic social and biophysical systems are deeply intertwined with our planet's social and biophysical systems, so rapid, dramatic and unexpected changes in this sensitive region are likely to be felt elsewhere. As we are often reminded, what happens in the Arctic doesn't stay in the Arctic.

The Arctic Resilience Report is the final output of a process set in motion at the start of the Swedish Chairmanship of the Arctic Council (2011–2013). The project has been led by the Stockholm Environment Institute and the Stockholm Resilience Centre, in collaboration with the Resilience Alliance. It has been pursued in consultation with Arctic countries and Indigenous Peoples, and has included collaboration with several Arctic scientific organizations.

An integral part of the assessment is to identify policy and management options that may be needed for strengthening resilience, for adaptation, and for transformational change when this is necessary. We hope this work will inform, inspire and lay the groundwork for collaborative action.

Johan Rockström
Executive Director
Stockholm Resilience Centre
Co-chair of the ARR Project
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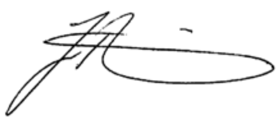

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Humans in nature – Village of Kulusuk, Greenland

Arctic Resilience Report Executive Summary

Introduction

Change – even rapid change – is the norm in the Arctic. But environmental, ecological and social changes are happening faster than ever, and accelerating. They are also more extreme, well beyond what has been seen before. And while some changes, such as warming temperatures, are gradual, others, such as the collapse of ice sheets, have the potential to be not only abrupt, but also irreversible. This means the integrity of Arctic ecosystems is increasingly challenged, with major implications for Arctic communities and for the world as a whole.

The main driver of these changes is human activity, 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 ways. Within the Arctic region, population growth and movement, communication, and shifts in culture and self-government are changing how people live and the livelihoods available to them. Understanding how these changes interact with one another, and what they mean for people and ecosystems alike, requires a holistic approach that looks at human and natural dynamics together.

This report uses the concepts of resilience and social-ecological systems to provide a holistic view of the Arctic. A social-ecological system is the combination of the human and natural systems in any given place: for example, the Skolt Sámi communities in Finland, and the ecosystem that sustains them, including the salmon in the Näätämö River. Resilience, as we define it in this report, is the capacity to buffer and adapt to stress and shocks, and thus navigate and even shape change. 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'

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Sustainable Development Goals, and the Sendai Framework for Disaster Risk Reduction, among others. Given the large and rapid changes occurring in the Arctic, resilience is immensely relevant to the people of the Arctic, its ecosystems, and the management and governance or the region's natural resources. The approach taken in this report builds upon decades of research on social-ecological resilience, and a growing body of knowledge on the Arctic in particular.

This report is the concluding scientific product of the Arctic Resilience Assessment, a project launched by the Swedish Chairmanship of the Arctic Council. The project's 2013 Interim Report provided the conceptual foundations for this final report, as well as a detailed survey of resilience research in the Arctic to date. This Final Report extends that effort by providing a novel assessment of Arctic change and resilience, including factors that appear to support or weaken resilience. It provides an overview of tools and strategies that can be used to assess and build resilience in the Arctic, and considers how the Arctic Council can contribute to those efforts. We hope the insights presented here will help Arctic nations to better understand the changes taking place in the region, and contribute to strengthening Arctic people's capacity to navigate the rapid, turbulent and often unexpected changes they face in the 21st century.

Part I: One Arctic, multiple visions, shared responsibility

The fact that the Arctic is changing fast is well known: The extent of sea ice, the condition of the Greenland ice sheet, the unusually warm temperatures are all widely reported – as are the new shipping routes opening up, and the oil exploration efforts. Less prominent, but also reported, are the stories of Indigenous Peoples whose livelihoods are disappearing, or whose villages are becoming uninhabitable.

Yet almost always, the stories (and the studies, policies, and government actions behind them) touch upon just one aspect of Arctic change at a time, missing the big picture. The reality is that changes across the Arctic are closely interconnected. The drivers of change – many of them external to the Arctic – cascade across geophysical, ecological and human elements of social-ecological systems. Because people rarely look at the system as a whole, with all its regional and global connections, we do not fully understand the changes taking place, or what to do about them.

The complexity of the Arctic also makes it challenging to monitor and forecast change – even more so because of the vastness, variety, low population density, and extreme conditions of the Arctic. There are other challenges as well that are equally important: First of all, knowledge that has been developed about the region is often compartmentalized within disciplinary or sectoral boundaries. Indigenous Knowledge, which is crucial to the resilience of many local communities, is often not considered together with scientific knowledge. Although important strides are being made to transcend these divisions, they continue to manifest themselves in much of the discussion of the Arctic, as well as in the organizational structures through which new knowledge is pursued and solutions are developed.

We use the concept of social-ecological systems as a framework for integrating the diverse types of knowledge needed to understand the interactions taking place in the Arctic, and for better understanding how social and ecological systems evolve in concert with one another. Such a framework helps identify common drivers of change, interactions among different processes, and gaps in response strategies, and thus develop more effective approaches to building resilience in the Arctic. A social-ecological systems approach is required to better facilitate resilience-building, a key component of sustainable development.

A key aspect of this approach is that it sees people as a fundamental – and increasingly influential – part of nature. It emphasizes the unique human capacity for agency – for engaging in deliberate action. While we all understand this at some level, our scientific methods often seek to screen out human action and the ways in which it is steered. It is this capacity that not only is accelerating the changes taking place in the Arctic, but also provides the means for purposefully and effectively navigating that change. The challenge in the Arctic is that it requires collective deliberation, decision-making

Responding to Arctic change: a selection of 25 case studies from across the Arctic were analysed for this report. The cases illustrate both loss of resilience and resilience, including instances of transformational change.


Mark Tozer

and action by a very wide range of actors, within and outside the Arctic.

The theme of the US Arctic Council Chairmanship, "One Arctic, Shared Responsibility", highlights that important reality: The Arctic is a unique, ecologically and economically crucial region for which responsibility must be shared. It is home to many, a source of resources for others, and a key part of a global system of climate regulation. Yet, while there is only one Arctic, diverse Arctic actors define their interests and goals related to the Arctic in very different ways. The Arctic can be perceived through lenses that emphasize security, tourism, extractive industries, nature, or the well-being of Indigenous Peoples. These distinctions are more than matters of philosophy or perception; they have material consequences. Oil and gas extraction may directly conflict with commercial fisheries, and both may be at odds with the subsistence livelihoods of a local community. The clear demarcation of property lines may favour new development, but hinder the seasonal movements of reindeer herders.

If there is only one Arctic, all parties must share responsibility because activities pursued in one place influence what is possible elsewhere. The Arctic can accommodate very diverse pursuits, but only to the extent that they are either compatible, or else separated by enough time and distance. Some activities may conflict at first, but be reconciled if both sides agree on shared goals and mutually acceptable conditions. A key first step in achieving this is to build a common understanding of the ways in which the diverse aspects of the Arctic – social, ecological and biophysical – are intertwined and co-evolve.

Part II: How is the Arctic changing, what forces are driving change, and how are communities responding?

Arctic ecosystems are changing in dramatic ways: ice is melting, sea levels are rising, coastal areas are eroding, permafrost is thawing, and landscapes are changing as the ranges of species shift. People's lives are changing as well, with new livelihoods, new technologies, increasing connections to the outside world, and new forms of Arctic governance. Resilience enables people and ecosystems to cope with the shocks and stresses associated with these changes, and to adapt and even transform themselves as needed. Yet some changes are so substantial (and, often, abrupt) that they fundamentally alter the functioning of the system: an ecological "tipping point" has been crossed. Scientists call such largely irreversible changes "regime shifts".

Chapter 3 of the report examines 19 documented or potential regime shifts in the Arctic – from a shift to sea-ice-free summers, to collapse of different Arctic fisheries, to the transformation of landscapes: from bogs to peatlands, or from tundra to boreal forest or to steppe. These regime shifts are having large impacts on the availability of wildlife, the stability of the climate, and Arctic people's sense of place and well-being. They affect many ecosystem services that are important to people within and outside the Arctic: from regulating the climate, to providing sustenance (e.g. through fishing).

Our analysis shows that these regime shifts are driven by a variety of forces, most notably human-induced climate change, but also resource exploitation, fishing and tourism, among others. Drivers of change frequently originate from outside the Arctic – for example, the burning of fossil fuels, and decisions related to fishing and mineral exploitation. Others are the result of Arctic people's own actions.

Our analysis shows that the risk of most Arctic regime shifts is increasing, but the risk of particular regime shifts varies among Arctic nations. While some regime shifts are well known, such as loss of summer sea ice, most regimes shifts are neither widely known nor well understood; far more research is needed. Another key finding is that climate change is an important driver in all the regime shifts. This means that reducing the risk of regime shifts will require strong action to mitigate climate change, not just by the Arctic countries, but by the global community. At the same time, the analysis points to several potential actions within local or national governments' control that can decrease the risk of regime shifts. Considering the risk of regime shifts when designing natural resource management systems, policies and plans could increase resilience.

Many regime shifts involve similar processes, which means that there is potential for some regime shifts to trigger or increase the risk of other regime shifts occurring. We know that such "cascading" regime shifts can occur, but need to learn more about the extent to which different regime shifts reinforce changes that are under way, or how to mitigate this risk. We also know that the consequences of some of these shifts are likely to be surprising and disruptive – particularly when multiple shifts occur at once. By altering existing patterns of evaporation, heat transfer and winds, the impacts of Arctic regime shifts are likely to be transmitted to neighbouring regions such as Europe, and impact the entire globe through physical, ecological and social connections.

Chapter 4 complements this analysis with a review of 25 case studies of how Arctic communities have responded to change: whether they have demonstrated resilience and adapted or achieved transformational change, or lost resilience. Resilience has always been crucial for people living in the Arctic – and it is even more so amid the rapid changes taking place today. The case study analysis helps us to understand the social, behavioural and ecological processes that are already building (or eroding) resilience in the Arctic.

A systematic comparison of the cases identified four key factors that contribute to resilience: 1) the capacity for self-organization – that is, to make decisions and implement responses to change; 2) diversity of responses to change; 3) the ability to learn from and integrate diverse types of knowledge; and 4) capacity to navigate surprise and uncertainty. These findings align with previous research on resilience.

The capacity for self-organization is particularly crucial. A resilient community has the ability to come together to effectively identify and respond to challenges, and can resolve conflicts and disagreements. Our analysis showed a decline in the capacity for self-organization was strongly associated with a loss of resilience. Capacities linked to learning, the maintenance of social memory, and learning from crisis were also very important for enhancing resilience.

Some cases provided examples of how people and communities in the Arctic have transformed the way they live and interact with nature and natural resources. For example, the Inuit of Cape Dorset, in Nunavut, Canada, formerly nomadic hunters, have become internationally recognized artists. The fishing community of Húsavík, on Iceland's Skjálfandi Bay, turned itself into a tourist destination for whale-watching after cod-fishing quotas and a moratorium on whaling ended their traditional livelihoods. The attributes of cases of transformation are similar to those of resilience, but their small number makes it hard to identify more specific shared traits. More research is needed on both successful and unsuccessful Arctic transformations.

Part III: Shaping change

As noted above, the human capacity for deliberate action (i.e. agency) is central to the humans-in-nature perspective of this report. In the Arctic, as elsewhere, people take action as individuals, as communities, and through various organizations. Institutions play a key role in bringing people together to make decisions and to steer their activities. They help define common policy problems, assemble the required knowledge, create rules and norms to guide responses, marshal the needed resources, and facilitate action.

As the Arctic's sole circumpolar high-level policy forum, the Arctic Council plays an increasingly important role in issues that have major social and environmental implications. Over its brief history it has played a central role in identifying issues of common concern in the Arctic and developing the knowledge necessary to tackle those issues. It has helped devise novel ways of fostering pan-Arctic collaboration, and bridged and brokered between different levels of decision-making. As the Arctic

Mike Beauregard/Flickr

changes, the Arctic Council continues to evolve to meet the region's needs.

To better understand what engagement with the challenges ahead might look like, Chapter 5 reviews the evolution of shared decision-making in the Arctic, with a particular focus on the Arctic Council's 20-year history. In Chapter 6 we analyse how the Council has grappled with three global drivers of change that are especially important in the Arctic: transboundary pollution (i.e. across national borders), climate change, and demand for natural resources and its link to extractive industries. The substance and scale of these issues pose very different challenges for the Council, and offer different opportunities.

Amid constant change, the Arctic Council has been able to deal with new challenges by modifying how it works: incorporating new types and forms of knowledge and opening up to new kinds of participation. It has also set new activities in motion – especially when policy problems cannot be managed within national borders. Going forward, it will be important for the Council to continue to be agile and able to evolve with changing needs.

Finding ways to strengthen connections across issues, both in research and in policy, is a key challenge for the Arctic Council and its activities. Studies and debates too often occur within "silos": focusing on pollution, or culture, or resource extraction, but less on the interconnections between these activities. By more systematically bringing these different perspectives together, the Arctic Council can support the development of more integrated – and more effective – strategies to address trade-offs and, where possible, find synergies. As with other endeavours, the development of knowledge depends on the organizational structure that is in place. A more integrated approach to Arctic research and decision-making will require institutional changes to bring together diverse perspectives and forms of knowledge

Achieving such an integrated approach will likely require building local people's capacity to engage with a multitude of relevant regional and global processes. It will also require navigating the often-complex allocation of decision-making power among different key actors – no small task in an increasingly dynamic and congested geopolitical context. Another aspect of this effort is to find new ways to connect decision-making activities at the local and international levels.

Organizational learning is a fundamental element of the social response to social-ecological change and thus to resilience. Organizational learning at the level of the

Arctic Council has been and will continue to be important as the political landscape evolves and as new knowledge challenges emerge. Arctic decision-making and management systems are currently challenged to respond to rapid change in the region by developing capacities to facilitate the speed and effectiveness of both learning and translating into action.

The basis for decision-making structures and management strategies focusing on the Arctic plays a central role in shaping how Arctic people can influence and are influenced by internal and external changes in climate, ecosystems, politics or economics. As a process of shared deliberation and decision-making, such structures and strategies play a central part in shaping continuity and change by defining goals, who and which knowledge gets considered in decisions, and who owns and has access to Arctic land, seas and resources.

Part IV: Building resilience

Resilience can be cultivated and strengthened. If we understand the key components of resilience, and the extent to which they are present in a given context, we can target activities to enhance each component and fill any gaps. One way to think of these components is as forms of capital; the Interim Report identifies seven types as crucial to resilience: natural capital, social capital, human capital, infrastructure, financial capital, knowledge assets and cultural capital.

These elements are interlinked and should be viewed as "bundles" of resources that complement one another, in different combinations, depending on the context. For example, a community looking to adapt to change by developing tourism might draw on natural capital (wildlife, the beautiful landscape), cultural capital (Indigenous People's culture and art), financial capital (money for renovations and new amenities), infrastructure (e.g. roads, a port), and social capital (connections within the community and with outsiders who can help attract tourists).

Efforts to measure and monitor these components of resilience in the Arctic are only in their early stages. Our research highlights the need to develop indicators that could be used to monitor and assess the status of different aspects of adaptive and transformative capacity and how they are developing over time. Such a system could be used for evaluating different policy options and how their outcomes influence resilience.

Yet while the bundles of resources are important preconditions for successful adaptation, they are not enough. Adaptive capacity needs to be activated, and in the Arctic context, significant barriers often arise. Two key factors for activating adaptive capacity are enabling institutions and a social and environmental space that allows for flexibility. For instance, reindeer herders have traditionally used migration as a way to cope with unfavourable grazing conditions in any one place; as government policies and industrial development restrict their mobility, they have less capacity to adapt.

A number of Arctic Council initiatives have already contributed to building resilience and adaptive capacity in the region. It has played a crucial role in building knowledge assets, particularly with regard to the Arctic's natural capital, and in shaping policies on natural resources. For example, the Arctic Climate Impact Assessment helped set the stage for action by providing an in-depth review of the implications of climate change for Arctic people, and by including local and Indigenous Knowledge. The Arctic Council has also helped to build social capital, by providing a forum for international political cooperation, and by enabling new knowledge networks in connection with producing scientific assessments. It has also played some role in building human capital, indirectly supporting education in the Arctic by building knowledge assets that have served as the basis for new educational activities.

The Arctic Council has taken initiatives to strengthen infrastructure for search and rescue and oil spills, but more remains to be done in addressing this key aspect of adaptive and transformative capacity. Similarly, there is a crucial need for support of research to understand how Arctic economies are changing, and how the formal economy and the availability of financial capital affect both households' incomes and well-being, and communities' capacity for adaptation.

The final chapter of the report focuses on how to translate the concept of resilience into action in the Arctic. A key starting point is to understand what we mean by resilience: the concept means different things in different contexts, and can be laden with judgements about whether systems are fragile or strong, and whether change is desirable or not. In practice, the best way to think about resilience is to think of navigating change as a complex process of identifying the desirable features of a system and strengthening them, while letting other features become weaker to allow for change.

We identify six basic "rules of thumb" – heuristics – for evaluating activities, programmes, practices and/or strategies in terms of their likely contribution to support resilience-building. They are: 1) Are the goals clear? 2) Are multiple kinds of knowledge being integrated? 3) Are place-based community partnerships being supported? 4) Are linkages being made across scales? 5) Is social learning being facilitated? 6) Is culture being taken into account?

We also identify several practices and strategies that can be used to build resilience in the Arctic. The first is to monitor the status of social-ecological systems and how they are changing. Closely related to this are two other practices: tracking and learning from regime shifts, and undertaking resilience assessments. Model simulations – particularly agent-based models, which incorporate the motivations of different actor types – can help decision-makers to understand the implications of different policy options. Participatory scenario analysis is another valuable tool that can provide a platform for addressing and bridging different approaches to knowledge, world views, and values. "Decision theatres" – large, shared visual spaces for exploring an issue collaboratively – are a promising new option. Developing regional and global strategies to build resilience is a valuable approach as well.

Resilience practices are most effective when they avoid panaceas or one-size-fits-all solutions, as these almost always undermine rather than enhance resilience. Instead, there is a need for experimentation and innovation to benefit from insight of theory as applied with the conditions of specific contexts. Resilience-building needs to be a multi-scale enterprise, sensitive to power imbalances, issues of justice (and injustice), and local-level needs. Bottom-up and top-down approaches are needed, and should both have good communication flows, well-articulated and coordinated actions, and high responsiveness.

Institutions will play a key role in building resilience in the Arctic. Informal institutions, such as communities of practice, shadow networks, and boundary organizations can be powerful forces of change when there are no formal arrangements to address a problem. Formal institutions such as the Arctic Council are crucial as well, as they can help establish and support resilience-building programmes.

The Arctic is undergoing rapid and dramatic changes. Building resilience is an urgent, immediate need across the region, and while the challenges of Arctic change are great, the people of the North have a long history of successfully navigating uncertainty and fluctuating conditions. Living in one of the world's most variable biomes means that people of the Arctic, and in particular the Indigenous Peoples of the Arctic, know a great deal about resilience. But the current scope and pace of change means they cannot do it alone. The resilience of Arctic communities and ecosystems depends not only on the commitment and imagination of Arctic people, but also on the active support of Arctic countries' governments and other partners. Most of all, the people of the Arctic need support to organize, define challenges in their own terms, and find their own solutions, knowing that they will have the flexibility and external backing to implement their plans.

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Glossary of terms

Adaptive capacity: The ability of a system or individual to adjust to changing conditions or recover from the impacts of change. In ecological systems, adaptive capacity is influenced by the biodiversity and the degree of redundancy in the system. In social systems, it is determined by the structures and processes that enable or constrain choices for action and that shape people's ability to anticipate and plan for future change.

Agency: For the purposes of this report, agency is defined as the capacity of people to make choices and take action.

Controlling variable: A system component that has a dominant influence on the functioning of the system. Often, these are slowly changing components that trigger fast changes in other variables.

Cultural ecosystem services: The cultural values and benefits provided by ecosystems, including values such as recreation opportunities, aesthetic inspiration and spiritual values.

Driver: A natural or human-induced factor that causes a change in a system. Note that a driver that is seen as an external process when viewed at one scale may be seen as an internal process when viewed at another.

Ecosystem services: The benefits to human society that arise from ecosystem processes.

Feedback: A change within a system that occurs in response to a driver, and that loops back to control the system. A feedback can help to maintain stability in a system (negative or balancing feedback), or it can speed up processes and change within the system (positive or enhancing feedback). Feedback processes play a very important role in determining system thresholds and in maintaining system resilience.

Forcing: In climate science, forcing refers to an external driver of change in the physical climate system.

Function: The activities that are characteristic of a system, and that maintain its structure and services.

Provisioning ecosystem services: The goods directly obtained from ecosystems, such as food, fibre, fuel and fresh water.

Regime shift: For complex systems, a substantial and enduring reorganization of the system, where the internal dynamics and the extent of feedbacks undergo change.

Regulating ecosystem services: The beneficial ecosystem processes that help to maintain ecosystem function, such as pollination, erosion control, carbon sequestration and water filtration. These services provide indirect value to people.

Resilience: The capacity to cope with stress and shocks by responding or reorganizing in ways that maintain essential identity, function and structures, as well as the capacity to navigate and shape change, including transformational change.

Social-ecological system: An integrated system that includes human societies and ecosystems. The functions of such a system arise from the interactions and interdependence of the social and ecological subsystems. The system's structure is characterized by reciprocal feedbacks.

Structure: The web of interactions that link a system's key actors or processes.

System state: The configuration of a system defined by its structure, function and feedbacks.

Threshold: An abrupt breakpoint between alternate states of a system, where a small change in the controlling variable produces a large change in the characteristic structure, function and feedbacks of the system.

Tipping point: A specific kind of threshold, characterized by bifurcation in a system, often recognized in systems that show oscillations between alternative states.

Transformation: A fundamental change to the coupled social-ecological system. It can be unintended, or actively navigated by people involved through the alteration of a system, when current ecological, social or economic conditions become untenable or are undesirable.

A village on the Greenland shore.

PART I

Humans in Nature – Arctic Social-Ecological Systems

Mads Pihl/Destination Arctic Circle

Arctic social and ecological change threatens the integrity and sustainability of Arctic communities and ecosystems. These changes are driven primarily by human activities – and mainly from outside the Arctic. While human-caused climate change is the single largest driver, migration, resource extraction, tourism and shifting political relationships also play a major role in reshaping Arctic landscapes, people's lives and their livelihoods.

Resilience is crucial for navigating and shaping change. We define the term in Chapter 1 as the capacity for navigating change by adapting or reorganizing in response to stress and shocks in ways that maintain essential identity, function and structures.

We view the Arctic as an integrated *social-ecological system* – that is, we examine the human and natural systems as parts of a larger whole – and focus on understanding their interactions. The social-ecological perspective recognizes that human and natural systems are closely intertwined, and views people as an integral part of ecosystems. Local interactions between social and ecological systems are critically important to resilience, but they are also embedded within regional and global social-ecological dynamics that shape local outcomes.

The theme of the US Arctic Council Chairmanship, "One Arctic, Shared Responsibility", highlights the Arctic as a unique, ecologically and economically crucial region for which responsibility must be shared. It is home to many, a source of resources for others, and a key part of a global system of climate regulation. Yet while there is only one Arctic, diverse Arctic actors define their interests and goals related to the Arctic in very different ways.

Chapter 2 shows some of the many different perspectives from which the Arctic has been studied, with emphasis on the physical environment, ecosystems and people, often each examined separately. The Arctic can also be analysed from the perspective of security, tourism, extractive industries, nature, or the well-being of Indigenous Peoples.

The Arctic can accommodate very diverse activities, but only to the extent that incompatible activities are either separated by enough time and distance, or made compatible. Because activities pursued in one place influence what is possible elsewhere in the Arctic, all parties must share responsibility.

CHAPTER 1

An Arctic Resilience Assessment

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Key Messages

- The Arctic is undergoing rapid, sometimes turbulent change beyond anything previously experienced. That change is due to climate change, resource extraction, tourism, political change and other factors, driven primarily from outside the Arctic – and it has global implications.
- Within the Arctic, the integrity of ecosystems and the sustainability of communities are being challenged, affecting how people live and pursue their livelihoods.
- Understanding Arctic change requires a systemic perspective that integrates human and natural dynamics. We apply a social-ecological systems approach, which assumes that to adequately understand either social or ecological systems, we need to understand how they interact.
- Our analysis focuses on the resilience of social-ecological systems in the Arctic, which we define as the capacity to navigate change by adapting or reorganizing in response to stress and shocks in ways that maintain essential identity, function and structures.

Ville Miettinen/Flickr

Sea ice conditions around the village of Kulusuk in eastern Greenland are changing at an unprecedented pace.

1.1 What's new about Arctic change?

I too have noticed changes to the climate in our area. It has progressed with frightening speed especially the last few years. In Iqaluktutiaq, the landscape has changed. The land is now a stranger, it seems, based on our accumulated knowledge. The seasons have shifted, the ice is thinner and weaker, and the streams, creeks and rivers have changed their characteristics. (Analok 2001)

Change is occurring in the Arctic at an unprecedented pace. This dynamism is, first and foremost, a consequence of biophysical processes, and especially the cluster of developments we ordinarily lump together under the rubric of climate change. These developments are real; they are occurring now and are not just matters of speculation about the future. (Young 2010)

And what these rising temperatures mean is that the resilience of our communities and our ecosystems, the ability of future generations to be able to adapt and live and prosper in the Arctic the way people have for thousands of years, is tragically but actually in jeopardy. (Kerry 2015)

Change is proceeding with a pace and breadth that bears with it uncertain consequences for the peoples of the Arctic, the eight Arctic nations, and the world at large. Many, if not most, recent examinations of the Arctic note the increasing rapidity with which change is cascading across the region. Yet, as anyone who has lived or spent time in the Arctic will quickly note, change – even rapid change – is hardly a new characteristic of the far North. What is different is the scope of change – some aspects of the Arctic's social and ecological systems are changing fundamentally, shifting past what may well be irreversible thresholds, while in other instances seasonal variations now move far outside of their previous norms (Committee on Emerging Research Questions in the Arctic et al. 2014; Arctic Council 2013). The sheer scope of these conditions is producing a "maelstrom of competing commercial, national security, and environmental concerns, with profound implications for the international legal and political system" (Ebinger and Zambetakis 2009). It also has profound implications for those who call the Arctic home.

1.1.1 Not only the Arctic

It has long been understood that the Arctic is intimately connected to geophysical and ecological systems at a global scale. The reflectivity of Arctic ice and snow, for example, plays a central role in the Earth's climate system (Milankovic 1998; Labeyrie et al. 2003). Many of the Arctic's links to global ecosystems are also well established. Some Arctic bird populations or whale species migrate enormous distances to feed and reproduce (Ganter and Gaston 2013). And the Arctic Council itself has its roots in these connections: the international agreement that was its predecessor, the Arctic Environmental Protection Strategy (AEPS), was developed in large part to tackle the problem of long-distance transport of persistent chemical pollutants accumulating in the Arctic and working their way into the food chain, ultimately affecting human health and threatening food security in some Arctic communities (see Chapter 6).

While the ongoing flow of change in the Arctic has always opened and closed off options for human activity, the wider variability – and the lopsidedness of some kinds of variability – are opening the way for new activities that were not possible only a few decades ago. Increasing global resource demand is converging with changes in accessibility, new transport opportunities, and even geopolitical changes, to generate commercial and political interest from far outside the Arctic (Ebinger and Zambetakis 2009). Significant concern tempers that interest, as the scientific community demonstrates how Arctic change may reinforce feedbacks that amplify climate change (IPCC 2014). Other concerns focus on how, and the extent to which, new opportunities can be

Jeff Schmaltz/NASA, GSFC, MODIS Land Rapid Response Team

Loss of sea ice is one of the many socio-ecological changes that are increasing uncertainty for the peoples of the Arctic.

pursued in ways that work to the benefit of people living in the Arctic and help them to develop more prosperous communities, and to do so while retaining their identities and ways of staying connected with the land.

Much of the increased pace and scope of Arctic change can ultimately be linked to the impacts of human activities. These impacts are in some instances mediated through global environmental changes, while other Arctic human impacts are experienced more directly through new or expanded activities. As one prominent Arctic scholar describes it,

> *"The Arctic has become a highly dynamic socio-ecological system due largely to the interacting forces of climate change and a suite of factors that we commonly group together under the rubric of globalization. The result is a cascade of developments that are accentuating the links between Arctic processes and global systems and generating new needs for governance to maintain sustainable human-environment relationships in the circumpolar north."* (Young 2010)

These changes in turn impact both ecosystems and communities, and not only in the Arctic (AMAP 2011; Arctic Council 2013). These links to ecosystems, communities, and beyond the Arctic are discussed further in Chapter 3 in terms of "regime shifts", and Chapter 5 in terms of "connectivity".

As a part of this whirlwind of change, new forms of cooperation have emerged that transcend both national boundaries and conventional thinking about security. Much of this combined effort is channeled via the Arctic Council, which has established itself as the region's primary forum for international cooperation, particularly among the eight countries whose territory extends above the Arctic Circle. As Exner-Pirot (2015), an informed (and highly positive) observer, has put it: "The Arctic is a place where cooperation is sought, Indigenous Peoples are respected, development is increasingly sustainable, and scientific research is supported and used in decision-making processes. It is a model of success." And while such unbridled optimism is perhaps not universally shared – and has more recently been tested in the wake of new international tensions over developments elsewhere in the world – efforts to maintain the cooperation under the Arctic Council as a space to meet, discuss, and tackle common problems remain a widely shared priority among Arctic countries.

Mads Pihl/Destination Arctic Circle

The reflectivity of Arctic ice and snow plays a central role in the Earth's climate system.

1.1.2 The Arctic Resilience Assessment

This context of profound change is the backdrop against which the Arctic Resilience Assessment (ARA) is being carried out. Building on the Arctic Resilience Interim Report (Arctic Council 2013), this final scientific report addresses itself to interconnectedness, thresholds, stewardship and governance, and, of course, resilience. Where the Interim Report aimed to provide a state-of-the-art overview of resilience thinking in the Arctic and examine some of its potential applications, this concluding report of the Arctic Resilience Assessment seeks to further develop that foundational work in ways that help to facilitate decision making and subsequent action. It proceeds by extending the concept of resilience in ways that strengthen the potential to make it more actionable, by incorporating new developments and new research carried out subsequent to the Interim Report, by examining the rapidly changing and increasingly complex policy context in which decisions about the Arctic are carried out, and by identifying activities – some currently underway in the Arctic – that can contribute to strengthening resilience.

A central task of this first chapter (and more generally, of Part I) is to place the Arctic Resilience Assessment in its broader context. It examines the broader discourses of resilience, explores the dynamics of social and ecological systems, and also points to trends toward interdisciplinarity,[1] in scientific investigation of the Arctic.

1.2 Resilience

The discourse of resilience is seemingly everywhere, yet the concept is used with varied meanings as a result of its widespread applications (Brand and Jax 2007; Baggio et al. 2015). This is not unlike "sustainable development",[2] which, while it has usefully encouraged discussion and innovative work across different disciplines and practices, the diverse ways that it has been applied have also generated confusion. Addressing the key question of "resilience of what, to what" helps resolve some of this definitional confusion, in part by specifying the character of the system being examined and the nature of the pressures that may be buffeting that system. We take up this point in greater detail in Section 1.2.3. First, however, we briefly examine some of the different definitions of resilience and how they are related, and also some of the arguments that resilience ought to be practical, enhance interdisciplinary exchange, and properly encompass both the social *and* the ecological.

1.2.1 The "spectacular rise" of resilience

"Resilience" is being embraced as a useful concept across a diverse range of endeavours. In the last few years, there has been a "spectacular rise" in the use of the term, as it has

1 We define interdisciplinarity as an approach to scientific problem solving that supersedes conventional disciplinary boundaries, thereby creating new knowledge. This is also sometimes described as transdisciplinarity.

2 Resilience is also distinct from sustainable development. Understanding the system dynamics that are part of resilience "is important to sustainability because it enables decision-makers to choose between actions that involve adaptation to future changes, and actions that mitigate those changes" (Perrings 2006).

BOX 1.1 Background to this report

Speaking to the dynamic of Arctic Change, the May 2011 Nuuk Ministerial Declaration highlighted the need for "an integrated assessment of multiple drivers of Arctic Change as a tool for Indigenous Peoples, Arctic Residents, government and industry to prepare for the future…" Beginning as a Swedish initiative during its Arctic Council Chairmanship (2011–2013), the Arctic Resilience Report is intended to contribute to filling this gap, and was specifically charged with identifying potential "cliffs" or tipping points, assessing challenges to the communities in the Arctic, and identifying ways in which the Arctic Council might contribute to preserving and/or strengthening resilience across the Arctic. The project's Arctic Resilience Interim Report (Arctic Council 2013) was delivered at the conclusion of the Swedish Chairmanship in Kiruna at the 2013 Ministerial. Subsequently, as it became apparent that the United States Arctic Council Chairmanship would include a significant focus on resilience, the U.S. joined Sweden to co-chair the project through the remainder of its work, also extending the time frame to coincide with that of the U.S. Chairmanship. The overall project was renamed by its Project Steering Committee from Arctic Resilience Report to Arctic Resilience Assessment, and plans were laid for both this Arctic Resilience Final Report for September 2016, and for the delivery of its Synthesis for Arctic Leaders to the upcoming Arctic Council Ministerial meeting slated for Fairbanks, Alaska at the conclusion of the U.S. Chairmanship.

As part of its assessment, ARA has engaged most with Arctic Council Working Groups with which there are clear synergies. In addition to consultation with the Working Groups, ARA has worked closely with the Arctic Monitoring and Assessment Program (AMAP) through the AACA-C, where ARA authors are contributing a resilience perspective to the regional reports. ARA has also explored possible links with the work of the Sustainable Development Working Group (SDWG), which also has projects dealing with resilience in the Arctic. The ARA also engaged experts from around the Arctic in several workshops intended to inform both the content and the structure of this final report. A summary of these activities can be found in Appendix 1 of this report.

gone from being a largely academic concept to becoming a popular buzzword defining successful response to disruptive forces (Brown 2014). But because the concept has to a large extent been developed independently in fields as diverse as psychology, engineering, disaster response and systems ecology (Baggio et al. 2015), it is defined and used in substantially different ways. In particular, it has been used to understand qualities that strengthen individuals' ability to navigate adversity (APA 2016), how to make cities more robust in the face of climate change (ICLEI 2016; The Rockefeller Foundation 2016), to understand how to reduce vulnerability in the context of disaster risk (Klein et al. 2003), and in efforts to strengthen stewardship of ecosystems (Chapin III et al. 2015). *Time Magazine* recognized the emergence of resilience into the mainstream by dubbing it the "environmental buzzword of 2013" (Walsh 2013). Resilience also figures strongly in the Sustainable Development Goals (United Nations 2015) and the Paris Agreement on climate change (UNFCCC 2015). Speaking to the resilient cities movement, *The Guardian* points to resilience as "a global attempt to address two of the longest-standing and most vital questions facing theorists, planners and leaders. Namely, what is the purpose of society, and what is a society's responsibility to its citizens" (Watson 2014). And whatever that responsibility, it must also encompass the ecosystems upon which societies depend for their life support.

BOX 1.2 Differing definitions of resilience

"The essence of resilience is … the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress." (Hollnagel et al. 2006)

"[a] component of stability is resilience, or the rate of return to pre-existing conditions after a perturbation" (Tilman and Downing 1994)

"A social system's capacity to facilitate human efforts to deduce the trends of change, reduce vulnerabilities, and facilitate adaptation; and the capacity [of a social-ecological system] to sustain preferred modes of economic activity" (Kofinas 2003)

"The capacity of a system to absorb disturbances while retaining essentially the same function, structure, identity and feedbacks" (Walker et al. 2004)

"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR 2007)

"The existence, development and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability and surprise" (Magis 2010)

"Resilience is a property of social-ecological systems. It relates to their 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, transform" (Arctic Resilience Interim Report 2013)

Resilience has been widely adopted especially in contexts in which the capacity to cope with disruptions or unexpected shocks is deemed important, with at least some of its growing popularity attributable to positive associations of "bouncing back" after disruption. However, discussions of resilience frequently emphasize that *undesirable* systems or conditions can be resilient (e.g. systems that leave people impoverished can be robust and resistant to change), or that maintaining or returning to the status quo is often not the preferred condition (Manyena et al. 2011; Kresge Foundation 2015). Academic discussions of resilience often focus on the factors that shape the broader dynamics of systemic continuity and change, and on understanding the factors that contribute to resilience and enable both adaptation and systemic transformation (Gunderson and Holling 2001; Folke 2006; Folke et al. 2010).

Box 1.2 lists a selection of the different ways resilience is being defined – in some cases for scientific analysis, in others as part of an effort to mobilize resources and people to address potential or currently pressing problems. After reviewing the qualities that make the concept appealing and useful, and important critiques of it, we extend our earlier definition (from the Interim Report) to better encompass aspects of social-ecological resilience that make it actionable.

The rapidly expanding popularity of resilience has also borne with it critique, of which three are especially relevant for this report. First, as discussed above, definitions of resilience vary widely, which can undermine the analytical leverage of important concepts. This is of course a problem not unique to resilience. For example, a search of other important concepts ranging from "sustainable development" to "governance" to "agency" quickly reveals a diversity of uses and meanings. As we take up in greater detail in Section 1.2.2, this issue is addressed by clearly specifying how the concept is applied in the research and analysis in this report.

A second critique is that resilience often tends to be highly theoretical (Klein et al. 2003), with too little attention

Lawrence Hislop/Grid Arendal Photo Library (http://bit.ly/2ciBBD9)

Thick surface meltwater covers the sea ice near Uummannaq, Greenland, where the local Inuit population relies heavily on ice coverage for fishing and travelling with dog-sleds.

to practical use. We see carefully linking abstract understanding with practical application as essential to the goals of this report. The Arctic Resilience Assessment is charged both with assessing Arctic Resilience and with providing practical insights to the Arctic Council and Arctic leaders at all scales that can facilitate policy choices, planning, and the development of activities. In order to facilitate bridging between theory and practice, this first chapter emphasizes aspects of a resilience approach that can inform action, and questions of "what can be done?" are highlighted throughout the report. Each of the subsequent chapters in this report contributes to this larger puzzle.

Finally, resilience research has been criticized as tending to "constrain the interdisciplinary dialog" (Olsson et al. 2015) – partly due to its emphasis as a systems approach for understanding social and ecological systems as parts of an integrated whole. This critique argues that social and ecological systems are not commensurable, and that a more discipline-centered, but pluralistic approach to interdisciplinary collaboration is preferable. There are of course many challenges involved in transcending the protective silos of different academic disciplines and knowledge systems. However, different strategies for better understanding the characteristics of ecology and society and how they interact need not be seen as an either-or proposition. The integrative framework used in this report – working from a social-ecological systems perspective – is summarized in greater detail in Section 1.3. Further, in Section 1.5, we examine the broader call for interdisciplinarity as well as a review of the body of systems-oriented research (Hollingsworth et al. 2008a) that indicate how holistic, integrative perspectives promise important scientific and policy-relevant insights.

1.2.2 What do we mean by resilience?

The Arctic Resilience Interim Report (2013) defines resilience as 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, transform*" (Arctic Council 2013). This way of defining resilience makes explicit the importance of acquiring new knowledge in order to deliberately respond to change. Learning constitutes an important addition to what has become a standard working definition for research on social-ecological systems: "the capacity of a system to absorb disturbances while retaining essentially the same function, structure, identity and feedbacks" (Walker et al. 2004). The Walker et al. definition characterizes resilience as a system property independent from judgments that might be made about its desirability, although this definition is sometimes applied to current ecological conditions to which communities have accustomed themselves and therefore wish to perpetuate (Kofinas et al. 2013). The "disturbances" referred to in that definition might be generated by natural phenomena such as a thunderstorm or fire, or they might be the known but unintended result of human activities such as the burning of fossil fuels. In this final report, we take the additional

Human activity can threaten the livelihoods of Arctic inhabitants through unintended consequences, such as depletion of fish stocks.

step of explicitly incorporating human *agency*[3] and its role and influence in the evolution of social-ecological systems. Agency is a central reason that Adger (2000) distinguishes social resilience from ecological resilience, while in a similar vein Moberg and Galaz (2005) argue that social resilience "differs fundamentally from ecological resilience by having the added capacity of humans to anticipate and plan for the future". Knowledge of social and ecosystem interactions may guide (or fail to guide) the exercise of agency both in the form of decisions and subsequent actions.

Agency as a fundamental dimension of social systems is a central feature in the scholarship on community resilience and also represents an important element of the academic and practical work on disaster risk reduction (e.g. it features strongly, if not explicitly, in UNISDR's definition of resilience – see Box 1.2). While work on community resilience or disaster risk reduction tends to leave the dynamics of ecosystems in the background, the two fields do often acknowledge the environment as a source of both well-being and risk. The capacity for deliberately and consciously charting a course into the future is not only the central distinction between social and ecological systems; it is also the key juncture where policy choices are relevant (discussed further in Section 1.2.5, below) and where knowledge is brought to bear. Therefore, in order to advance practices addressed to social-ecological resilience – and understanding that we cannot control ecosystems, but can influence human activities within it – we propose the following definition of resilience:

> *"The capacity of people to learn, share and make use of their knowledge of social and ecological interactions and feedbacks, to deliberately and effectively engage in shaping adaptive or transformative social-ecological change".*

The engagement referred to may be in response to disturbances, to strengthen a desired set of functions, to stave off unwanted changes, or to pursue a more desirable set of arrangements. People exercise agency both individually and collectively. Their continually developing knowledge of the coupled dynamics of social and ecological systems forms an explicit element of their "adaptive and/or transformative capacity".

The definition above provides an overarching framing of social-ecological resilience for this report. Nevertheless, we need to embed multiple perspectives within this overarching definition of resilience – in this instance, resilience that encompasses the unique characteristics of both social and ecological components. As a result, we emphasize different aspects (and to some extent, the various definitions) of Arctic resilience across the chapters of this report. The discussion of social-ecological systems in Section 1.3.1 further illustrates these different aspects.

3 By the term agency we mean the human capacity to consciously and deliberately choose and carry out a course of action. This capacity can be exercised individually or in conjunction with others (see Emirbayer and Mische 1998).

1.2.3 Resilience, adaptation and transformation

While there is wide variation in both the scientific literature and common discourse on the ways that resilience relates to adaptation and transformational change, *resilience in this report should be understood as a system property that provides the underlying capacity for navigating social-ecological change* – whether by adapting to it, or by embracing the kind of fundamental change that is characterized as transformation. Social and ecological systems are frequently characterized as "coupled" because they are intimately linked, as discussed in detail in Section 1.3. Adaptation "usually refers to a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity" (Smit and Wandel 2006). The Intergovernmental Panel on Climate Change (IPCC) defines adaptive capacity as "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC 2014). Because "adaptive capacity" refers to the underlying capacity to adjust to changing conditions, it can be considered an important expression of resilience. "Transformative capacity", on the other hand, implies a capacity to embrace more fundamental and far-reaching changes (Folke et al. 2010) In this sense, resilience can be described as an essential underpinning of both adaptive and transformative capacity. An inability to adapt or transform implies a lack of resilience, and therefore an inability to successfully navigate a chosen trajectory in pursuit of goals within the broader cycles of social-ecological change.

The relationships between resilience, adaptation and transformation are important throughout this report. Chapter 3, for example, highlights transformational, mostly ecosystems changes believed to be under way or currently being observed, which are broadly characterized as "regime shifts". Chapter 4, which examines resilience in communities grappling with the diverse expressions of Arctic change, highlights adaptive responses and focuses on livelihoods. Chapter 4 also includes examples that entail deliberate transformational change, as well as instances of loss of resilience that are reflected in weakness in the ability to successfully adapt or transform. Chapter 7 examines resilience-building activities through the lens of different types of "capital" and the ways in which these activities can contribute to resilience.

1.3 A systems perspective

Many scientists investigating complex social-ecological challenges such as climate change, chemical pollutants or biodiversity loss, have concluded that these problems cannot be adequately understood without proper attention to interactions that play out both within social and ecological systems, and between them. This trend is based on the realization that seemingly disparate phenomena are interconnected, and that because causality is complex, change does not confine itself to the disciplinary categories and structures through which scientific inquiry has often been pursued. In keeping with this insight, scientific assessment of developments in the Arctic is increasingly oriented toward the interplay between social and ecological systems. We see with growing regularity efforts to transcend the confines of disciplinary training, substantive focus, knowledge systems, and also efforts to bridge science to policy and knowledge to practice. Collaboration between the natural and social sciences, and across disciplinary boundaries more generally, is increasingly recognized as essential for grappling with multi-scalar, complex systems (Schmidt and Moyer 2008; Krupnik et al. 2005; Waring and Richerson 2011; Filotas et al. 2014; Binder et al. 2013).

BOX 1.3 Indigenous Knowledge: an ongoing discussion on terminology

While the term Traditional Knowledge (TK) is now well established within the Arctic Council context and elsewhere, there is an ongoing discussion both in the research community and among Indigenous Peoples Organizations on the terminology that best captures the nature of the social and ecological knowledge carried by the Indigenous Peoples of the Arctic. The Ottawa Traditional Knowledge Principles (2015) define Traditional Knowledge as "a systematic way of thinking and knowing that is elaborated and applied to phenomena across biological, physical, cultural and linguistic systems". Ongoing discussions highlight concerns that the term "traditional" gives the impression of a static, even antique form of knowledge with decreasing relevance to current conditions. "Indigenous Knowledge" (IK) has been proposed as a more accurate way to represent both the historic nature of the experiential and observational knowledge that is part of the Arctic's indigenous cultures, and the character of this knowledge as both systematic and dynamic (Johnson et al. 2016). Consistent with the Ottawa Principles, Indigenous Knowledge can be defined as "a systematic way of thinking applied to phenomena across biological, physical, cultural and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive and multi-generational observations, lessons and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation" (ICC 2013). Although the question of terminology remains a subject of discussion, we use the term Indigenous Knowledge in this report based on the logic of the arguments expressed, and the broader principle that knowledge and the concepts used to convey it should remain subject to revision.

FIGURE 1.1 **Interactions across physical, ecological and social systems**

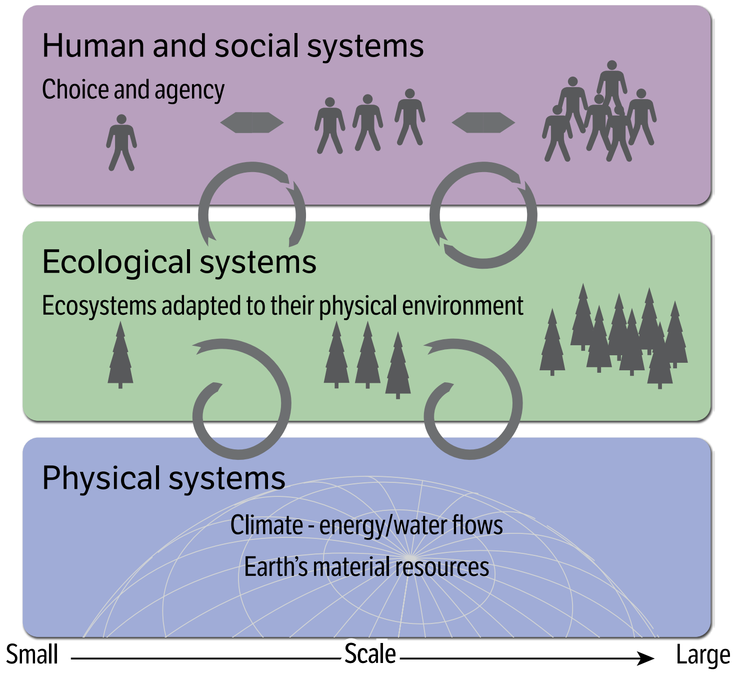
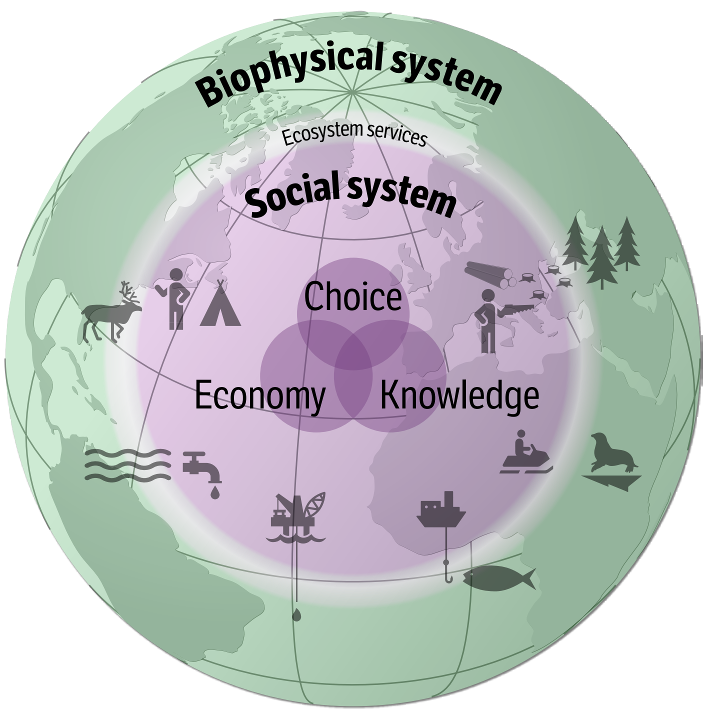


FIGURE 1.2 **Social systems dependent on biophysical systems via ecosystem services**



These overarching complexities are very much a part of the challenges to which resilience thinking has addressed itself. Its focus on "coupled" systems compels research in the social-ecological systems framework to use an interdisciplinary or transdisciplinary approach. Resilience scholars have also been receptive to multiple knowledge traditions and supported their contribution to the broader enterprise of strengthening understanding of social-ecological change (Berkes 2012). In its holistic perspective, resilience shares important commonalities with Indigenous Knowledge (see Box 1.3), which "generally views all elements of matter as interconnected and not easily understood in isolation" (Henry et al. 2013).

Figure 1.1 at left, drawn from the Interim Report, highlights the interactions across geophysical, ecological and social systems. It also provides a useful illustration of the disciplinary organization of science into the physical, biological and social sciences. In Figure 1.2 we develop this scheme to further illustrate the relationships between these different systems.

Figure 1.2 highlights what are often conceptualized as separate "pillars" of sustainability – environment, society and economy – but presents them in terms of their dependency relationships. Modified from Figure 1.1, this second figure illustrates how a social system is positioned within and is dependent on the benefits provided by biophysical systems, with a variety of the human activities by which resources are secured from nature represented in the space labeled ecosystem services. Key elements of social activity – economic exchange, knowledge production, and choice (individual and collective) – are represented as subsets of society. Societies are wholly dependent on the resources they derive from nature, yet at the same time influence nature, making them also interdependent. Economy, knowledge and choice do not exist outside of society, and while these spheres of human activity certainly overlap, none of the three is reducible to the others.

Among the variety of analytical frameworks that seek to consider the interactions between social and ecological systems, many treat either environmental/ecological factors or social factors as drivers of change, but do not pursue analysis of social-ecological

Marcus Carson/SEI

Some biophysical processes, such as loss of the ice sheet that covers Greenland, are almost impossible for humans to halt once far enough advanced.

systems and the complex feedbacks between them with comparable depth (Binder et al. 2013). The social-ecological systems framework has attracted the attention of a variety of scholars and practitioners who have considered both the degree to which and the ways in which proper attention can be given to both social and ecological components (Standish et al. 2014; Brown 2014; Miller et al., others 2010; Stone-Jovicich 2015).

1.3.1 Social-ecological systems

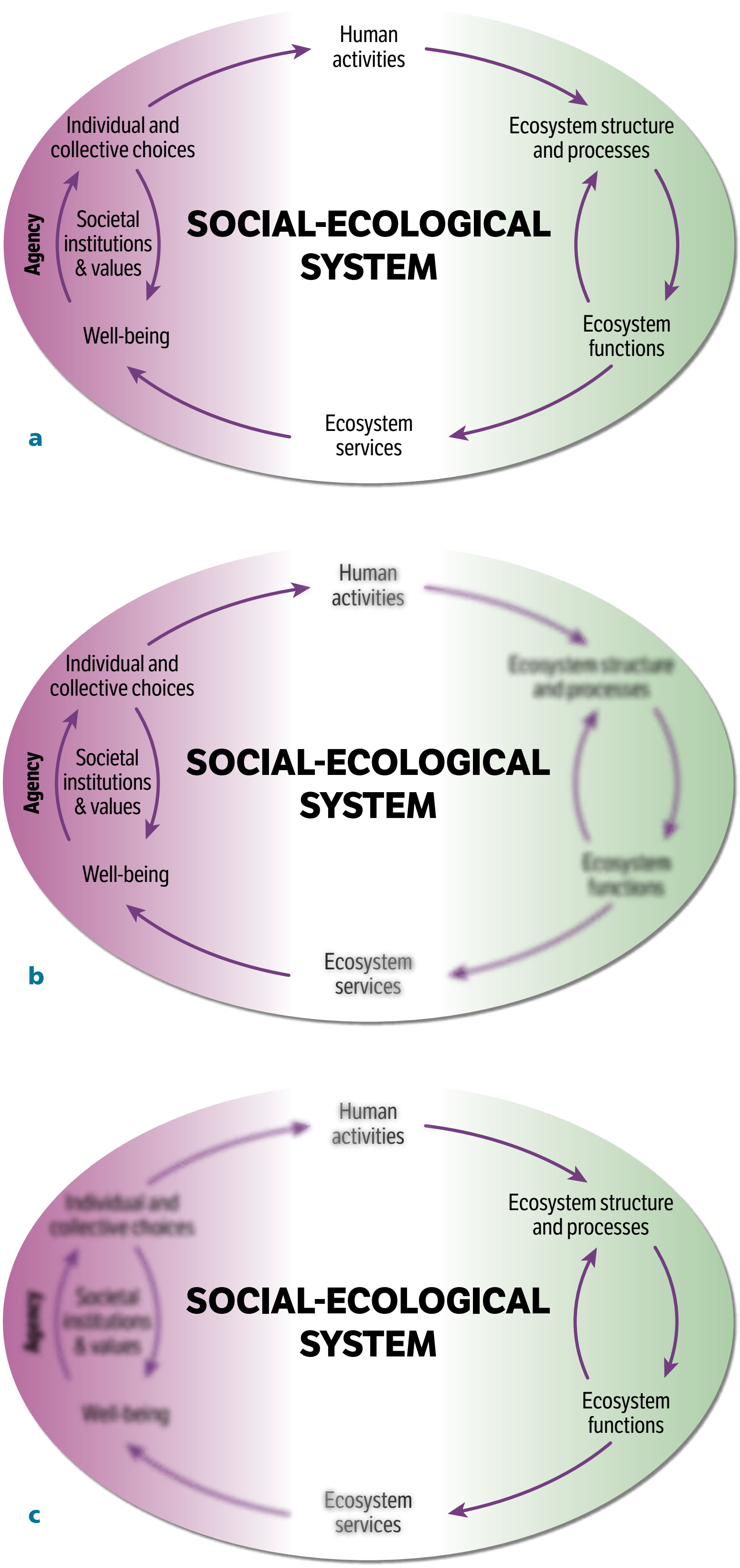
We have already noted the general appeal of resilience. Yet, its use has also grown because resilience provides an integrative concept around which a growing body of research thoughtfully grapples with fundamental properties of the world in which we live: its complex, multi-scale interactions across time and space. As illustrated in Figure 1.2, a resilience approach conceptualizes biophysical systems (geophysical systems and ecological systems combined) and social systems as fundamental elements – sub-systems – of a single system that is not reducible to its component parts (Gunderson and Holling 2001). Berkes and Folke (1998) point out that "social and ecological systems are in fact linked, and that the delineation between social and natural systems is artificial and arbitrary." We would reformulate that insight by instead saying that social and natural systems are in reality parts of a single system, each with their own particular characteristics and capacities. The distinction between the two sub-systems is analytical and a function of the different roles they play and the distinct capacities they possess. When we use the term social-ecological system, we therefore refer to a single system.

Figure 1.3 (p. 12) summarizes this humans-*in*-nature, single-system perspective, illustrating how social-ecological systems are conceptualized in the framework used for the Arctic Resilience Final Report. It illustrates the interactions between the sub-systems taking place iteratively via feedbacks, represented by the arrow around the periphery of the figure. These system-wide feedbacks play out through the physical consequences of human activities, through the benefits of the various ecosystem services that communities and societies enjoy, through the informational feedbacks that come as part of ecosystem services, through the practical benefits of ecosystem services and their distributional effects, and through the ways that the practical and knowledge feedbacks are used in decision-making. Human activities influence and shape ecosystems (and even geophysical aspects of the planet), while human activities and options are also influenced by those ecosystems and the resources we are able to derive from them.

There are also processes, illustrated by the circular arrows on either side of the diagram, that are primarily biophysical or ecological, in that they are governed by factors only marginally susceptible to intentional human modification. The natural forces that govern climate change, sea level rise, or the size and location of fish stocks in the seas are a few examples. Other processes are primarily social, in that they are subject to rather little influence from ecosystems. These would include institutional arrangements for conducting elections, rules that determine the voting majorities needed for enactment of new policies, or regulation of financial transactions. Yet in each of these examples, there are pathways for societies to influence ecosystems and vice versa.

This assessment is especially concerned with the key linkages between the ecological and the social components of the system (see chapters 2, 3 and 4), and with how those

FIGURE 1.3 **Social and biophysical systems linked by ecosystem services and effects of human activities**



linkages might be deliberately managed or governed (see chapters 5, 6 and 8). The linking elements between the sub-systems are human activities and ecosystem services, represented in the lighter shaded area in the middle of Figure 1.3. This overview only briefly summarizes categories that include many possible social and ecological dynamics in the Arctic region. Yet it also supports closer examination and analysis of the social side of the diagram where human agency is involved. It is here the benefits and impacts of ecosystem services are experienced, and where knowledge of ecosystems, social processes and the dynamics of their linkages is revised and used in an effort to determine preferred paths into the future. The feedback in the social system where benefits are experienced and knowledge is processed to guide action encompasses the process where shared decision-making is carried out – often referred to in terms of "governance" – through which learning, knowledge and power are converted into new rules for action.

This figure highlights that what happens where the interactions between people and the environment are most direct is shaped by the biophysical dynamics of the natural environment and also by social dynamics, including economics, culture and the political sphere. It also highlights the fact that there are complex dynamics in both the biophysical and social sub-systems due to feedbacks. In ecosystems, changes in the physical or biological structural conditions affect ecosystem functions, which determine what the future physical and biological conditions will be, and therefore will determine the quality and rate of supply of ecosystems services.

Looking again at the example of sea ice, a defining feature of many parts of the Arctic ecosystem, we can see that it is both a habitat and an important factor in climate regulation. Warming temperatures are shifting the balance of reflective ice and light-absorbing seawater, accelerating the melting of ice through the albedo effect. As the ecosystem structure changes, the functions change and with it the ecosystem service of climate regulation (Post et al. 2009). Similarly, feedbacks can be a feature of social systems, but while these are not characterized by the same kinds of causal relationships as ecological systems, feedbacks can still lead to abrupt changes. Social choices are shaped not only by social values, social or political goals, or knowledge of potential outcomes or consequences, but also by institutional arrangements that structure participation in, and how (and which) knowledge is employed in, collective decision-making. The confluence of these factors is where people's well-being and future values and choices are played out.

Figure 1.3 also helps clarify the distinctions between some of the different definitions of resilience and how some approaches to investigating the relationship between humans and the rest of nature emphasize the interactions of only part of the system. Figure 1.3b illustrates the community resilience perspective and that of some social science analyses of humans in nature. It places great emphasis on the social dimensions and the presence of agency, but ecosystems and nature remain less well defined.

Similarly, many ecosystems-focused analyses pay less attention to the broad insights available from the social sciences regarding the exercise of agency, the steering effects of institutional arrangements, of institutional inertia, and the limits of rationality at both individual and collective levels. This perspective is most apparent in more technocratic approaches built on a belief that incomplete knowledge is the most important barrier to changes in policy and practice. Figure 1.3c illustrates such perspectives.

There are clearly good reasons for focusing on phenomena that reside on one or the other side of this system diagram – not least the practical considerations involved in designing research, and the focus of much academic training. The key hazard of leaving indistinct either side of this system is that many important questions are never raised, and it can hamper effective collaboration between the branches of science.

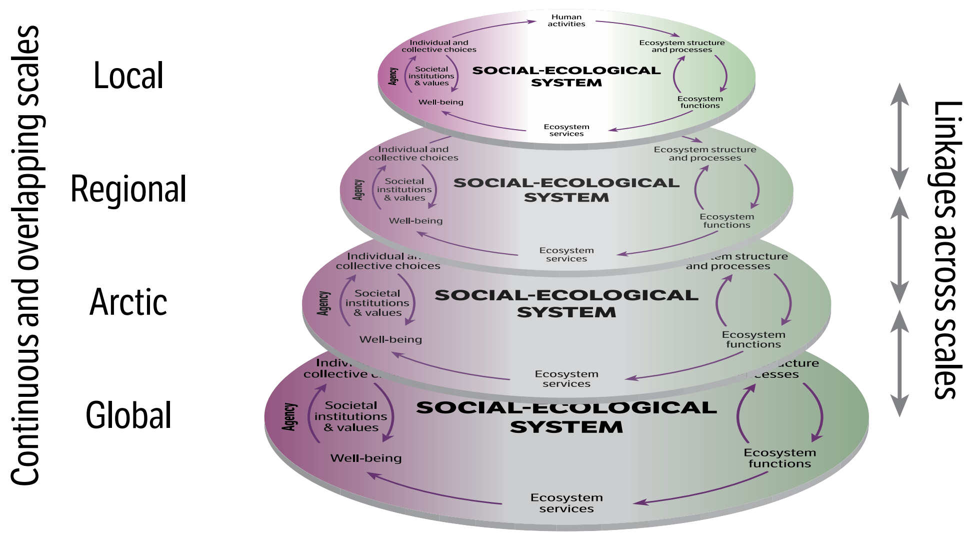
1.3.2 Scale

Any assessment of a system's resilience requires the system itself to be defined. The Arctic is a regional social-ecological system that is part of a global social-ecological system, and composed of its own diverse sub-regions.

The interactions of the dynamic, complex system that is the Arctic play out not only at a single scale, but also across multiple spatial and temporal scales, bringing additional complexity. Spatial scales may range from local to regional to global, while temporal scales range from seconds to eons. These interactions play out in processes that at some times reinforce continuity and at others generate change. Here, climate change provides a well-known example. The local human activity of burning of fossil fuels produces local and relatively immediate effects (pollution from particulate matter, for example), but it is the accumulation of greenhouse gases which happens at a global level over decades, which in turn feeds back to generate the often severe consequences now being experienced in different forms across the Arctic.

One important consequence of this multi-scalar nature of systems interactions is that there is often a mismatch between the origins of environmental disturbances and where their consequences are experienced. This was clearly the case in the instance of pollution from persistent organic pollutants (POPs), which were produced and largely used outside the Arctic, but which generated problems that became a catalyst for the creation of the predecessor to the Arctic Council (see Chapter 6).

FIGURE 1.4 **Social-ecological systems interactions across multiple spatial scales**



Mismatch at the spatial scale between cause and consequences, and accompanying lack of alignment between where policy authority is located and the source of environmental problems, is one of the significant challenges faced in policy-making both in the Arctic and elsewhere (Young 2002).

Peter Prokosch/Grid Arendal Photo Library (http://bit.ly/2cc9wKu)

The Inuits' use of kayaks for travelling and hunting is an example of natural resource management adapted to the Arctic seascape.

1.4 Feedbacks: proximity, cascades and co-evolution

One motivation for using the term "coupled" social-ecological systems is that it emphasizes the ways in which the two sub-systems are connected in a complex web of causal and contingent relationships, and therefore interdependent. This web of interactions includes mitigating and amplifying feedbacks that reach not only across the interfaces where the social and the biophysical meet, but also across scales from local to global. The ocean's absorption of a portion of the effects of warming is an example of a mitigating feedback, as it tends to maintain the stability of the climate system. The ways in which greater accessibility afforded by Arctic sea ice loss may lead to expanded exploitation of Arctic fossil fuel reserves, thereby producing more greenhouse gasses and accelerating warming, is an example of an amplifying feedback. These feedback processes are often non-linear – meaning they can rapidly accelerate or slow – and can sometimes produce rapid and irreversible change with little warning (Berkes and Folke 1998), and which also make accurate prediction a challenge (Allen et al. 2014).

The terms variability and change, although related, differ in meaning. In complex systems, variability is the norm. In the "Arctic system", just as within the "Earth system", climate, ecosystem productivity, population size of particular species, and people's harvest often vary from year to year, or between places in the same biome. The overall system state or trajectory is enforced by the combined action of feedbacks that develop between system components over a period of time. The particular timescale or spatial scale over which feedbacks occur causes patterns of fluctuations, or variability. Examples include multi-year oscillations of regional climate, like the Arctic Oscillation (Turner et al. 2007) or waves in population size of Arctic foxes preying on tundra rodents (Angerbjorn et al. 1999).

However, the system starts *changing* when forces that are new to the system emerge, either from within or from outside it, and which are not matched by the existing feedbacks. This situation allows some system components to connect with different sets of feedbacks in a process that can bring about a change in the entire system to a state dominated by those different sets of feedbacks (Walker et al. 2004). A prominent example of such change is the recent transition of Arctic sea ice from a system dominated by multi-year ice to one composed of mostly annual ice in a warming world (Stroeve et al. 2012). In its current state, the heat accumulated in the system over an extended open-water season feeds back on sea ice by preventing ice from persisting over several years.

Some kinds of feedbacks can be deliberately structured through policy and management choices. The concept of ecosystem services provides a useful way to characterize the feedbacks that link ecological and social systems. Ecosystem services can be described in terms of the broad range of benefits humans receive from nature, such as the provision of food and water; the regulation of climate and disease; the supporting of nutrient cycles and crop pollination; and cultural benefits (Millennium Ecosystem Assessment 2005).

1.4.1 Proximity

As people's values change, so too do societies' choices on how to use nature and its resources, and on which combinations of ecosystem services to prioritize. In many cases people receive feedback in close proximity to their interactions with the environment, making it possible to adjust those interactions and see the results quickly. For example, environmental pollution in the form of the mercury and particulate emissions that result from burning coal can result in health problems in nearby populations, while harvesting too much of a particular resource in one year reduces its availability for the neighbour or in the next year. In such instances, communities and societies have often deliberately negotiated and established rules, norms, laws, and cultural practices that formalize and often institutionalize feedbacks governing the effects of people on their surrounding ecosystems. Using such governance feedbacks, the dynamics of a coupled social-ecological system can be strongly influenced by actions taken in the social parts of the system (Lade et al. 2013).

However, there are many instances where the conditions under which people receive feedback on their interactions with the environment are made more complex either due to mismatches in spatial scale (see Section 1.3.2) or long time lags. Long time lags mean that proximate feedback is delayed, increasing the time it takes to identify links between cause and effect for slow-changing system variables. This is a problem because slow-changing variables – for example soil quality or nutrient levels in freshwater on the ecosystem side, or legal systems and cultures on the social side – determine the underlying structure of social-ecological systems (Chapin et al. 2009). Thus, management of slow-changing variables is a particularly important aspect of resilience in social-ecological systems (Biggs et al. 2012). Slow variables are often linked to regulating ecosystem services, yet they often cannot be effectively governed at the location where their impacts are most felt (Cumming 2011), because the forces that drive them are generated elsewhere, at a different time or spatial scale. In the Arctic context, this issue is illustrated by the service of climate regulation, where identifying feedback was not only delayed by issues of monitoring and attribution (e.g. of fossil fuel burning causing sea ice melt) but also by the challenge of negotiating rules at the global scale to secure climate regulation that doesn't compromise the resilience of social-ecological systems at the regional scale (e.g. the Arctic).

1.4.2 Cascading effects within and across linked systems

The details of many of the kinds of dramatic changes noted in the opening paragraph of this chapter are well catalogued, not least by the Working Groups of the Arctic Council. Across the Arctic region, temperature rise due to climate change is progressing at roughly double the average global rate of warming, directly contributing to shrinking glaciers, permafrost melt, and loss of sea ice (AMAP 2011). Ocean acidification, also having increased to a level roughly twice as high as what is being observed elsewhere, is due to the greater CO_2 uptake of the Arctic's frigid waters (AMAP 2013). These cascading effects – secondary effects where impacts themselves become part of a chain of drivers of change – are a further manifestation of the feedbacks discussed in the previous section. Some of these cascades (see Chapter 3 for examples of these cause-effect relationships, feedback effects, and causal chains) are described for the geophysical realm, as with warming temperatures contributing to sea ice loss, which in turn leads to rougher Arctic seas and increased coastal erosion. Similarly, it is increased CO_2 concentrations that contribute to temperature rise and which also acidify the northern seas. Some of these chains constitute critical, potentially self-reinforcing feedback loops, such as when declining snow and sea-ice cover caused by temperature rise reduce reflectivity (albedo), and in turn feed back to increase heat absorption and amplify temperature increases.


Kathryn Hansen/NASA

Two scientists from the ICESCAPE mission study how changing conditions in the Arctic affect the ocean's chemistry and ecosystems.

While some cascading effects remain largely within the sphere of geophysical phenomena, others cross over to impact Arctic ecosystems, Arctic communities, or even global systems. Physical changes such as sea ice loss are already being observed to produce ecosystem impacts, such as migration of species, which can profoundly impact the biodiversity and productivity of marine ecosystems (CAFF 2013a). For example, changes in the extensive Arctic shelf seas (Fossheim et al. 2015) strongly influence the population and distribution of species (e.g. seals and whales) that are linked directly to sea ice (Eamer et al. 2013). Species migration can subsequently cascade additional steps to influence Arctic communities dependent on those species. The cascade of impacts produces tangible effects for Arctic communities both along the coasts and far up-river, such as varying availability or quality of food and material from fish or seal, or impacts on economies linked to fisheries.

The effects are often mixed. While sea ice loss is opening new opportunities for commercial activities and economic opportunities that range from resource extraction to shipping and eco-tourism, in coastal areas it may limit human mobility and the capacity to hunt or pursue other livelihoods that depend on ice (see Chapters 3 and 4). And the reach of these effects extends well beyond food sources or economic activity; they can also have dramatic consequences for cultural practices, identity, and spirituality, for example in the case of Inuit hunters who use sea ice as a platform (AMAP 2011). Decrease in sea ice extent and duration also increases coastal erosion, which can produce devastating impacts on Arctic communities and threaten their very existence.

Affected communities typically seek to respond to these kinds of changes and adapt to new conditions. However, new uncertainties can emerge when people turn to alternative food sources or introduce new practices and activities, because these can generate their own cascading effects and exert new pressures on other components of ecosystems. Under more stable conditions, people can use the informational feedbacks generated by such adaptations to make ongoing adjustments. But this is far more difficult to do under conditions where rapid change and unpredictability are defining characteristics, and is even more the case when change extends beyond boundaries where historical knowledge can provide guidance. One of the Inuit languages has a concept for this sort of unpredictability and surprise: *nalunaktuq* (see Box 1.4).

While the climate-induced cascades observed to date are for the most part still gradual, one doesn't have to project far into the future to see them crossing critical thresholds – both for discrete locations in the Arctic and for the Arctic as a whole. For example, northward movement of southern species is already displacing assemblages of Arctic species (Fossheim et al. 2015), a pattern that is expected to continue. Because terrestrial habitats in the Arctic are bounded in the north by the Arctic Ocean, northward ecosystem shifts are expected to cause the disappearance of Arctic terrestrial ecosystems in many places. High-Arctic habitats and the species associated with them are likely only to survive at altitude or in island refugia (CAFF 2013a) – or may disappear altogether in many places.

Communities that use such Arctic habitats, ecosystems, and species for livelihoods – or even activities that support industrial economies such as tourism or reindeer herding – will need to respond to the crossing of such thresholds or to the possibility of their occurrence. Yet, responding entails significant challenges. Arctic inhabitants and leaders expressed concern about the difficulties involved in demonstrating causal links between the changes they are experiencing and their root causes operating at larger scales or external to the Arctic, identifying effective strategies to address social-ecological changes, and in preparing for anticipated cascading effects and thresholds (ARA 2015). In order for responses to be effective, people and communities need access to relevant knowledge, and they have to be able to engage at the appropriate scale. In the case of climate mitigation, many of the crucial actions must be organized at the scale at which climate change drivers operate and mitigation actions can be implemented – the national or global scale, and often multiple scales – to achieve meaningful impacts, thereby increasing the odds of avoiding some critical thresholds. For example, reducing emissions of black carbon (soot) within the Arctic is expected to have significant effects on slowing warming (UNEP 2011). Other mitigation actions such as moving to renewables must also ultimately be carried out at the local scale, but are on a case-by-case basis hardly noticeable at that scale (Carson 2015). At the local or regional scale, community actions are mostly likely to produce tangible results where they are focused on local adaptation options.

Virtually all of the cascading change processes noted above share a common upstream source: human activity – activity that is frequently engaged in far from the Arctic. It would be difficult to over-emphasize how human actions carried out or decided upon elsewhere are affecting Arctic social and ecological systems, and how they are intertwined with both ecological and social cause-effect feedback loops. This means that while the effects of change cascade across physical, ecological and social systems, they also exert their influence over time and across geographical space. As just one example, "a key lesson from IPY (International Polar Year 2007–2008) is that Arctic marine systems cannot be fully understood simply by reference to science conducted exclusively in Arctic marine areas. Non-Arctic, terrestrial and atmospheric factors are important components in building a better understanding of Arctic marine ecosystems" (PAME 2015). These causal linkages across sub-systems and across scales have important implications for developing response strategies and plans, whether the emphasis is on major changes to ecosystems, (see Chapter 3) the livelihoods of Arctic communities (see Chapter 4), or planning, coordinating policy responses and building resilience (see chapters 5, 6 and 7).

BOX 1.4 *Nalunaktuq* – harsh lessons from the land

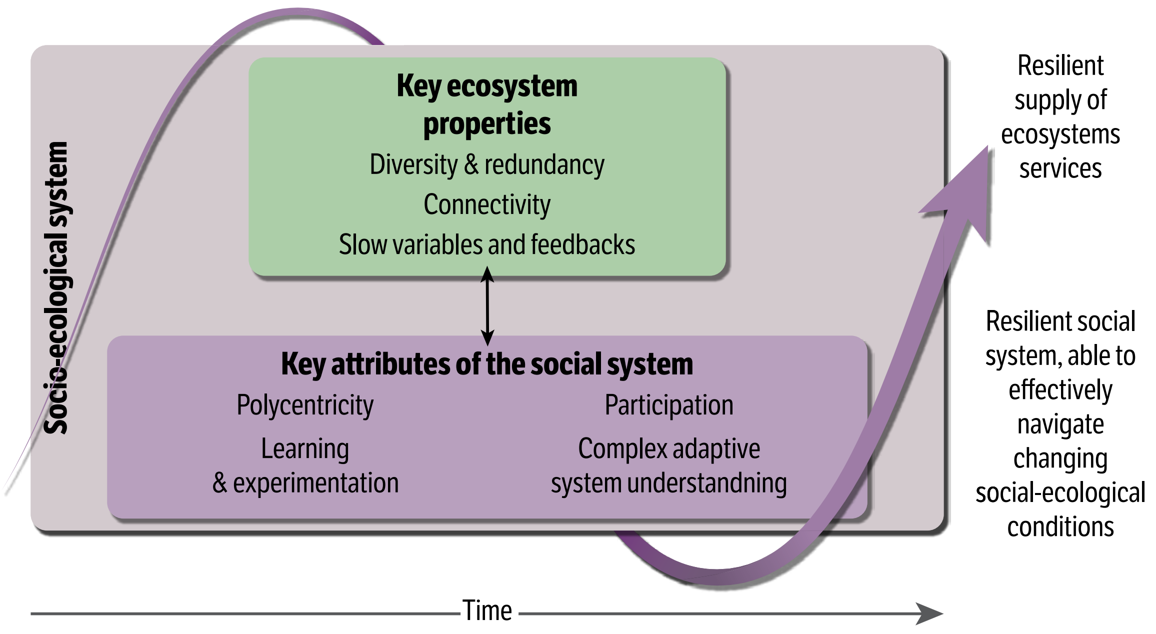
Nalunaktuq translates loosely as "difficult to comprehend" or "unpredictable" in the Inuit language Inuktitut. In describing the traditional wisdom that *nalunaktuq* embodies, Rachel Qitsualik observes that "the Inuit have learned the harshest lessons from the Land. The best such lesson has been that of *nalunaktuq*: the fact that general trends serve as poor indicators of what the Arctic will actually do" (Qitsualik 2006).

1.4.3 The Arctic: co-evolving social and ecological systems

One important effect of social and ecological systems being linked, interdependent, and constantly interacting is that they evolve over time in concert with one another. Change occurs through co-evolution, in which "evolving socio-cultural systems are increasingly affecting their biophysical environment…" and "evolving ecological systems are increasingly affecting socio-cultural change" (Gual and Norgaard 2010). There are numerous examples of such co-evolution. Recent research has identified a genetic change among the Inuit in Greenland that has helped them adapt both to cold and to the high-fat diet obtained from locally available food sources such as seal and whale (Fumagalli et al. 2015). There is also evidence to support the proposition that socio-cultural evolution has influenced genetic evolution of both humans and animals. Most adult humans lack the lactase enzyme that enables people to metabolize milk. Yet the "geographic distribution of lactase persistence in adults matches the distribution of dairy farming" (Bersaglieri et al. 2004). The domestication of animals over the past 10,000 years has shaped the biological evolution of many globally important agricultural species, such as goats, pigs, sheep, chickens, horses and dogs (Thompson 2009), while at the same time, the development and distribution of these species has helped shape the evolution of cultural and economic systems. In the Scandinavian and Russian Arctic, reindeer would also make this list. Important large-scale examples of socio-ecological co-evolution include burning fossil fuels, which remain the hallmark of modern industrial societies. These have altered both the physical and ecological systems of our planet through the activities required to secure these resources, and through the pollution generated by their use (Zalasiewicz et al. 2010). Clearly, humanity interacts with the rest of nature and vice versa, and each influences the other's development at multiple scales. Analyses that fail to adequately take such interactions into account contain critical gaps that will hamper effective responses to change. Such gaps increase the risk of crossing thresholds that entail the collapse of

FIGURE 1.5 **The co-evolving relationship between nature and society**

This illustration acknowledges that the distinction between society and nature is an analytical one, and one which takes account of the different mechanisms by which change unfolds over time.



ecosystems and communities, even societies, and which represent points of no return.

The idea of the co-evolution of humanity with nature is not new. For societies that live in close interaction with nature, humans are conceptualized as part of nature (Henry et al. 2013). The industrial age carried with it a Cornucopian view of nature as a near endless basket of resources from which resources could be drawn – as well as a space into which waste products could be conveniently disposed (Beckerman 2002; Simon and Kahn 1984; Murphy 1967). The currently evolving appreciation in the industrialized world of the integral relationship between humans and nature could be characterized as coming full circle back toward a holistic understanding of humanity and nature as part of our one-planet larger system – that humans are a fundamental part of nature and that while we are utterly dependent on nature, we are also a powerful force of nature (Sörlin 2011; Dryzek 2013). The core message in the idea of "the Anthropocene" is that we are sufficiently numerous and our actions are sufficiently magnified by technology that human actions have become a powerful biophysical force at a global scale (Crutzen and Stoermer 2000; Carson 2015).

While evolutionary theories have earned broad consensus within the natural sciences, they remain somewhat controversial within the social sciences. Resistance within the social sciences is rooted in rejection of ideas of "intrinsic progress" in Herbert Spencer's early work (Spencer was one of the primogenitors of sociology and a contemporary of Darwin), or of explanations deemed deterministic (Weisz and Clark 2011). Yet, important work on socio-cultural and/or socio-economic evolution emphasizes that such processes are by no means deterministic, nor do they necessarily result in progress (Gual and Norgaard 2010; Dietz and Burns 1992; Dietz et al. 1990; Weisz and Clark 2011). What these and other studies point out is that while socio-cultural and biological evolution influence one another, they play out through very different kinds of processes and mechanisms.

Attention to the complex interactions of social-ecological systems, including their non-linear nature and inherent uncertainties, can help foster collective engagement "to manage ourselves within the resource instead of trying to manage the resource" in isolation (Schreiber 2002). This observation from one of the First Nations of Canada describes a perspective that acknowledges a process of co-evolution of people and ecosystems. It therefore informs holistic strategies for ways forward, or development, of social ecological systems, including actions on (human) adaptation and (ecosystem) stewardship in a rapidly changing Arctic that is part of the globalized world of the 21st century.

1.5 Navigating Arctic change

Andrew Revkin, an environmental reporter for *The New York Times,* noted in an interview about the societal response to climate change in 2012 that it was not the glaciology or climate science that worried him the most, but rather the sociology of the problem (Science Friday 2012). Societies and policy-makers struggle to respond to problems that develop incrementally, are caused by diffuse sources or diverse activities, and which generally entail complex cause-effect relationships, in which cause and effect may be widely separated across space and/or time. In a similar vein (and similar time frame), Schmidt and Moyer (2008) have called for "a new kind of scientist", noting that "it is a truth universally acknowledged that interdisciplinary science is essential for furthering understanding of climate change". They argue for combining climate science, economics and sociology to inform both knowledge of what is taking place, and what might be done about it.

These observations highlight the uneven development of scientific knowledge on environmental problems, with the result that much more is understood about complex physical and biological systems than the social systems that are a part of, and also heavily influence, the ongoing development of systems as a larger whole. One important consequence is that policy-makers are better informed about scientific insights into environmental problems than about how to effectively tackle them. While establishing effective feedbacks for rule-making to manage and govern social-ecological systems is challenging, it can certainly be strengthened (see Section 1.4).

1.5.1 Scientific evolution toward holistic models and complex systems

The issues outlined above call for multiple remedies. The need for interdisciplinarity within science has been widely embraced in principle, but it has proven easier to identify the need than to negotiate the different epistemological, methodological, and substantive focus of disciplinary "cylinders of excellence" (Winthrop 2015). Where such bridging efforts are pursued with determination and under conditions conducive to ploughing new ground, meaningful breakthroughs are more likely (Hollingsworth 2012). Other important bridging efforts are under way in the Arctic to incorporate Indigenous Knowledge into the Working Groups' scientific assessments (e.g. (PAME 2013; CAFF 2013b; AHDR 2014; Larsen et al. 2010; AMAP 2016).

The past decade especially has seen an effort to move from the "heavy emphasis on reductionism" toward more holistic approaches (Hollingsworth et al. 2008b). Where reductionist approaches have focused on understanding the individual parts of a system, systems-oriented science emphasizes phenomena-in-context – complexity, identification of interconnections and patterns, and ways in which the whole is greater than the sum of the parts.

TABLE 1.1 **Comparison of reductionist versus systems science paradigms**

	Reductionist science	**Systems science**
	Dominant paradigm: classical physics	*Dominant paradigms: evolutionary biology, science of complexity*
Theoretical goal	General, universal laws	Pattern formation and recognition
Theory structures	Axiomatic, reductionist	Phenomena nested in multiple levels of reality simultaneously
Forecasting capacities, ability to make predictions	High	Low
Complexity	Low	High
Ontology	Dualism	Emphasis on interconnectedness of phenomena
Leading metaphors	Clocks	Complex networks, living cells, clouds
Cognitive distance between natural and social sciences	High	Medium
Inspirational scientists	René Descartes, Isaac Newton, Adam Smith	Charles Darwin, Ilya Prigogine

Source: (2008a)

The *Helmer Hanssen* vessel conducts marine biological, geological and oceanographic surveys in perpetual twilight.

Table 1.1 below highlights the differences in these two approaches to science. And as discussed in Chapter 2, the trend toward increased interdisciplinary collaboration approach can be seen among the Working Groups of the Arctic Council.

1.5.2 Agency, learning, and self-organization

Social and ecological systems share numerous characteristics, including change processes that can pass thresholds or tipping points which may be abrupt and unexpected, and beyond which return is difficult or unlikely. They also both exhibit heterogeneity and diversity, nodes and networks, interaction across space and time, as well as capacity for adaptation and transformational change. However, as noted earlier in this chapter, key characteristics are found only on the social side of the system: agency, the capacity for learning and operationalizing knowledge, and for self-organization. Governance – broadly defined as collective processes for identifying, defining and responding to problems or pursuing shared goals (Bevir 2013) – is an important expression of agency, particularly through its role in establishing norms and formal rules.

We have also discussed how the capacity for learning, applying and revising knowledge links social and ecological systems by informing agency (Rocha et al. 2015). This applies particularly to knowledge on the continued capacity of ecosystems to provide support for human life and well-being, and to knowledge of likely ecological impacts of human activities. Both types of knowledge inform the choices communities make and actions they take at all scales. The capacity for self-organization channels and organizes the exercise of agency, and while both social and ecological systems possess this capacity, in social systems it is informed by social-structural factors, including knowledge, belief systems and the values embedded in them, and by the institutional arrangements that shape how different interests may pursue their respective ambitions (Carson et al. 2009).

Because knowledge, values, and power will vary among diverse individuals, groups and organizations, they are likely to answer the question of "resilience of what, to what" in different ways. Consequently, resilience will be defined and valued differently from different perspectives (Tanner et al. 2015). Disagreement or conflicts between ways of defining a place or a problem mean that different actors may pursue substantially different courses of action to address a shared problem, and these interactions make the exercise of agency emergent and complex. Alternative definitions of a particular social-ecological system – springing from different views or values, different definitions of a system, and different beliefs about how the world works – may suggest actions that from one perspective increase resilience, yet which from another can easily erode it. This is also true temporally, because actions that strengthen resilience in the short term may not do so over the long-term (Carpenter et al. 2001).

This brings us back to our definitions of resilience (see Box 1.2). While the Walker et al. (2004) definition can be correctly applied to the entirety of the system illustrated in Figure 1.3, it fits most clearly with the interactions that take place on the ecosystem side where the human capacity for deliberately navigating into the future is not a factor. Without humans there are no value judgments about the system state, and, as has been noted more generally, it is not the planet that needs to be saved, but rather ourselves. Resilience approaches that focus on human agency, including the UNISDR and community resilience definitions, tend to emphasize the social system side of the diagram and also include judgments about desirability. As previously noted, these approaches to resilience tend to consider the environment out of the corner of the eye, as a source of threat from drought, torrential rains, or other environmental forces, but generally emphasize the social. The overarching definition used in this report doesn't make a judgment about the desirability of particular system states, but it does make an explicit judgment that the capacity to deliberately navigate into the future making use of knowledge of ecosystem functions and services is a desirable condition. We apply our overarching definition to the social-ecological system as a whole because, once humans are in the picture, choice has important consequences. Informing effective choices to successfully navigate social-ecological change in the Arctic is a central aim of the Arctic Resilience Assessment.

1.5.3 Translating resilience thinking into practice

Assessment of the Arctic is particularly challenging because important data is often scarce, time consuming and costly to collect, with the result that knowledge about many aspects of the Arctic remains inadequate (AHDR 2014; Larsen et al. 2010; Larsen et al. 2015). Developing a comprehensive base of knowledge is complicated by the fact that there are many different perspectives on what the Arctic is or represents (see Chapter 2). Like other regions, the Arctic includes a complex mix of social "sub-systems", with many distinct parts – political, economic, cultural – operating within the broader social system, each with its own characteristics and dynamics. Activities informed by one or more of these "multiple Arctics" are constantly vying for position and priority in the same physical space (see Chapter 2). Moreover, the different properties and interplays of geological, hydrological, climatic and ecological parts of the biophysical system influence overall developments in different ways. And they substantially influence many of the potential options that people can choose between, thereby shaping the dynamics of the overall social-ecological system.

Navigating Arctic change entails bridging multiple knowledge traditions in science. It also entails strengthening the capacity of policy-making institutions to take action that contributes to resilience, and to monitor diverse feedbacks to ensure that policy actions can be assessed for their effectiveness and modified as needed. On this, much remains to be done. One important goal of this assessment is to provide insights relevant to the regional or circumpolar scale at which the Arctic Council works. Another is to provide analysis that can inform and potentially link the more locally grounded activities that are in various ways products of Arctic Council initiatives. A number of these kinds of applications are examined in Chapter 8, with the intention of supporting further development of robust policy instruments that can contribute to strengthening resilience in the Arctic.

One important contribution to tackling data and knowledge gaps is that a diverse body of observational and experiential knowledge of many Arctic processes is carried in the accumulated knowledge of the Arctic's Indigenous Peoples, which has been broadly defined as Indigenous Knowledge (Ottawa Principles 2015). Several of the Arctic Council's working groups are engaging with carriers of Indigenous Knowledge and Local Knowledge[4] in order to better understand how the different knowledge systems can complement one another. As noted earlier in this chapter, the holistic orientation of the scholarship on social-ecological resilience has contributed to numerous efforts to bridge scientific knowledge and Indigenous Knowledge. These efforts share similarities with efforts to bridge disciplinary boundaries in science in that they bring exciting potential and can offer promising insights, yet the need to reconcile or translate underlying epistemological assumptions, methodological differences, and terminologies requires painstaking effort and open mindedness to bear fruit.

Let Ideas Compete/Flickr

Sámi and other Arctic Indigenous Peoples have deep knowledge of the Arctic environment that is essential for understanding and responding to Arctic socio-ecological change.

4 What is often referred to as local knowledge is distinct from Indigenous Knowledge because it does not necessarily entail long-term systematic observation.

1.6 Overview of the report

Part I defines resilience for the purposes of this report, delineates its social-ecological systems framework, and examines how differing perspectives on One Arctic can lead to vastly differing goals. Following this introductory chapter, Chapter 2 continues by articulating some of the multiple ways the Arctic has been conceptualized and defined, which in turn informs a variety of different kinds of goals, policies and pursuits. As these diverse pursuits sometimes collide, mechanisms for reconciling differences are clearly of interest, as are examples of where such differences have been bridged with success.

Part II, which includes Chapters 3 and 4, examines the different ways the places and people in the Arctic can lose or gain resilience. Chapter 3 focuses in particular on a variety of regime shifts being observed in the region or believed to be imminent. These regime shifts are largely the movement of systems in the region past biophysical tipping points, with a focus on how they interact with both one another and shared upstream causal forces, and how many of the causal forces originate with human activities. The resilience considered in these examples emphasizes the systems property definition of Walker et al. (2004). Chapter 4 examines how different types of actions have social and ecological consequences that contribute to or erode resilience across a diverse selection of case studies. Here, agency is a central concern, as communities grapple with choices and trade-offs that shape their livelihoods options – and their future.

Agency is also a central concern of Part III, which includes Chapters 5 and 6. Part III examines the decision and policy context of the Arctic at the circumpolar level and assesses how actions of the Arctic Council have and might further contribute to Arctic resilience. Chapter 5 examines the emergence of institutional arrangements for cooperation, collaboration and policy development in the evolution of the Arctic Council. In Chapter 6, the process of learning and operationalizing knowledge and organizing policy responses at a regional and pan-Arctic scale are a central theme. Through the examination of three case studies of issues highly relevant to the Arctic, we see how differences in the nature and scale of specific issues and their origins influence how they can be engaged with through efforts of the Arctic Council. Here we see also the rapidly changing international context to which the Arctic Council must orient itself, including multiple international treaties and agreements.

Part IV, the final section, speaks to the question: what can be done to more effectively navigate change? It examines strategies for operationalizing the kinds of tools and activities that are part of a resilience approach. Chapter 7 draws on a typology of different kinds of capital that underpin adaptive and transformative capacity. It is intended to inform a discussion of how the Arctic Council might help strengthen adaptive and transformative capacity in the Arctic, and consequently, resilience. Finally, Chapter 8 examines a variety of activities and practices currently under way under the auspices of the Arctic Council that could help to strengthen resilience. It also considers how the design and implementation of monitoring programmes influence their capacity to inform decision-making in the context of change.

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Under pressure: traditional livelihoods are essential building blocks of resilience in the Arctic.

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CHAPTER 2

Multiple Arctics: Resilience in a region of diversity and dynamism

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Key Messages

- There is only one Arctic, but there are multiple perspectives on the region: as a homeland, a source of resources, a key part of a global system of climate regulation. In that sense, there are multiple, diverse Arctics.

- Differing perceptions of the Arctic lead to fragmentation: different aspects of the region are experienced, observed, researched, planned and managed separately. However, because the Arctic is actually a single place with interlinked, interacting pieces, actions in one realm can have unintended and sometimes unexpected consequences.

- The efforts of Arctic Council Working Groups to integrate research and observation across disciplines and knowledge systems represents a crucially important development for understanding how human-ecological interactions shape the Arctic.

- Some goals and ambitions for the Arctic are likely to be mutually exclusive, but many can be aligned through consultation and negotiation. There are several examples of cooperation for mutual benefit and resilience-building. A key first step is to build a common understanding of the ways in which the diverse aspects of the Arctic – social, ecological and physical – are intertwined and co-evolve.

Ronel Reyes/Flickr

Reindeer racing at the annual Sámi Week in Tromsø, Norway: the main street becomes a racetrack where skiers pulled by reindeer compete to be champion of Norway.

2.1 One Arctic, or many?

Conversations about the Arctic are happening in multiple places, and interests are pulling in multiple directions. The widespread focus on resilience in these debates is driven by a sense of urgency about the scale, complexity and pace of change. At the same time, in many decision contexts, Arctic change is often discussed as if it were a steadily progressing, manageable – even inevitable – process. However, the Arctic is dynamic and diverse. Choices being made now will shape both the region and the world, and will play out in complex ways.

The theme of the U.S. Arctic Council Chairmanship – One Arctic, Shared Opportunities, Challenges and Responsibilities (U.S. Chairmanship of the Arctic Council 2015) – signals that while there is only one Arctic in the literal sense, there are multiple perspectives on it (MASD 2013). This chapter focuses on the main social and environmental perspectives, spotlighting what is seen, and also illuminating what might be hidden, from any one viewpoint. In this sense, this chapter is more an assessment of the evolving state of knowledge about the Arctic than an assessment of Arctic change itself. Our approach also enables an analysis of where, when and how knowledge leads to action in response to change, and, in some cases, where action may be needed.

Where there is incompatibility among perspectives, opportunities and forums for effective participation and negotiation are especially important. The Arctic Council has established itself as just such a forum. Its Members, Permanent Participants and Observers represent enormous social, political and cultural diversity, yet face shared development challenges and economic pressures. The Arctic Council allows for options and their consequences to be weighed and balanced in the same space, explicitly and under shared scrutiny, and allows diverse perspectives to be expressed in ways that build up a fuller, coherent picture of the complex reality.

We take the straightforward approach of looking back at published assessments of the Arctic environment and the region's sustainable development. We focus on documents produced by and for the Arctic Council, along with some ancillary reports. Indigenous perspectives are still often under-represented, so we have also striven to draw on materials published by the Permanent Participants of the Arctic Council.

2.1.1 Multiple perspectives

Beliefs, ideologies, understandings and built-in mental models shape goals and guide actions that have environmental and social consequences (Carson et al. 2009; Hulme 2009). Arctic change is shaped by actions pursued by Arctic and non-Arctic states, by business interests both within and far distant from the region, and communities for whom the Arctic has long been home as well as those that give little thought to the North. It is through the accumulated actions of all these actors that we bear shared responsibility. However, some combinations of actions will work together better than others; issues seen as priorities from one perspective will be seen differently (or may even be entirely invisible) from another; and actions successful at one scale may fail at another. Some goals and activities may even be mutually exclusive.

The power of a systems approach is that it can link information from all these different contexts and perspectives, helping analysts and decision-makers to focus on the processes that matter (Brown 2014; Laszlo 1996). But the challenge it presents is that a system's boundaries and components are defined for a specific context, leaving other issues out of view (Resilience Alliance 2010; Emery 1981).

The Arctic Council's Working Groups were established to deal with different systems. For example, the priority of Conservation of Arctic Flora and Fauna (CAFF) is ecosystems, while the Arctic Monitoring and Assessment Program (AMAP) has a strong focus on the physical climate system, and the Sustainable Development Working Group (SDWG) is concerned with human development (see Figure 2.1, p. 30).

Although Arctic assessment reports rarely include diagrams showing their systems of interest, the way they describe issues and structure their analysis allows us to identify the main components and hierarchical relationships in the systems. Figure 2.1 sketches out the systems studied in three recent influential assessments.

CAFF's *Arctic Biodiversity Assessment: Status and Trends in Arctic Biodiversity: Synthesis* defines ecosystems as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit." (CAFF 2013b). The main CAFF *Arctic Biodiversity Assessment: Status and Trends in Arctic Biodiversity* (CAFF 2013a) specifies what aspects of the physical environment are targeted for monitoring, and how species and populations of organisms are studied.

The *Snow, Water, Ice and Permafrost in the Arctic* (SWIPA) report (AMAP 2011) covers few physical and biogeochemical aspects of the climate system compared with global assessments, but focuses in detail on the region's changing albedo and carbon cycle. "Loss of ice and snow in the Arctic enhances climate warming by increasing absorption of the sun's energy at the surface of the planet. It could also dramatically increase emissions of carbon dioxide and methane and change large-scale ocean currents. The combined outcome of these effects is not yet known."

Mike Beauregard/Flickr

Stone carver Jerry Ell atop an outcrop of quality soapstone near Baffin Island, Canada. Besides being important components of indigenous cultures, arts and crafts also provide important income for communities.

The second *Arctic Human Development Report* is clear about its system components and its priorities: "The chosen Arctic Social Indicators […] have provided the framework for measuring and tracking change in Arctic human development while emphasizing those aspects of well-being that are particularly important to Arctic residents" (Larsen et al. 2015).

The three system sketches in Figure 2.1 show that, conceptually, an issue may be a critical system component in one context, expressed as a connection or flow in another, and invisible in another. For example, "ice" is a structural part of the Arctic environs (see Figure 2.1a), and contained within "cryosphere" as an important control on physical climate change (see Figure 2.1b). Although it is unstated in the Arctic Human Development Report's framework, ice is also an ultimately defining element in the identities, livelihoods and cultures of Arctic societies (see Figure 2.1c). Similarly, an "organism" can be simultaneously part of an ecosystem (see Figure 2.1a), a factor in the carbon cycle (see Figure 2.1b), and an essential dimension of people's diets, property rights, cultural identities, and even spiritual life (see Figure 2.1c).

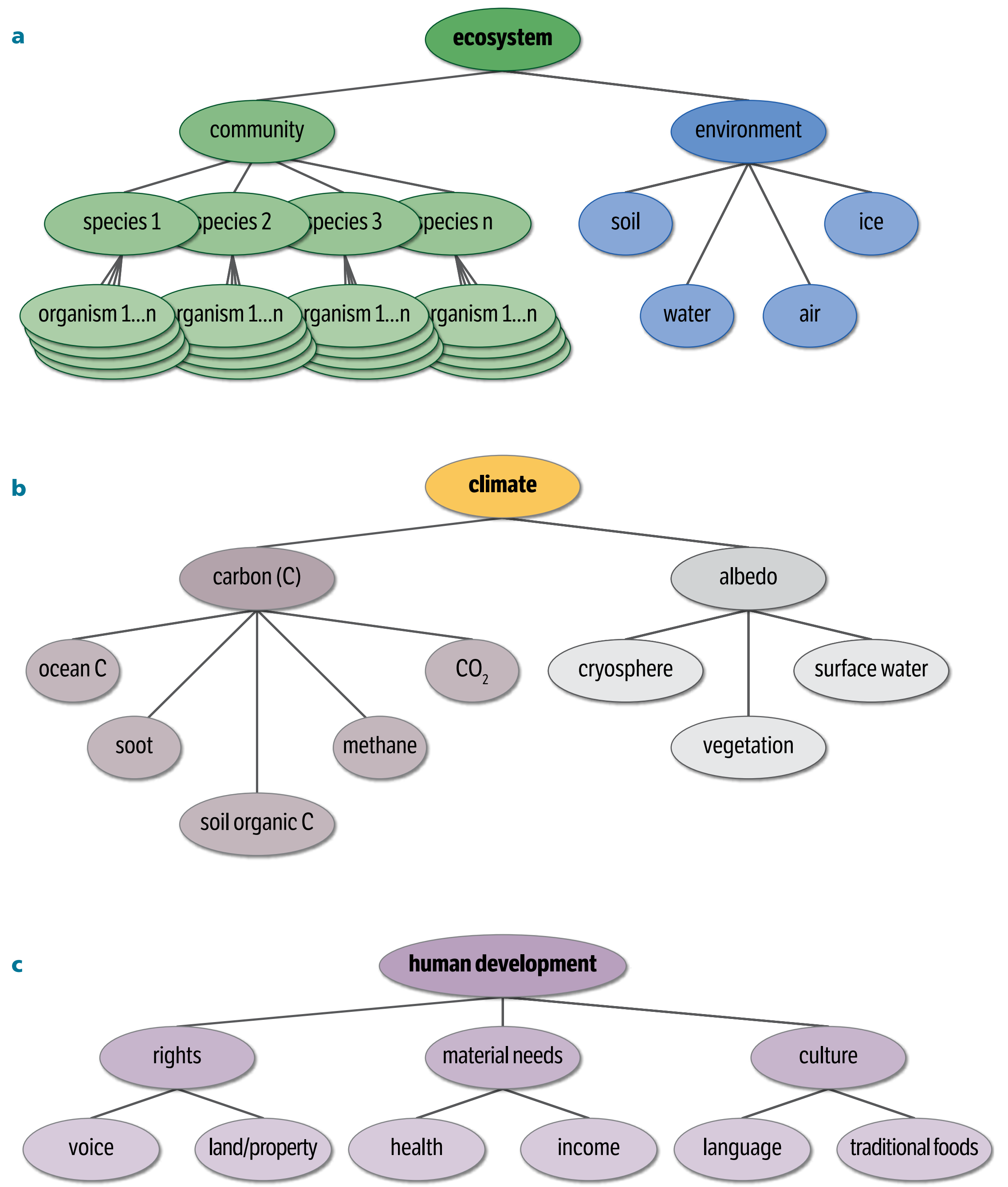
There are profound differences in the dominant ways that these systems are conceptualized, but of course there are connections between them, too. These connections need to be viewed from a more overarching perspective in order to make sense of change in coupled human and natural systems (see Chapter 3 in Forbes, Kremer, et al. 2011).

The same systems may also look very different when viewed from other perspectives. For example, the Arctic Biodiversity Assessment (CAFF 2013a) states that "humans are both considered part of the ecosystems and as outside agents influencing the environment." In many indigenous cultures (Kawagley and Barnhardt 1998), the interconnectedness within and among systems is emphasized. Integrating knowledge means untangling these different positions.

2.1.2 Multiple connections

The complex connections of the Arctic operate at multiple rates and scales (see Chapters 1 and 5). This complexity has tended to mean that different aspects of the region are experienced, observed, researched, planned, and managed separately rather than as an integrated and interacting whole. Social structures, including national institutions, political and economic constituencies, and local community-based perspectives, are often seen as distinct systems. And similar divides exist in the management and analysis of physical, chemical and ecological dimensions of the environment. These "multiple Arctics"

FIGURE 2.1 **Examples of system components of a) ecosystems, b) the climate system, and c) the human development system.**
Based on the assessment priorities of CAFF, SWIPA and AHDR II.



have been examined through separate academic disciplines, and are steered through separate policy channels. Combining information across these domains is a powerfully effective way of dealing with complexity.

Where assessments call for better integration, it is often described as a task of "nesting" systems (PAME 2013b; Hoel 2009). However, integration depends on seeing and understanding the many connections *between* systems (Cash et al. 2006; Peters et al. 2004), not simply slotting insights from a small scale activity into a bigger picture (or vice versa). Shifts and gaps in system connections, especially those bridging different decision-making scales, can create vulnerabilities and constrain adaptive responses to change (Klein et al. 2014). "Inevitable surprises", such as the increasing impacts of extreme weather events, can happen where risks and consequences that are well understood – and even predictable – from one systemic perspective are not recognized in another (Streets and Glantz 2000). At the same time, system connections can also offer opportunities to make small "nudges" that can drive larger changes in intended directions.

Two broad scientific fields have had a major impact on our understanding of the system connections shaping Arctic change. The first, Earth system science, underpins the Arctic Council's assessments of climate and physico-chemical change. This field has yielded robust information about linked physical and biogeochemical processes (Weart 2003), enabling quantitative medium- to long-term predictions of global environmental change. As human processes are increasingly recognized to have planetary consequences, linking these global dynamics of the "Anthropocene" is a new focus within the field (Steffen et al. 2011; Committee on Emerging Research Questions in the Arctic; Polar Research Board; Division on Earth and Life Studies; National Research Council 2014; Dalby 2007; Malm and Hornborg 2014).

The second is the science of resilience, which has focused on understanding the connections within human and natural systems. It is generally used at smaller scales, such as communities, cities or catchments, for the practical management of issues and crises (Weichselgartner and Kelman 2015; Lewis and Kelman 2010). It frequently defines system boundaries qualitatively, in terms of what matters to the people in the system (Resilience Alliance 2010). This field has been influential in CAFF and SDWG assessments.

While combining insights from these complementary fields is challenging, doing so can give a better understanding of how system connections play out at different time and spatial scales (Blaikie et al. 2014; Cornell and Jackson 2013). As Arctic change emerges as a global issue (World Economic Forum 2016; Paglia 2015; Galaz et al. 2011), there is an urgent need to improve the flow of knowledge into decision-making and action. In practical terms, the scope of research, policies and interventions needs to match the real dynamics of the issues.

2.1.3 Multiple options for action

A key theme in this chapter is the place of knowledge in informing choices and action. Resilience depends on timely recognition of the dynamic interactions among the multiple Arctics, and on awareness of how choices that affect any "one" Arctic drive change through all the others. Trajectories of Arctic change already cause concern, and demand creative and flexible responses. Knowledge is growing about the unique role of the Arctic in Earth system dynamics, and the immense change caused by human influences from inside and outside the Arctic.

Mike Beauregard/Flickr

Inuit sculpture, *Two Waiting for Seals*. Resilience depends on awareness of how choices that affect the Arctic for one group bring change for others. For example, the 2009 European Union ban on trade in seal products had a strong impact on the Inuit subsistence economy.

Social systems have the capacity for purposeful action (Ackoff and Gharajedaghi 1996). However, the language of systems can disguise the fact that action involves and affects people, with their diverse needs, fears and hopes, and differences in knowledge, world views and values. Some people have more influence than others, giving them a privileged position in determining what is articulated and what is left invisible in decision contexts.

Scientific knowledge about possible futures is now a major factor in shaping action, with key social choices relying on the increasing capacity to predict aspects of change. For example, data on the likely rate of ice-melt in the Arctic is shaping debate and plans to open the Arctic to industry and shipping (Arctic Council 2009a).

While proactive choices can be made in more informed ways than ever before, more information can also bring new risks. For example, action based on confidence in an assessment of just one part of a complex system may have negative consequences for other parts of the system, or the whole of it. Better ways of handling this mix of partial certainty and deep uncertainty need to be incorporated in decision-making about linked social and environmental systems (Rammel et al. 2007; Cornell and Jackson 2013).

TABLE 2.1 **Evolving concerns in Arctic Council ministerial declarations**

Declarations	Priority concerns	Systemic perspective
1996 Ottawa 1998 Iqualuit	*The basic social and environmental priorities established:* • Well-being of the inhabitants of the Arctic (especially Indigenous Peoples) • Protection of the Arctic environment	The Arctic portrayed as a self-contained place/system needing help from outside to deal with external harms.
2000 Barrow	*New emphasis:* • Addressing impacts and consequences of climate change • Collaboration across working groups	Acknowledgement of global climatic change affecting Arctic people – cross-scale dynamics linking biophysical and social systems.
2002 Inari 2004 Reykjavik	*New emphasis:* • Economic development fuelled by natural resource use • Growing knowledge needs – for oil and gas, shipping	The system extends to non-Arctic states through the influence of international stakeholders.
2006 Salekhard	*New emphasis:* • Engagement of Indigenous Peoples in policy planning and implementation, improvement of their capacity to adapt	The system is heterogeneous and complex – cultural diversity recognized; importance of observation networks for 'sensing' change.
2009 Tromsø 2011 Nuuk	*New emphasis:* • Increased marine access to natural resources (oil and gas) needing institutional control (rule of law, international cooperation	System disconnections: environmental change and risks are anticipated, but attention to their societal causes is lacking.
2013 Kiruna 2015 Iqualuit	*New emphasis:* • Exploiting economic potential for region's prosperity, while managing Arctic cultural and ecological harm	Strong system disconnections: wider social and ecological harms and risks are invisible in the text (despite rich documentation in assessments).

2.2 Recognizing resilience

In recent decades there has been very substantial international investment in assessments of Arctic change. Arctic Council assessments have become the keystones of this work, developing into exemplary processes for scientific synthesis and building communities of expertise about pressing environment and human development issues. In this section, we outline some important messages expressed in Arctic Council documents, interpreting them in terms of coupled social and ecological systems, and assessing the extent to which they enable complex change to be sensed.

2.2.1 The social Arctic

In light of the complex patterns of environmental change, the Arctic Council has increasingly recognized the need to consider Arctic resilience.[1] But even before resilience was developed as a concept, both ecological and social priorities were the basis of the Council's activities and its high-level strategic communications. Concerns have shifted over time, however. The timeline in Table 2.1 highlights the emerging priorities that are emphasized in the Ministerial Declarations of the Arctic Council, from a systemic perspective.

Economic changes in global context

Expansion of the extractive Arctic economy comes at a largely under-acknowledged price.

The first serious efforts at oil exploration in the late 1960s marked a shift, now seen across the Arctic, away from locally determined economies, where social and ecological connections are close and self-correcting feedbacks are essentially immediate, towards globalized economies, where decisions appear largely disconnected from their social and ecological consequences. This global shift in interest in the Arctic's economic potential is increasingly evident in national Arctic strategies (at least of those countries that have one: see Appendix 2.2). Arctic states have placed progressively stronger emphasis on exploiting the economic opportunities of the Arctic (Wilson Center 2014; Emmerson and Lahn 2012a), while adverse social and ecological consequences of present economic pathways are downplayed or even dismissed in political

1 The 2011 Nuuk Declaration and the 2013 Kiruna Declaration both emphasized the need to increase Arctic resilience, especially in the context of climate change. The 2015 Iqaluit Declaration flagged the critical importance of resilience for Arctic communities and for the unique ecosystems of the Arctic seas.

Guido Appenzeller/Flickr

A former whaling boat near Ilulissat, Greenland: Arctic communities sometimes find their economic destiny is out of their hands because decisions taken far away, for example on whale hunting quotas, can affect their access to resources.

and economic documents (See Table 2.1 and Conley et al. 2013; Bert 2012; World Economic Forum 2014).[2]

In reality, Arctic economies are strongly coupled with the Arctic's interacting biological, geological and physical features (Glomsrød and Aslaksen 2009; Cicero 2015; Wilson and Stammler 2016). Ecosystem shifts impact on the subsistence economy; the natural resources of the Arctic underpin the subsistence and primary (extractive) economies; and the production, construction, and services sectors develop around geographic opportunities and increasingly shape the physical environment. This means that the economic outcomes of Arctic development are far greater than just the revenues earned and additional operational costs borne by companies working in the region's tough environment. CAFF's scoping study on the economics of ecosystems and biodiversity for the Arctic (CAFF 2015) noted that known biophysical feedbacks associated with expanding exploitation of Arctic resources can to lead to irreversible, rapid and large-scale environmental change, with negative impacts on people's well-being. It also noted that decisions are being made "blind"; that is, there is not enough information to give a clear picture of how Arctic ecosystem services will change under different development pathways (CAFF 2013b).

The social reality of economic change is also complex. Economies are diverse, not monolithic, and cannot be understood without consideration of the societies that surround them (Glomsrød and Aslaksen 2009). Markets and the corporate economy co-exist with the public sector, the commons, and a wide range of other social mechanisms and forums for exchange (Larsen et al. 2010b), but this diversity is masked by referring simply to "the economy". One economy is heavily based on extractive industries generating income and rents that tend to flow out of the Arctic; another consists of public services and transfer payments from central to regional governments; and another consists of local subsistence activities – and focusing only on one type of economy can negatively affect the others. It is well documented that people in Arctic communities have difficulties in influencing their

2 See e.g. WEF (2014: 8): "The ecological outcome of continued warming is difficult to predict, but will very likely pose challenges to some of the world's most iconic species."

BOX 2.1 **One Arctic, many economies**

FIGURE 2.2 **The importance of Arctic natural resources to national and regional economies**

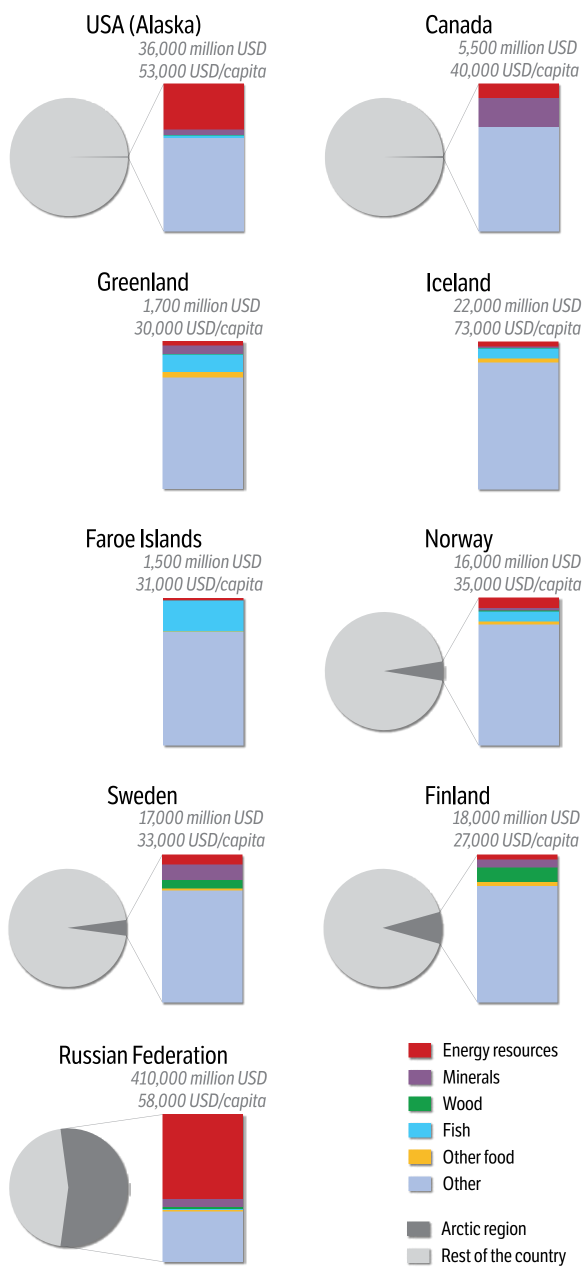


Figure 2.2 shows the added-value contribution of different industry clusters to the regional and national economies of the Arctic. Arctic states all draw different benefits from the Arctic, both in terms of the resources that are most valuable and in terms of the relative importance of Arctic resources to national economic activity. In Russia, for example, oil and gas in the Arctic make a large contribution to national GDP. Minerals are important for the regional economies of Canada, Greenland and Sweden.

Not all options for the use of living and natural resources are compatible, requiring balanced decision-making. If Arctic exploitation develops, pan-Arctic policies will need to tackle potential conflicts of interest. Additionally, new countries are entering the field. Many of the natural resources of the Arctic lie beyond national jurisdictions, so the design and control of the region's exploitation is a truly global endeavour with high political and economic stakes.

The importance of Arctic natural resources to national and regional economies varies greatly. Figures a–f show proportion of regional economy to national GDP in pie charts, and industry cluster contributions to gross regional product for the Arctic in bars. For Faroe Islands, Greenland and Iceland, bar charts show entire GDP).

Source: Regional economy value-added data for 2005 from http://www.ssb.no/a/english/publikasjoner/pdf/sa112_en/kap4.pdf; 2005 GDP data from http://data.worldbank.org/indicator/NY.GDP.MKTP.KD?page=2; currency conversion rates to 2005 USD for regional contribution to GDP: http://www.canadianforex.ca/forex-tools/historical-rate-tools/yearly-average-rates.

economic destinies. And there are geopolitical dimensions at play, too. The Arctic's regional economies are often sharply disconnected from the national economies that they are nested within (Glomsrød and Aslaksen 2006), and each Arctic nation has access to different resources, so interests and incentives for resource use or conservation vary greatly between nations (see Box 2.1).

The SWIPA assessment (AMAP 2011) discussed Arctic change in terms of "winners and losers", as if the interests in the region were involved in a zero-sum game. Indeed, in the context of rapid biophysical change, there is an increasingly clear scenario of positive opportunities for the few, and negative impacts for the many – often devastating ones for people, cultures and the life around us. There is a clear scientific message that unfettered economic exploitation (with associated oil spills, soot plumes, greenhouse gas emissions, air and ocean acidifying substances, systemically harmful and ecologically disruptive pollutants, invasive species, and direct ecosystem damage) sets in train global impacts. The biophysical effects of accelerated loss of Arctic ice are comparable to the destruction of the entire tropical rainforest ("the lungs of the Earth"), or indeed the removal of entire mountain ranges ("the water-towers of the world" (Dadson et al. 2013)). This loss and its global impacts are a real prospect, in part because the economic and environmental perspectives of Arctic decision-makers, both in and far beyond the region, are disconnected.

Societies and communities

People's voices, networks and power influence choices and consequences – and conflicts.

The Arctic Council's working groups and task forces (see the overview in Appendix 1) address issues affecting Arctic communities and Indigenous Peoples. Arctic residents emphasize that Arctic communities are many and diverse. In many decision-making contexts, they call for the scope of Arctic life to be represented with a broader palette (Larsen et al. 2010a; Glomsrød and Aslaksen 2009; IPS and ANNDC 2015). The context of each community will determine how its people think about handling social and ecological change.

The Arctic's diverse ways of life bring many different voices to decision-making arenas, but not all voices are equally heard (SDWG 2015). Politically powerful and well-resourced groups obviously have greater influence, especially when major decisions are made in capital cities and corporate headquarters sited far from the Arctic. And some messages are lent greater weight because they fit dominant narratives about Arctic change (see Box 2.2).

To redress these power imbalances, transparent and accountable processes are required that do not disadvantage Arctic residents simply because they are few in number. When institutions fail to meet these standards, the consequences can be serious. Repeated conflicts over the management of Arctic wildlife have been driven by failure to resolve competing claims about the state of the ecosystem (Hay et al. 2000; Kendrick 2002; Kofinas 2005). The best documented example of such a conflict is over the management of polar bears (Meek 2011; Nirlungayuk and Lee 2009; Tyrrell and Clark 2014), where scientific management institutions and local Canadian Inuit communities disagree on estimates of bear populations. Overly strict quotas meant that hunters lost vital income, and the erosion of trust has genuinely harmed relations between the Inuit and the state. Despite these societal consequences, national and international measures to protect polar bears have achieved no net conservation gain (Weber et al. 2015).

Furthermore, Arctic change is increasingly framed in terms of issues affecting people far beyond the Arctic (including in this report). As the populations and demographics of Arctic communities change, through migration in and out of the region (Bogoyavlenskiy and Siggner 2004; Larsen and Fondahl 2015), there are clear trends, enabled by technology and travel, of increased and international social connectedness, and widened global awareness and engagement in Arctic issues. These external voices are also entering decision arenas, changing established institutional structures and power relations, often shifting attention away from local needs, altering expectations of development pathways, and changing the nature of development risks.

BOX 2.2 Arctic narratives

Narratives are important: they inform and justify decisions, legitimize the behaviour of some actors over others, and guide the interpretation of formal and informal rules (White 1980; Patterson and Monroe 1998). So narratives help define what are perceived as the "most important" drivers of socio-ecological change, and determine the attention and action that they deserve.

External and indigenous narratives

Several observers have identified a range of dominant but strongly contrasting Arctic narratives (Berger 1977; Young and Einarsson 2004; Steinberg et al. 2015). External players tend to stress the control and exploitation of resources and territory, as compared with narratives of Indigenous Peoples that describe the Arctic as a homeland. The external narratives perceive the region variously as a theatre for military operations, as the Arctic of imagination or adventure, and as an area for scientific study. A variant of this scientific narrative is the narrative of the Arctic as an environmental lynchpin, which emphasizes the role of the region in global environmental dynamics, and the need to preserve the Arctic environment. This narrative often leaves out social, cultural and economic issues.

Steinberg et al. (2015) emphasize the governance implications of comparatively recent indigenous narratives. They describe two: on the one hand there is the narrative of indigenous statehood, notably where Greenlanders as an ethnic minority are seeking to establish their own independent nation; on the other there is the narrative of transcendent nationhood, which corresponds to the idea of an indigenous (primarily Inuit) community spanning the Arctic across national borders.

External players are increasingly shaping Arctic narratives, notably as Observers to the Arctic Council. Bennett (2015) shows that narratives in China's official statements depict the Arctic as part of a global environmental and political landscape – where China itself may play a role. Thus Arctic boundaries and institutions can evolve from the interaction of narratives within and beyond the region.

Narratives and the Arctic Council

The narratives of Indigenous Peoples and external players have often clashed (Hastrup 2009). In a 2015 workshop (ARA 2015), Indigenous Peoples' representatives criticized a "big geopolitics" narrative for diverting attention away from practical solutions to Arctic challenges. Development mistakes made in other contexts can be avoided, through planning that addresses the real impacts of rapid social and ecological change (see Chapter 6).

Cultural perspectives

Cultural well-being underpins resilience at local scales, but also at much larger scales.

Shifting economic development pathways and accelerating environmental changes in the Arctic are breaking traditional patterns of activity and indigenous ways of life. At the same time, the vital importance of Indigenous Knowledge for ecological conservation and sustainable resource use is increasingly recognized and reflected in assessments and policy (Larsen and Fondahl 2015; SDWG 2015). The capacity of communities – and the ecosystems they are part of – to adapt to change is hampered by their loss of local traditional knowledge and by the broken transmission of knowledge and skills across generations, so there is a need for continued effort and investment aimed at holding on to cultural heritage and Indigenous Knowledge.

An important trend across much of the Arctic, and elsewhere in the world, is the revitalization and empowerment of indigenous culture (Larsen and Fondahl 2015; Larsen et al. 2015; Inuit Circumpolar Council 2014) (Appendix 2.1 summarizes the priorities of the Permanent Participants of the Arctic Council). Many of the SDWG's assessments show that within this trend there is much complexity: there are diverse interests and perspectives both between and within Indigenous Nations and Indigenous Peoples, shaped by contemporary opportunities and historic trajectories (see Box 2.3).

Another growing trend is the recognition that traditional and scientific knowledge can complement each other in dealing with rapid change. However, it is challenging to integrate these different knowledge cultures (Tengö et al. 2014; Cornell et al. 2013; Shari Gearheard et al. 2006; Huntington et al. 2004). The lived experiences on which traditional knowledge is based can be difficult to communicate to those who do not share similar experiences, value systems and worldviews, while academic language, institutional systems and disciplinary divides all hinder the accessibility and direct usability of scientific knowledge.

For both transmitting and integrating knowledge, there is no substitute for inclusive and transparent dialogue over extended periods (Forbes, Kremer, et al. 2011). Discussing different points of view and sharing expertise of multiple kinds, with the aim of generating relevant and usable knowledge, takes time, effort and mutual respect. In the region, multi-stakeholder forums are the structural foundation of indigenous-state co-management organizations, whether established under indigenous land claim settlements or as self-organized responses to specific issues (Armitage et al. 2011; Natcher et al. 2005). There are many new calls for more multi-stakeholder forums with a broader perspective that bring together local and Indigenous Peoples with the business, policy and academic communities.

Kamil Jagodzinski

Shifting patterns of economic development, including increasing trade, are changing traditional patterns of activity and indigenous ways of life in the Arctic.

The political arena

Environmental dynamics are not politically negotiable, but human response pathways are.

In the last decade, the Arctic Council's major environmental assessments (AMAP 2011; AMAP 2013; Arctic Council 2013b; CAFF 2013b) have achieved a sophisticated integration of social/cultural, political/economic, and biophysical dimensions. In contrast, politically influential strategy documents (Wilson Center 2014; Emmerson and Lahn 2012a; Foreign and Commonwealth Office 2013) tend to keep social/cultural and ecological dimensions comparatively separate, although some call for much more engaged and integrated approaches to Arctic management (Clement et al. 2013).

When choices are politically contested, informed political dialogue can make it possible to negotiate more balanced outcomes. But when issues are discussed separately, it is difficult to reach a clear and consistent basis for decisions. Instead, climate change and biodiversity loss need to be understood more as social issues, and economic development as an ecological one. In particular, climate change impacts need to be taken into account in political processes because they will not disappear if ignored, and they cannot be negotiated away. Even with strong mitigation action, climate warming and sea-level rise will continue because of slow responses in the Earth system to historic greenhouse gas emissions. With this in mind, in 2011, SWIPA's regional expert report on climate change (Callaghan, Johansson, Brown, et al. 2011) included very clear recommendations on climate adaptation and mitigation.

Adaptation is needed – to all dimensions of global change, not just climate (AMAP 2016) – but present choices also shape future options. SWIPA's calls for upgrading emergency-response capacity and improving weather forecasting are presented as a way to reduce the impact of climate variability; but from another perspective, these technological improvements can be seen as enabling a causal driver of climate change. They represent major international investment in a tacitly made decision, not a politically negotiated one, to increase shipping, infrastructure, and extractive industry in the Arctic.

Mitigation of greenhouse gas emissions is conspicuously missing from Arctic Council literature,[3] except for the expert assessments of short-lived climate forcers (AMAP 2015a; AMAP 2015b: 110), which make recommendations for research and monitoring rather than

3 For instance, there is no substantive mention of climate change mitigation in the *Arctic Ocean Review Final Report* (PAME 2013b), *Arctic Council Arctic Marine Strategic Plan 2015–2025* (Arctic Council 2015a), or the *AMAP Assessment 2013: Arctic Ocean Acidification* (AMAP 2013).

BOX 2.3 Perspectives on cultures, corporate power, and neocolonialism

In much of the Arctic, the politics of indigenous self-determination and recognition are entangled with the shrinkage of the state and the rise of corporate power. Different perspectives abound on these processes.

Historically, the relationship of states with indigenous communities was tied to an agenda of unimpeded exploitation of resources. In some places, the new relationships of neo-liberalism (Jegorova 2013) seem to be re-inscribing settler-colonial power on Arctic Indigenous Peoples. Elsewhere, Indigenous Peoples' dependence on corporations is seen as a "mutual benefit":

> *"In Alaska, the $350 million annual budget of the North Slope Borough government is funded with tax revenues paid by oil companies operating in the state waters of the North Slope onshore and offshore. In addition, Alaska residents pay no state income tax; in fact, they receive checks from the Alaska Permanent Fund, a corporation financed largely by oil revenues."* (Wilson Center 2014)

But is industrial development a free choice if it threatens to destroy indigenous culture? Arctic Indigenous Peoples occupy traditional territories that span vast geographical areas and transcend the boundaries of nation states, yet Indigenous Peoples remain heavily under-represented in mainstream political institutions. The stakes are so uneven that the outcomes of decisions about economic development are taken as given, and not a matter for negotiation. For example, the Inuit Circumpolar Council's (ICC 2014) reflections on Inuit use of sea ice and shipping take "predictions" of increased Arctic shipping as fact, not mentioning the cascades of decisions that need to be made in order for this change to happen:

> *"While we have resolved to adapt to the changed climate and thinning ice as best we can – and show considerable confidence that we will succeed – we are less sure about what increased shipping and northern development may mean for our future. … Inuit vary in their levels of concern, resignation, or acceptance that the number of ships coming through their homeland will increase. All agree that a higher tempo and new forms of maritime activity pose serious risks to Inuit and to the marine environment upon which we depend for sustenance."* (Inuit Circumpolar Council 2014)

Independence means having more control over one's own affairs. Meaningful Indigenous autonomy and resilient "self-determination through market partnerships" involves looking beneath the surface of simplified political narratives and ideologies and beyond immediate and short-term exchanges.

TABLE 2.2 **Change in aggregate greenhouse gas emissions for Arctic states, 1990–2012, excluding and including land use, land-use change, and forestry (LULUCF).**

	% change in emissions	
Country	Excluding LULUCF	Including LULUCF
Iceland	+26.3	+9.8
Canada	+18.2	+42.2
Norway	+4.6	-35.3
U.S.	+4.3	+2.4
Finland	-13.3	-38.0
Sweden	-20.8	-34.8
Denmark (incl. Greenland)	-24.1	-30.6
Russian Federation	-31.8	-50.3

Notes: LULUCF is an emissions category for national reporting under the UN Framework Convention on Climate Change. Activities that lead to carbon loss or accumulation in land vegetation and soils are included in greenhouse gas inventories. See: http://unfccc.int/land_use_and_climate_change/lulucf/items/1084.php

Global transparency on national commitments and mitigation progress is helped by public information. See: http://climateactiontracker.org/countries

Denis Caviglia/Flickr

Sámi Parliament in Karasjok, Norway: Arctic Indigenous Peoples occupy traditional territories that span vast geographical areas and transcend the boundaries of nation states.

for specific mitigation action. In 2011, SWIPA called for action to "urgently negotiate global reduction of greenhouse gas emissions, with Arctic Council leadership". As Table 2.2 shows, the current state of play is mixed:

The choice for societies remains open – whether to slow the path of climate change through concerted mitigation action, or to accelerate it through opened oil and gas exploration. In this context, the choice not to articulate the issue of mitigation in political arenas is a choice that drives society along a particular environmental pathway, even though the global risks ahead are increasingly clear.

2.2.2 The ecological Arctic

The physical environment

Arctic warming triggers worldwide climate impacts, but Arctic actors have power to mitigate risks.

The physical climate of the Arctic fundamentally shapes the region's landscapes and seascapes. It also plays a strong controlling role in Earth's climatic and long-term geological conditions. Three influential Arctic Council assessments have dealt comprehensively with the physical science of Arctic climate (AMAP 2011; ACIA 2005; Macdonald et al. 2002). Arctic change also features prominently in the global assessment reports of the Intergovernmental Panel on Climate Change (IPCC) (Lemke et al. 2007; Vaughan et al. 2013; Christensen et al. 2013).

Earth's climate is unequivocally changing under human influence, at rates that are unprecedented over millennia of Earth history (IPCC 2014a). This transforms land and marine environments in the Arctic, but climate assessments increasingly pinpoint the multi-scale systemic behaviour of Arctic change, as in this statement from the SWIPA report:

> *Cryospheric degradation will result in cascading effects on Arctic environments and peoples; their livelihoods, living conditions, and quality of life; and the regional climate systems. These effects will have global consequences* (Hovelsrud et al. 2011) (emphasis added).

Improved scientific understanding increases the predictability of climate phenomena and their teleconnections. Briefly, global consequences of Arctic change include:

- **More rapid global warming:** climate change is amplified in the Arctic region, which is now warming roughly twice as much as the global average (Screen and Simmonds 2010; Pithan and Mauritsen 2014).

- **Global sea-level rise and transformation of coastal zones:** ice melt in the Arctic region is currently the biggest contributor to observed changes in these phenomena (Chen et al. 2013; Church et al. 2013).

- **Extreme weather events:** the behaviour of large-scale linked weather systems (i.e. the Northern Annular Mode and North Atlantic Oscillation) is very difficult to predict. These systems are a prime factor behind both warm and cold extreme weather events in the northern hemisphere – and their costly impacts (Hurrell et al. 2013; Christensen et al. 2013). As the global climate warms, regional climate will depend critically on the high variability of these systems (Rind 2005; Barnes and Polvani 2013; Gillett et al. 2013).

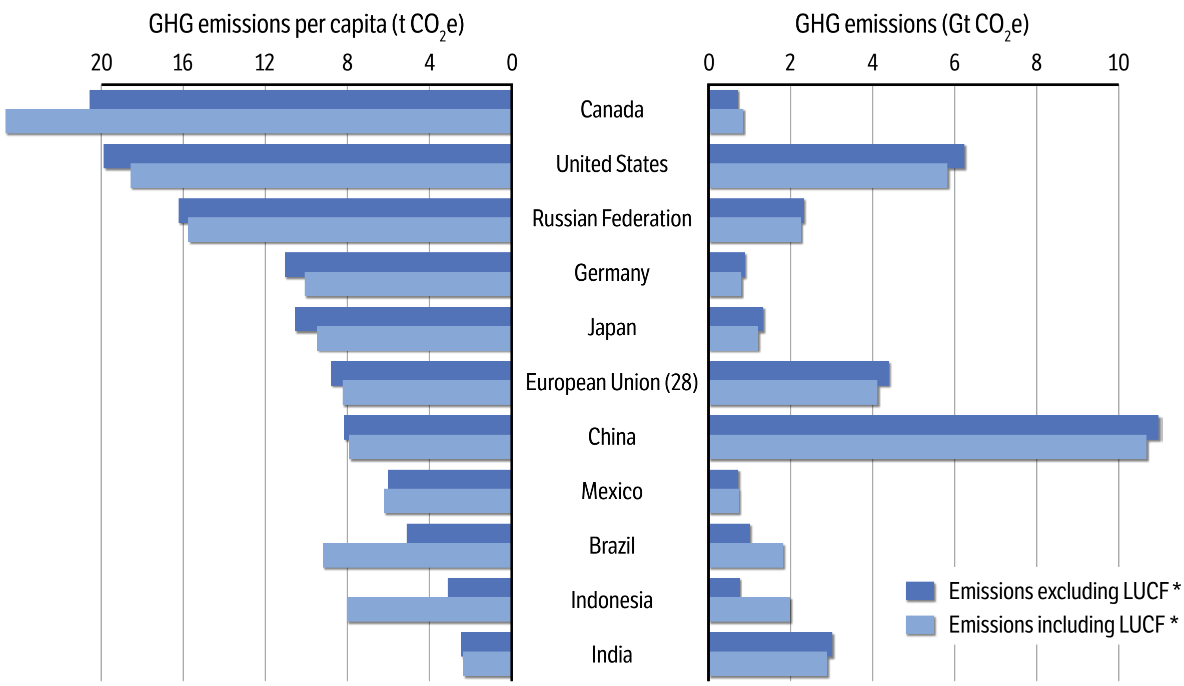
- **Altered global thermohaline circulation:** melting ice alters ocean salinity, currents and heat flows. Interactions of physical feedback processes have long-term effects on regional climates worldwide (Dahl-Jensen et al. 2011; Callaghan, Johansson, Key, et al. 2011; Rhein et al. 2013; Jackson et al. 2015; Stocker et al. 2001).

Most importantly, the human imprint on global climate change is now detectable and attributable (IPCC 2014a). Anthropogenic carbon dioxide emissions continue to accelerate (Le Quéré et al. 2015), driven by everyday decisions made by people around the world on industrialization, globalized trade, land-use change, and energy-intensive transport and habitation. And the impacts on society of climate change are already evident (ACIA 2005; Larsen et al. 2014; IPCC 2014b). Impacts are projected to increase in severity and cost in the coming few decades (Burke et al. 2015; Revesz et al. 2014).

Most Arctic Council assessments of climate issues emphasize that the societal driving forces of global climate change are largely *external to the Arctic* (see section below on the human-controlled environment). And this is true in both physical and demographic terms: the small Arctic population is responsible for a tiny fraction of global emissions.

However, viewed politically, the Arctic nations are prime actors in climate change. Arctic nations – and now also several observers to the Arctic Council with strong interests in the region – are among the major emitters of greenhouse gases, both on a per capita and an absolute basis (see Figure 2.3). The eight Arctic nations emit about 20% of global emissions of methane, a potent greenhouse gas (AMAP 2015), and together have the largest technical abatement capacity of any world region. Decisions made (or deferred) by these countries largely determine global exposure to climate risks.

FIGURE 2.3 **The world's top 10 greenhouse gas emitters include major Arctic states and Arctic Council observers.**



*LUCF is land use change and forestry.

Source: World Resources Institute

The living environment

Arctic ecological protection is now a global concern, and worldwide monitoring is inadequate.

Ecosystems are changing across the entire region, on land and in the sea, often abruptly and sometimes irreversibly (Arctic Council 2013a). These changes are accelerating in response to physical climate changes (AMAP 2013; AMAP 2011; Sommerkorn and Hamilton 2008; ACIA 2005). They have been most comprehensively described in CAFF reports (CAFF 2001; CAFF 2010; CAFF 2013b) and include disappearance or dramatic modification of habitats, ecosystems and populations; shifts in the usual geographic range of species and the timing of ecological events (e.g. flowering, migration and breeding); and outbreaks of pests and disease affecting plants and animals.

These changes test the capacities of people living in the Arctic to cope and adapt (Larsen and Fondahl 2015; Arctic Council Sustainable Development Working Group 2009; Forbes, Stammler, et al. 2011; Magga et al. 2011; CAFF 2013b), but Arctic ecological change also has systemic global consequences that need to be brought into view.

Changes in Arctic ecosystems both affect and are affected by Earth's global metabolic pathways and biogeochemical cycles. In addition to the physical climate feedbacks already mentioned (i.e. albedo and thermohaline circulation), *biophysical* feedbacks play a critical role in maintaining or altering Earth's climate and ecological conditions (Prentice et al. 2004; Murray et al. 2008; Reinhardt et al. 2010).

Several of these feedbacks were explained in the 2011 SWIPA report. Some are negative, balancing feedbacks, tending to offset the current climate warming (see Figure 2.4).

Others are positive, self-reinforcing feedbacks, where temperature increases in the region lead to even more warming globally (see Figure 2.5). The balance of evidence from observational and palaeo-data and model analysis is that the accelerating effects are currently stronger than the negative feedbacks (Finzi et al. 2011; Sommerkorn and Hassol 2009; Koven et al. 2011; Pearson et al. 2013).

Describing feedbacks in simple mechanistic terms suggests that they operate rather like a thermostat, turning smoothly up or down. However, these Arctic feedbacks have different strengths, timeframes and spatial scales of impact. They interact in ways that can cascade and amplify each other (Pearson et al. 2013; Bartlein et al. 2015) leading to abrupt environmental change or "inevitable surprises" (Committee on Understanding and Monitoring Abrupt Climate Change and Its Impacts; Board on Atmospheric Sciences and Climate; Division on Earth and Life Studies; National Research Council 2013). Recent rapid, unexpected ecological changes leading to large pulses of carbon release include bark-beetle outbreaks in high-latitude forests and large-scale tundra fires, both of which become more likely as climate warms (Mack et al. 2011; Schuur et al. 2013; Musolin and Saulich 2012).

FIGURE 2.4 **Negative, balancing feedbacks between Arctic ecosystems and the cryosphere**

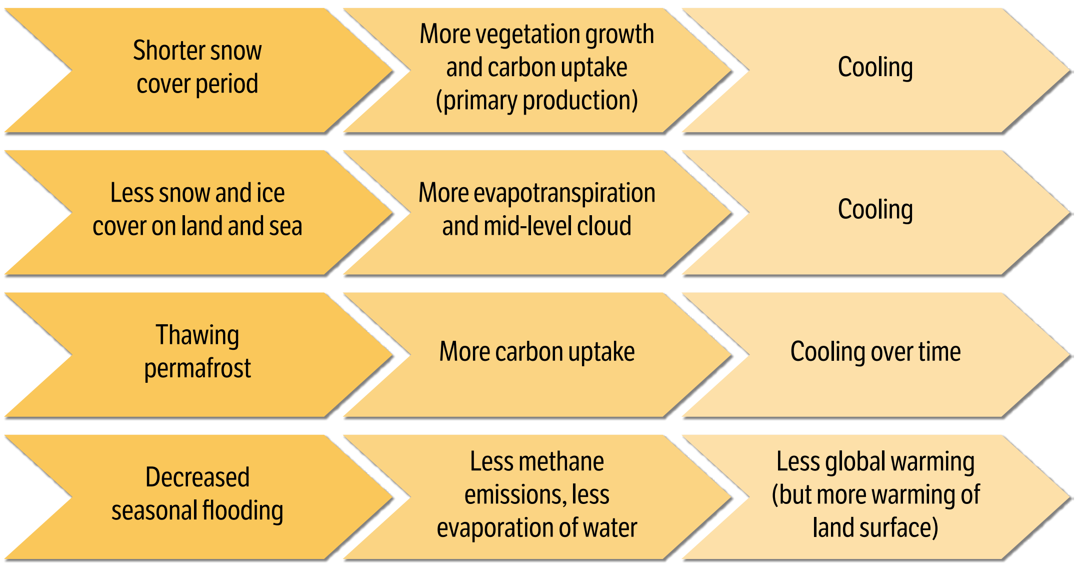
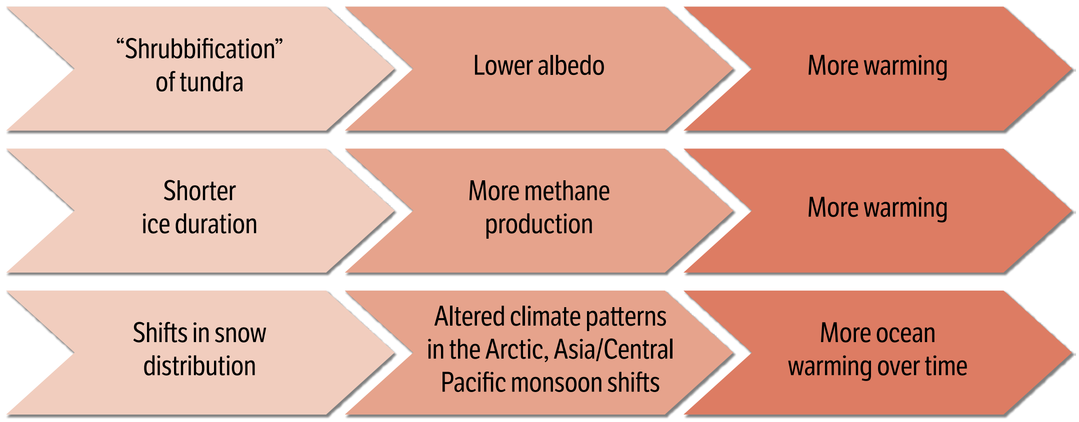


FIGURE 2.5 **Positive, self-reinforcing feedbacks between Arctic ecosystems and the cryosphere**



The directions and relative strengths of major biophysical feedbacks are qualitatively well understood (Finzi et al. 2011; Lengaigne et al. 2009; Hinzman et al. 2013). Research is advancing rapidly (Wolff et al. 2015), but quantitative prediction of the effects of Arctic change is constrained by the intrinsic complexity of land and marine ecosystems, their responses to environmental change, and the context of multiple human influences (discussed more in the following section).

Societies in the Arctic and worldwide depend on ecosystems that function in relatively reliable ways. Compounded climate change impacts and human pressures are rapidly eroding this reliability.

The Arctic Council has recognized the need for a shift to integrated ecosystem-based management (See Table 2.3), defined as:

> *"The comprehensive integrated management of human activities based on best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of ecosystems thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity."* (Arctic Council 2013b)

TABLE 2.3 **Ecosystem-based management in Arctic Council Declarations**

2004	Reykjavik Declaration	"Note that an **ecosystem-based management approach** underlies the [Arctic Marine Strategic Plan] and call upon Member States, Arctic Council working groups and relevant regional and international bodies to further the application of this approach to the Arctic marine environment."
2011	Nuuk Declaration	"Decide to establish an expert group on Arctic **ecosystem-based management** (EBM) for the Arctic environment to recommend further activities in this field for possible consideration by the SAOs before the end of the Swedish chairmanship."
2013	Kiruna Declaration	"Welcome the report on **ecosystem based management**, approve the definition, principles and recommendations, encourage Arctic States to implement recommendations both within and across boundaries, and ensure coordination of approaches in the work of the Arctic Council's Working Groups."
2015	Iqaluit Declaration	"Recognize the multiple stresses on the Arctic environment and the need for an **ecosystem-based approach to management**, welcome and continue to encourage progress toward implementation of the **ecosystem-based management** recommendations approved by Ministers in Kiruna, and request the development of practical guidelines for an **ecosystem-based approach** to the work of the Arctic Council be completed as soon as possible."

Note: The text extracts in this table are the explicit mentions of ecosystem-based management in the declarations. The Barrow (2002), Inari (2002), Reykjavik and Tromsø (2009) declarations also welcome studies and reports on using an integrated ecosystem approach (e.g. the UNEP/CAFF/GEF study ECORA in the Russian Arctic).

Many practices of Indigenous Peoples in the Arctic, such as reindeer herding, are centuries old.

To date, work on ecosystem-based management is most advanced for marine environments, led by PAME[4] (Joint Group of Experts on the Ecosystem Approach to Management 2015; Arctic Council 2015b). CAFF has built up a strong scientific basis for ecosystem management, implementing strategies for biodiversity monitoring (CAFF 2013b; CAFF 2011; CAFF 2016) and piloting ways to bring ecosystem processes into mainstream decision-making (CAFF 2015).

However, options for future development in the Arctic are still generally described in ways that focus on local ecological impacts and on parts of the ecosystem. The 2013 Arctic Ocean Review (PAME 2013b) highlights the shortcomings of management that overlooks dynamic biophysical interactions. But like other reports (Arctic Council 2009b; EPPR 2015) it recommends *"identifying and protecting Special Areas, Particularly Sensitive Sea Areas and other sensitive ecological/biological and cultural areas, and possibly emission control areas".*

Protected areas are vitally important, but ecosystems do not operate within human-drawn boundaries. Conservation piece-by-piece is not an adequate response to today's complex change. The 2013 Arctic Biodiversity Assessment is clear about what a systemic response entails: large areas of the Arctic need protection to safeguard "critical habitat" (and biophysical stability), and protected areas need to be strategically networked, and managed in a wider context of environmental stewardship (CAFF 2013c; Runge et al. 2015). Responses in light of known biophysical dynamics include monitoring designed to sense change, not just in the Arctic but worldwide. And as stated in the UN's Convention on Biodiversity and Agenda 2030 the continued human-caused loss of biodiversity needs urgently to be halted, everywhere (United Nations 1992; United Nations 2015).

4 See: www.pame.is/index.php/projects/ecosystem-approach

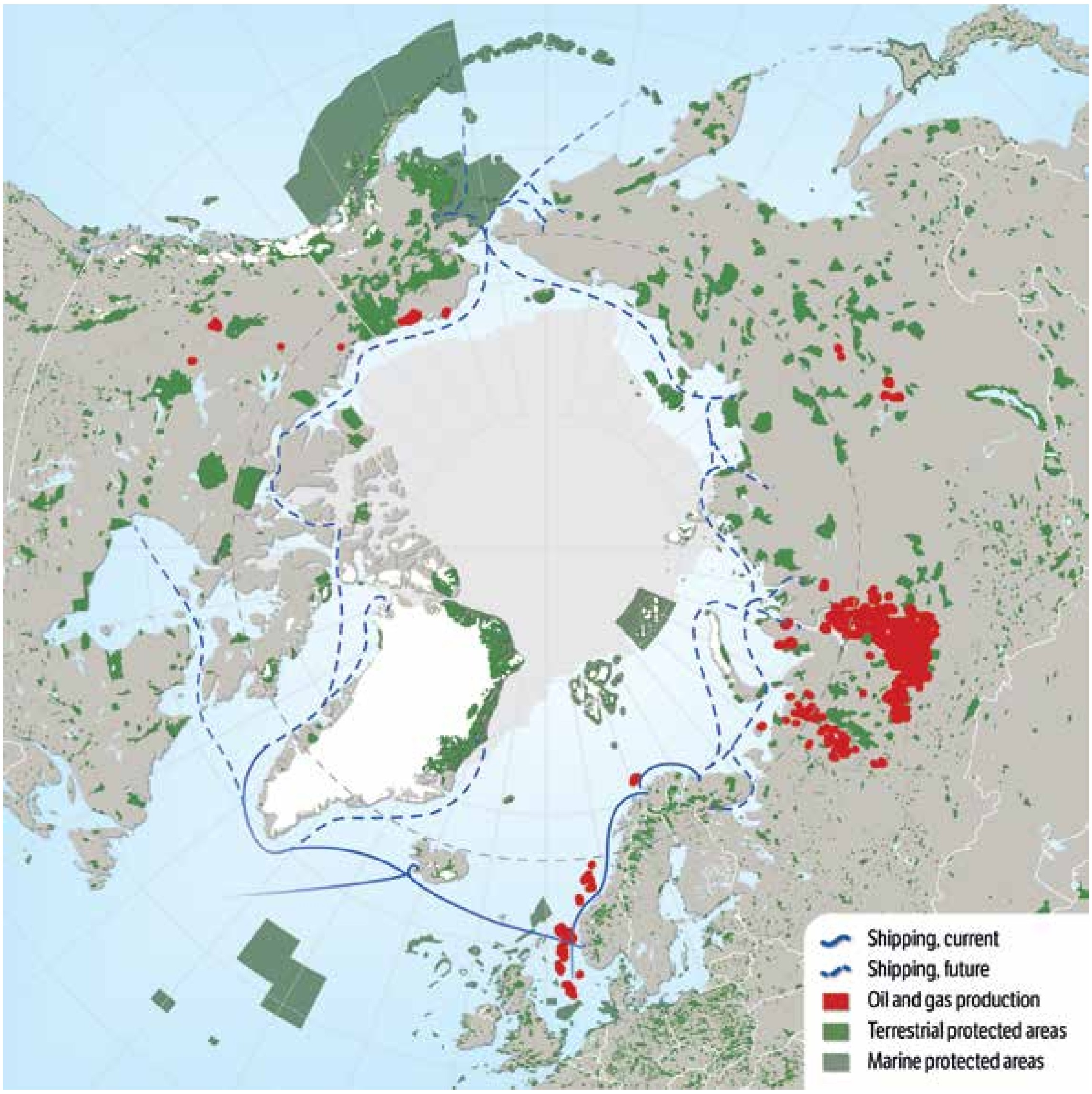
The human-controlled environment

Human-caused pressures are accelerating in all ecological domains, but Arctic assessments are seldom integrated to show the entire picture.

Many practices of Indigenous Peoples in the Arctic are centuries old. The Arctic has also seen several decades of industrial expansion. Today's economic driving forces directly affect Arctic landscapes and seascapes. Roads, railways, airports, heliports and shipping ports connect communities in new ways and enable the increasing exploitation of the region, and patterns of settlement are changing (see Figure 2.6). A low-intensity, spatially extensive pattern of human imprint on the landscape has shifted to one with both localized acute impacts (Arctic Council Action Plan (ACAP) 2005; CAFF 2013b; EPPR 2011; EPPR 2015) and wide-ranging systemic disturbance (AMAP 2009a; AMAP 1998; AMAP 2013; AMAP 2009b).

These physical, chemical, biological, human health and socioeconomic impacts will worsen unless development

FIGURE 2.6 **Environmental imprints of local culture, regional security, and global trade**



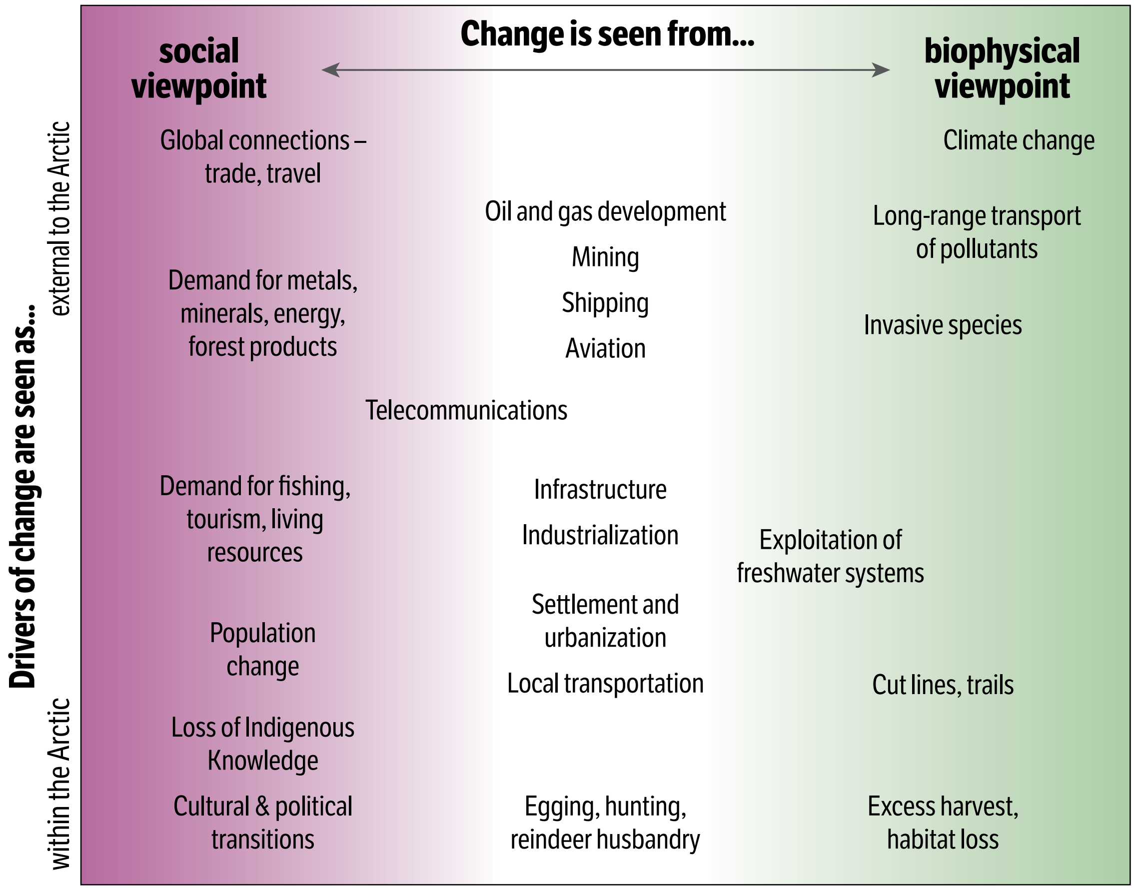
is strategically coordinated, and confined within ecological and societal adaptive capacities.

In 2002, CAFF recommendations (CAFF 2002) to the Senior Arctic Officials emphasised the cross-scale interplay of ecological and social dynamics:

> *"Although some impacts are largely localised, more insidious is the cumulative impact of a range of human actions over time and space. The collective impact of habitat destruction, pollution, over-harvesting, and climate change, for example, may be far greater than an examination of any one factor would suggest. A critical part of considering the Arctic as a system is considering the interactions among impacts."*

Since then, Arctic Council reports have documented the long and growing list of human-caused environmental pressures (see Figure 2.7), but it is obvious that different interest groups give central importance to different aspects of the system, and systemic connections are rarely explicit. In other words, Arctic assessment is still fragmented. Some reports emphasize the external global drivers, others focus only on endogenous change processes within the Arctic region. Issues are described variously in terms of social drivers and biophysical characteristics – but social drivers are poorly connected to their biophysical impacts, and the human actors causing biophysical change are very rarely identified.

FIGURE 2.7 **Human-caused pressures on the Arctic are framed in different ways according to context**



However, important signals of a more integrated approach are appearing in several Arctic Council Working Groups. In AMAP, the aims of the 2011 SWIPA report (AMAP 2011) were explicitly systemic, highlighting the interplay of internal and external drivers of change (Skovgaard Olsen et al. 2011; Hovelsrud et al. 2011). AMAP's 2014 assessment of socio-economic drivers (Andrew 2014) outlines major trends and projections for broad categories of drivers. CAFF's Arctic Species Trend Index explicitly includes five human environmental variables for ongoing monitoring (Bohm et al. 2012), and its 2013 Arctic Biodiversity Assessment details the knowledge gaps that still obstruct a systemic assessment (CAFF 2013a). The SDWG-endorsed Arctic Social Indicators were devised to improve assessment of well-being in the context of multiple stressors, multiple scales and rapid change (Larsen et al. 2015).

PAME and the Emergency Prevention, Preparedness and Response Working Group (EPPR) still have a more sectoral focus, often emphasizing the Arctic as a (passive) recipient of pollution and unwanted environmental impacts that have to be dealt with post-hoc. But the 2013 Arctic Ocean Review emphasises processes of change and "a host of environmental shifts". The 2015 Arctic Environmental Hazards assessment (EPPR 2015) only superficially mentions ecological dynamics, but it highlights the importance of Indigenous Knowledge and community networks in preparedness, detection, and responding to environmental incidents.

An exemplary report, which applies and recommends a reflexive, rigorous transdisciplinary approach, is State of the Arctic Coasts 2010 (Forbes 2011). It highlights the need in decision-making for integration of knowledge from different sources – indigenous, scientific, experiential – and the importance of a strong, local, and diverse resource base in providing communities with the capacity to adapt to changing conditions.

2.2.3 Sensing change and making choices

The Arctic today demonstrates how closely social and ecological systems respond to each other. People, social institutions, and organisms are exploiting new opportunities and seeking to avert harmful circumstances. When systems co-evolve in this way, mutually adapting to changing contexts, many system metaphors such as disturbance, collapse, or restoration to an "initial state" do not adequately describe the reality (Lade et al. 2013). Feedbacks between the systems limit the capacity to predict and control outcomes (Levin et al. 2012; Committee on Emerging Research Questions in the Arctic; Polar Research Board; Division on Earth and Life Studies; National Research Council 2014; Chapin III et al. 2006).

Finding multiple ways to sense and track change across the whole system is the basis of adaptive approaches to management (Leenhardt et al. 2015), and might give early warnings of large or sudden changes in both social and natural systems (Scheffer et al. 2009; Lindegren et al. 2012; Glantz 2009). But doing so requires more than just filling in gaps in knowledge. It should mean that the consequences of change in one domain are systematically scoped in other domains. In social terms, "sensing change" might mean expanding participatory processes to gather information from a wider range of viewpoints, or improving information flows between different decision-making processes, especially through cross-sector, international, multi-actor forums. Ecologically, it could mean the development of comprehensive monitoring systems that observe different aspects of ecosystems at different scales.

When environmental dimensions of social change are not recognized, and vice versa, pressures may not be identified and can mount up over time until it might be impossible to backtrack away from "tipping points" with severe impacts.

However, when it becomes clear that biophysical changes are driving social change, "tipping points" actually become *choice* points. One example of such a shift is the long-range transport of atmospheric pollutants, where the distinctive Arctic combination of climatic and ecosystem conditions has led to a unique complex of problems

Bretwood Higman and Erin McKittrick/Ground Truth Trekking

The Arctic has seen several decades of industrial expansion – for example at the Red Dog zinc mine in Alaska. Today's economic driving forces directly affect Arctic landscapes and seascapes.

(Bard 1999). Averting the serious environmental health risks of atmospheric pollutants has required deliberate policy choices – to reduce emissions of harmful and toxic substances, to protect populations, and to minimize exposure (AMAP 2009a; AMAP 2009b). Similarly, we see that instances of ecological disruption, like overfishing and invasive species, are shaping social choices about navigation, ballast water and waste management, and the role of sovereignty in ports, coastal zones and the high seas (Arctic Council 2009a; Humpert and Raspotnik 2012). We do not yet see a clear choice point for climate change and ocean acidification, although the physical and biogeochemical processes involved are robustly understood (IPCC 2014a; AMAP 2013).

The way in which drivers are framed affects the choices made in response to change. The Arctic environment is demonstrating that not everything is a matter of social construction or political negotiation. Wise choices involve ensuring that the social objectives are compatible with the environmental dynamics.

Marcus Carson

Kampe Absalonsen, at the Qajaq club in Ilulissat, Greenland: A traditional hunter and respected builder of Greenland kayaks, Absalonsen was for many years the chief judge for the Greenland Kayaking Championships.

2.3 Multiple Arctics, shared responsibility

2.3.1 Changing Arctic actors: Global is the new local

The Arctic, and its global footprint, has become extremely important in multilateral sustainability policy contexts, where previously it was just one among many of the world's regions. At the same time, these policy contexts have a vital new focus on what people and local communities know, see and do. The 2015 Paris Agreement under the UN Framework Convention on Climate Change emphasizes a system of transparency and stock-taking of global emissions, shifting responsibility across decision-making levels in a way that now allows the world's citizens to hold each other accountable for progress on climate mitigation (in principle, at least). Under the Convention on Biological Diversity, CAFF has agreed to cooperate on implementing the strategic goals of the CBD in the Arctic (CBD Secretariat and CAFF 2010). The CBD formally recognizes the globally important role of Indigenous Knowledge and local collective action in nature conservation and management (CBD 2012, Decision XI/6D), and drives new efforts in the Arctic and worldwide to ensure the full and effective participation of indigenous and local communities. It also pushes for the ecosystem approach to management to be implemented in larger-scale regions (PAME 2013a).

There are also moves towards more coherent and systemic policy integration on climate, ecosystems and pollution, in growing recognition of the global role of Arctic environmental processes. When the Convention on Long-Range Transboundary Air Pollution (CLRTAP) was established in 1979, it had minimal activity in the Arctic (Stone 2015, Chapter 3). Since then, AMAP has been highly influential in building the science base and policy impact of Arctic regional air quality issues. And in 2012 an amendment to the CLRTAP Gothenburg Protocol on black carbon (UNECE 2012, p.2) linked regional air quality to global climate benefits, explicitly highlighting the Arctic region.

The political structures and networks with a stake in Arctic decision-making processes are evolving rapidly, and clearly signal the globalizing scope of political choices (Paglia 2016). For example, apart from having prime responsibility for the Arctic region itself, Arctic Council nations are involved in international decision-making processes that affect global social drivers, such as the World Trade Organization (WTO), the Organization for Economic Cooperation and Development (OECD) and NATO. And increasingly the Arctic Council itself is a global forum.

Table 2.4, p. 49 shows that there are already many different configurations of actors in organizations and processes relevant to the Arctic, and new interests and influences are being added almost year on year. The Arctic Council brings actors from the region together, but member states differ in their geography of political and economic interests. The constellations represented within each column serve different power-holders, have different remits and priorities, and have different mechanisms of influence. Unstated objectives are also apparent in the strategies of many non-Arctic states (see Appendix 2.3). For instance, where an overt push for an economic or geopolitical presence in the Arctic would be politically unacceptable, science can offer a legitimate reason for physical and infrastructure presence in the region.

2.3.2 Changing knowledge connections

An integrative community is needed

The physical sciences play a pivotal role in Arctic change, perhaps more than for any other region in the world. Arctic science is a highly complex, globally distributed, multi-node knowledge system, poised between being a powerful actor in Arctic change and a pawn of the power holders (Paglia 2016). An increasingly important feature of scientific activity in the region is the use of high-tech observations (e.g. from satellites and underwater sensing systems), computer models (notably climate and Earth system models), and in-situ networks, which amount to a conspicuous physical and social presence in the region. This major multi-national investment in sensing many dimensions of Arctic change has been variously motivated by science, safety, resources, and security. The worldwide progress in scientific and computational capacity holds the promise that ever more challenging issues can be tackled.

For example, the IPCC's Coupled Model Intercomparison Project[5] now includes many models, and has very high standards of scientific transparency. The IPCC process yields the same messages now as informed SWIPA five years ago, but the messages are now more urgent because of societies' delayed response to them. They also point to greater risks in leaving knowledge gaps about the Arctic unfilled.

Rapid progress is being made in dealing with the complex dynamics and impacts of climate-biosphere feedbacks, and of large-scale, teleconnected weather systems. This progress, however, highlights the shortcomings in transdisciplinary integration, the disparity in investment in understanding social and ecological issues, and difficulties of enabling essential cross-connection among research networks. For instance:

> *"It is difficult to bridge the gap between the science of permafrost and the assessments of socio-economic impacts, which are studied by different communities with different cultures of publication. There should be a strengthening and integration of the projections of changing permafrost with socio-economic aspects of thawing"* (AMAP 2011).

Knowledge integration requires effort, learning and time, especially in Arctic science where stakes are high. However, facing real stakes and orienting on a shared real-world problem can motivate close collaboration (Robinson 2008). The IHOPE network (see Box 2.4) is

BOX 2.4 Deepening knowledge of the Arctic: circumpolar networks for understanding long-term social and environmental change in the Arctic

Long-term perspectives can remind us that contemporary views of what is "normal" in social-ecological systems are prone to shifting baselines. As part of the international research network *Integrated History and Future of People on Earth* (www.ihope-net.org), the multidisciplinary IHOPE Circumpolar Network was initiated in 2013. It takes a long-term perspective on cultural heritage in the context of climatic and environmental change. It adds important new insights to well known but overly simplistic views of environmental change as a driver of social "collapse". Several initiatives seek to build a detailed understanding of the processes that shaped the fate of historic settlements over several centuries:

- the North Atlantic Biocultural Organization, www.nabohome.org
- the Nordic Network for Interdisciplinary Environmental Studies, www.miun.se/nies
- the Global Human Ecodynamics Alliance, www.gheahome.org, and
- the Arctic project in Japan's Research Institute for Humanity and Nature, www.chikyu.ac.jp/rihn_e

With an even longer timeframe, the global change project Ecosystem Studies of Sub-Arctic Seas (www.imr.no/essas) explores how people dealt with change to coasts and seas from the Last Glacial Maximum 20,000 years ago to recent centuries.

Arctic warming now threatens irreplaceable environmental archives of millennial change (Erlandson 2008; Lankholm 2009). Archaeological sites give knowledge of how humans have interacted with a rapidly changing environment that is not available in any other way. The CyberNABO network (www.cybernabo.org) develops novel approaches to data coordination, networking and visualization, so that available knowledge can be shared widely.

5 See: www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6

an example of a deeply transdisciplinary effort, focused on cultural heritage in the context of global environmental change. Nonetheless, academic training is typically weak on how to integrate information about human and natural systems and to rigorously bridge theoretical frameworks. It is often simply assumed that a passing exposure to multiple disciplines will suffice (Clark et al. 2011). The group of experienced people with integrative skills is very small compared with subject experts (evidenced in the author lists of Arctic Council assessments), so there is a risk that it can become a closed and unchallenged community.

Bridging multiple knowledge systems

Integration across diverse knowledge systems requires even greater thoughtful effort (Wilkinson et al. 2007; Tengö et al. 2014; Cornell et al. 2013). Despite much posturing about working with Arctic communities to involve their knowledge in research and development planning, published scientific outputs do not show evidence of such a transition (Brunet et al. 2014). And there is sometimes overt resistance to integrating local ecological knowledge into the scientific evidence base for environmental management. In a striking example, Brook and McLachlan (2005) debated with Gilchrist and Mallory (2007) about the problems associated with testing traditional knowledge against the standards of academic science.

Since this debate, experience has grown in navigating multiple knowledge systems, each of which have their own rich and irreducible hinterland of cultural perspectives, traditions and world-views (Tengö et al. 2014). Effective environmental management (and ultimately empowerment, too) depends on reliable knowledge. A broad transdisciplinary consensus is emerging about principles for connecting knowledge systems, which emphasizes complementarity between indigenous, scientific, local, and other types of knowledge in a context of equity and transparency (IPS and ANNDC 2015).

Equipping and coordinating Arctic knowledge systems

The role of non-Arctic players is also changing (see Table 2.4, far left column). Key research initiatives established in the U.S. (Committee on Emerging Research Questions in the Arctic; Polar Research Board; Division on Earth and Life Studies; National Research Council 2014) and the EU (Immler 2014), and global change research programmes linked to Future Earth, the World Meteorological Organization (WMO) and Intergovernmental Oceanographic Commission of UNESCO (IOC/UNESCO), all emphasize the need for international collaboration to sensitively monitor Arctic change. Synthesizing information at the global level has become a pervasive research challenge as concern increases about the many interacting aspects of global change. There are major opportunities for information sharing and coordination, and several exemplary Arctic initiatives are already doing so, such as:

- Arctic expert assessments by the Arctic Council (e.g. IASC, IASSA).
- The EU Arctic Information Centre
- Arctic Portal
- Global Terrestrial Network for Permafrost
- Sustaining Arctic Observing Networks (SAON) data exchange (a contributor to the Group on Earth Observations, and
- The Circumpolar Biodiversity Monitoring Program's activities in capacity building, education, and working together with indigenous organizations and communities

However, large coordinated knowledge systems are not easy to maintain. They are costly, and can easily slip into bureaucratic and political tangles (e.g. as has occurred in the IPCC and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). An ideal pan-Arctic monitoring scheme capable of tracking the relevant dimensions of change is not feasible in the short term, and likely not at all. In the meantime, bottom-up community-initiated networks are struggling, and messages about emerging risks and effective responses are not reaching the places where they need to be heard.

So, despite existing scientific efforts, immense knowledge gaps still exist. And, as discussed in section 2.2, many are very clearly flagged in Arctic Council assessments. There is still a major need for more investment in basic research, knowledge synthesis, and translation of knowledge into measures for action if the consequences of current changes are to be sensed, monitored and understood in time to inform society's responses.

Choices and action should follow from knowledge

Investment in observing change does not remove the need to make decisions about managing or halting change. Across the Arctic, ecological damage is being observed ever more closely. There is a tacit assumption (evident in the emphasis that the Arctic Council places on stakeholder needs) that these observations of trends over time will enable changes to be predicted and managed, not merely tracked.

TABLE 2.4 The multiple national interests in the Arctic

	Arctic Council	Arctic coastal states	Arctic continental shelf claims under UNCLOS	UNCLOS signatory	Permanent member of UN Security Council	NATO	European Union	Dedicated polar research capacity
Canada	✔	✔	2012–13?	2003		✔		✔
Denmark/ Greenland	✔	✔	2013–14?	2004		✔	Not Greenland	✔
Finland	✔			1996			✔	✔
Iceland	✔		2009	1985		✔		✔
Norway	✔	✔	2006	1994		✔		✔
Russia	✔	✔	2001	1997	✔			✔
Sweden	✔			2003			✔	✔
United States	✔	✔	Data collection, not submitted	Not ratified	✔	✔		✔
Permanent Participants:* AIA, AAC, GCI, ICC, RAIPON, SC	✔							
China	Permanent Observer			1995				✔
France	Permanent Observer			1996	✔	✔	✔	✔
Germany	Permanent Observer			1994		✔	✔	✔
UK	Permanent Observer			1997	✔	✔	✔	✔
India	Permanent Observer			1995				✔
Japan	Permanent Observer			1996				✔
Republic of Korea	Permanent Observer			1996				✔
Singapore	Permanent Observer			1994				
Italy	Permanent Observer			1995		✔	✔	✔
The Netherlands	Permanent Observer			1996		✔	✔	✔
Poland	Permanent Observer			1998		✔	✔	✔
Spain	Permanent Observer			1997		✔	✔	

* Permanent Participants: Aleut International Association (AIA), Arctic Athabaskan Council (AAC), Gwich'in Council International (GCI), Inuit Circumpolar Council (ICC), Russian Association of Indigenous Peoples of the North (RAIPON), Saami Council (SC)

Source: adapted from Emmerson and Lahn (2012b) and http://earthdirectory.net/arctic.


Alexander Kutskiy/International Centre for Reindeer Husbandry

Herder's tent in Chuchotka, Russia: important messages from Arctic people about emerging risks and effective responses to socio-ecological changes are not reaching the places where they need to be heard.

Figure 2.8, from the 2012 CAFF ASTI assessment of vertebrate populations, shows a large increase in observation sites. Ecological change is seen all across the Arctic, but the observed changes are not simple – populations are not increasing or declining steadily over time or across geographic areas. Recent reports (e.g. CAFF 2013b; Christie and Sommerkorn 2012) explicitly emphasize that assumptions of steady linear trends are no basis for robust conclusions about future outcomes.

CAFF reports acknowledge the partial and distorted picture that current observations provide. This distortion arises from the selection of species, observation mismatches (in time and spatial scales), station placements, and even the way that available data are combined. For example, the maps in Figure 2.8 combine observations of fish, birds, and mammals. A closer look at species in these classes shows a very mixed picture (see Figure 2.8), with some populations increasing and others declining. The maps represent small sites with large dots, which correspond to roughly 250 km diameter. This disguises the paucity of observations, which are still much too sparse to handle the spatial, temporal and genetic dynamics of populations and the shifting thresholds in habitat (e.g. the seasonality of sea ice proximity to coastlines).

And as yet, these maps show nothing about the role of people in shaping the observed trends, or the impacts on their lives, cultures, and livelihoods. Arctic ecological change has become deeply politicized. Simple maps, graphs, and headline statistics are vital tools for awareness-raising (e.g. Arctic Report Card), but by hiding the real complexity of ecosystems and the social systems that interact with them, they may not contribute to resilience in decision-making. Current ideological divides over whether and how to "save the Arctic" (and species in it) point to a need to not just expand and deepen observational networks, but also to re-examine narratives and values around Arctic change, how they shape what is observed, and how these observations are presented.

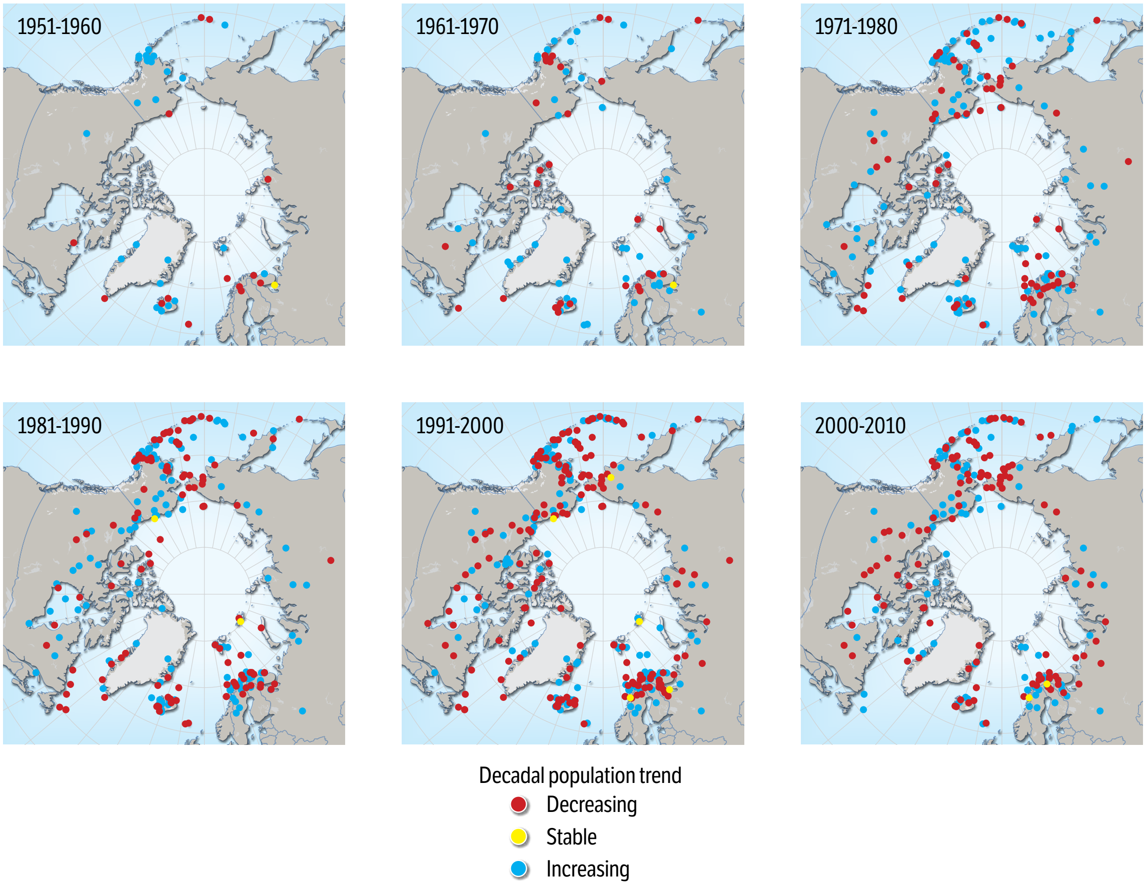
2.3.3 Changing conversations: policy, communities, business and science

The dynamism and diversity of the "multiple Arctics" offer new opportunities and contribute to resilience, but they also call for shared responsibility. The emerging challenge is to establish coherent (though not homogeneous) management goals and strategies for the future of all the Arctics.

Managing and navigating complex systems effectively demands adaptiveness and flexibility. It requires intelligent, informed and inclusive decision-making, involving broad participation and effective knowledge sharing among participants and across levels (see chapters 5–7). We argue that decision-making benefits from coordination and collaboration in research, external communication and action.

The Arctic Council provides a robust basis for coherence in multi-level, multi-sectoral decision-making. Its permanent members coordinate long-term working groups as well as responsive, shorter-lived task forces (see Appendix 1), and it has close associations with international and non-governmental organizations. These information-sharing connections can enhance the Arctic Council's ability to influence policy, both within and beyond

FIGURE 2.8 **Increasing biodiversity monitoring over time (number of vertebrate population data sites in the CAFF region) shows complexity of population trends.**



Source: Böhm et al. (2012).

the Arctic region. But if it is to do so successfully, it needs to effectively translate learning into policy, and for the messages of all its assessments to be heard over the clamour of external voices.

Throughout this chapter we argue that viewing the system from multiple perspectives is an important response to complexity and an essential precursor to informed choices. Many are calling for new and deeper kinds of dialogue among multiple participants and observers. Forbes et al. (2011) take the following view:

> *"Integrating science with local decision-making presents 'cross-cultural' challenges in the conventional sense (between parties of different ethnicities or socio-economic backgrounds), and in the equally significant respect of the 'cultures of mind' that are characteristic of individual disciplines. … The importance of institutional memory is greatly under-appreciated: human resource turnover interferes with the transmission of 'standard' and acquired operational procedures."*

A useful starting point for these deeper dialogues is a shared understanding of the underlying concepts of resilience. As discussed in Chapter 1, the term itself is increasingly widely used in many different contexts with diverse definitions, interpretations, and perspectives. The essential point of commonality, regardless of technical definitions, is the recognition that complex change is happening, and that individual societies alone cannot manage it.

In addition to the activities and projects of the Arctic Council, several forums have been designed to increase opportunities for multi-actor dialogue. These include the Arctic Circle, established in 2013 and science-policy conferences like the Trondheim Conference series on

Anita Ritenour/Flickr

The Alaska Eskimo Whaling Commission, together with fossil fuel companies, has set out measures enabling oil and gas extraction to co-exist with the bowhead whale subsistence harvest. Here Kaktovik native Iñupiat villagers cut up whale meat for distribution to the community.

biodiversity. Arctic sessions are becoming more prominent in other settings, too. Examples of forums that have a strong resilience perspective include:

- The U.S. Embassy-convened Arctic Fulbright Workshop in Abisko, 2013, which brought together scholars of governance and security to discuss how social-ecological resilience can enhance understanding of their fields
- Activities of the European Commission, such as the summer school for researchers jointly convened in Stockholm, 2014, by the ARA and the transdisciplinary EC FP7 research project Arctic Climate Change, Economy and Society – ACCESS;[6] and the Directorate General Research 2015 conference Ocean of Tomorrow,[7] focused on the bioeconomy as the new wave in economic development.
- The Government of Yukon's 2016 Science Strategy (Government of Yukon 2016), developed in the territory and built around guiding principles that recognize both the importance of science in policy-making and the need to incorporate traditional and local knowledge.
- The ARA 2015 multi-stakeholder workshop in Washington, D.C., co-convened by the US Department of the Interior, where there was strong representation of Indigenous Peoples, participation by corporate shipping representatives, engagement with national policy-makers, and the opportunity for multidisciplinary academic exchanges.
- An international round-table discussion on Safety and Sustainability of Shipping and Offshore Activities in the Arctic, hosted by the Institute of Marine Engineering, Science & Technology.[8]
- An Arctic working group in the Netherlands Ministry of Foreign Affairs Planetary Security Conference 2015, bringing together interests in defense security, environmental security and human security.[9]

6 See: http://www.access-eu.org
7 See: http://ec.europa.eu/research/bioeconomy/pdf/ocean-of-tomorrow-2014_en.pdf
8 See: http://www.imarest.org/events-courses/events-conferences/arctic-roundtable
9 See: http://www.planetarysecurity.nl/documents/reports/2016/01/22/conference-report

2.3.4 Resilience through shared opportunities

"For those of us who live there, change is pretty much all we've ever known. We have adapted to any change that we have faced for thousands of years. If policymakers and regulators want to succeed in the Arctic, they will be wise to respect and learn from our approach to problem solving and conflict resolution, using stakeholder processes that are adaptable to the changing needs and environment of the Arctic" (Willie Goodwin, as quoted in Strambo 2015).

Anthropogenic climate change and new economic activities combine to accelerate change in the Arctic, bringing both conflict and opportunity. Despite often diverging worldviews, Arctic communities and industrial entrepreneurs also share a variety of interests. When industry developers struggle with the Arctic's sometimes challenging environmental conditions, they can learn how important traditional knowledge is for thriving (and even surviving) in these latitudes, and may reconsider initial development plans to better account for environmental and social impacts. At the same time, the new work opportunities that come with industrial development are important to Arctic communities. A strategy based on mutuality is increasingly understood as being more effective in delivering the desired benefits.

There are experiences that show how new opportunities can be mutually shared, with industrial activities being managed in a way that respects and allows for the maintenance of traditional livelihoods.

The Red Dog Mine in Alaska works with a Subsistence Committee of local Native hunters, exchanging information about mine impacts (Coil et al. 2010) and negotiating seasonal timings of operations that interfere with subsistence hunting of marine mammals and caribou (Teck 2015; Kasannaaluk Green 2010).

The Alaska Eskimo Whaling Commission, together with oil and gas companies, has defined measures enabling hydrocarbon extraction activities to co-exist with the bowhead whale subsistence harvest. They hold regular meetings to review and revise their Conflict Avoidance Agreement (Arctic Eskimo Whaling Commission 2015).

A third example is the Arctic Waterway Safety Committee, a voluntary organization that gathers the principal users of waterways in the northern Bering Sea, Chukchi Sea, and Beaufort Sea. Together, subsistence hunters, municipal governments, the Alaska Marine Pilots, oil and gas developers, and vessel operators seek to develop best practices to ensure a safe, efficient and predictable environment for all, reducing the hazards of increasing vessel traffic.

These three bodies all rely on dialogue and interaction to solve problems, making use of local Indigenous Knowledge and observation as well as science and technology in guiding decision-making. In each case, negotiated outcomes recognized the food security and cultural needs of local communities and the operational needs of industrial companies.

Chapter 7 develops the discussion of mechanisms that are better able to respond to new adaptation challenges and manage conflicts of interests. Resilience assessments (such as this one) help to join the pieces of this complex picture in practical ways across the multiple Arctics. Knowledge about the dynamics of linked social and environmental change can help in: choosing responses to the challenges and opportunities; identifying gaps in knowledge, policy, and action; and potentially spotlighting important connections or intervention points. A resilience perspective also highlights the need to look to the global context, and at the same time recognize and respect the diversity of the local contexts when choices are being made for the multiple Arctics.

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Industry in Murmansk, Russia: navigating change in Arctic urban areas does not necessarily entail the same challenges as in rural areas.

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Tourist boats follow a pair of whales into the Ilulissat Icefjord, Greenland.

PART II

The Drama of Change

Mark Tozer

Arctic ecosystems are changing in dramatic ways: the ice is melting, sea levels are rising, coastal areas are eroding, permafrost is thawing, and the areas where plants and animals live are shifting. People's lives are also changing, with new livelihoods, new technologies, increasing connections to the outside world, and new forms of Arctic governance.

Resilience enables people and ecosystems to navigate the shocks and stresses associated with these changes, and to adapt and even transform as needed. Some of these changes push systems across tipping points past which system structure and behaviour is fundamentally altered. Scientists call such changes regime shifts.

Chapter 3 examines 19 Arctic regime shifts, mostly ecological, that are documented, believed to be under way or possible – from a shift to sea-ice-free summers, to changes affecting the oceans' thermohaline circulation, to collapse of different Arctic fisheries, to the reorganization of landscapes.

These regime shifts have substantial impacts on wildlife, the availability of food from nature, the stability of the climate, and Arctic people's sense of place and well-being. Our analysis demonstrates that these regime shifts are driven by forces originating mostly outside the Arctic – most notably human-induced climate change, but also resource exploitation, fishing and tourism.

Chapter 4 complements this analysis with a review of 25 case studies of how Arctic communities have responded to change. Some have demonstrated resilience, others have achieved transformational change, and others have lost resilience and are struggling. The case study analysis helps us understand the diverse processes already building (or eroding) resilience in the Arctic.

A systematic comparison of the cases identifies four key factors that contribute to resilience: 1) capacity for self-organization – that is, to make decisions and implement responses to change; 2) diversity of responses to change; 3) ability to learn from and integrate diverse types of knowledge; and 4) capacity to navigate surprise and uncertainty. These findings align with previous research in the Arctic and on resilience.

In particular, maintaining capacity for self-organization was a key source of resilience in case studies, and its absence was strongly linked to loss of resilience. A resilient community is able to come together to identify and respond to challenges, as well as resolve conflicts and disagreements. This finding suggests that maintaining and rebuilding this capacity should be a focus of resilience-building activities.

CHAPTER 3

Arctic regime shifts and resilience

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Key messages

- We have identified 19 "regime shifts" – hard-to-predict, persistent reorganizations of Arctic ecosystems – that can and have occurred in Arctic marine, freshwater and terrestrial ecosystems. These regime shifts impact the stability of the climate and landscape, the ability of people to travel, the presence of plants and animals, and people's sense of place.
- All Arctic countries are vulnerable to 10 or more regime shifts. Russia, the US and Canada are exposed to 18 of 19 regime shifts – more than other Arctic countries.
- The potential impacts of Arctic regime shifts on the rest of the world are substantial, yet poorly understood. Oceans, air movement, animals and people connect changes in the Arctic to the rest of the world and may transmit change in surprising ways.
- Human-driven climate change greatly increases the risk of Arctic regime shifts, so reducing global greenhouse gas emissions is crucial to reducing this risk.
- There is some potential to increase the resilience of current Arctic regimes to climate change, because the risk of 14 of 19 regime shifts is influenced by local practices such as grazing and fishing. Maintaining diversity, monitoring gradual changes in feedbacks, and preparing for surprise are strategies to build resilience to cope with regime shifts.

Naql/Flickr

Shishaldin Volcano, Aleutian Islands: From Alaska to Oriental Siberia, Arctic socio-ecological systems are under pressure.

3.1 What's new in the Arctic

Arctic ecosystems and Arctic societies are both experiencing diverse types of rapid change. Ice is melting, sea levels are rising, permafrost is thawing, and coastal areas are eroding. Landscapes are changing as water flows in new channels, wildfires burn in new places and in new ways, and new species arrive while the ranges of others shift. These changes are shaped by local geography and ecosystems, but are largely due to climate change that is caused primarily by fossil fuel use and agriculture outside the Arctic.

Similarly, Arctic cultures are changing, as new livelihoods emerge, along with new forms of Arctic governance, new communications technologies, and new connections outside the Arctic. The decisions of Arctic people play a key part in shaping these social changes, but the context in which these decisions are made has been strongly shaped by the legacies of European and North American exploration, territorial expansion and colonialism that reshaped Arctic societies, through violence, trade and cultural interactions. The increasing connectivity of the Arctic also means that its social changes are being shaped by social forces outside the Arctic, such as fluctuations in financial markets, growth in global trade, and demand for minerals, energy, and novel cultural experiences.

This chapter presents a new analysis of a wide variety of potentially large, persistent social-ecological changes in the Arctic. We call these persistent changes regime shifts. Regime shifts pose challenges to ecological management and governance, because they are difficult to predict and reverse and substantially alter the availability of benefits that people receive from nature.

We begin by briefly reviewing the theory of regime shifts. We then describe each of the potential regime shifts, and examine the main drivers of Arctic regime shifts. Third, we address what is known about the impacts of those regime shifts on ecosystem services within the Arctic, as well as potential impacts in other parts of the world through domino and cascading effects. The chapter ends with a discussion of response options – that is, what can be done, locally within the Arctic and globally, to decrease the risk of regime shifts.

The importance of social-ecological regime shifts is increasingly recognized (Folke et al. 2004, Scheffer 2009, Biggs et al. 2011, Rocha et al. 2015a). Yet the variety of Arctic regime shifts, the internal and external forces that drive them, and their impact on people are not well known. The accelerating pace of global change is generally expected to increase the frequency and intensity of regime shifts (Gordon et al. 2008, Lenton et al. 2008). However, little is known about how global change might lead to surprising social-ecological reorganizations in the Arctic.

Peter Howe/Flickr

Recent observations suggest that major changes in parts of Greenland's ice sheet are accelerating.

3.2 Regime shifts

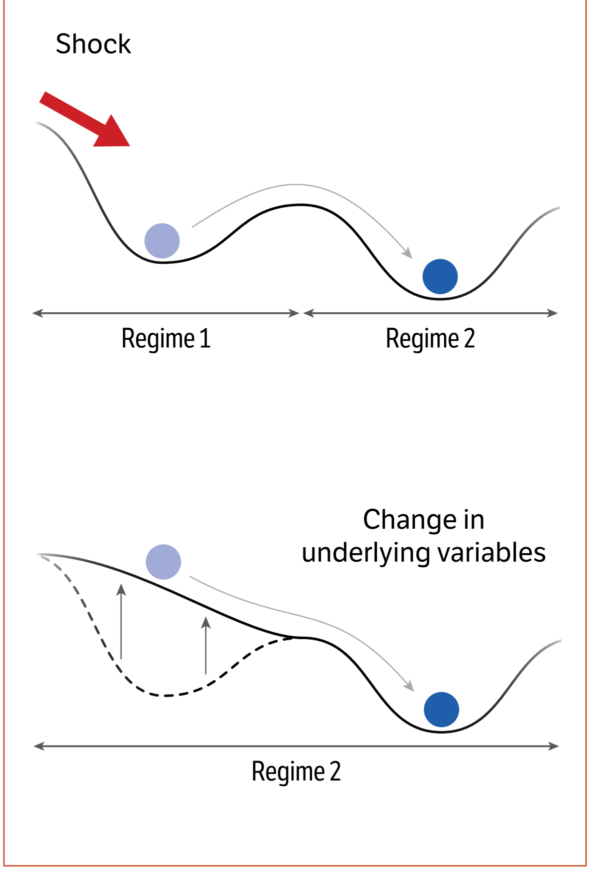
Regime shifts are large, persistent changes in the structure and function of social-ecological systems that occur abruptly relative to the temporal dynamics of these systems (Scheffer et al. 2001; Scheffer and Carpenter 2003). Regime shifts have been empirically documented in a variety of terrestrial and aquatic systems and studied in mathematical models. Examples include the shift from forest to savannah (Hirota et al. 2011) and the collapse of ice sheets in the Arctic and Antarctic (Schoof 2007).

What these phenomena have in common is that they can be understood using the same mathematical theory of dynamic systems, where the behaviour of a system can be described by the values of its variables of interest (Scheffer et al. 2001; Beisner et al. 2003). The structure and dynamics of each system is shaped by its history. A common way of conceptualizing such systems is a ball-and-cup diagram (Figure 3.1). The valleys or cups in this diagram represent different regimes; when the ball (the system) moves from one cup into another, this indicates a regime shift. A system can shift from one regime to another due to a large shock, such as a strong storm, or because of a change in one or more key variables that underlie the regime (e.g. a change in the climate, or the end of a key economic activity).

Within a regime, a system can fluctuate – the ball can move up and down within the cup, even going up to the edge – but fluctuations are limited by stabilizing feedback processes that keep the system within a "basin of attraction" (the cup). Complex systems contain many feedback loops, but these can typically evolve and combine in only so many ways. Over time, a particular combination of feedbacks will tend to become dominant, leading the system to self-organize into a particular structure and function, or "regime".

FIGURE 3.1 How regime shifts occur

Regime shifts are often illustrated through ball-and-cup diagrams. The light-blue ball at left represents the current state of the system and the valleys represent regimes. In (a), the ball is in a valley, or regime, but a shock can still push the ball, representing the system, into an alternative regime. In (b), a change in underlying processes has changed the dynamics of the system, in which one of the regimes has vanished. Consequently the system is forced to change and shift into an alternative regime. Regime shifts are usually due to a combination of both shocks and slow changes in underlying dynamics. Figure modified from Biggs et al. (2012).




JLS Photography/Flickr

A tanker plane uses borate salts to tackle a wildfire. New types of wildfires are changing Arctic landscapes and vegetation.

Regime shifts occur when a shock or a change in underlying variables overwhelms the stabilizing feedbacks, or when the stabilizing feedbacks are weakened or replaced by new feedbacks that change the structure and function of the system (Scheffer and Carpenter 2003). Understanding of regime shifts is important for ecosystem management, as such shifts may have substantial impacts on human economies and societies and are often difficult to anticipate and costly to reverse (Biggs et al. 2012; Crépin et al. 2012).

3.3 Arctic regime shifts

Based on a structured literature review, we identified 19 Arctic regime shifts in terrestrial, marine and polar ecosystems. Here we present a synthesis of Arctic regime shifts based on a recently developed comparative framework (Biggs et al. 2015) that allows us to identify the most influential drivers of change and expected impacts on ecosystem services. We only include regime shifts where the literature suggests that the regime shifts had i) potential impacts on ecosystem services and human well-being, and ii) potential feedback mechanisms that make them difficult to reverse.

This set of regime shifts includes the best-understood Arctic regime shifts, but omits possible regime shifts whose dynamics have not been studied or that do not appear to be regime shifts. For example, changes in snow, ice cover and permafrost are likely to amplify processes such as coastal erosion or river delta accretion (Karlsson et al. 2011; AMAP 2012; Koven et al. 2015), but is not yet clear that such phenomena will result in regime shifts. Another example is coastal erosion, which is likely to occur in wide areas of the Arctic and sub-Arctic, forcing relocation of many coastal communities (see the case of Newtok, Alaska, in Chapter 4). While this change is irreversible and thus important to predict and prepare for, there do not seem to be feedback mechanisms that would result in a regime shift.

Similarly, ocean acidification will affect regime shift dynamics (e.g. shifts in marine food webs, or primary production of the Arctic Ocean), but evidence to date is not strong enough to consider acidification a regime shift in itself. The evidence of feedback mechanisms that reinforce the acidified ocean state is highly contested (Six et al. 2013; Nagelkerken and Connell 2015). We expect that there are many unidentified or unanticipated Arctic regime shifts that will surprise both scientists and the world in the 21st century. This review should thus be considered an initial assessment rather than a comprehensive study.

3.3.1 Overview of Arctic regime shifts

Regime shifts in the Arctic encompass a broad range of dynamics that typically occur on a time scale of decades to centuries, and a spatial scale from local and landscape dynamics, to subcontinental ones, with consequences that may be felt globally. The rest of this section summarizes the most established regime shifts reviewed in the academic literature. Most (12 out of 16) are difficult to reverse or irreversible on a 100-year time scale. The evidence supporting the existence of these regime shifts comes primarily from contemporary observations, paleo-records and models (13 regime shifts); experimentation has only been possible on six. In fact, the scales at which these regime shifts dynamics occur, both in space and time, make experimentation a rare option. Hence, identifying the mechanism underlying some Arctic regime shifts is a challenging task that relies heavily on modelling and the synthesis of studies of long-term changes in the ecology, hydrology, geology and climate of the Arctic. Most of regime shifts identified occur in marine and polar systems; the others occur in tundra, temperate and boreal forests, and freshwater lakes and rivers.

Partly melted sea ice on an August day in Kulusuk, Ostgronland, Greenland.

An extended review, regime shifts analysis and corresponding references are available at www.regimeshifts.org. Two regime shifts described below (salmon collapse and Arctic mobility) correspond to regime shifts that only apply to the Arctic, so they are found in the Regime Shifts Database under case studies. All other regime shifts are classified as generic types of regime shifts.

Arctic sea ice loss

Type: Earth system

Scale: Sub-continental/ regional

Alternative regimes: Summer sea ice, ice-free

Evidence of regime shift: Contested – reasonable evidence both for and against its existence

Underlying mechanism: Well established – wide agreement on the underlying mechanism

A regime shift towards ice-free summers is occurring as the Arctic warms, evident from reductions in sea ice surface area and ice volume during the summers. Ice-free summers are expected to occur well within the 21st century (Livina and Lenton 2013). The primary driver behind the shift is warming of the Arctic due to climate change. Several feedback mechanisms have been proposed that may help maintain the reductions in Arctic ice under the new regime (Zhang and Walsh 2006). The primary and best understood is the ice-albedo feedback mechanism: A thick sheet of white ice reflects a large share of the solar

Paul Williams/Flickr

Fisheries can trigger and be impacted by Arctic regime shifts.

radiation that strikes it, while the much darker surface of ocean water absorbs most of the radiation. The radiation, in turn, further warms the water, leading to more sea-ice loss. Thinning ice is also likelier to melt under sunshine, further reducing albedo.

Consequences: The mobility of Arctic people and animals who use the ice to travel will be greatly reduced. Many Arctic people will experience a substantially reduced sense of place, and may see their livelihoods compromised. For marine animals, reduced sea ice could make it more difficult to obtain food, and reshape marine and terrestrial ecological connectivity and dynamics (Post et al. 2013). The timing, type and amount of marine primary productivity are shaped by the extent and temporal dynamics of sea ice. The loss of summer sea ice is also expected to make the Arctic more accessible by sea, opening up new shipping routes, bringing tourism and facilitating resource extraction. This change may provide new jobs and economic opportunities but may also increase risks such as oil spills or collisions between ships and marine mammals. Loss of summer sea ice will also have impacts far beyond the Arctic. Sea ice decline and reduced albedo are already reshaping how heat flows through the atmosphere, resulting in altered patterns of atmospheric circulation and precipitation, and these impacts are expected to increase (Serreze and Barry 2011).

Response options: Slowing or preventing this regime shift requires halting climate change by halting emissions of greenhouse gases, and likely reducing atmospheric concentrations of greenhouse gases from current levels.

Further information: Rolands Sadauskis, Garry Peterson, Reinette (Oonsie) Biggs, Juan Carlos Rocha. Arctic Sea-Ice Loss. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2013-02-22 15:20:50 GMT.

Greenland ice sheet collapse

Type: Earth system

Scale: Sub-continental/regional

Alternative regimes: Ice sheet, no ice sheet

Evidence of regime shift: Contested – reasonable evidence both for and against its existence

Underlying mechanism: Well established – wide agreement on the underlying mechanism

The great ice sheet of Greenland was long believed to be resistant to climate change, as it takes thousands of years to respond to changing conditions. Recent observations suggest, however, that major changes in the dynamics of parts of the ice sheet are occurring over time scales of only years. The ice has been thinning at rates higher than expected due to warmer summers as atmospheric temperatures rise. The main identified direct driver behind the loss of ice sheet volume is warmer temperatures caused by climate change. Two important feedback mechanisms play important roles in destabilizing the ice sheet: an ice-albedo feedback where melting ice lowers albedo, increasing local warming, and that meltwater from ice melting can lubricate the ice sheet, exposing its edges to warmer water (Holland et al. 2006; Rigor et al. 2002). Chapter 4 further develops case studies related to ice melting in Greenland.

Consequences: The Greenland Ice Sheet covers approximately 1.7 million km^2 or 80% of Greenland. It rests on land, mostly near or above sea level. If it melted completely, it would raise global sea levels an average of 7.4 metres (Vaughan et al. 2013). The melt rate of Greenland is quite uncertain, but it is slow, and most forecasts suggest that even with rapid climate change and relatively strong melting feedbacks, the melt would take centuries to millennia. The new ecosystems that are created in the glaciated landscape of Greenland are likely to provide benefits to Greenlanders, but the loss of the Greenland ice sheet would alter global climate dynamics, with uncertain but likely substantial consequences for other Northern Hemisphere ecosystems and societies.

Response options: Slowing or preventing this regime shift requires halting climate change by halting emissions of greenhouse gases, and likely reducing atmospheric concentrations of greenhouse gases from current levels.

Further information: Rolands Sadauskis, Juan Carlos Rocha, Reinette (Oonsie) Biggs, Garry Peterson. Greenland ice sheet collapse. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2013-08-23 08:05:19 GMT.

Thermohaline circulation

Type: Earth system

Scale: Sub-continental/ regional

Alternative regimes: Thermohaline circulation, collapse of thermohaline circulation

Evidence of regime shift: Contested – evidence that this regime shift has occurred previously, but believed to be unlikely under current forecasts

Underlying mechanism: Well established – wide agreement on the underlying mechanism

Thermohaline circulation is the global movement of ocean water from the surface to the deep ocean. Relatively warm water moves on the surface areas in the northern Atlantic and around Antarctica, where it cools and sinks (Hofmann and Rahmstorf 2009; Buckley and Marshall 2016). A key part of this circulation is Atlantic meridional overturning (AMOC). This circulation can be disrupted by large-scale freshwater release that reduces the water salinity and density differences between South and North Atlantic. These differences help drive water movement from the tropical Atlantic into the North Atlantic. This movement of water transports large amounts of heat around the world and has a major impact on global climate; it also influences the rate of global warming by controlling the rate at which heat and carbon are stored in the deep ocean. This regime shift has occurred at the end of past ice ages. Analysis points to the possibility of this regime shift, but models suggest that at forecast levels of climate change, the shift is highly unlikely (Buckley and Marshall 2016). Nevertheless, some scientists believe that models underestimate this risk (Hofmann and Rahmstorf 2009).

Consequences: This regime shift would change global ocean heat transport, altering the world's climate in a potentially abrupt and substantial way. This could lead to a southward shift of tropical rainfall belts that would likely trigger declines in agricultural production and disruptions to marine ecosystems (Srokosz et al. 2012). Changes in Atlantic circulation can have large effects on marine ecosystems and biogeochemical cycles, even in areas remote from the Atlantic, such as the Indian and north Pacific oceans. Changes in salinity and temperature will cause shifts in populations of marine plants and animals. Fishers would have to adapt to new circumstances, which would likely affect their livelihoods and economic activity. In addition to the above impacts, regional changes in sea level could cause localized sea-level rise of tens of centimetres in the North Atlantic, which would affect the coastlines of the United States, Canada and Europe, causing coastal erosion and affecting security of housing and infrastructure. A warmer and more stratified North Atlantic would also take up less anthropogenic CO_2, thus adding to the climate warming (Buckley and Marshall 2016).

Response options: Reducing the risk of abrupt ice melt is the main way to decrease the risk of this regime shift. This can be done by slowing climate change by reducing emissions of greenhouse gases.

Further information: Rolands Sadauskis, Juan Carlos Rocha, Reinette (Oonsie) Biggs, Garry Peterson. Thermohaline circulation. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2013-08-23 10:13:55 GMT.

Hypoxia

Type: Marine

Scale: Seascape-region/ sub-continental

Alternative regimes: Normal oxygen levels, low oxygen levels in ocean

Evidence of regime shift: Well established

Underlying mechanism: Well established – wide agreement on the underlying mechanism

The critical variable in the hypoxia regime shift is dissolved oxygen in the water. Different self-reinforcing regimes can be identified as normal oxygen, hypoxia (low oxygen) and anoxia (no oxygen) in seawater (Diaz and Rosenberg 2008). Hypoxia is typically due to excess nutrient inputs from fertilizers or untreated sewage causing eutrophication. Hypoxic environments are sometimes called "dead zones", as they are areas with reduced populations of marine life due to the lack of oxygen.

Consequences: Hypoxia reshapes ecosystems, reducing fisheries and employment in fisheries communities. Dead zones due to hypoxia have affected several fisheries, including those in the Baltic Sea and coastal Norway (Diaz and Rosenberg 2008). Hypoxia can also impair the health and well-being of people and wildlife. Decaying matter after mass mortality events create foul smells and increases risk of disease, both of which reduce opportunities for recreation, tourism and appreciation of place.

Response options: Response options include the reduction of nutrient inputs (nitrogen and phosphorus) from landscapes or urban areas. Reducing climate change can also reduce the risk of hypoxia, as risks of hypoxia are generally increased by warmer temperatures.

Further information: Juan Carlos Rocha, Reinette (Oonsie) Biggs, Garry Peterson, Rutger Rosenberg. Hypoxia. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2012-03-22 23:29:11 GMT

Marine food webs: Community change and trophic level decline

Type: Marine

Scale: Seascape-region/ sub-continental

Alternative regimes: Predator-dominated, planktivore-dominated

Evidence of regime shift: Speculative

Underlying mechanism: Contested

This regime shift involves a change from an ecosystem with high numbers of larger predatory fish to one dominated by smaller fish, which often eat plankton and are the prey of other fish (Salomon et al. 2010; Estes et al. 2011). The shift is often initiated by high fishing pressure on predatory fish, whose population decline results in the increase in populations of their former prey, and corresponding decreases in those species' prey. This type of dynamic is known as a trophic cascade. This shift can also be caused by environmental factors, such as climate change and an increase in upwellings. The planktivore-dominated regime can be reinforced and maintained by a variety of biological mechanisms that make it difficult for populations of predatory fish to recover. The shift has been observed in some locations in the Arctic (Kortsch et al. 2015).

Consequences: Food web regime shifts can have substantial impacts on commercial fisheries, as often, but not always, predatory fish are more valuable than plankton-eating fish. These regime shifts can increase the vulnerability of an ecosystem to eutrophication, hypoxia and invasion by non-native species.

Response options: Response options include regulating fishing of top predators while favouring fishing of over-abundant species, as well as regulating nutrients use and leakage to water bodies (Beddington et al. 2007). Because variation in natural sources of nutrients is often periodic and difficult to control, coordinating management actions with natural cycles (e.g. the El Niño-Southern Oscillation) has been proposed as a means of increasing the chance of avoiding or reversing these regime shifts (Scheffer et al. 2009).

Further information: Susa Niiranen, Garry Peterson, Reinette (Oonsie) Biggs, Juan Carlos Rocha, Henrik Österblom. Marine food webs: community change and trophic level decline. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2014-10-15 03:05:20 GMT.

Fisheries collapse

Type: Marine

Scale: Seascape-region/ sub-continental

Alternative regimes: Fishery, collapsed fishery

Evidence of regime shift: Contested – reasonable evidence both for and against the existence of regime shift

Underlying mechanism: Contested

A fishery collapses when the structure of the marine community (i.e. its species composition) changes radically, creating a situation in which a high-value commercial species cannot recover (Hutchings 2000; Kirby et al. 2009; Hutchings 2015). These dynamics are often characterized by cascading effects across multiple links (trophic levels) in marine food webs (Litzow and Urban 2009). Both top-down and bottom-up drivers can contribute to the collapse of commercial fisheries. Overfishing is the main top-down driver. Overfishing is produced by social processes that maintain fishing effort despite variation in demand, such as fishing fleets and catch quotas that are insensitive to stock variation, as well as indirect drivers which increase fishing effort, such as demand from new markets, new possibilities to export fish, and technology improvements (Anderson et al. 2008). The chief bottom-up drivers of collapse are processes that influence the productivity of the base of marine food web (Bakun et al. 2010). These include both anthropogenic and natural climate change that can shift the intensity and frequency of upwelling of cool nutrient-rich water. Other factors, such as the spread of diseases, changes in ocean circulation, winds and temperature variation, can also contribute to collapses (Litzow and Mueter 2014).

Consequences: The collapse of a commercial fishery can have substantial economic and social impacts, reducing economic activity, and also reducing both employment and the availability of food. In some instances, the collapse of fisheries has even led to the abandonment of entire communities. (For an example from the Gulf of Alaska, see Anderson and Piatt 1999.) Fisheries collapse can also contribute to marine regime shifts. These impacts are further discussed in Chapter 4.

Response options: The risk of fisheries collapse can be reduced by effective fisheries management within national borders and among nations. Effective regulation and policing of fishing can reduce illegal fishing, while comprehensive fisheries policies can reinforce sustainable fishing practices across nations. These strategies should also include ways of preventing the arrival of many new fishers in a place and enabling fishers to exit fishing. Similarly, the establishment of marine protected areas that provide refuge from fishing and ecological diversity to support fish populations can reduce risks of fisheries collapse. Good management of fishing pressure has been able to restore fisheries stocks, but such strategies need to be designed to fit their ecosystem and political context (Beddington et al. 2007).

Further information: Garry Peterson, Juan Carlos Rocha, Henrik Österblom, Reinette (Oonsie) Biggs. Fisheries collapse. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2014-10-15 13:09:17 GMT.

Primary production in the Arctic Ocean

Type: Marine

Scale: Region/ sub-continental

Alternative regimes: Polar marine primary production, temperate marine primary production

Evidence of regime shift: Contested –reasonable evidence both for and against its existence

Underlying mechanism: Contested

A shift from polar to temperate primary production patterns has been detected in the Arctic Ocean (Ardyna et al 2014). Climate change-driven warming of atmospheric and oceanic temperatures has caused a variety of changes in the Arctic. These include a long-term decline in the extent and thickness of summer sea ice, an extension of the growing season of primary producers, and a northward shift of temperate marine species. These changes have caused pronounced changes in the annual population dynamics of primary producers.

Consequences: Ice-dependent species, such as cod, shrimp, marine mammals and seabirds, have decreased due to warmer temperatures and changes in their ecosystems (Wassmann et al. 2011). In contrast, other more temperate species are thriving due to rising sea surface temperatures and increased food abundance (Hátún et al. 2009). These changes indirectly impact Indigenous Peoples' well-being and livelihoods by shifting the availability of food and commercially harvested fish. Alternatively, the shift to a temperate regime may bring gains to tourism (e.g. whale watching) and commercial fishing, helped by easier navigation in ice-free waters, although these changes will likely benefit non-Arctic residents. Disentangling the relative importance of these changes is difficult, and it is uncertain how this shift to more temperate primary production will reshape Arctic food webs and ecosystems.

Response options: The primary way to slow or prevent this regime shift is to halt global greenhouse gas emissions. With more understanding of this shift, other response options may become available.

Further information: Patricia Villarrubia Gomez, Karl Samuelsson, Helene Albinus Søgaard, Sophie Laggan, Thorsten Blenckner. Primary Production in the Arctic Ocean. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2015-05-22 17:19:35 GMT.

Mandy Lindeberg/NOAA,NMFS,AKFSC

Thawing permafrost in the Arctic can change the course of rivers.

Salmon collapse

Type: Marine

Scale: Seascape-region/ sub-continental

Alternative regimes: Salmon population, minimal or no salmon population

Evidence of regime shift: Speculative

Underlying mechanism: Contested

Salmon are born in rivers, migrate to the ocean, and then return to rivers to breed. Their life cycle connects oceanic and freshwater ecosystems. The potential for a salmon regime shift has been identified in Alaska (Krkošek and Drake 2014), but similar possibilities exist across the Arctic. The present regime is characterized by a high abundance of salmon. However, the population could decline into a persistent low-abundance regime (Krkošek and Drake 2014). Feedback mechanisms also connect local communities' needs, fishery regulation, salmon population and hatcheries to salmon abundance.

Consequences: This regime shift would result in the loss of food and undermine maintenance of cultural traditional livelihoods, as well as the reduction of marine nutrient inputs into coastal ecosystems (Schindler et al. 2008).

Response options: Hatcheries can compensate for some of the depletion of salmon stocks, but they also undermine the resilience of the system by reducing the genetic and spatial diversity of salmon populations. Reducing climatic change, regulating fishing pressure, maintaining population heterogeneity, and maintaining the river habitats in which salmon reproduce can all contribute to maintaining salmon populations (Schindler et al. 2008; Schindler et al. 2010).

Further information: Daniele Crimella, Linnéa Joandi, Hanna Kylin, Kavita Oehme, Hanna Kylin, Reinette (Oonsie) Biggs, Jennifer Griffiths, Garry Peterson, Juan Carlos Rocha. Potential Salmon Collapse. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2015-05-22 17:24:47 GMT.

Steve Jurvetson/Flickr

As permafrost melts, thermokarst lakes can drain and be replaced by tundra vegetation.

Arctic benthos

Type: Marine

Scale: Seascape

Alternative regimes: Algae-dominated marine sediment, macroalgae-dominated marine sediment

Evidence of regime shift: Well established

Underlying mechanism: Well established – wide agreement on the underlying mechanism

Climate change is expected to shift southern species poleward. Such shifts may produce regime shifts. A regime shift occurred on the west coast of Svalbard in 1996 and 2000, where the flora and fauna in marine sediments (Arctic benthos) shifted from algae and filter feeders to seaweed (macroalgae) (Beuchel et al. 2006; Kortsch et al. 2012; Kortsch et al. 2015). The most important factors driving this shift are increases in sea surface temperature and increased light penetration, both of which are due to both global warming and changes in the North Atlantic Oscillation.

Consequences: Changes in species that occupy coastal sediments (benthos) could cascade to impact other species that eat them, with the potential to impact both commercial fisheries and tourism (Kortsch et al. 2015). The broader implications for ecosystem services and human well-being are highly uncertain.

Response options: The primary means for slowing or preventing this regime shift is a dramatic reduction in global greenhouse gas emissions. Research that identifies more cases of this regime shift, and better identifies its mechanisms, may be able to identify other local response options.

Further information: Sara Andersson, Linn Järnberg, Katharina Fryers Hellquist, Noah Linder, Juan Carlos Rocha, Thorsten Blenckner. Arctic Benthos Borealisation. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2015-03-26 07:49:44 GMT.

Kelp transitions

Type: Coastal

Scale: Landscape

Alternative regimes: Kelp forest, urchin barrens

Evidence of regime shift: Well established

Underlying mechanism: Well established – wide agreement on the underlying mechanism

Kelp forests are marine coastal ecosystems located in shallow areas where large macro-algae ecologically engineer the environment to produce a coastal marine environmental that is substantially different from the same area without kelp. Kelp forests can undergo a regime shift to urchin barrens, in which the kelp is gone, replaced by sea urchins and sheets of algae on the sea floor. This shift leads to loss of marine habitat and ecological complexity. Shifts to algae are related to nutrient input, while shifts to urchin barrens are related to food web (trophic-level) changes (Ling et al. 2009; Ling et al. 2015), such as declining populations of sea urchin predators.

Consequences: The loss of habitat complexity due from this regime shift affects fish habitat and can thus can impact commercially important fisheries, and it and reduces other regulating and cultural ecosystem services (Ling et al. 2015).

Response options: Response options include restoring or maintaining top predators, such as sea otters, and installing wastewater treatment plants in coastal zones (Ling et al. 2015).

Further information: Juan Carlos Rocha, Reinette (Oonsie) Biggs, Garry Peterson. Kelp Transitions. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2013-10-08 08:18:32 GMT.

Coastal marine eutrophication

Type: Coastal

Scale: Seascape-region/sub-continental

Alternative regimes: Clear, low-nutrient water; murky, high-nutrient water

Evidence of regime shift: Well established – wide agreement on the underlying mechanism

Underlying mechanism: Well established – wide agreement on the underlying mechanism

Eutrophication is a process in which low-nutrient, clear water shifts to nutrient-rich, turbid water. Marine eutrophication is primarily caused by nutrients (both nitrogen and phosphorus) from land sources, such as agricultural fertilizer, urban sewage and industrial waste. Nutrients enhance algal growth, leading to a higher level of cloudiness due to water-borne particles (turbidity). Algal decomposition can reduce the oxygen available in the water, harming marine animals, and light reduction, due to turbidity, can limit growth of plants and macroalgae. Globally, nutrient runoff from land as well as atmospheric deposition have increased due to increased use of fossil fuels, urbanization and increased use of fertilizers in agriculture. Other human impacts can also contribute to eutrophication, including fishing, which can lead to declines of algae-eating fish. Climate change is expected to intensify eutrophication, especially due to increased rainfall intensity increasing runoff of nutrient-rich sediments from land. Local characteristics of the sea, which alter mixing and dilution of nutrients, affect the intensity of eutrophication and the ecosystem's vulnerability to eutrophication (Boesch 2002; Smith 2003).

Consequences: Eutrophication often results in an increase in the frequency of algal blooms that can harm the health of fish, marine mammals and people. Algal toxins can kill wild and farmed fish, as well as shellfish and other animals. Eutrophication can also alter the composition and structure of food webs, reducing the quality of nursery and spawning grounds, and cause commercial fish species to migrate away or die (Smith 2003). In addition, algal blooms can harm tourism and the amenity value of coastal waters.

Response options: If industrial activity, urbanization and human settlement increase in the Arctic, the risks of eutrophication will increase from their currently low level. Strategies to maintain a low risk of eutrophication include reducing nutrient outputs from urban areas, maintaining intact ecosystems, and halting climate change. Eutrophication is well understood, and major commitments have been made to reduce eutrophication. These include regulatory measures, nutrient reduction goals, as well as monitoring and assessment programmes (Boesch 2002). However, most of this knowledge is not from the Arctic, and melting glaciers and arrival of new species have produced unexpected eutrophication events.

Further information: Johanna Yletyinen, Thorsten Blenckner. Coastal Marine Eutrophication. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2014-03-19 14:15:10 GMT.

Peatland transitions

Type: Land/water

Scale: Landscape

Alternative regimes: Moss-dominated bogs, vascular plant-dominated peatlands

Evidence of regime shift: Speculative

Underlying mechanism: Well established – Wide agreement on the underlying mechanism

Peatland systems can shift from bogs, sphagnum-dominated peatlands with long-term carbon storage in peat, and fens, to peatland in which vascular plants, such as shrubs and trees, have a more dominant role, leading to higher productivity but reduced long-term peat accumulation. The most important variables and mechanisms considered are peat accumulation and height of the surface above the water table, nutrient flux, and competition between plant functional groups. The key drivers of the shift are changes in climate (precipitation and temperature) and in nutrient input. However, it is not clear how the combination of changes in rainfall and temperature will alter the risk of peatland regime shifts (Belyea and Baird 2006; Morris et al. 2011).

Consequences: The relevance of this shift in terms of ecosystem services and human well-being is the trade-off between potential gains of nutrient-rich soils for agricultural activities on drained peatlands, versus the loss of long-term carbon accumulation and potential release of this accumulated carbon, both of which have the potential to accelerate climate change by increasing atmospheric concentrations of greenhouse gases (Ise et al. 2008).

Response options: The primary way to reduce risks of this regime shift is to halt global greenhouse gas emissions. Locally, water management can be used to maintain these regimes.

Further information: Daniel Ospina, Helen Moor. Peatland transitions. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2013-12-18 02:00:42 GMT.

Thermokarst lake to terrestrial ecosystem

Type: Land/water

Scale: Landscape

Alternative regimes: Lake, tundra

Evidence of regime shift: Speculative

Underlying mechanism: Well established – wide agreement on the underlying mechanism

Thermokarst lake-dominated landscapes are transforming into terrestrial ecosystems (e.g. tundra). There is a natural fluctuation between these two ecosystems. However, the rate and scale at which those fluctuations occur are increasing due to permafrost melting caused by climate change (Smith et al. 2005; Hinzman et al. 2005). Warmer air temperature increases soil temperature, which melts permafrost (permanently frozen soils found in Arctic regions). The shift in ecosystems occurs when permafrost degradation becomes severe enough for the lakes to completely drain, allowing terrestrial tundra vegetation to establish itself (Smith et al. 2005; Hinzman et al. 2005; Karlsson et al. 2011). The increased rate and scale of these land cover changes have extensive impacts on food and freshwater provisioning, but its greatest impact is expected to be on the ability of the landscape to store carbon (ACIA 2004).

Consequences: The melting of permafrost can release greenhouse gases, including CO_2 and methane, which further increase climate change, potentially creating a reinforcing feedback. However, which gases are released depends on local conditions that determine whether the soil is waterlogged and which plants are able to grow.

Response options: Halting the emissions of global greenhouse gas emissions will reduce the risk of this regime shift.

Further information: Hannah Griffiths, Elinor Holén, Jessica Spijkers, Reinette (Oonsie) Biggs, Juan Carlos Rocha. Thermokarst lake to terrestrial ecosystem. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2014-11-19 15:33:25 GMT.

River channel position

Type: Land/water

Scale: Landscape-region/sub-continental

Alternative regimes: Old river channel, new river channel

Evidence of regime shift: Well established – wide agreement on the underlying mechanism

Underlying mechanism: Well established – wide agreement on the underlying mechanism

In freshwater lake and river systems, a river channel position regime shift occurs when the main channel of a river abruptly changes its course to a new river channel (Dent et al. 2002). Meandering and braided rivers are especially vulnerable to such shifts (Stølum 1996). The actual shift of the channel usually follows a large flood event, but a variety of factors determine whether such an event is likely to occur. Most commonly, channel change occurs when sediment build-up blocks the river flow due to changes in river flow and the slope of the river. In rivers with frequent meanders, floods can cut across the river's curves to follow a shorter route. Human activities such as land clearance, which increases erosion, and artificial channel widening can also make the river system vulnerable to a sudden course change (Hooke 2003; Dent et al. 2002). In the Arctic, permafrost melting can both change streamflow, and increase river channel erosion and sediment load (Bogaart et al. 2003; Kanevskiy et al. 2016), which can increase the risk of a shift in river channel position, but these processes are not well understood.

Consequences: If a shift in river channel position occurs near an Arctic community, it could have a substantial impact on their well-being, due to changing access to water, transport, and fish and wildlife. On a 100-year timescale, the shift is likely irreversible.

Response options: Avoiding sediment accumulation in rivers is a strategy for reducing the risk of a river channel regime shift, but this strategy is less likely to be an option in the Arctic, where permafrost melting is a primary source of sediment. Only enormous engineering efforts can prevent a river from switching to a new channel, or restore a former river course. However, such efforts are very complex and costly. Avoiding the permafrost melting that hastens or triggers river channel shifts requires halting the greenhouse gas emissions driving climate change.

Further information: Henning Nolzen, Reinette (Oonsie) Biggs, Garry Peterson. River Channel Position. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2013-06-21 16:12:18 GMT.

Salt marshes to tidal flats

Type: Land/water

Scale: Landscape

Alternative regimes: Salt marsh, tidal flat

Evidence of regime shift: Contested – reasonable evidence both for and against its existence

Underlying mechanism: Well established – wide agreement on the underlying mechanism

The shift from a salt marsh to either a tidal flat or sub-tidal flat is usually driven by the rate of sea-level rise and the rate of sediment delivery to the coast (Murray et al. 2008; Kirwan et al. 2010). Salt marshes have the capacity to regulate their elevation in response to rises in the sea level through a series of non-linear biophysical feedback mechanisms (Koppel et al. 2005; Marani et al. 2007). However, if the rate of sea-level rise is too rapid or the rate of sediment delivery decreases, the feedbacks that maintain the salt marsh can be overwhelmed and will be no longer able to keep up with sea-level rise (Bertness and Silliman 2008; Bertness et al. 2014). In the Arctic, rising sea level is likely to threaten marshes and coastal plains. Sea-level rise varies widely on Arctic coasts, depending on local ocean conditions and whether land is rising due to the decline of ice. Many low-lying coastal plains in the Arctic are not rising, which makes them more vulnerable to sea-level rise (Carson et al. 2016). Changes in animal grazing on salt marsh vegetation can also drive this shift. This can occur either through the growth of herbivore populations or the introduction of invasive/exotic species. For example, this regime shift has occurred across large areas of coastal Hudson's Bay due to disturbance and grazing from populations of snow geese on salt marshes in Hudson's Bay. These populations have greatly increased due to the growth of agriculture in the US Midwest, which is their winter habitat (Jefferies et al. 2006).

Consequences: Both salt marshes and tidal/sub-tidal flats provide similar and significant ecosystem services, although in slightly different ways. However, the shift from a salt marsh to either a tidal flat or sub-tidal flat can lead to a significant loss of ecosystem services such as pollution filtration, storm protection, and fisheries enhancement (Gedan et al. 2009). For example, while salt marshes serve as nurseries for some fish species, tidal flats provide important habitats for certain molluscs and crabs.

Response options: The risk of this regime shift can be reduced by the reintroduction of predators, which reduce grazing on salt marsh vegetation, or the removal of invasive/exotic species. River management can be done to increase the supply of sediment pulses (Gedan et al. 2009). The rate of sea-level rise can be slowed by reducing the emission of greenhouse gases.

Further information: Steven Alexander, Reinette (Oonsie) Biggs. Salt Marsh to Tidal Flat. In: Regime

Shifts Database, www.regimeshifts.org. Last revised 2013-02-21 11:37:31 GMT.

Arctic mobility

Type: Land/water

Scale: Region/ sub-continental

Alternative regimes: Mobile, less mobile

Evidence of regime shift: Speculative

Underlying mechanism: Speculative

Due to anthropogenic climate change and lack of viable sea ice, the mobility of Arctic residents may be undergoing a regime shift, and by extension, so are their livelihoods. Many indigenous communities have mixed economies that combine wage employment and subsistence harvesting. However, the loss of mobility, combined with changes in the availability of wildlife to hunters, threaten to drive a shift away from subsistence hunting (Sørensen 2010; Nuttall et al. 2005; Hastrup and Olwig 2012). The main drivers of this transition are anthropogenic climate change, restrictions on hunting, the availability of wage employment, and increased access to imported food (Power 2008; Wesche and Chan 2010; Ford and Goldhar 2012).

Consequences: Secure access to food (either traditional or store-bought), the erosion of traditional knowledge, and shifting cultural norms are the key processes impacted by these drivers (Wesche and Chan 2010; Ford and Goldhar 2012).

Response options: These feedbacks are poorly understood, and it not known whether these changes in mobility are actually regime shifts and, if so, how they can be reversed. However, slowing the rate of climate change by decreasing greenhouse gas emissions would facilitate human adaptation.


David Stanley/Flickr

The melting of the Greenland ice cap will raise sea levels and affect weather patterns across the planet.

Further information: Cláudia Florêncio, Tove Björklund, Rawaf al Rawaf, Rawaf al Rawaf, Tove Björklund, Juan Carlos Rocha. Arctic mobility. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2015-07-01 13:45:25 GMT.

Tundra to boreal forest

Type: Land/water

Scale: Landscape-region/ sub-continental

Alternative regimes: Tundra, boreal forest

Evidence of regime shift: Speculative

Underlying mechanism: Well established – Wide agreement on the underlying mechanism

By warming the Arctic, climate change is allowing shrubs from boreal forest to spread into tundra (Olofsson et al. 2009; Myers-Smith et al. 2011). The actual shift to boreal forest with spruce and pine as the dominant species is unlikely to occur in this century, due to the long time periods required for tree growth and migration. Shrub expansion into the Arctic tundra is the first phase of this regime shift, which can be reinforced by carbon release due to permafrost degradation, and decreases in albedo, which in turn increases climate warming and microbial activity, enhancing shrub growth (Loranty and Goetz 2012).

Consequences: The shift from tundra to boreal forest is projected to occur over large geographic areas throughout the tundra zone, with substantial transformations of ecosystems and opportunities for local populations (Hinzman et al. 2005; Scheffer et al. 2012). Changes in vegetation, shifting populations of foraging mammals and birds, and decreasing forage for reindeer are due to this shift. Increased abundance of woody shrubs will make travelling across the tundra more difficult for caribou and people. Forests may provide new ecosystem services, such as wood production, and provide habitat for boreal animals, which could potentially provide new resources for local communities. However, the livelihoods of reindeer herders and caribou hunters would likely be harmed by this regime shift. The large extent of this region suggests that this shift could substantially alter the climate system with uncertain impacts outside the Arctic.

Response options: Halting the emissions of global greenhouse gas emissions will reduce the risk of this regime shift. Herbivore browsing at an intensity level that limits shrub expansion can also help inhibit shrub growth and help maintain tundra.

Further information: Rolands Sadauskis, Juan Carlos Rocha, Reinette (Oonsie) Biggs, Garry Peterson. Tundra to boreal forest. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2013-11-29 13:11:02 GMT.

Tundra to steppe

Type: Land

Scale: Landscape-region/ subcontinental

Alternative regimes: Tundra, steppe

Evidence of regime shift: Well established

Underlying mechanism: Contested

The transition from steppe (a grassland) to tundra (mosses and shrubs growing in waterlogged soils), or vice versa, is a regime shift that can occur in cold terrestrial ecosystems. This regime shift is typically found where permafrost occurs, which is mostly in the Arctic and north of the tree line, where mean temperature remain below 10–12°C for the warmest month. Climate change and changes in the population density of large herbivores are the main drivers of regime shifts between steppe and tundra. Climate changes that reduce soil moisture can favour steppe over tundra, and vice versa. Tundra is favoured by moss growth, which is more limited by water than by nutrients. Steppe is favoured by grass growth, which is improved by drier soils with available nutrients. Large herbivores can shape ecosystems through their impact on vegetation species composition, soil structure, and ecological dynamics. Large herbivore trampling and grazing can slow moss growth and convert tundra to steppe vegetation.

Consequences: Arctic soils covered by mosses and permafrost are less susceptible to degradation. Transition from tundra to steppe implies a loss of this buffering layer. This shift would also decrease soil moisture, likely leading to a decline in the number of lakes and wetlands (Wrona et al. 2016). It would also accelerate permafrost melting, leading to infrastructure destabilization, and increase the risk of fire and subsequent release of greenhouse gases. Steppe is more biologically productive than tundra and would likely benefit grazing animals and some pastoralists. However, such a change would harm pastoralists who rely upon tundra.

Response options: Halting the emissions of global greenhouse gas emissions will reduce the risk of this regime shift. The possibility of this regime shift can be modified by the presence of large herbivores. In Siberia, for example, a project is working to restore the Pleistocene steppe ecosystem by the reintroduction of large herbivores and intensive grazing (Zimov et al. 2012).

Further information: Rodrigo Martinez, Nicole Reid.. Steppe to Tundra. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2016-05-11.

Coniferous to deciduous boreal forests

Type: Land/water

Scale: Landscape-country

Alternative regimes: Coniferous tree-dominated forest, deciduous tree-dominated forest

Evidence of regime shift: Well established – Wide agreement on the underlying mechanism

Underlying mechanism: Well established – Wide agreement on the underlying mechanism

Coniferous-dominated forests are slowly being replaced by deciduous trees due to recent climate warming and changes in the frequency and intensity of wildfires. Coniferous trees thrive in cold, moist soil conditions, and coniferous forests help soil conditions favourable to them once they are established. The moisture of the soil prevents frequent fires from occurring, and when fires do occur, the soil organic layer is usually wet enough to not be entirely consumed by a fire (Johnstone et al. 2010). Because coniferous trees regenerate well in organic soil, only severe fires that consume most of the soil organic layer will disrupt the coniferous-promoting soil conditions (Hollingsworth et al. 2013). Deciduous trees, on the other hand, thrive in nutrient-rich, dry and warm soils. Deciduous trees help produce such soils, enabling more decomposition, which keeps the soil organic layer shallow. Fires tend to be more frequent than in coniferous-dominated forests, but not as intense. However, since the soil organic layer is shallow, it is often consumed by fire, exposing mineral soil (Johnstone et al. 2010). Deciduous trees have well-developed strategies for regenerating in mineral soil, which means that deciduous trees tend to return to these areas after a wildfire (Hollingsworth et al. 2013). A severe fire can shift forest from one regime to the other, while changes in climate (i.e. mainly temperature or precipitation) can change the underlying conditions to make each regime less resilient (Johnstone et al. 2010) – for example, by making the soil more or less moist.

Consequences: The shift from boreal forest to deciduous forest changes the set of ecosystem services available to people, but both types of forest provide diverse sets of benefits. This suggests that these shifts will have complex sets of winners and losers in local communities who prefer or use different types of forest. Mature deciduous forests tend to have lower fire frequency than coniferous forests (Johnstone et al. 2010), but the future incidence of fires in the Arctic is quite uncertain. The shift to deciduous forest also increases regional albedo, which will likely slow regional warming. The shift from boreal to deciduous forests over large areas would likely substantially disrupt regional climates due to changes they would produce in heat and moisture transport.

Response options: Reducing the risk of this shift requires a halt of global greenhouse gas emissions. Other strategies can be used to manage the regime shift. Fire suppression could slow the rate of change, but it is not feasible in large forest areas (Chapin et al. 2008). Benefits can be maintained despite regime shifts by the protection of relatively small areas that are culturally important or critical to protection of life and property. Furthermore, the exploration of opportunities (transformations) associated with the new regime (e.g. better moose habitat, more productive forests), could reduce the undesirable ecological impacts of the regime shift.

Further information: Linda Lindström, Katja Malmborg, Lara D. Mateos, Juan Carlos Rocha, Garry Peterson. Coniferous to deciduous boreal forest. In: Regime Shifts Database, www.regimeshifts.org. Last revised 2014-12-02 12:34:08 GMT.

3.3.2 Drivers of regime shifts

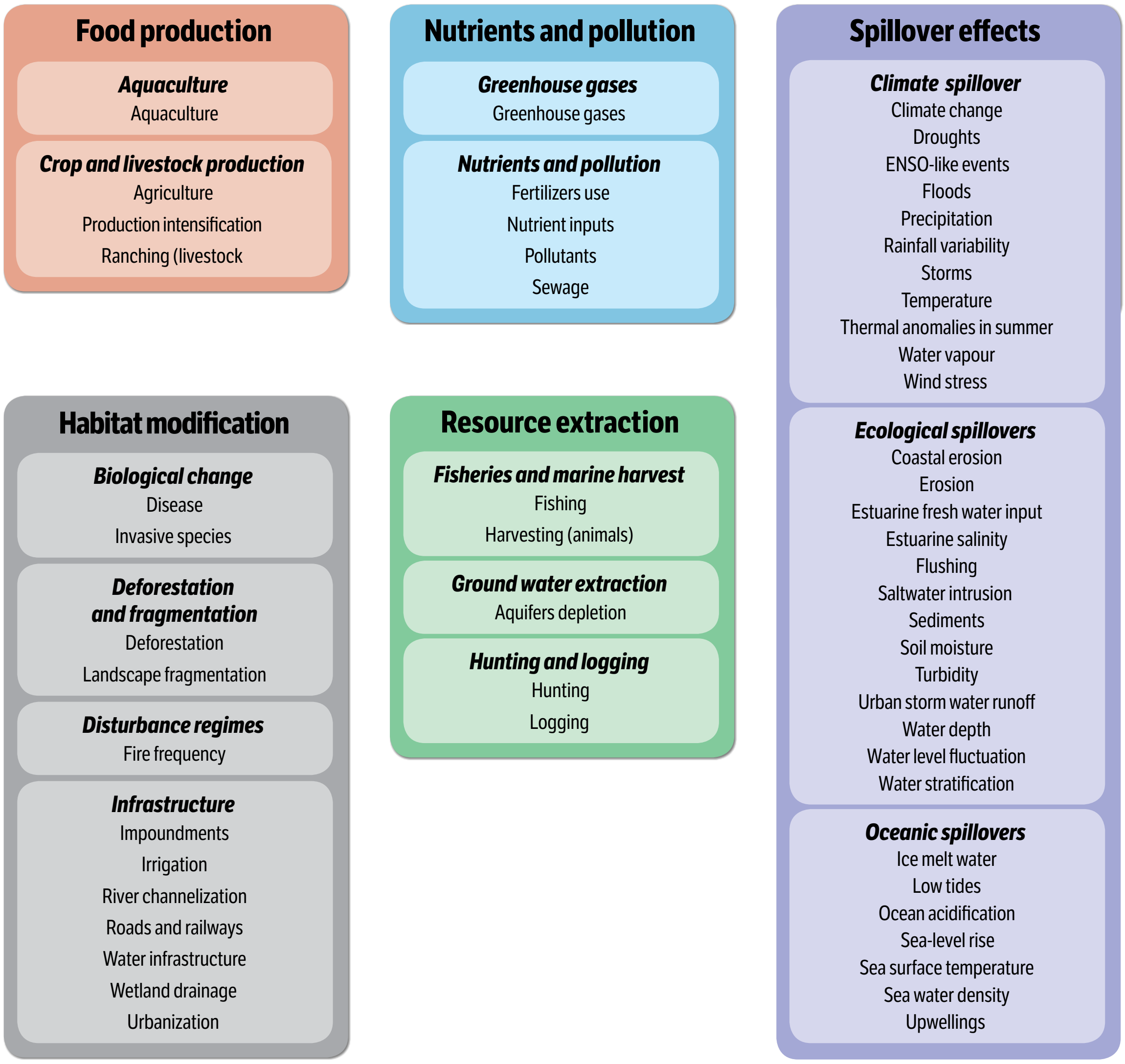
Regime shift drivers are natural or human-driven changes that have been identified as directly or indirectly producing a regime shift (Nelson et al. 2006; Rocha, Peterson, et al. 2015). To ensure consistent classification of regime shift drivers, we organize them into 15 categories, further grouped into five broader categories: habitat modification, food production, nutrients and pollutants, resource extraction and spillover effects (Figure 3.2). Thus, we distinguish between drivers stemming directly from human activities (e.g. hunting) and drivers affected by the knock-on or "spillover" effects of these activities on natural processes (e.g. sedimentation).

Drivers of specific regime shifts were identified by creating causal loop diagrams (Sterman 2000; Schaffernicht 2010). These diagrams, available at www.regimeshifts.org, synthesize the scientific literature on each regime shift.

chrys/Flickr

The shift from tundra to boreal forest has the potential to occur across millions of square kilometres during this century.

FIGURE 3.2 **A classification of regime shift drivers by broad and more specific categories**



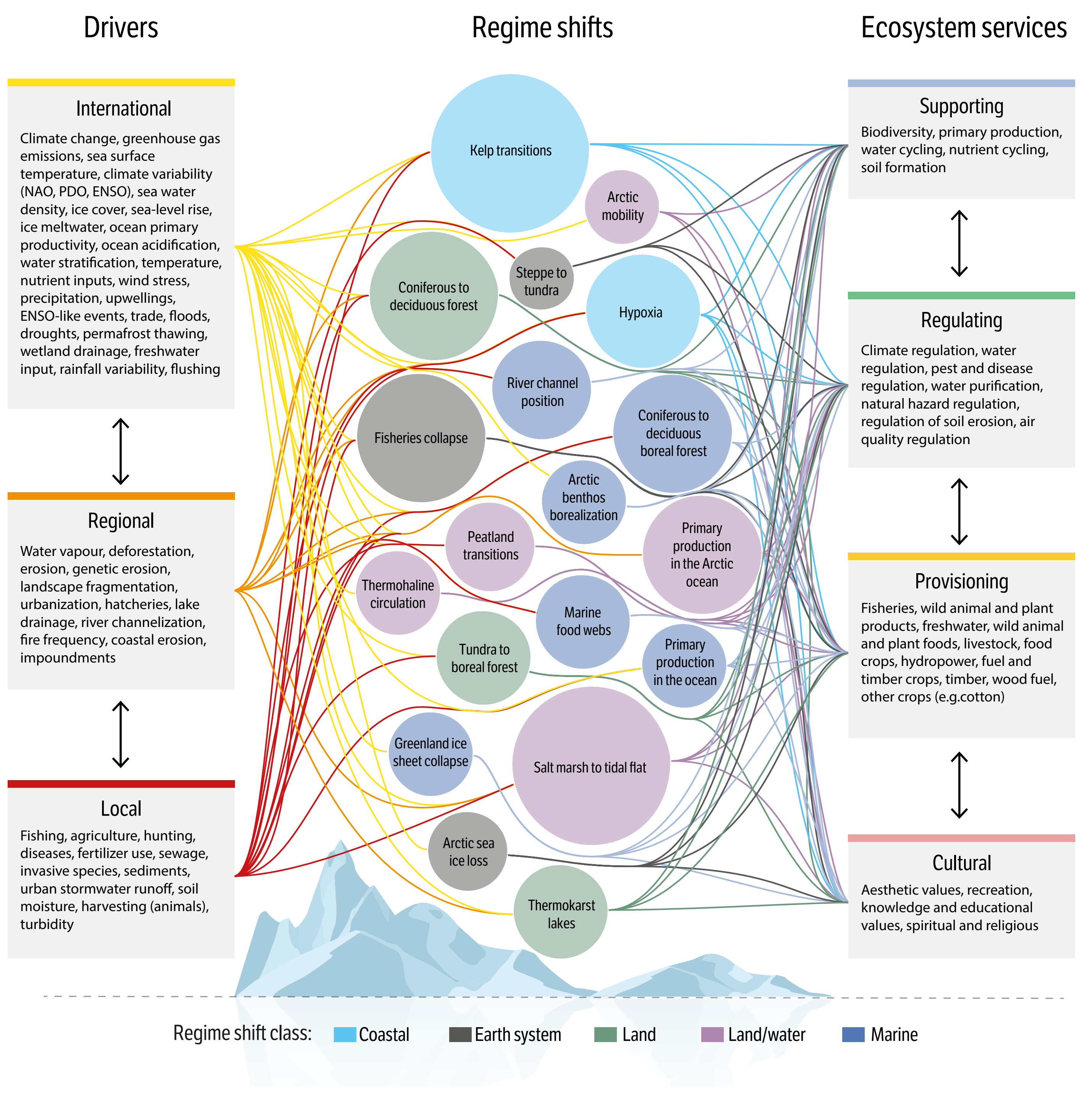
To ensure quality and consistency, we focus only on drivers that have been reported in the scientific literature. This limits our review to regime shifts covered by the literature, and to the drivers of regime shifts that have been studied. For example, there has been more research demonstrating that greenhouse gases cause rising temperatures than on how colonialism or globalization indirectly drive any Arctic regime shifts. While other sections of the report address these indirect drivers, here we focus on drivers that have been directly or indirectly linked to regime shifts.

For each regime shift, we define drivers as variables that influence but are external to the feedback mechanisms of the regime shift being analysed. Direct drivers are those that influence the internal processes or feedbacks underlying the regime shift, while indirect drivers those that alter one or more direct drivers (Nelson et al. 2006). The same driver may be a direct driver for one regime shift and an indirect driver for another. For detailed descriptions of the method, see Rocha, Peterson et al. (2015), Biggs et al. (2015), and Rocha, Yletyinen et al. (2015).

All Arctic regime shifts analysed are directly or indirectly driven by global climate change (Figure 3.3, p. 80). However, it is not only climate change that drives regime shifts in the Arctic. Non-climate drivers of regime shifts include fishing, nutrient inputs, aquaculture and infrastructure development, among others. Climate change and greenhouse gases are the most common drivers of regime shifts in the Arctic, followed by sea surface temperature, nutrient inputs, water stratification and agriculture. These drivers are linked to many regime shifts and often occur together (five to 12 regime shifts).

FIGURE 3.3 **Drivers and impacts of Arctic regime shifts**

A variety of Arctic regimes occur. Larger circles show regime shifts that are connected to more drivers and ecosystem services. Arctic regime shifts are driven by a wide variety of processes operating at international, regional and local scales, and the consequences of these regime shifts alter the potential availability of supporting, regulating, provisioning and cultural ecosystem services. This figure shows that most regime shifts have many drivers and impact many ecosystem services, that many regime shifts share drivers, and that ecosystem services are impacted by various regime shifts.



Climate change and weakened sea ice affects Arctic people's ability to traverse the landscape, which can limit their access to food and other key resources.

The regime shifts with higher numbers of identified drivers are kelp transitions (21 drivers), salt marshes to tidal flats (16) and fisheries collapse (15); those with the fewest identified drivers are the collapse of Arctic sea ice (three), the shift from steppe to tundra (three), and loss of Arctic mobility (four).

Aquatic regime shifts, especially in marine ecosystems, tend to share more drivers and processes. Fisheries collapse and kelp transitions have up to 15 drivers in common; shifts from salt marshes to tidal flats, shifts in marine food webs, and shifts in primary productivity in the Arctic ocean have four or more drivers in common. Terrestrial regime shifts share fewer drivers and are more idiosyncratic in the diversity of factors that drive them. Subcontinental regime shifts, such as the collapse of the Greenland ice sheet or the Arctic ice sheet, have fewer drivers and are exclusively related to climate-related variables.

This drivers analysis uses a network approach to understand the relationships between drivers and regime shifts. Because the relative influence of different drivers on regime shifts is not known, we analyse which drivers are more common and which clusters of drivers tend to co-occur most often in the Arctic. This approach allows us to identify drivers that affect many regime shifts, which drivers occur together, and what opportunities there are for management and policy-making. Technical details about the network methods used can be found in Rocha, Peterson et al. (2015) and Rocha, Yletyinen et al. (2015).

3.3.3 Impacts of regime shifts

Arctic regime shifts affect a variety of ecosystem services and important aspects of human well-being, both in the Arctic and elsewhere. Ecosystem services are the benefits that people obtain from nature; for this analysis we follow the Millennium Ecosystem Assessment in dividing these benefits into four categories: *provisioning services*, such as food, and drinking water; *regulating services*, which modulate changes in climate and regulate floods, disease and water quality; *cultural services*, such as recreational, aesthetic and spiritual benefits; and *supporting services*, such as soil formation and nutrient cycling (Millennium Ecosystem Assessment 2003).

The most common provisioning services affected are fisheries production, followed by animal (e.g. reindeer) and plant products. The ecosystem processes most affected are primary production (10 regime shifts), water and nutrient cycling (seven regime shifts) and soil formation (five regime shifts) (Figure 3.4b, p. 83). In the case of primary production, in most cases a potential increase of primary production is suggested, especially in marine areas. However, it is unclear, given climatic and biological uncertainties, whether productivity will increase the productivity of higher trophic levels (e.g. commercially important fish stocks) or be locked into lower trophic levels (e.g. plankton and jellyfish) (Ardyna et al. 2014).

Cultural services are particularly important in the Arctic. Aesthetic value, recreation and knowledge are the cultural services most affected, by six to 12 regime shifts. Similarly, human well-being is expected to be significantly affected by the loss of livelihoods and traditional economic activities (12 regime shifts), impacts on food security and nutrition (10), and impacts on security of housing and infrastructure (six). As described in more detail in Chapter 4, opportunities for tourism do exist in the Arctic; however, communities whose livelihoods are transforming towards tourism services might be the exception rather than the rule, while other traditional livelihoods and access to food sources are being compromised.

The impact of Arctic regime shifts on culture, social memory and sense of place is likely to be large and substantial. The cumulative impacts of multiple regime shifts are likely to severely disrupt the Arctic landscape and substantially reshape how people live and move around the Arctic. Change in the Arctic has consequences for the global climate, but for the people who live there, the most

FIGURE 3.4a **Regime shifts have a diversity of causes, occur in a variety of locations, and vary in their impacts**

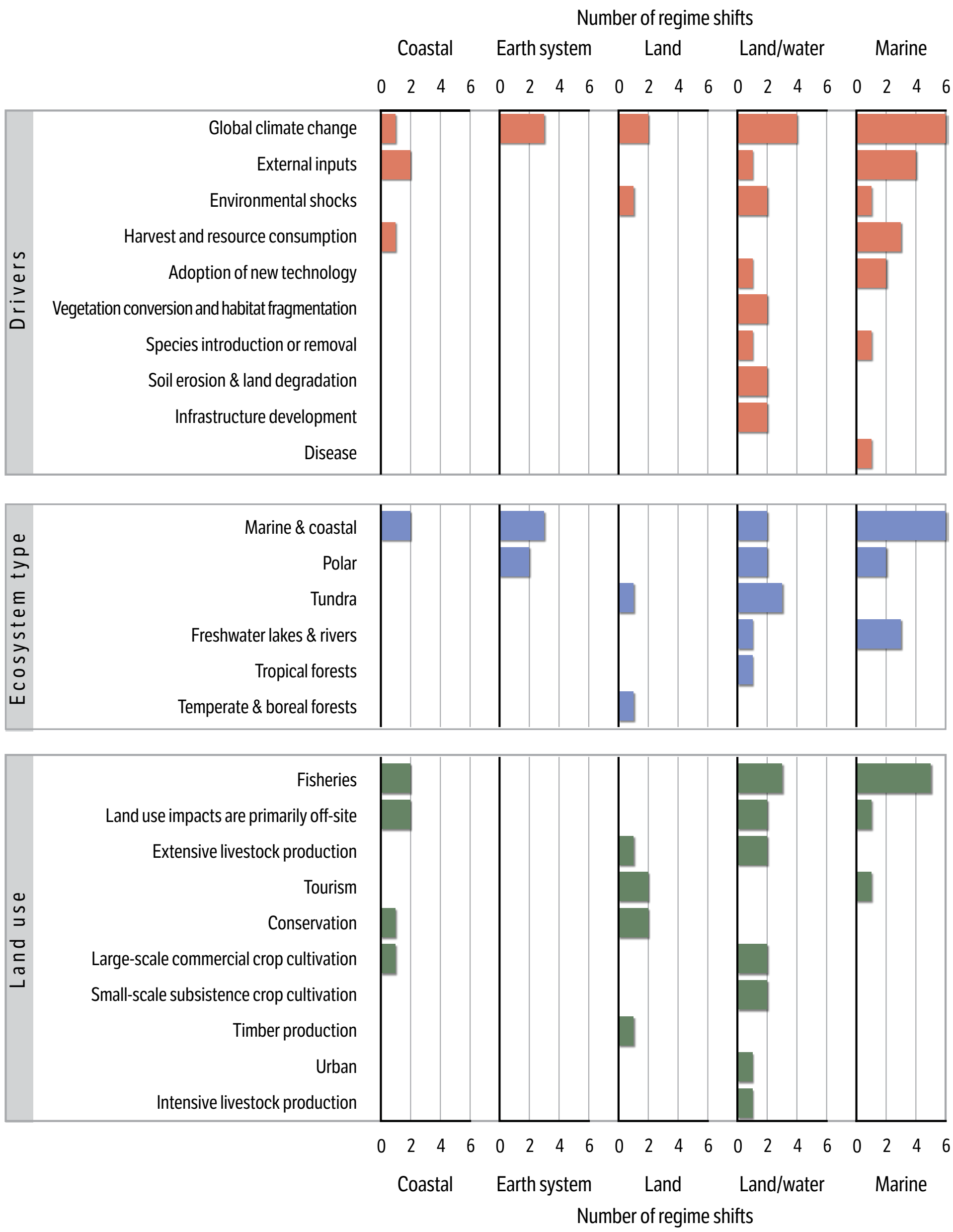


FIGURE 3.4b **Regime shifts impact a wide range of ecosystem services**

Mining facilities in Norilsk, Russia: Changes in the Arctic are often not produced nor requested by those experiencing them.

direct impact will be a major disruption of their ways of life. The landscape will change as permafrost melts, and people's ability to move will be substantially limited as sea ice and frozen ground become less available. The arrival of new species of plants and animals, changes in the ability of species to move and changes in animal numbers and behaviour will challenge people's ecological knowledge, alienate them from their own memories and places, and require them to adapt to a new environment.

These impacts are often not measured in Arctic research, but given the scope and scale of the transformation that is beginning in the Arctic, they should be. The changes are not being produced or requested by those experiencing them, and the ability of Arctic peoples and cultures to remember, learn and innovate should be supported by those who are responsible for these impacts.

Several Arctic regime shifts affect climate regulation (eight regime shifts) and natural hazard regulation (five regime shifts). Because all regime shifts are driven by climate change, this finding suggests that Arctic regime shifts are likely to produce cascading effects across the Arctic, as the occurrence of one regime shift increases the likelihood of others by influencing their drivers or feedback processes. For example, the reduction in albedo produced by Arctic sea-ice loss or the Greenland ice sheet collapse will further increase warming and thus increase the likelihood of other regime shifts related to climate (Curry et al. 1995; Chapin et al. 2005). Another mechanism underlying these cascading effects occurs through biological amplification; for example, the increase of phytoplankton biomass in the upper layers of the ocean can increase sea surface temperature, further increasing warming in the Arctic (Park et al. 2015).

Arctic regime shifts are also prone to cross-scale interactions, when the occurrence of several shifts in the same system type can activate larger-scale feedbacks that further exacerbate their occurrence (Peters et al. 2004; Peters et al. 2007). Melting of both the Greenland and Arctic ice sheets (Hohenegger et al. 2012), the collapse of thermokarst lakes (Kirpotin et al. 2008), other processes related to permafrost thawing (Marsh et al. 2009), and regime shifts mediated by fire, such as shifts from coniferous to deciduous forests, are examples of potential cross-scale interactions that amplify regime shifts (Peterson 2002; Peters et al. 2004; Jones et al. 2015).

It is likely that the combination of these regime shifts will produce climate surprises that are currently poorly assessed or understood. Eight regimes shifts are expected to produce changes in ice cover, vegetation and water storage that will alter climate via changes in albedo, evapo-transpiration and soil moisture that will combine to have highly uncertain on regional, Arctic and likely, global climate. Understanding the potential consequences of these interactions should be a high scientific priority, and planners in the Arctic should expect increases in climate variability, extreme events and novel surprising events.

The impacts of regime shifts on individual countries depend on the types of ecosystems present. Figure 3.6, p. 86 shows how Russia and Canada, with a larger extent of terrestrial ecosystems, are more vulnerable to terrestrial regime shifts than other countries, while countries with a larger proportion of marine territories, such as Norway, Denmark and Iceland, are primarily vulnerable to regime shifts in marine ecosystems. The "Arctic" that each nation is governing is composed of a diversity of ecological, political and socio-economic layers (see Chapter 2), so there is no blanket approach to dealing with their respective challenges in the Arctic, including regime shifts. Moreover, the management options for most Arctic regime shifts require coordinated actions at the international level (e.g. reducing greenhouse emissions), which often requires polycentric, coherent and robust institutions through international cooperation (Young 2011; 2012). Chapter 7 further discusses the challenges of governing the Arctic.

This section has summarized the impact of regime shifts on ecosystem services and potential cascading effects within the Arctic. It is clear that regime shifts have multiple impacts, some of which translate into effects on human well-being. However, our analysis also reveals that very little has been done to quantify these impacts and trade-offs in the context of ecosystem services and human well-being; there is a need for future research. Quantified measures of the impacts of regime shifts on human well-being can help support management decisions – for example, to prioritize strategic actions to address some regime shifts or their drivers earlier than others.

3.4 Response options

Arctic regime shifts present multiple challenges. First, regime shifts can have substantial impacts that are difficult to predict or reverse (Biggs et al. 2012). Second, the complexity of regime shifts requires integrated and holistic rather than fragmented adaptation actions. Some of the expected changes to which Arctic communities will need to adapt are uncertain, and some impacts will be mostly unexpected. Third, the key processes driving these regime shifts are generated by human activities outside the Arctic; consequently, it is difficult for Arctic people to change these processes themselves. Below we outline three types of responses to regime shifts: mitigating regime shift drivers, estimating risk of regime shifts, and preparing for change.

3.4.1 Mitigating regime shift drivers

Avoiding Arctic regime shifts will require major remedial action outside the Arctic. (Figure 3.5). Most of the human activities identified as increasing the risk of regime shifts occur primarily outside the Arctic, yet the benefits of these activities arguably accrue primarily to people living outside the Arctic (see Chapter 1 discussion on

FIGURE 3.5 **Scales of management**

Each bar shows the proportion of regime shift drivers whose management must be coordinated at the international, regional/national or local level.

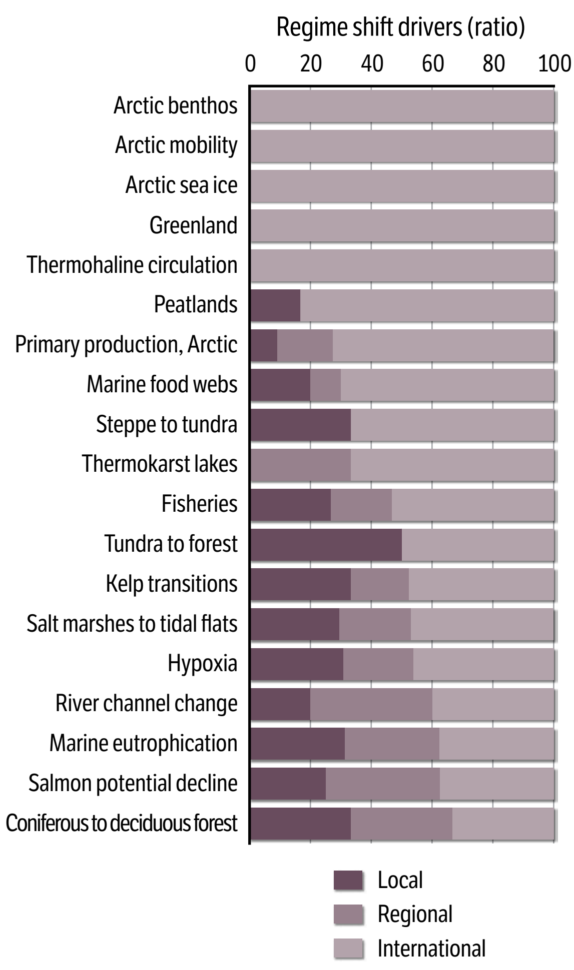
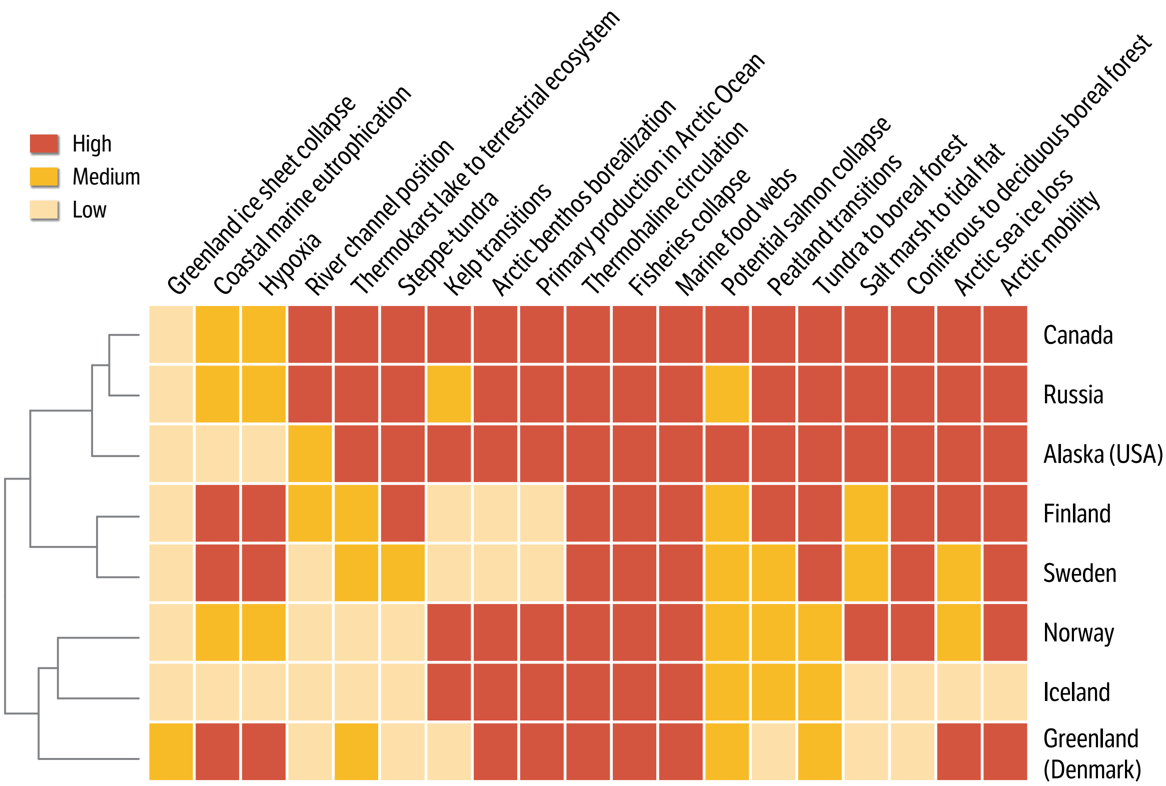


FIGURE 3.6 **Exposure to regime shifts varies across Arctic nations**

While all nations are exposed to regime shifts, there are distinct clusters among nations in the types of regime shifts they are exposed, due to their size, geography and land covers.



proximity). Climate change, the most common driver of Arctic regime shifts, is caused mostly by greenhouse gas emissions produced by the economic activities of people outside the Arctic – particularly energy production and transport, but also agriculture. Fishing, agriculture and the input of nutrients into the ocean outside the Arctic also drive Arctic regime shifts. For example, several case studies documented in Chapter 4 refer to potential collapse or increased variation of fish stocks (e.g. cod, salmon) across the Arctic. Despite strict regulations, such fish stocks are not confined to a national marine territory, and many species migrate across national borders. Most communities have a limited ability to mitigate the external drivers, exemplified by climate change, that are primarily responsible for the regime shifts presented in this chapter.

Tackling the global drivers of Arctic change has proven difficult. However, the experience of rapid change in the region, combined with the unique and diverse global leadership roles of the Arctic nations and observer states, creates opportunities for coordination of action via the Arctic Council that could generate benefits far beyond the region (see Chapters 5 and 6). Nevertheless, it is clear that global-level changes cannot be realized quickly, due to the difficulty of changing built energy, agricultural and transport infrastructure, and even with aggressive action it will take decades of work to achieve substantial declines in these drivers of Arctic change. At the scale of Arctic nations, resilience to drivers that cannot be controlled within the Arctic can be strengthened by managing drivers that can be addressed by local or regional action.

3.4.2 Estimating risk of regime shifts

Regime shifts have occurred before in the Arctic, but human activity is simultaneously amplifying the most important drivers of Arctic regime shifts, thus increasing the risk that they will occur. Although accurate prediction of regime shifts may be impossible, the ability to estimate the risk can be significantly improved. Monitoring of early indicators of regime shifts can be used to try to reduce the likelihood of undesirable shifts and prepare for shifts that cannot be averted.

There are two broad approaches to forecasting regime shifts based on process understanding and statistical analysis. If the processes that produce regime shifts are well understood, it may be possible to identify the factors that regulate critical thresholds of key variables (Andersen et al. 2009). Such thresholds are typically produced by the interaction of local context and processes, such as soils, rainfall and ecological dynamics. Because these thresholds typically vary over time and across space, it is often difficult to identify an exact threshold (Hastings and Wysham 2010), but these methods can identify a range of situations in which there is increased likelihood that a regime shift will occur.

The types of knowledge required to create this type of early warning indicators are not available for most types of Arctic regime shifts. Early-warning indicators based on the statistical analysis of time series or spatial data can provide indicators of an impending regime shift in the absence of detailed knowledge (Scheffer et al. 2009; Dakos et al. 2012). Because these early-warning indicators are based on generic changes in system behaviour, they can potentially be used to detect new or unknown thresholds. While such indicators can be useful in areas in which regime shifts are not well understood, such as the Arctic, they require long-term monitoring data and cannot predict all types of regime shifts (Hastings and Wysham 2010). While the ability of science to predict ecological regime shifts is improving, unless the underlying mechanisms of regime shifts are well understood, it is difficult to produce indicators that will provide sufficient warning to avoid a regime shift.

3.4.3 Preparing for change

Arctic people have historically coped with many types of regime shifts, and even though prediction of regime shifts is often difficult, more general strategies can be employed to prepare for change. For example, a variety of coping strategies have been deployed by Arctic communities (see Chapter 4). Among the case studies analysed in Chapter 4, communities that were more effective at adapting and transforming themselves in response to change either diversified their livelihoods and resource exploitation to reduce pressure on targeted resources, or transformed livelihoods completely (e.g. from whaling to tourism). However, many social factors that have historically enabled people to cope with and adapt to past regime shifts have been eroded. For example, past adaptations have often relied on the ability of pastoralists, hunters and fishers to remain mobile, but the ability of people to move has often been restricted by governments, and is now also being restricted by climate change impacts (see the discussions of Greenland mobility in Disco Bay and Qaanaaq in Chapter 4).

Other social factors, such as regulations and investments in infrastructure, have also constrained the options available to Arctic communities for adapting to resource fluctuations, whether natural or driven by human activities. Chapters 4 and 7 further elaborate on aspects of adaptive capacity as an expression of resilience. (See also Chapter 1, where the relationship between resilience, adaptation and transformation is clarified.) Consequently a challenge for the Arctic is to develop ways to ensure that government, corporate and other larger-scale actions and policies enhance the ability of local places to anticipate, respond and adapt to regime shifts.

Formal planning processes can present a barrier for planning to substantial changes if they assume that change will only occur gradually. To ensure that this does not occur, the possibility of large, substantial and surprising changes should be more widely considered in formal environmental management and assessment. This is particularly important because managing regime shifts requires quite different approaches than managing ecosystems where change is predictable and reversible (Carpenter 2003; Scheffer et al. 2001). Furthermore, Arctic ecological forecasts that do not consider the possibility of abrupt change are likely to systematically underestimate the impacts of ecological changes. In particular, the possibility of many different types of regime shifts should be considered more widely in government, social and corporate plans.

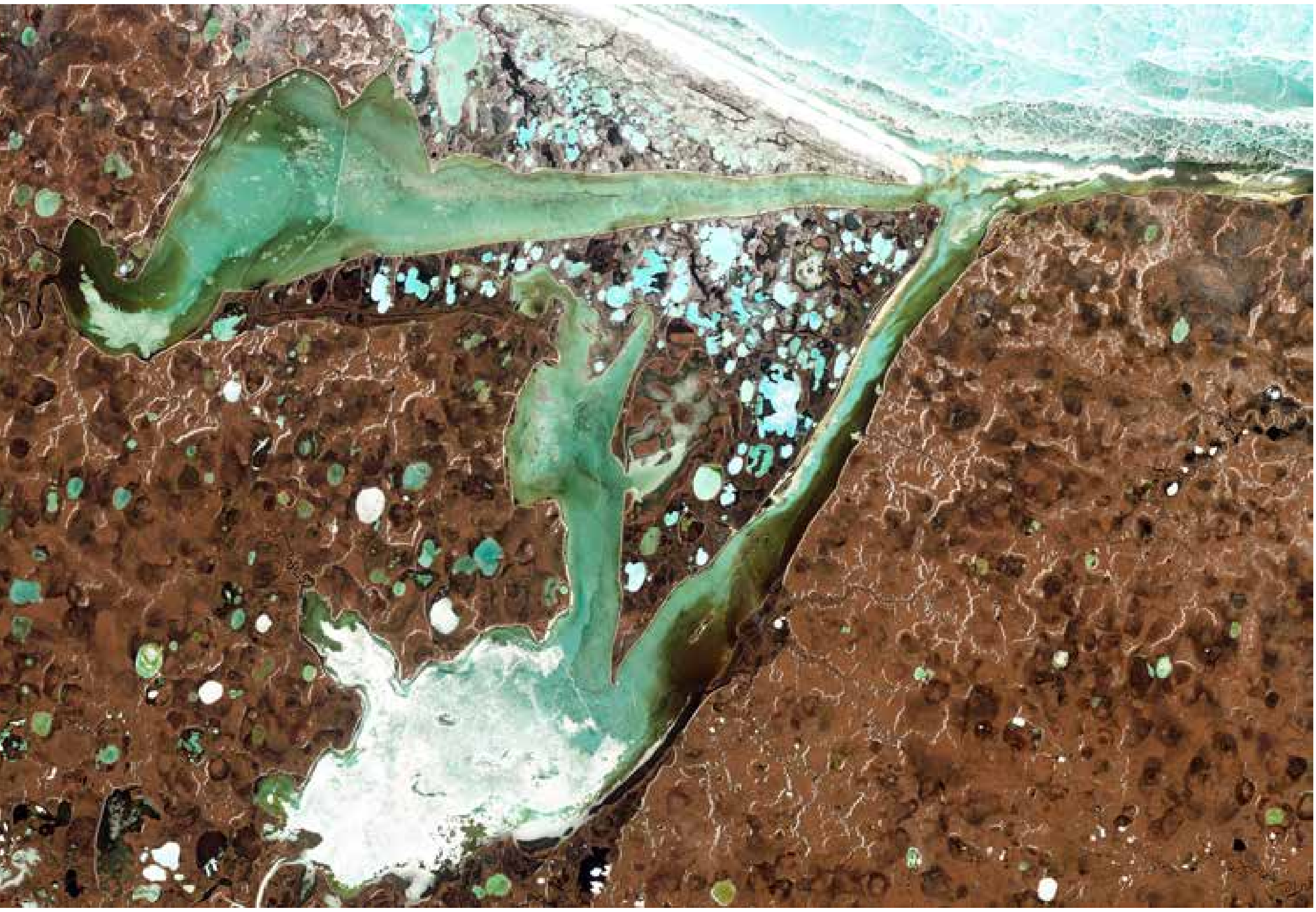
A second barrier to effective responses to regime shifts is the problem of institutional fit. Institutions tend to operate at spatial and temporal scales that may not match those of the ecological dynamics they need to address. They may be focused on a specific state or province, for example, but face a problem that spans a much larger region. Or they may be making decisions in five- or 10-year increments, while the ecological dynamics at stake span multiple decades or even centuries. This phenomenon is known as the problem of misfit (Ekstrom and Young 2009; see also Chapters 5 and 6). For example, Chapter 4 shows how external subsidies can mask the effects of slow-onset changes and thus hinder learning and diverse social responses; while the intention may be good, the ultimate impact is harmful.

Collaboration and dialogue across sectors, institutions and organizations can help address this problem. For example, the role of the Arctic Council in facilitating knowledge flow and connecting experimentation could enable communities to increase their capacity to respond to potential regime shifts. Such learning networks can speed up local knowledge generation and regional sharing of successful stories while keeping an eye on failures and the characteristics that preclude adaptation and transformation.

A more active way to respond to the risk of regime shifts is to develop ways to build the resilience of desirable regimes and/or strengthen the various ingredients of resilience (see Chapter 7). Such an approach requires an integrated and holistic approach that can be hindered by disconnected policies and lack of flexibility. Building resilience to regime shifts typically emphasizes maintaining response diversity and redundancy (Mori et al. 2013). Response diversity is a concept from ecology that denotes in how many different ways species with similar ecological functions respond to environmental change. The concept has been applied in broader social-ecological contexts and has been used to analyse livelihood and business response diversity. Redundancy describes the capacity among species to functionally replace one another, and has also been applied to social settings. For example, a village that has several fishing boats has redundancy, while a village that has only one does not. Similarly, a fishing community whose members catch different types of fish and shrimp has more response diversity than one whose members all catch the same fish species.

Management strategies that bolster both these properties help prevent regime shifts by ensuring that critical system feedbacks are maintained in the face of unexpected shocks and disturbances to the system. Similarly, spatial heterogeneity – diversity across a broader landscape – maintains resilience by ensuring response diversity and redundancy across that landscape (Cumming 2011). While some heterogeneity is defined by the physical landscape, other types of diversity are provided by diverse rather than homogenous land ownership, management and institutions. Due to the variation in social and ecological processes across a landscape, some locations will be more vulnerable to regime shifts than others (Brook et al. 2013).

By identifying locations where processes that maintain an existing regime are weak, managers can identify where regime shifts are likelier to occur and focus their rehabilitation or monitoring efforts where they are likely to have the greatest effect. For example, research on eutrophication has shown that relatively small areas in watersheds that combine high soil phosphorus concentrations and high runoff potential are disproportionately responsible for the majority of phosphorus runoff into lakes (Carpenter 2003). The risk of a regime shift can thus be most effectively reduced by focusing especially on these critical source areas. Such concentrations of impact are common for many social and ecological processes.



NASA Earth Observatory

Satellite image of melting permafrost on the northern Siberian coast: Changes in sea ice, vegetation and permafrost are likely to combine to affect the regional and global climate in ways that are tough to predict.

3.5 Impacts of Arctic regime shifts outside the Arctic

It has already been noted that Arctic regime shifts are interconnected, and these interconnections can produce cascading effects and cross-scale interactions within and outside the Arctic. Many regime shifts affect ecosystem processes and services that, in turn, affect the drivers of other regime shifts. The clearest example is climate regulation. Most regime shifts in the Arctic are believed to amplify climate change (Figure 3.4b), which in turn will increase the likelihood of climate-driven regime shifts worldwide. As noted above, the combination of changes in sea ice, permafrost and vegetation are likely to have difficult-to-predict impacts on regional and even global climates. It is likely that these combined impacts will result in a less predictable, more variable and more surprising Arctic and global climate. This will affect people within the Arctic and may also trigger further impacts outside the Arctic (Figure 3.7, p. 90), such as tropical forests turning to savannahs, monsoon systems weakening, mangroves collapsing, coral reefs becoming dominated by algae, and the West Antarctica ice sheet collapsing (IPCC 2014).

The effect of Arctic regime shifts on biodiversity, fishing and primary productivity is highly uncertain; while some authors suspect that productivity will increase with warmer temperatures, it is unclear whether higher energy input in the ecosystem will stay in lower trophic levels, or will actually flow towards higher trophic levels, where most commercial and livelihood important species coexist (Edwards et al. 2013; Ardyna et al. 2014). With higher biomass production and nutrient availability, it is uncertain how periodic phenomena such as fires or algae blooms will evolve. For example, it has been reported that increasing fire frequency initiates thermokarst development (Jones et al. 2015). Nevertheless, increases in the frequency and severity of such periodic phenomena can trap ecosystems in undesirable regimes, so higher energy and nutrient availability does not necessarily translate into an increase in ecosystem services or human well-being; the trajectory of each ecosystem will depend on contextual development and the timing of disturbances.

The diversity of social, ecological and physical process that connect the world means that changes in one place can produce impacts in another. Because regime shifts are large, persistent changes, their potential to cascade through these global connections is substantial. In order to better estimate the consequences of planned activities, scientists and society need to better understand how different types of regime shifts are linked, and the potential for one regime to trigger another. Scientists know that there are cross-scale connections, where local and regional regime shifts interact, For example, the loss of sea ice can influence the climate, increasing the likelihood of other terrestrial regime shifts. There are also horizontal connections, where a regime shift in one ecosystem can trigger a shift in a connected ecosystem, such as when freshwater eutrophication triggers coastal hypoxia downstream. Identifying the processes that connect different regime shifts and mediate the strength of these connections is vital for understanding the ability of ecosystems to respond to global changes such as climate change and increased habitat conversion.

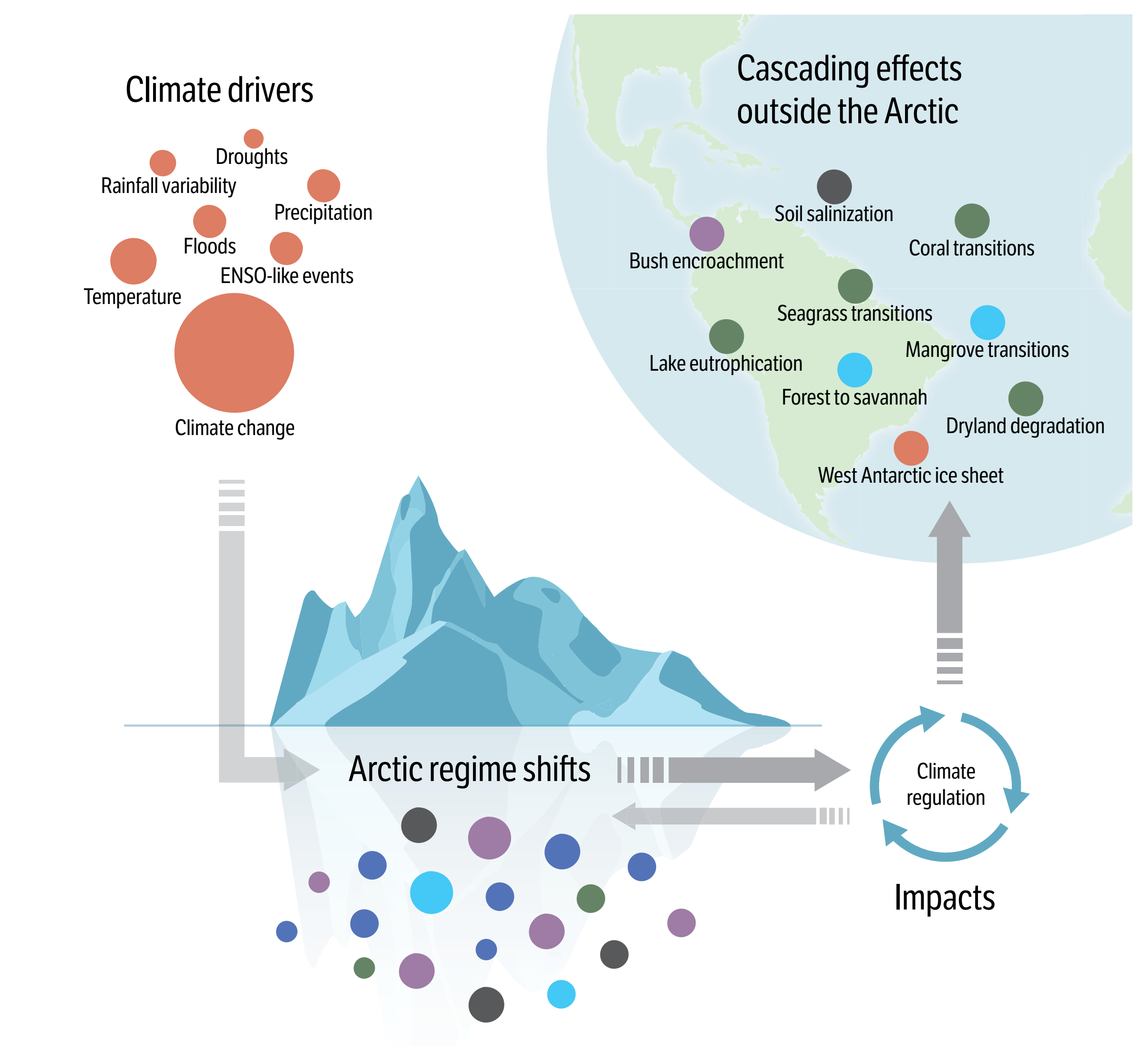
3.6 Enhancing understanding of regime shifts

This chapter has reviewed and presented evidence of potential regime shifts in the Arctic. The review is restricted to what has been reported in scientific publications, where hypotheses regarding regime shifts or persistent reorganizations have been proposed, and where evidence of drivers and feedback mechanisms has been discussed. The review thus covers the most studied Arctic regime shifts, but is not an exhaustive survey, and more research is needed to identify missing and unknown regime shifts and to better understand their underlying feedback mechanisms. Most evidence to date centres on ecological regime shifts, as their biophysical drivers and feedbacks have been studied better. Research about social-ecological regime shifts is scarcer, so it is imperative to learn more about causality in the social dynamics underlying regime shifts, especially as these are likely to have strong impacts of human well-being.

The characterization of drivers and feedbacks presented here has been largely qualitative – this chapter assesses the evidence for these different regime shifts, but not their relative strength, nor how close different parts of the Arctic are to critical thresholds. While predicting regime shifts is difficult and may be often impossible, it is possible to assess when the risk of regime shifts is increasing. However, in the Arctic, the kind of long-term monitoring programmes needed to apply statistical techniques for detection of early warning signals of regime shifts is largely lacking (Scheffer et al. 2009; 2012). Knowledge about the structure and function of systems prone to regime shifts is needed to better select observable indicators for early warnings. We hope our review has helped to identify key variables that can serve as indicators of multiple regime shifts through the set of drivers presented or the feedbacks available at the Regime Shifts Database.

FIGURE 3.7 **Cascading regime shifts**

Climate-related drivers, particularly climate change, are central to the set of drivers that cause Arctic regime shifts. Some of the Arctic regime shifts have impacts on climate regulation, so they can act as drivers of other Arctic regime shifts or potentially trigger cascades of other regime shifts outside the Arctic.



Spatial heterogeneity might reduce the likelihood of synchronization in time and scaling up in space of many regime shifts (Brook et al. 2013). Yet the Arctic landscape is characterized by large and continuous areas of ice, boreal forest, tundra or permafrost. Mapping vulnerability to regime shifts, the spatial scope of their drivers and potential impacts on ecosystem services is at the frontiers of Arctic research. As suggested by our analysis, the Arctic is likely to be a region where regime shifts scale up and generate cascading effects within and outside the Arctic. Assessing the likelihood of these teleconnections requires better understanding of the spatial dynamics of drivers and feedbacks.

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CHAPTER 4

What factors build or erode resilience in the Arctic?

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Key messages

- The ability of people to self-organize underlies resilience in the Arctic. The erosion of this ability is found in all cases we examined that exhibited a loss of resilience. Self-organization requires knowledge, local-level monitoring, and the ability of people to define problems and implement an agreed-upon plan.
- Historically, many policies of Arctic nations have eroded and restricted self-organization, but adopting new policies that enable and support it can build resilience.
- The ability of people to navigate change and uncertainty, nurture diversity, and learn by combining different types of knowledge also contribute to resilience, though not as strongly as the ability to self-organize. It is important to improve monitoring of these capacities.
- There are multiple examples of Arctic people transforming how they live and connect to nature while maintaining their identity. We found cases of communities developing new forms of art, food production and tourism. These transformations are not well understood, but there are substantial opportunities to learn from both successful and unsuccessful examples of transformation.

Maia C/Flickr

Inuit Bird by Toonoo Sharky: Art has supported the Inuit of Cape Dorset as hunting has become a less viable form of livelihood.

4.1 Introduction

Resilience, including the capacity for transformation, has always been crucial for living in the Arctic – and it is even more so amid the rapid changes taking place today. A key first step towards enhancing resilience across the Arctic is to understand the social, behavioural and ecological processes that are already building (or eroding) resilience in the Arctic. This chapter compares 25 case studies to identify commonalities in cases where resilience has been maintained or lost, or where transformation has occurred. The findings have important implications for the design of policies and measures to build resilience in the Arctic.

The case studies, presented in Section 4.2, include examples from all Arctic Council countries, covering an array of sectors, types of actors, institutional settings, and ecosystems. Though they cannot capture the full range of different Arctics (see Chapter 2), they were chosen to provide diverse perspectives. The location and distribution of the cases is shown in Figure 4.1, p 98.

Our analysis shows that cases that possess key social-ecological attributes suggested by resilience theory are more likely to be resilient than those that lack such attributes. However, other potentially important social-ecological attributes are poorly documented or monitored. Furthermore, often policy has eroded rather than enhanced attributes promoting resilience. This chapter begins with an outline of the cases and of the methods used to select, analyse and compare them. It then presents the results of the comparisons, and concludes with reflections on what is needed to both monitor and build resilience across the Arctic region, based on this analysis.

4.1.1 Living with change and unpredictability

Arctic people are accustomed to an environment with a high degree of unpredictability, and have adapted to this. Reindeer herders adjust their migrations depending on snow and ice cover and quality, for instance, and move to highlands to get away from pests (Forbes et al. 2009). Even communities that maintain their traditional livelihoods and culture have adopted useful new technologies – using Facebook and mobile phones to communicate,

Nelson Minar/Flickr

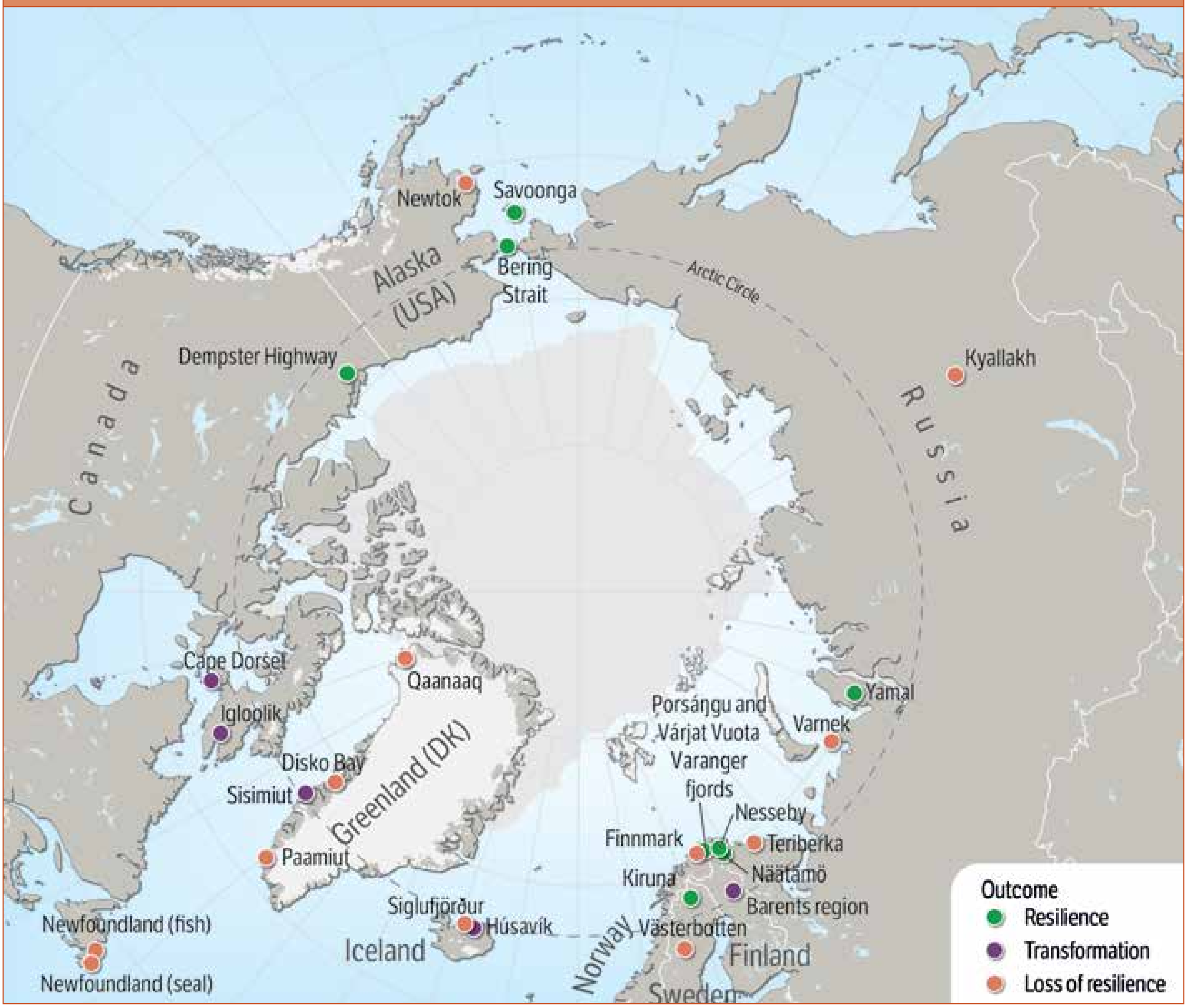
Lofoten, Norway: New economic activities, such as tourism, are reshaping communities across the Arctic.

for example. What is different now is that human activities linked to the global economy are reshaping the Arctic faster and on a larger scale than ever before.

Three key dimensions of these changes are resource extraction, social change and ecological change. Larsen and Fondahl (2015) have observed that the nations that have territory in the Arctic have long viewed it as a remote region with valuable resources to extract, often without thinking more broadly about sustainable development. The Arctic has been a hub not only for extractive industries such as oil, gas and mining, but also for commercial whaling, fishing and fur trade, often following boom-and-bust patterns (see, e.g., Haley et al. 2011, as well as Chapter 2). Resource booms have often brought new people and infrastructure to the Arctic, but they have not been well integrated with local people, livelihoods or infrastructures, with negative impacts on communities and ecosystem functioning (Larsen and Fondahl 2015); for an example, see the Teriberka (Russia) case study in Section 4.2. The extent of these boom-and-bust events has varied, depending both on local conditions and on colonialism and its legacy in different places. The extent of the impacts depends in part on the available alternatives (e.g. employment and livelihood options), as well as the relative volatility of the industry and how well higher levels of governance have worked to address the impacts.

Externally driven migration, investment and development – all largely related to oil, gas and mineral extraction – are transforming Arctic societies. Climate change is also reducing many of the costs of entering and working in the Arctic, attracting new actors and activities. These external drivers, combined with historical and

FIGURE 4.1 **Map of the Arctic region, showing the location and type of each case study**



Ninara/Flickr

Teriberka, Russia: While resource booms have often brought new people and infrastructure to the Arctic, they have often not been well integrated with local people or livelihoods.

current colonial relationships, have affected settlement patterns, infrastructure development, languages, education systems, diets and cultures in the Arctic.

The ecological changes taking place in the Arctic are similarly complex. Major external drivers include climate change, the long-distance transport of air pollutants, and long-distance migrations of animals and movement of plants. However, although the extent and novelty of these changes pose new challenges, many Arctic communities are more concerned about acute disturbances related to geopolitics and mineral resource extraction. For example, reindeer herders in the Arctic are exposed to ecological pressures driven by climate change, but their most immediate problem is that their migration area is shrinking due to encroachment from mineral extraction (Yamal-Nenets in Russia, Sámi in Sweden) as well as agriculture and tourism (Sámi in Norway).

Governmental interventions in the Arctic have often reduced resilience, disrupting many of the structures and processes that nurture resilience by limiting people's ability to move, imposing forced schooling, and restricting hunting and other food-gathering activities. Yet Arctic nations could instead invest in supporting capacities that enable local people to construct their own resilient futures. For example, on St. Lawrence Island (US), the Yupik whalers in Savoonga created a new whaling season in response to changing weather and ice conditions (see Section 4.2). This was possible due to local knowledge and organization, but also because of sufficient flexibility in international whaling law. Examples like these can provide valuable insights for the Arctic Council and its members.

4.2 Comparing case studies across the Arctic

This chapter uses a set of case studies to paint a pointillist picture of the Arctic that, from the bottom up, captures some of the rich diversity than can be missing from top-down assessments. The case studies illustrate different ways in which local people have managed to navigate multiple drivers of change, shocks and sometimes regime shifts (see Chapter 3). Understanding the complexity of Arctic change and people's responses to it requires approaches that combine social and ecological perspectives to examine the interactions and feedbacks at play (see Chapter 1). As discussed in more detail in Section 4.3, we apply a resilience framework to link together biophysical and social changes in order to assess what social-ecological features of the cases build and erode resilience.

We used a standardized template to collect information from the cases, based on a template developed for the Regime Shifts Database framework (Biggs, Peterson, et al. 2015), and then coded the cases using the selected resilience framework (Berkes et al. 2003; Biggs, Schlüter, et al. 2015). The complete case templates used for the

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The fishing and whaling community of Húsavik, Iceland, has successfully shifted to tourism-based livelihoods, notably whale-watching.

analysis are available at http://stockholmresilience.su.se/ARA.

Each case study represents a perspective on a place based on multiple strands of expert knowledge, and on a facet of the many activities and aspects of life in these places. Although the case studies focus on particular time frames, most build on centuries of history. As discussed in more detail below, the cases are presented in three categories: as examples of resilience, loss of resilience, and transformation.

4.2.1 Case study selection and classification

The case studies were selected to illustrate the diversity of challenges that communities face in the Arctic. They span a range of countries, ecosystems and cultures. They include people with a variety of livelihoods who face both unique and shared challenges. Four sets of shared challenges are found across the cases. Several cases relate to reindeer husbandry and caribou hunting, and fishing and marine mammal hunting, two sets of activities that are particularly relevant to the food security, culture and identity of many Arctic peoples. A third set of cases relates to physical relocation of communities, as these cases capture the extreme options that communities face when changing conditions make a central aspect of their way of life infeasible. These relocations are difficult and challenging, and learning from others' processes can hopefully avoid previous mistakes and learn from successes. A fourth set of cases relates to the arrival of new actors and/or activities, such as companies pursuing mineral and gas exploration and shipping. These cases are relevant throughout the Arctic as many new activities and actors enter the Arctic, reshaping already existing relationships, collaborations, tensions and pressures on Arctic social-ecological systems.

The case studies are based on published peer-reviewed and grey literature provided by Arctic Resilience Assessment workshop participants and their networks. In many cases, we supplemented or confirmed the interpretation of the literature material through personal communications with case experts. The final selection of cases represents a geographically diverse selection of cases where sufficient knowledge was available to code each case. Almost all of the case information was reviewed by a case expert, who has research, professional or lived experience of the case. Our coding methods are described in more detail in Appendix 4, and a sample of the case study template is provided at http://www.stockholmresilience.org/ARA/resilience-template.html.

The review below groups the cases based on the outcome noted above: (maintained or increased) resilience, loss of resilience, and transformation.

Cases exhibiting **resilience** are those in which the social-ecological system has been able to maintain its identity, function and structure despite changes in the broader social or ecological context. It has the ability to self-organize and the ability to experiment, learn and thus adapt

(Berkes et al. 2003). An illustrative example, described below, is the Yamal-Nenets, a reindeer-herding community in Western Siberia that has withstood changes due to climatic variability, changing Russian political regimes and industrial development, and still conserves its livelihoods and traditions (Forbes et al. 2009).

Cases exhibiting **loss of resilience** are those in which there has been a loss of livelihoods, identity, function and structure. An illustrative example is the community of Teriberka, Russia, where a former reindeer herding and fishing community was transformed into an industrial fishery during the Soviet era. A series of major changes as well as failed plans have greatly reduced local capacity to develop alternative strategies (traditional knowledge was lost). The outcome is a community in decline with significant out-migration, unemployment, deteriorated infrastructure and high food prices.

Cases exhibiting **transformation** are those in which people have acted to purposefully modify the system's identity, function and structure to better suit their needs (Folke et al. 2010). An example is Húsavík, Iceland, a fishing and whaling community that successfully shifted to tourism (whale-watching) after the traditional livelihoods became infeasible. Transformative capacity is an aspect of resilience, but it does not guarantee success in the long term; stabilizing the new transformed state depends on various conditions (e.g. windows of opportunity, political climate). Apart from the Cape Dorset case, the transformation cases collected are too young to assess whether the long-term outcome is truly a success.

4.2.2 Case studies of resilience

Savoonga: Maintaining traditional Yupik whaling practices

Location: Alaska, US

Key reference: Noongwook et al. (2007)

Savoonga is a Yupik village located on St. Lawrence Island in the Bering Sea. Bowhead whales migrate by St. Lawrence Island with routes and timing that depend on sea ice seasonality. Whaling has a long history in Savoonga. It was re-established in the 1970s, after nearly a century in which it was not practiced. However, due to climate change and associated changes in sea ice seasonality, the whaling season stopped corresponding to the whale migration. Climate change has led to later formation of sea ice in the fall, so the bowhead whales migrate south while there is still open water.

The Yupik whalers in Savoonga created a new whaling season in response to changing weather and ice conditions. This allowed them to hunt from the village, in November and December, rather than having to cross the island. The new whaling season was established by mobilizing Indigenous Knowledge – in particular, the Yupik concept of ecological stewardship "yaayasitegpenaan", observation and organization based on a strong connection between people and nature. Flexibility within international law also helped enable this change.

Ben Matheson/KNOM Radio Mission

On St. Lawrence Island, Alaska, the Yupik whalers in Savoonga have created a new whaling season in response to changing weather and ice conditions.

Dempster Highway: Highway development and the Porcupine caribou herd

Location: Yukon and Northwest Territories, Canada

Key references: Padilla and Kofinas (2014); Bali and Kofinas (2014)

The construction of the Dempster Highway in the 1960s, together with the introduction of new hunting strategies, made remote communities and caribou more accessible. This transformed local social systems and how they managed their primary resource: the Porcupine caribou herd. Historically, indigenous local populations had a migratory lifestyle, but the highway's construction triggered a shift to a more sedentary settlement and the introduction of new hunting strategies.

Fearing that the caribou migratory route would be affected and population would decrease, policies were changed to include local people in the management of the herd through co-management. Co-management between the Yukon territorial government and indigenous leaders on the Porcupine Caribou Management Board enabled Indigenous Knowledge to be used in management and demonstrated the scope for integrating different interests, scales and knowledge types in management and governance. The case also demonstrates the challenges of co-management when there are conflicting views regarding land use and management.

Näätämö River: Skolt Sámi salmon fishing and river restoration

Location: Finland

Key reference: Mustonen and Feodoroff (2013), supplemented by a personal communication from T. Mustonen, January 2014

Ville.fi/Flickr

Neiden District, northern Norway: Skolt Sámi people have adapted to the decreasing salmon population by fishing for other species.

Skolt Sámi fishing communities have relied on the highly productive salmon population of the Näätämö River, located between Finland and Norway, for decades. Not only are the salmon a source of food, but salmon and salmon fishing are deeply embedded within Skolt Sámi traditions and culture. However, climate change, mining, aquaculture, and tourism development are now threatening the Näätämö River salmon population, and as a result, the Skolt Sámi way of life.

The communities have used their traditional holistic view of people and nature to cope with these stresses and to guide efforts to restore the Näätämö River. For example, having more sensitive, locally devised indicators of environmental change than the national regulatory parameters has allowed them to detect and address the

Astrid Van Wesenbeec/Flickr

Dempster Highway, Canada: Out of concern that the caribou migratory route and population would decrease with the construction of the highway, policies have been changed to include local people in the management of the herd.

Andriy Baranskyy/Flickr

There is a risk that mining operations could cause part of Kiruna, Sweden, to collapse, so there are plans to move the centre of the city 3 km to the east.

changes in a pre-emptive fashion. They have also adapted by shifting their fishing effort to other fish species that inhabit the river.

Skolt Sámi fishing communities are currently demonstrating resilience, but the scale of existing challenges (development, climate and institutional) will affect their ability to maintain the state of the river. There is tension among multiple actors in the region over how to use and manage the landscape, but the authority of the Skolt Sámi Village Council over salmon in Näätämö River is recognized by the Finnish government.

Kiruna: Relocation for mining activities

Location: Sweden

Key reference: Nilsson (2010)

Kiruna is a town of 20,000 people about 145 km north of the Swedish Arctic Circle. The town was established in 1900 for iron mining. Today, the mine is the largest underground mine in the world, and the parts of the town on top of the mine and are at risk of collapsing. Kiruna Municipality, advised by the Swedish state-owned mining company Luossavaara-Kiirunavaara Aktiebolag (LKAB), decided to relocate the affected parts of the town about 3 km east. The process began in the early 2000s and will be completed in the coming decades.

The ability and willingness to move the town demonstrates resilience, despite the economic, technical and social difficulties involved. The high value of the iron ore to the city and nation, together with well-coordinated connections between the mining company and the municipality, have made it possible to move the town despite the economic, technical and social difficulties involved. Still, it is unlikely that this could have been achieved without substantial support from the national government.

Porsáŋgu and Várjat Vuota Varanger fjords: Social-ecological change in coastal communities

Location: Norway

Key references: Broderstad and Eythórsson (2014); Sundby and Nakken (2008)

Coastal communities along the Porsáŋgu and Varjat Vuota fjords in Norway have suffered due to declines in coastal cod populations, which may be due to multiple ecological regime shifts (see Chapter 3). Cod have disappeared from local spawning sites, and the overall cod stock is low. Kelp forests have declined due to an increase in sea urchins. Harp seals have migrated, and the red king crab, an alien species without local predators, has been introduced.

The communities living along the shore are heavily dependent on fishing for both their economic and cultural well-being. The region's ecological changes have triggered several social and governance responses in order to maintain the benefits from the fishing industry, and the Sámi Parliament has strongly advocated for the communities. To date, these responses have enabled these communities to adapt to the changes and thereby maintain their livelihoods.

Unjarga/Nesseby: Adaptation of local sheep farming and reindeer herding to moth larvae outbreaks

Location: Norway

Key reference: Rybråten and Hovelsrud (2010)

In Unjarga/Nesseby, Norway, there were extensive caterpillar outbreaks between 2005 and 2009. These outbreaks, believed to have been caused by milder climate and changing seasonality, have resulted in the reduction

Gunn Nilsen/Flickr

Shepherds in Nesseby, Norway, have adapted their grazing practices to include wavy hairgrass, which has allowed for local livelihood practices to persist despite caterpillar outbreaks.

of grazing land, affecting both shepherds and reindeer herders. They also caused extensive defoliation of birch forest and damage to heath and berry plants, which have reduced the food available to moose and ptarmigan populations and led to their decline.

However, the outbreaks also caused an increase in wavy hairgrass, a useful species for both sheep and reindeer. This increased the availability of an alternative grazing source, providing a way to cope with the immediate impacts of the outbreak. Shepherds and later reindeer herders adapted their grazing practices to include wavy hairgrass, which allowed for local livelihood practices to persist despite the outbreaks.

Reindeer herding in the Yamal-Nenets Autonomous Okrug

Location: Yamal Peninsula, Russia

Key references: Forbes (2009); Degteva and Nellemann (2013); supplemented by a personal communication from S. Mathiesen, January 2014

Reindeer herding is an important livelihood for many communities across the Arctic. On Russia's Yamal Peninsula, an increase in gas exploration and transportation infrastructure has disrupted ecological dynamics that are important to the cultural practices and well-being of Nenet reindeer herders. The infrastructure reduces, fragments and interrupts the migration routes up and down the peninsula, requiring the herders to adapt, even as they also experience the impacts of climate change.

Reindeer herding on the Yamal Peninsula has been relatively resilient compared with other places in Siberia. This is due to relatively little interference by outside organizations, which has allowed Indigenous Knowledge to be maintained and herders to organize themselves.


Kenny Louie/Flickr

The EU ban on trade in seal products has severely affected local economies in the Arctic – for example in St. John's, the capital of Newfoundland, Canada.


Joseph/Flickr

Three main Arctic shipping routes pass through the Bering Strait, where there is a high risk of collisions between whales and boats.

Bering Strait: Arctic shipping

Location: International

Key reference: Humpert and Raspotnik (2012)

Climate change is allowing increased shipping through the Bering Strait, an important whale migration route. The narrowness of the passage brings whales and ships close together, so the increased traffic could disturb whale migrations and increase whale/boat collisions that could affect whale populations. Whales and other marine mammals are important to the livelihoods, food security and cultural identity of many Arctic people, so these collisions will also impact human well-being. The risk for whale/boat collisions and disruptions is particularly important in the Bering Strait, as the three main Arctic shipping routes pass through it. However, efforts to develop plans for this region by learning from the experience in Alaska and applying the knowledge to the Bering Strait before whale/shipping conflicts occur represents a potentially proactive approach to building resilience.

4.2.3 Case studies of loss of resilience

Great Northern Peninsula: Seal industry

Location: Newfoundland, Canada

Key references: Sellheim (2015); Barry (2005)

The Great Northern Peninsula had a commercial seal hunt that has largely been halted due to international campaigns by animal rights organizations and a subsequent EU ban on trade in seal products. These campaigns and the ban have affected communities across the North American Arctic. In this case, while the sealing communities' traditional knowledge has been maintained despite legal and external cultural pressures, the EU ban on trade in seal products has severely impacted local economies and reduced livelihood options, adding to other stresses on rural resource-dependent communities.

Finnmark: Traditional reindeer herding and development

Location: Norway

Key reference: Tyler et al. (2007)

In Finnmark, reindeer herding has been a traditional livelihood for centuries. As is the case across the Arctic, herders' cultural practices and well-being are closely linked to ecological dynamics that could change in the near future. Political, economic and social pressures have restricted herding in Finnmark both in terms of area and in its traditional practices. This case study contributes to understanding the resilience of traditional livelihoods to changes driven by climate change, energy and infrastructure development, and to the cultural conflict between an indigenous community and modern Norway. While traditional knowledge of reindeer herding in Finnmark has been a source of resilience, development continues to affect traditional practices.

Vilhelmina North reindeer herding community and reindeer husbandry

Location: Västerbotten, Sweden

Key references: Löf (2013; 2014); Sandström and Widmark (2007)

In Västerbotten, in northern Sweden, reindeer herding has long been a traditional Sámi activity. The Vilhelmina North Sámi reindeer herding community has been forced to change its reindeer herding practices due to climate change, increased motorization, and reduced freedom of movement across the landscape. While technological innovations have enabled adaptation of reindeer herders' activities, they have also eroded Indigenous Knowledge. Institutional inconsistencies in Sweden have provided little protection for Sámi reindeer herders, and often inhibit innovative responses. Technological, social, and governance change have decreased the diversity of herders' strategies and inhibited adaptive strategies, reducing the resilience of reindeer herding.

Teriberka: Gas and institutional drivers

Location: Russia

Key references: Mikhailov (2014); Mel'nikov and Kalashnik (2012); Mineev (2010)

Teriberka has undergone a series of resource booms and busts since the 1960s that have greatly reduced the villagers' resilience. The main economic activities were originally reindeer herding and coastal fishing, but in the Soviet era, collectivization and nationalization efforts transformed the local economy. First, Teriberka became the region's main hub for industrial fishing, but later the hub was relocated, in essence eliminating the local fishing industry. Then a shipyard was built, bringing new economic activity, but it was subsequently closed.

Since the dissolution of the Soviet Union, the village has been socially and economically isolated due to the poor quality of the roads and degrading infrastructure. This isolation has resulted in landfills full of waste, high food prices, and a scarcity of needed health services. The village has been in constant decline, many residents have left, and unemployment is high. In the early 2010s, economic activity surged as part of the development of the Shtokman gas field, including the start of infrastructure development. However, following the collapse of global oil prices in 2014, the development ground to a halt.

Svein Mathiesen/International Centre for Reindeer Husbandry

Reindeer herding on the Yamal Peninsula: Because there has been little outside interference in this community, it has been relatively resilient.

Varnek: Shipping in the Barents Sea

Location: Russia

Key reference: Davydov and Mikhailova (2011)

The Nenet residents of the village of Varnek on Vaygach Island, in the Russian Arctic, are expanding their use of resources as ship traffic increases. The main challenge associated with increasing ship traffic is that a growing number of island visitors are transforming the local traditional economy. Residents exchange local traditional food (fish, berries, etc.) for goods (mostly alcohol) brought by visitors. The exchange has had negative social consequences for traditional economic activities, since natural resources are being collected for both residents' consumption and for visitors. In order to gather enough exchange goods, Nenets sometimes break hunting rules and become poachers, and also suffer the negative impacts of increased alcohol consumption. Additional impacts of increased ship traffic are collisions and pollution.

gerogeri/Flickr

Lena River, Siberia: After several catastrophic floods, the government of Sakha, Russia, decided to relocate the most affected villages.

Kyallakh: Flooding and relocation

Location: Russia

Key reference: Filippova (2011)

Kyallakh village is on an island in the Lena River that has experienced an increasing number of climate-related catastrophic floods. After several catastrophic floods in 2002, the government of Sakha decided to relocate the most affected villages. However, the local government did not adequately consider residents' needs and priorities during the relocation. The attempted relocation of the people of Kyallakh in 2005 created a variety of problems for the residents, who are mostly pastoralists, and only a few people actually moved. Those who relocated experienced major social shocks, and had difficulties adapting to the new place and living conditions. Those who did not move remain vulnerable to flooding.

Great Northern Peninsula: Cod fishery collapse

Location: Newfoundland, Canada

Key references: Hamilton and Butler (2001); Hamilton et al. (2004)

For communities on the Great Northern Peninsula, cod fishing was essential for the economy, culture and well-being. However, the cod catch and cod stocks collapsed in the early 1990s due to intensive fishing from large, non-local boats and the arrival of cold waters. The cod collapse resulted in a moratorium on cod fishing in 1992. This may have led to a marine food web regime shift. Shrimp were already increasing before the cod collapsed, but the cod collapse likely influenced the shift.

Fishing shrimp replaced cod fishing, and a special 1997 shrimp quota helped this region immensely. However, many fishing jobs were lost, which led to a strong out-migration of youth to towns in other parts of Canada. This loss of human capital, in turn, made it difficult to build new, diversified livelihoods for resilient communities, and government policies to facilitate the relocation of remote fishing villages further reduced resilience. While this case is set in the sub-Arctic in Newfoundland, the impacts of rapidly changing fish stocks and influence on industrial fishing fleets are relevant to many areas in the Arctic.

Newtok: Climate change-driven relocation of coastal indigenous communities

Location: Alaska, US

Key references: Bronen (2011), Lovecraft and Eicken (2011)

The Yupik people of Newtok in western Alaska have lived on the Bering Sea coast for at least 2,000 years. However, climate change has caused rising temperatures, melted

Pierre Lesage/Flickr

The Great Northern Peninsula, Canada: Here, as in many areas of the Arctic, changing fish stocks are having a big impact on industrial fishing.

sea ice, and altered precipitation patterns. Increased wave action, combined with thawing permafrost, has increased coastal erosion. In a number of places, including Newtok, erosion is seriously threatening coastal communities and has led to plans for relocation.

Newtok is the furthest along in its relocation plans. However, developing these plans is complicated by cultural, financial and in particular unclear jurisdictional conflicts that impeded the development of alternative strategies. While the community has identified and supports a new location, the costs for relocating and building a new village are too high for the community. US government agencies could provide funding for the relocation, but an unclear division of responsibilities and regulatory confusion have inhibited government responses. Furthermore, it is unclear how to address the need to relocate while avoiding the problems that previous forced relocations of indigenous communities have created.

Paamiut: Cod to shrimp fishery transition

Location: Greenland

Key reference: Hamilton (2007)

The cod fishery in Paamiut developed slowly compared with those in neighbouring towns (e.g. Sisimiut). However, the Danish government invested in the industry here and built the town up as a specialized cod centre. The heavy emphasis on cod contributed to a lack of diversity in other skills and initiatives in Paamiut, and when cod disappeared, the entire economy and community suffered. The region may have experienced a marine food web regime shift, because other species have started to appear on the shores of Paamiut (e.g. shrimp, snow crabs). However, the local industry was slow to build new infrastructure to target these new species.

Paamiut demonstrates that access to natural resources does not guarantee prosperity, but rather it depends on the human and social capital of a community. In this case it may be that highly specialized external investment left Paamiut in a less adaptive state, by producing a non-diverse, brittle set of livelihoods that were not flexible when confronted by change.

Disko Bay: The impact of sea ice reduction on resource-dependent communities

Location: Greenland

Key references: Ford and Goldhar (2012); Holm (2010)

The town of Qeqertarsuaq and the village of Qeqertaq in Disko Bay have mixed economies that rely both on subsistence hunting and fishing, and on wage employment in commercial fishing, the public sector and tourism. The communities are closely connected to the local environment and dependent on natural resources. The average temperature in Disko Bay has increased by 3.5°C over the past three decades. Sea ice cover has decreased by about

Patrick Müller/Flickr

After the collapse of cod stocks, the Paamiut fishing industry in Greenland has been slow to build infrastructure to target new species, such as shrimp.

euphro/Flickr

Loss of mobility is a key factor affecting the resilience of communities in the Qaanaaq district of Greenland.

half; the timing of sea ice has shifted, and the duration of ice cover has decreased. The warmer climate and reduction in sea ice have altered the distribution, migration and behaviour of marine mammals, birds and fish.

These changes in local ecosystems have triggered changes in communities' living conditions and livelihoods, such as shifting from hunting and fishing on the ice to the open sea, as well as changes in transport, food security, safety and gender roles. Although local residents are learning to cope with continual changes in ice conditions, government regulations and new living conditions limit local residents' ability to be as flexible and mobile as they need to be in their response to environmental change.

Qaanaaq district: From migratory fishers and hunters to relocated communities

Location: Greenland

Key references: Hastrup (2009b); Sørensen (2010)

Thule, Siorapluk, and other communities in the Qaanaaq district of Greenland have subsisted on hunting and fishing for thousands of years. These activities rely upon the ability to travel across ice. Culture and social capital also rely upon this mobility, as families travel between towns to visit and help one another, and such mobility is essential for many cultural practices. Climate change is shortening the duration of the ice cover, reducing mobility and making traditional modes of fishing and hunting more difficult and more dangerous. This loss of mobility is a key factor driving young people to towns and cities, undermining traditional livelihoods and local practices and thereby decreasing the resilience of these communities.

Göran Ingman/via Flickr

Changes to local ecosystems in Disko Bay, Greenland, have triggered changes in communities' living conditions and livelihoods.

Sela Yair/Flickr

Investing only in herring fishing has reduced the resilience of the fishery industry in Siglufjörður, Iceland.

Siglufjörður: Collapse of the herring fishery

Location: Iceland

Key references: Hamilton et al. (2004); Hamilton et al. (2006); Feldental (2013)

Siglufjörður is a small town on the northern coast of Iceland that was once the country's herring capital. The industry collapsed, partly due to over-exploitation, but also due to changes in water conditions that reduced the availability of herring. Investing in and focusing on a single activity and species reduced resilience to disturbances to the fishery. Siglufjörður's economy and existence were centred on the herring fishery, with few other livelihood options. In recent years there have been efforts to diversify the economy and build faster transport connections, but their impact cannot yet be evaluated.

4.2.3 Case studies of transformation

Cape Dorset: From nomadic hunters to international art sensations

Location: Nunavut, Canada

Key references: Rathwell and Armitage (2016); Coward Wight (2012)

The Inuit of Cape Dorset have navigated a transformation from nomadic hunters to internationally recognized artists. They have adapted their cultural practices to transmit knowledge between generations and cultures, and to nurture resilience during change and transformation over the past 60 years. The Cape Dorset Inuit have thus demonstrated resilience to the systematic repression of their language and culture by the Canadian government, as well as to dramatic changes in the sea ice that is vital to Inuit food security and well-being. Inuit craft traditions have been adapted and taught, so local artists and artisans can produce art for international markets. The Cape Dorset Inuit have also used art as a way to communicate ecological change and Indigenous Knowledge, both to local youth and to global decision-makers.

Sisimiut: Cod to shrimp fishery transition

Location: Greenland

Key References: Hamilton (2007); Hamilton et al. (2003)

Sisimiut has a historically diverse economy and strong social capital, with many locally driven initiatives. Greenland experienced a cod-to-shrimp transition in the 20th century, mediated by climatic changes and overfishing. This transition is similar to those of other Atlantic fisheries. Sisimiut was able to make use of shifting natural resources and quickly adapt to changes. Diversification of resources allowed Sisimiut people to change their economy in response to the decline of the cod fishery. After snow crab populations started to appear around Sisimiut, it became a centre for this new fishery. Today, snow crab makes up only a small part of fishery landing values in Greenland, while shrimp and halibut are the two main species.

Metal mining for northern communities

Location: Barents Region, Finland

Key reference: Suopajärvi (2013)

In the Barents Region in northern Finland, there are immense reserves of raw materials, including gold, nickel, chromium, iron, zinc and copper. However, the mining industry has considerable environmental and social impacts. Environmental impacts include pollution of water, air and soil, loss of biodiversity, and destruction of landscapes. From a social perspective, the harsh working conditions in the Arctic winter and health issues for workers are of particular concern. A variety of regional and international initiatives, including laws, regulations and certifications, are being developed and implemented within the region to enable industrial development in a way that reduces environmental and social impacts. These changes demonstrate a shift in the thinking behind mining operations, recognizing that mining relies upon and affects the social-ecological systems in which it is embedded. This shift is transforming how the industry operates.

Timo/Flickr

Chromium mining in northern Finland has considerable environmental and social impacts.

Húsavík: From fishing to whale-watching tourism

Location: Skjálfandi Bay, Iceland

Key references: Einarsson (2009; 2011)

Iceland's industry has historically been dominated by fishing. However, over the last few decades, changes in international regulations affected the productivity of the fishing sector. Employment in fishing communities declined due to reduced cod quotas and the introduction of tradable quotas, which led to the fishing industry consolidating into a few larger companies. Fishing also decreased due to the international whaling moratorium, which also led to increases in whale populations. These changes stimulated a reorganization of Húsavík's fishing community to whale-watching tourism, based on a new application of existing knowledge and skills. Today, Húsavík is one of the main whale-watching hotspots in Iceland. Several other Icelandic fishing communities have made a similar transition.

Igloolik: Food security in an Arctic Inuit community

Location: Nunavut, Canada

Key references: Ford and Goldhar (2012); Chan et al. (2006); Power (2008)

Igloolik is an island community of 1,600–2,000 people, 95% of them Inuit. The food system has been transformed by Inuit people's shift from harvested traditional foods (e.g. seals, walrus, caribou), to a dual system that combines traditional foods with store-bought food imported from mainland Canada.

Food security can be defined in terms of food access, availability and utilization. While this transformation has greatly increased food availability, and snowmobiles have greatly increased access to wild foods, poverty, combined with high store prices, limits the ability of people to purchase food. The shift from harvested to purchased food has not been well integrated with traditional food systems, so although it has improved some aspects of food security, many people still experience food insecurity. This transformation has also weakened Inuit culture and social networks based on sharing food.

4.3 How the case studies were coded and analysed

In Appendix 4, we provide a detailed description of the methodology used to code and analyse the case studies. Below we summarize key aspects of the methodology, but first we provide a more detailed overview of the resilience framework that underpins the entire analysis.

4.3.1 The resilience framework

Resilience thinking is an approach to understanding, managing, and governing systems (Walker et al. 2012; Folke et al. 2010). A resilience assessment applies that approach to a specific social-ecological system to understand the key factors that are building or eroding resilience, often with the purpose of guiding decisions (Resilience Alliance 2010). Resilience assessments start by defining what, precisely, is being analysed: resilience *of what* (defining the system in question), *to what* (defining the disturbances being addressed)? This generally also defines *for whom* the assessment is most relevant.

In the cases examined here, the "of what" is the livelihoods of Arctic people – the ways in which they secure their material and non-material well-being from nature (Tanner et al. 2015; Chambers and Conway 1991). The "to what" differs with each case study, but typically links to a set of disturbances related to potential regime shifts and to effects from specific drivers, including a) effects of climate change; b) new political and social pressures from emerging economic opportunities such as development of oil and gas industries; c) issues related to insufficient or failing infrastructure; d) conflict with other stakeholders; e) social dynamics such as migration into and/or out of Arctic communities; and f) food security challenges.

Resilience assessments are typically participatory processes that involve a diverse set of people with different knowledge, skills and perspectives to collaboratively define how people and ecosystems systemically interact, and then identify factors that build or erode their system's resilience (Resilience Alliance 2010). They tend to be constrained to local-scale or landscape-scale case studies (e.g. a town, a city, a river catchment, a farm, a national park, a wetland), or are developed as a set of cases that share the same attributes (e.g. the coral reefs of the Caribbean).

In order to carry out a resilience assessment at the Arctic level, we needed first to make cases comparable around a theoretically grounded set of variables. Berkes et al. (2003) defined a conceptual framework of social behavioural responses that contribute to resilience. This framework was selected because it is well established within social-ecological systems research and provides a good fit with the cases analysed in the Arctic, having been developed from the comparison of similar case studies. It identifies four key behavioural responses that are required for building resilience: i) navigating change and uncertainty, ii) nurturing diversity for reorganization and renewal, iii) combining different types of knowledge for learning, and iv) creating opportunity for self-organization towards social-ecological sustainability.

In order to apply the framework to a comparison of Arctic case studies, we revised and updated the second tier of variables to make them more measureable, and added a third tier to define each of the second-tier variables and make the assessment more explicit. The variables were adopted from recent synthesis literature on resilience in social-ecological systems (Biggs, Schlüter, et al. 2015; Biggs et al. 2012; see also Figure 4.2, p. 112). By comparing cases in the Arctic, we empirically test the extent to which these behavioural responses support resilience.

4.3.2 Case study coding, calibration and notation

Each of the 25 case studies was analysed based upon a data collection template. Each case is complex and unique, but the template was used to identify patterns and commonalities across case studies.

Qualitative comparative analysis was used to investigate which behavioural responses or combinations of these responses enhances resilience (Ragin 2008). Qualitative comparative analysis is a relatively new approach that enables comparison across multiple qualitative cases, making it well suited to the nature of our cases. The method provides a formal logic to coding each case and then comparing them to identify combinations of conditions that produce a certain outcome – in this study, resilience, loss of resilience, or transformation.

The causal variables for each case study were coded using a tiered system that was designed to accommodate missing information. Each of the third-tier variables was coded as missing, present or no-information for each case study. These codes were converted into a numerical score of -1, 1, or 0. For example, if the case study mentions that there are "harvesting bans", then the variable is coded as 1; if it says there are no harvesting bans, it is coded as -1, and if there is no information, it is coded as 0. Each second-tier variable was then represented as the average of all the third-tier scores for that case. Similarly, the first-tier variables are produced from the average of the second tier variables.

Our analysis identifies what combinations of the behavioural responses discussed above are associated with resilience, loss of resilience, and transformation.

FIGURE 4.2 **Key behavioural responses, and their variables, of adaptive capacity**

The first and second tiers of variables (in bold) were adapted from those proposed by Berkes et al. (2003). The third tier was developed for this study based on recently developed principles for building resilience (Biggs, Schlüter, et al. 2015; Biggs et al. 2012).

Navigating change and uncertainty

Evoking disturbance

- Practices that initiate small scale perturbations to enhance diversity (e.g. burning, grazing)
- Management that emulates endogenous natural disturbance processes
- Avoiding suppression of endogenous disturbances

Learning from crisis

- Maintaining memory of responses to past crises
- Practices that enable social learning from novel crises
- Management models include complexity thinking (slow processes, feedbacks, adaptation)
- Single-loop learning
- Double-loop learning
- Triple-loop learning

Expecting the unexpected (living with disturbance)

- Avoiding release of key resources during disturbance
- Maintaining social response diversity (diverse livelihoods and institutions)
- Maintaining ecological response diversity (species, landscapes)
- Maintaining support areas
- Social support mechanisms (insurance; reciprocal gift-giving)

Creating opportunities for self-organization

Recognizing interplay of diversity and disturbance

- Disturbance needs memory
- Disturbance enhances diversity
- Avoiding suppression of disturbance that produces diversity
- Too much variation risks losing memory
- Not enough variation will lose diversity – experience with crisis & surprise
- Disturbance renews memory
- World view based on living with change

Accounting for external drivers

- Ability to mitigate impact of external drivers
- External restrictions on impact of drivers
- Local control over drivers

Negotiating cross-scale dynamics

- Managing slow variables
- Mechanisms to detect loss of resilience
- External subsidies that block learning about slow variables, erode knowledge
- Mechanisms to avoid external flows from eroding se memory
- Polycentric governance that is able to resolve cross-scale conflict
- Diversity and conflict resolution
- External institutions that enable local ecological knowledge generation abd maintenance

Matching ecological and governance scales

- Adaptive co-management (learning approach that links local people to larger scale management)
- Institutions match the scales of the problem
- Governance connections correspond to ecological connections

Nurturing diversity for reorganization and renewal

Nurturing ecological memory

- Biological legacies
- Mobile link species
- Managing connectivity
- Response diversity
- Functional diversity
- Harvesting bans
- Protecting key parts life cycle
- Support areas
- Managing modularity (pockets of experimentation)

Sustaining social memory

- Knowledge carriers and retainers
- Interpreters and sense-makers
- Networkers and facilitators
- Stewards and leaders
- Visionaries and inspirers
- Innovators and experimenters
- Followers and reinforcers
- Managing modularity (pockets of experimentation)

Enhancing social-ecological memory

- Stewards of wildlife habitats
- Rituals that enact social-ecological memory to practice
- Local monitoring
- Connecting across scales for ecosystem management
- Diversity of stores of social-ecological memory
- Diversity of carriers of social-ecological memory
- Institutions that operate and decide at same spatial and temporal scales as ecological dynamics
- Managing modularity (pockets of experimentation)

Combining different types of knowledge for learning

Experiential and experimental knowledge

- Monitoring programs
- Local ecological knowledge
- Mechanisms for experimentation
- Participation of different types of knowledge in management discussions

Knowledge of structure to knowledge of function

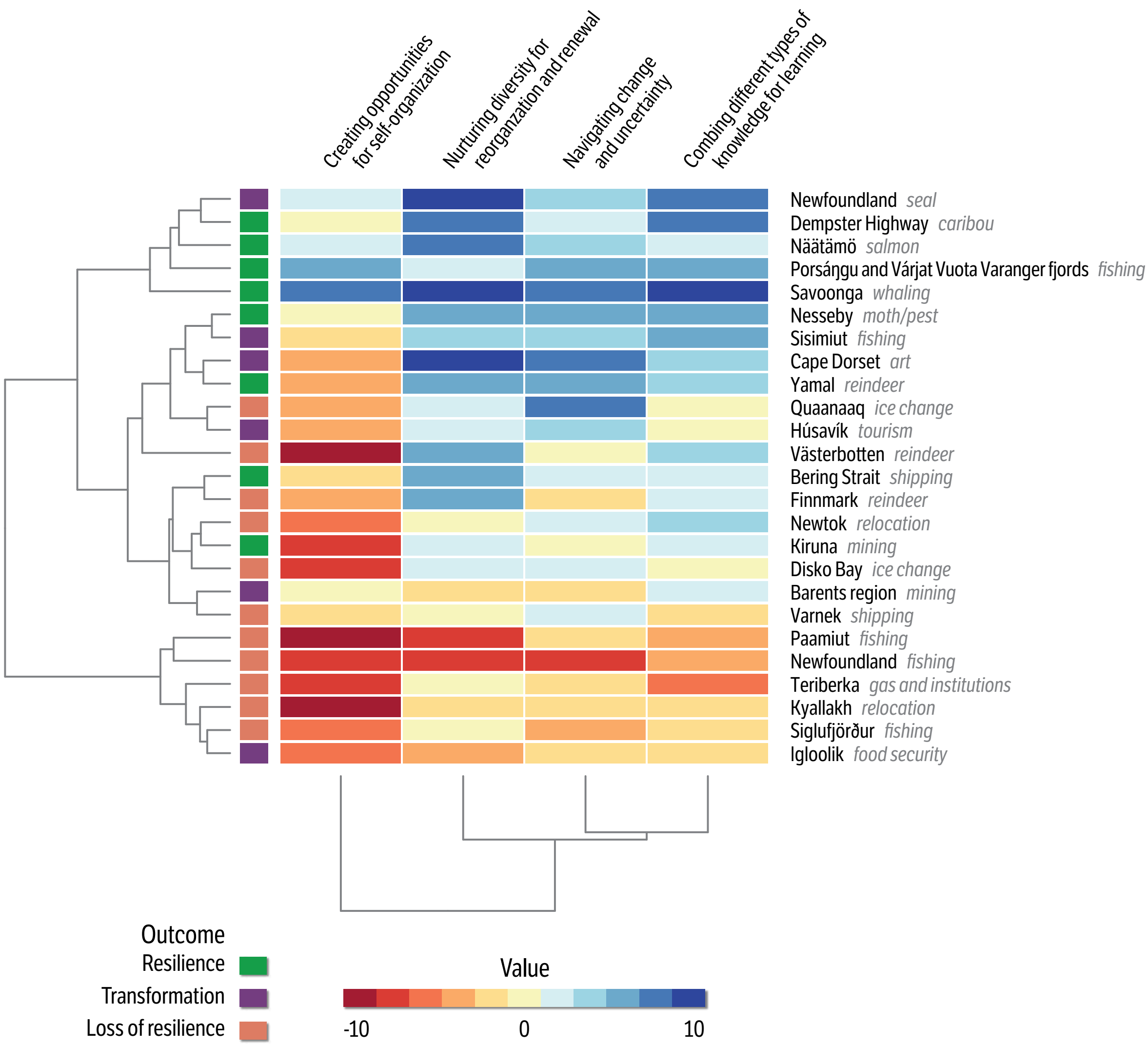
- Building knowledge of ecology into institutions (how learning about novelty is socially recorded and transmitted)
- Monitoring programmes match the scale of process of interest
- Power asymmetries are negotiated
- Feedbacks are recognized by different stakeholders
- Slow variables are clearly recognized

Fostering complementarity of different knowledge systems

- Qualitative monitoring during 'normal times'
- Refocusing scientific management on the back loop of the adaptive cycle
- Providing of long time series for understanding historical ecological context

FIGURE 4.3a **Aggregated data for the first-tier variables**

The higher the score (blue), the higher the presence of behavioural responses for adaptive capacity on the third tier of variables. Conversely, the lower the score (red), the higher the absence of behavioural responses for adaptive capacity on the third tier of variables. The column furthest to the left of the diagrams shows the output of the cases (resilient, loss of resilience or transformation). When the case information did not indicate presence or absence of behavioural responses, or when the proportion of positive and negative behavioural responses cancel out each other, the total score approximates zero (yellow) indicating maximum uncertainty. Values of responses range between -10 and 10.



It identifies behavioural responses that are "necessary" – those that are often present in the cases for a given outcome – as well as behavioural responses whose presence, or absence, can alone determine the outcome; the latter are called "sufficient" (Ragin 2008).

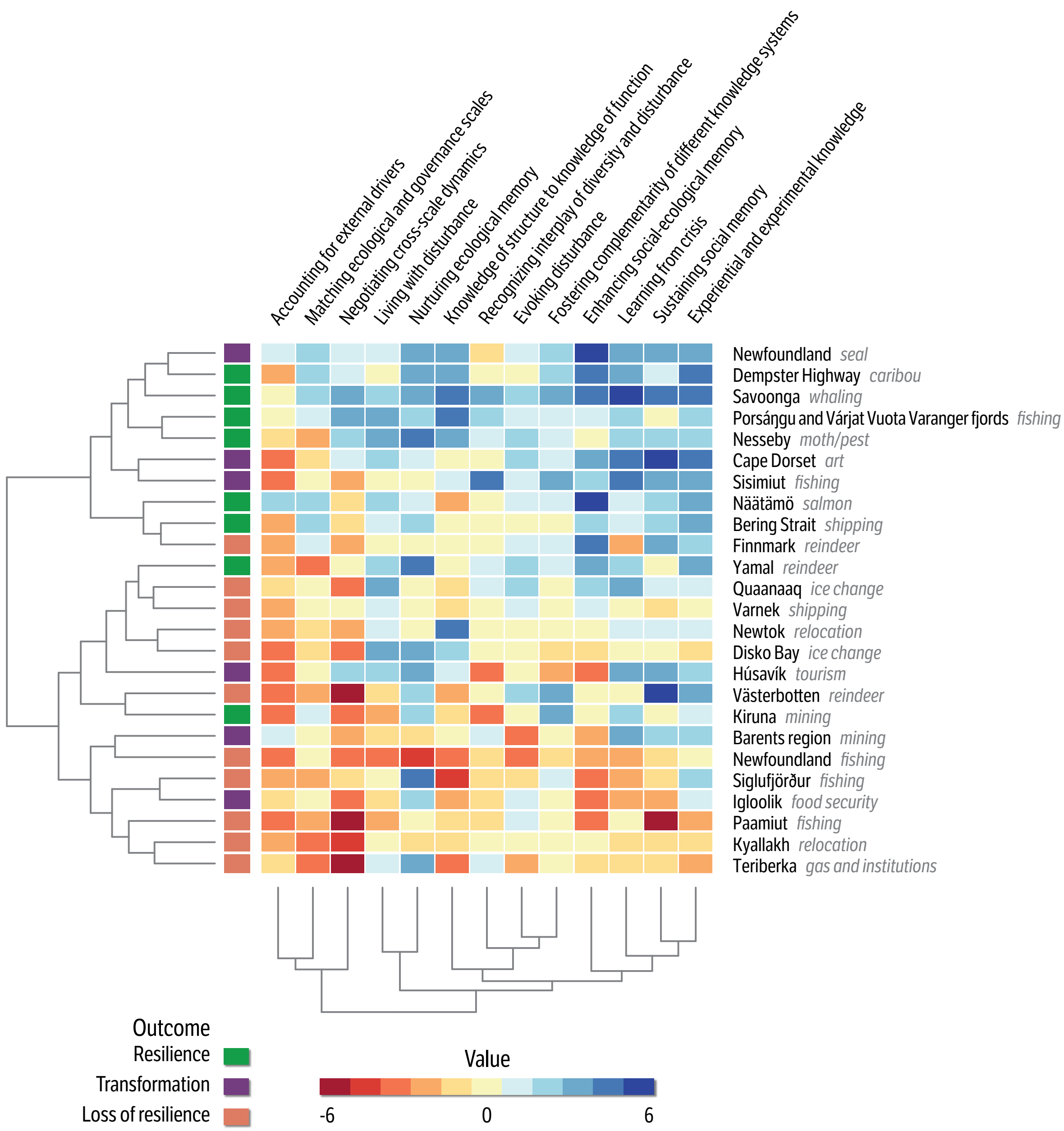
4.3.3 Case study analysis results

The analysis broadly supports the importance of all four types of behavioural response for enabling resilience and transformation in the Arctic. In particular, if systems are able to self-organize and maintain knowledge for learning, they are resilient; if they lack these responses, they are not resilient. Figures 4.4 and 4.5, pp. 115–116, show which individual and combinations of variables best explain the variation in outcomes among the cases.

The sufficient condition for cases exhibiting resilience was self-organization – significant capacity for decision-making and implementation of responses to change (SFO). While the other factors promote resilience, a high score on self-organization alone is sufficient to enhance resilience in a case. The necessary conditions of resilience cases are characterized by a combination of conditions

FIGURE 4.3b Aggregated data for the second-tier variables

The higher the score (blue), the higher the presence of behavioural responses for adaptive capacity on the third tier of variables. Conversely, the lower the score (red), the higher the absence of behavioural responses for adaptive capacity on the third tier of variables. The column furthest to the left of the diagrams shows the output of the cases (resilient, loss of resilience or transformation). When the case information did not indicate presence or absence of behavioural responses, or when the proportion of positive and negative behavioural responses cancel out each other, the total score approximates zero (yellow) indicating maximum uncertainty. Values of responses range between -10 and 10.



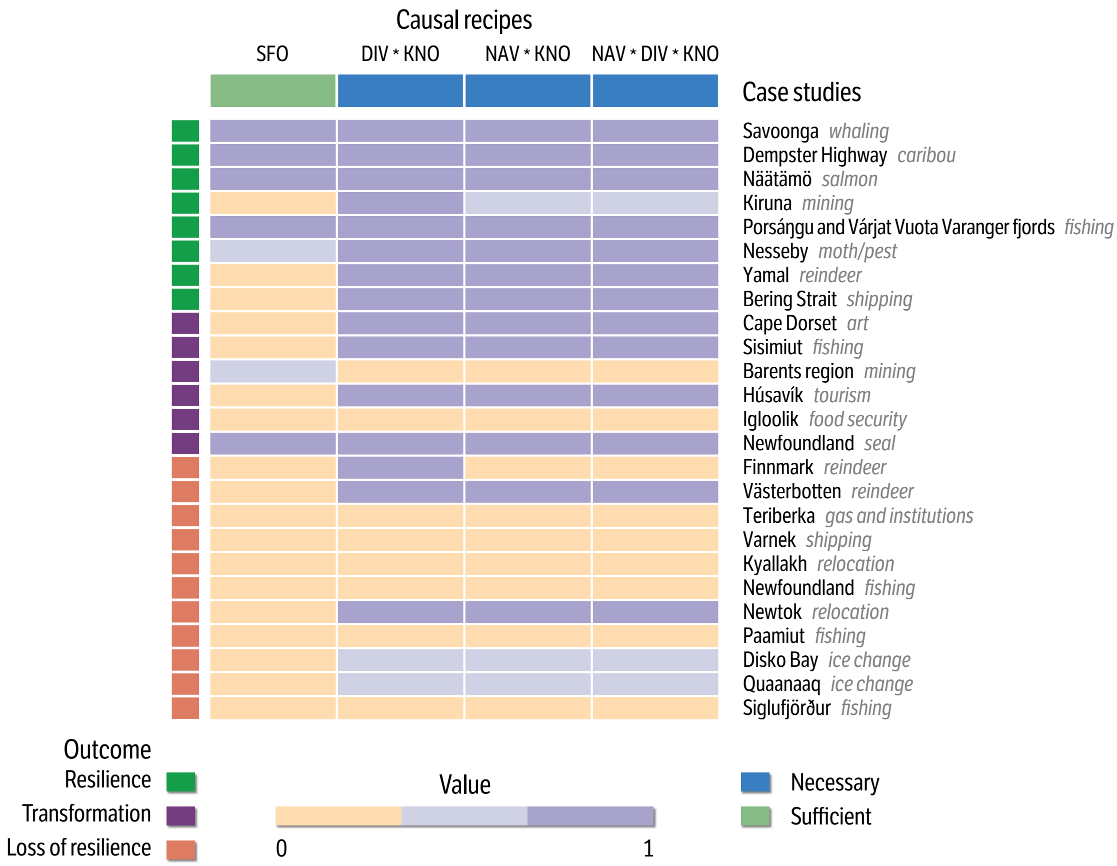
rather than single conditions (Figure 4.4). These combinations include:

- Drawing on diverse knowledge sources in responding to change (KNO),
- Nurturing diversity for reorganization and renewal (DIV); and
- Learning to live with change and uncertainty (NAV).

The second-tier variables that were present in resilient cases are enhancing social-ecological memory, learning

FIGURE 4.4 **Analysis of necessary and sufficient behavioural responses of cases exhibiting resilience**

The causal "recipes" are along the tops of the columns as sufficient behavioural responses (green) and necessary behavioural responses (blue) for the outcome "resilience". The behavioural responses are capacity for self-organization (SFO), drawing on diverse knowledge sources in responding to change (KNO), nurturing diversity for reorganization and renewal (DIV), and learning to live with change and uncertainty (NAV). The columns with more than one of the responses indicate that both responses are present. The side bar colours represent the different possible outcomes (resilience, transformation or loss of resilience) and the coloured matrix show the degree of membership of each case to a particular causal recipe. Values closer to zero (orange) show that the case does not belong to the causal recipe, while values closer to one (purple) show that the case belongs to a causal recipe.



from crises, and combining experiential and experimental knowledge (Figure 4.3).

A broadly opposite pattern can be seen when analysing the cases with the outcome of loss of resilience: Lack of self-organization (sfo) is a common necessary condition. Sufficient conditions for loss-of-resilience cases are:

- Low knowledge diversity (kno), or,
- The lack of learning to live with change and uncertainty, and lack of self-organization (nav * sfo).

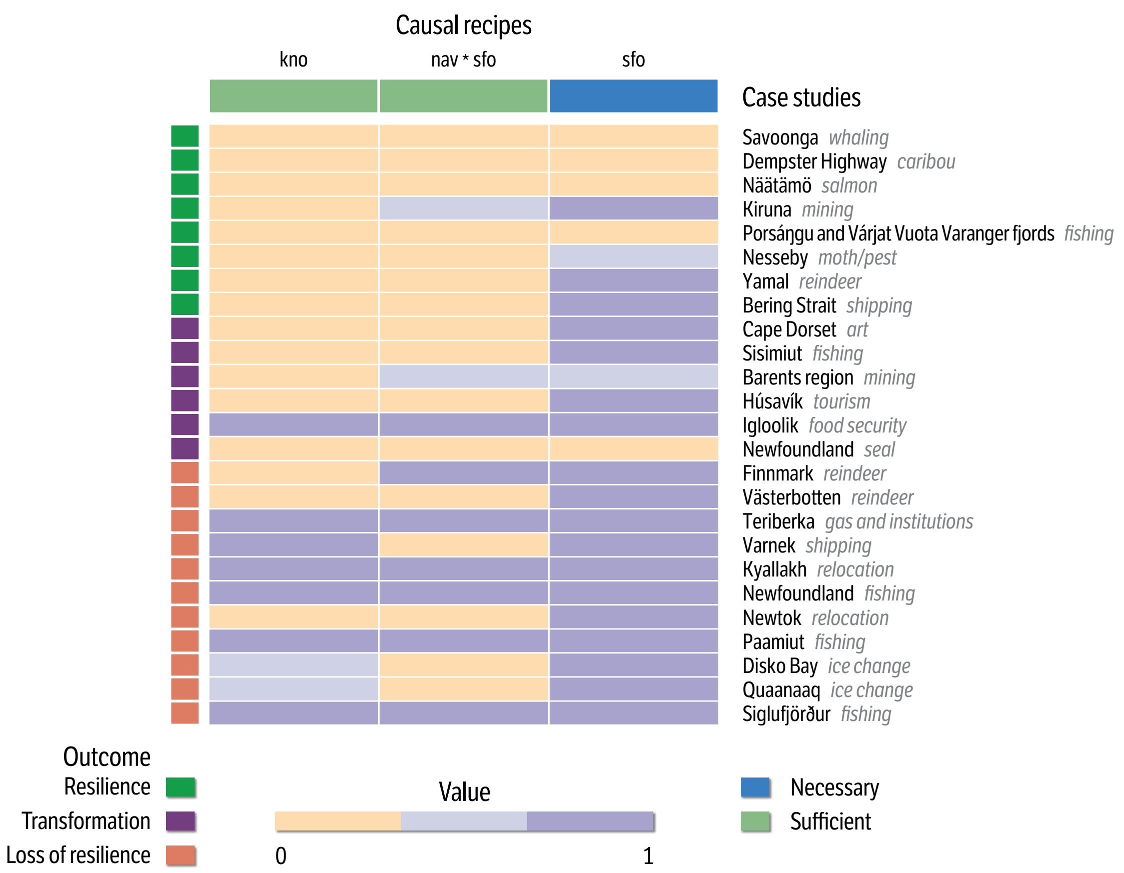
The second-tier variables that usually characterize the loss-of-resilience cases (Figure 4.3) are:

- Very poor accounting of external drivers;
- Very poor negotiation of cross-scale dynamics (decision making at different levels);
- A mismatch of knowledge of structure and function of the system; and
- Eroded social-ecological memory.

The transformation cases are more similar to the resilience cases than the loss-of-resilience cases. While the small number of transformation cases does not provide enough information to draw solid conclusions, preliminary insights can be identified. Figure 4.3 shows that transformations typically score higher values for

FIGURE 4.5 **Analysis of necessary and sufficient behavioural responses for cases with loss of resilience**

The causal recipes are shown on the columns as sufficient behavioural responses (green) and necessary behavioural responses (violet) for the outcome "loss of resilience". The absence of the behavioural responses: capacity for self-organization (sfo), drawing on diverse knowledge sources in responding to change (kno), nurturing diversity for reorganization and renewal (div), and learning to live with change and uncertainty (nav). The columns with more than one of the responses indicate that both responses are present. The lowercase version of a code (e.g. kno) indicates absence, versus the uppercase version of the code (e.g. KNO) in Figure 4.4, which indicates presence. The sidebar colours represent the different possible outcomes (resilience, transformation or loss of resilience) and the coloured matrix shows the degree of membership of each case to a particular causal recipe. Values closer to zero (orange) show that the case does not belong to the causal recipe, while values closer to one (purple) show that the case belongs to a causal recipe.



navigating change and uncertainty (NAV) and nurturing diversity (DIV), both key components of transformative capacity. We hypothesize that transformations closer to loss-of-resilience cases, such as food security in Igloolik, are less likely to succeed in the long run than those closer to resilient cases, given the similarity of shared attributes. This is expected to be particularly important for the four transformation cases in which there is a lack of capacity to self-organize (sfo). Given the foreseeable changes for the Arctic, there is a need for more research on transformations as well as monitoring of the evolution of these cases.

This case study comparison does not address external drivers and cross-scale dynamics, an important limitation because the Arctic is strongly influenced by change driven by external, cross-scale processes such as climate change, mineral extraction and changes in mobility. Cross-scale change and resilience are discussed further in Section 4.4.3.

4.3.4 Case study analysis lessons

The key lesson of this analysis is that when Arctic resource-user communities have had wide latitude and capacity to organize their own livelihoods and institutions, they are able to be resilient regardless of their broader economic or political settings. For example, in Yamal-Nenets in Russia, reindeer herders have self-organized rotation schemes and knowledge-sharing networks to deal with climate extremes, geopolitical changes, infrastructure development and mining exploitation (Forbes et al. 2009). In other cases, local-level management and decision-making have been developed formally. For example, in Canada, a local decision-making board was established to manage caribou hunting along Dempster Highway that used Indigenous Knowledge where scientific knowledge was lacking to deal with fluctuating migration patterns, changing harvest strategies, and technological developments (Padilla and Kofinas 2014).

While self-organization provides a capacity to adapt or transform in the face of change, it is not something that is only determined by a local community. Governance institutions at "higher" levels (see Chapter 5) can either degrade or enhance the ability of local places to self-organize. In many cases the capacity of people to self-organize has been suppressed rather than enabled by rules, policy and governance. These policies have frequently produced negative social-ecological impacts, which are further discussed below. The capacity to self-organize is enhanced where institutional support is provided from higher levels in the form of rights, policies and regulation – in essence developing cross-scale governance partnerships.

The cases also demonstrate that the degree of support being provided varies greatly between cases, again highlighting the importance of being aware of the local context. What is needed to enhance self-organization varies from place to place, but generally requires investment in diverse ways in local communities (see discussion of multiple capitals in Chapter 7), which can range from access to improved communications (road, sea, air, internet), to cultural revitalization, access to high-quality education and health care, access to healthy food, and investments in green infrastructure or ecological restoration.

4.4 Case studies and cross-scale dynamics

The case study analysis captures the dynamic nature of social-ecological systems. It is also important to consider the case studies within their larger contexts, which are sometimes made explicit in the case material, but are present in all cases in one way or another. We believe there are three key cross-scale aspects of the case studies, which we discuss in turn below.

4.4.1 Case studies are linked

Larger-scale ecological and economic dynamics connect some of the cases. The most obvious example of case study linkages are several of the fisheries cases, where large-scale collapses in fisheries stocks – such as cod and herring – have been experienced locally but without explicit knowledge or understanding of these interconnections. The two cases in Greenland, Sisimiut and Paamiut, involve very different outcomes: while the former has undergone a transformation, the latter has experienced a loss of resilience. The changes leading to the outcomes were based on large investments in the same stocks that collapsed. The transformation was aided by the option to shift target – to shrimp – that have moved to nearby waters. This was not the case for Paamiut. Yet these shrimp will migrate based on climatic conditions. This is an example where coordination between the local and national and even international scales is crucial to avoid a tragedy of the commons. These stocks are harvested locally, but they are not local, and if their dynamics are not properly understood, regime shifts can occur with devastating repercussions.

Connections between industrial activity and ecosystems also link several cases. This situation can be seen where the same area is used by different actors, often with conflicting interests. For example, the Bering Strait is simultaneously used by the shipping industry as well as by migrating bowhead whales and walruses that are important for food security in the Savoonga case study, as well as other communities on either side of the Strait.

4.4.2 How regime shifts connect to case studies

Of the 25 case studies, 21 occur in social-ecological settings that are prone to regime shifts (see Chapter 3). The clearest connections between the case studies presented here and the regime shifts presented in Chapter 3 occur when the dynamics of both operate at similar speeds and in the same areas. This includes the case studies focusing on the collapse of marine resources or abrupt transitions in the composition of marine food webs and subsequent impacts on local livelihoods: the collapse of cod in Newfoundland (Great Northern Peninsula, Canada), Paamiut and Sisimiut (Greenland), the fish stocks of Porsáŋgu and Várjat Vuota Varanger fjords (Norway), or the herring collapse in Siglufjörður (Iceland).

A number of the case studies do not mention changes relating to regime shifts, meaning that no relevant regime shifts have been identified. However, this does not mean these regime shifts are absent. The case studies are described from a livelihoods perspective; they often focus on immediate problems from the communities' point of view, rather than long-term ecological or climate dynamics. Cases are also often restricted to smaller spatial scales than the scales at which regime shifts typically occur. For these reasons, while the risk of regime shifts may not have been identified, it could loom outside the focus of researchers.

In other cases, regime shifts are considered a normal source of environmental variability (see, for example,

Shifts in Greenland's ice-scape: A glacier flows through a fjord carved by moving ice. Where the glacier meets the sea, a layer of floating ice is dimpled with chunks of iceberg that have broken off from the glacier.

Hastrup 2009a; Hastrup and Olwig 2012). Regime shifts should not be confused with variability of climate or ecosystems. The review of Arctic regime shifts presented in Chapter 3 reveals that if these phenomena occur, they will be very hard to reverse, at least on human timescales (centuries). For example, the melting of the Greenland ice sheet will take centuries, but the mobility issues arising due to early ice melt are being felt now, even though the system has not yet experienced a regime shift. When dynamics do not match in time (e.g. gradual changes) and space (e.g. processes at larger scales), the connections between case studies and regime shifts are not so obvious at the local scale, but they do exist.

The mismatch between the spatial and time scales at which regime shifts occur and at which people and societies can challenge efforts to build resilience. The cases of reindeer herding in Norway and western Russia are good examples of the scale and priority mismatch. Both cases occur in areas prone to regime shifts from 1) steppe to tundra, and 2) thermokarst lakes and tundra to boreal forests. These regime shifts impact grazing areas' size and distribution. Yet reindeer herders are more concerned with immediate problems such as infrastructure development and mineral exploitation that can disturb migration routes (Yamal-Nenets), or national legislation that restricts their ability to cope with disturbances (e.g. mandatory castration that reduces the power of the herd to find food in bad winters, or tight restrictions in Norway on alternative animal feed products such as pellets).

Another good example of the scale mismatch and masking of slow variables is the case of moth larvae outbreaks in Nesseby (Norway), where sheep farmers and reindeer herders have found temporary adaptations to the moth larvae outbreaks but were not reported to be addressing continued outbreaks or the threats of increased frequency of outbreaks with climate change. The same dynamic of increasing frequency of a periodic disturbance underlies the case of flooding of the Lena River that is forcing the relocation of Kyllakh village (Russia). With increasing temperatures, thawing permafrost, and higher precipitation, rivers and their tributaries are more prone to the river channel change regime shift (see Chapter 3) and increased flood frequency. This means that these communities are facing increasingly untenable conditions and therefore need immediate attention. This is true too for Newtok and other communities in Alaska, where although not a regime shift, the increased erosion that is occurring also means that the community's future here is untenable.

4.4.3 Drivers and the case studies

Case studies are also connected to larger scales via driving forces. Drivers are processes that impact processes and functioning in the social-ecological system, but that the system is unable to control. These drivers can be bio-geochemical, such as climate change, or social, such as externally decided and enforced institutional arrangements: laws, regulations, quotas, etc.

A review of the case studies found that more than three quarters of the cases report past and/or ongoing examples where national or international institutions have a negative impact on their system by constraining the capacity for self-organization. In many of these cases, it has reduced their ability to adapt in preferred ways to ongoing changes, particularly climate change. In a number of these cases, the negative impacts of climate change are being amplified by governance measures that

FIGURE 4.6 **Comparing drivers of change**

Comparing drivers of change across the cases, with both cases and drivers clustered by their similarity, shows that climate and geopolitical change are widely shared across the Arctic, but other drivers of change are more idiosyncratic. Negative impacts are shaded brown, and positive are purple. Cases are coded by their outcome type.

reduce the capacity of local people to adapt or transform, with direct impacts on food security, safety and livelihoods. This finding is not new, it has been said by many before, though mainly from either single case studies or a theoretical-synthetic perspective (Ruitenbeek and Cartier 2001; Brunner et al. 2005; Dietz et al. 2003; Ostrom 2007). The power of the result here comes from empirical comparison across our diverse sample of cases: The resilience-eroding impact of higher-scale decisions can be found across the Arctic in different sectors, countries, cultures and communities.

What these cases also reveal is that large-scale drivers are not by definition negative or a disturbance. The qualities of the impacts of many large-scale drivers (institutional, economic, political, environmental, climatic) are often largely dependent on local contexts (resilience at the local scale) as well as the conditions set by the larger, often political/regulatory, scale. If the conditions set at higher scales facilitate communities' capacity to self-organize, often allowing measures to be locally adapted, then the negative impacts of these drivers can often be mitigated.

One of the two successful examples of international institutions' impact is from St. Lawrence Island (Alaska), where the Yupik whalers in Savoonga, independently of the International Whaling Commission (IWC), created a new whaling season. The new season was defined in response to changing weather and ice that affected both whale migrations and livelihoods activities of the whalers. The change was possible because the international regulations set by the IWC are sufficiently flexible to allow local knowledge, observation and organization to actively contribute to local whaling management. Another successful example is that of mining regulation in Finland's Barents region, where legislation aims to have a pre-emptive role by minimizing the negative impacts of new actors moving into the region.

As the number of drivers and/or the number of actors increase, it becomes more important that the higher scale supports the adaptive capacity of communities at lower scales and manages emerging conflicts. This is the case in Finnmark (Norway), where the adaptive capacity of reindeer herders is being reduced by a variety of drivers: climate change, new actors and reduced grazing areas, as well as national top-down regulations on reindeer herding.

In case studies where several drivers, particularly socio-economic ones, are pushing the system, the result has often been a loss of resilience. As the quality and quantity of the behavioural responses in a case decreases, the vulnerability to new drivers increases. In these cases, encouraging the local level to self-organize will not be enough to increase resilience. An example is Teriberka (Russia), where higher-scale initiatives reduced local activities such as reindeer herding and small-scale fishing, initially in order to develop an industrial fishing industry. This was not locally rooted, however, so when the industry was moved to Murmansk, the town's economy collapsed. This happened again recently as plans to redevelop the town in conjunction with offshore fossil fuels exploration came to a halt when global oil prices fell. In this case more active support will be needed to not only facilitate the capacity to self-organize, but also to nurture other behavioural responses for this system.

4.4.4 Implications of these cross-scale dynamics

The case studies reveal that most Arctic communities are under pressure from a large variety of driving forces over which they exercise little influence. Regional, national and international organizations, including Arctic states, have greater power to engage at the scale needed to regulate and mitigate the impact of these drivers. While the local context matters, and local capacity to self-organize is a key factor supporting resilience, local resilience also depends on connections to higher levels of governance and other external actors. Several of the cases involve regime shifts and regime-shift-like dynamics that are making the current systems untenable. Enabling successful transformations of these cases, rather than a loss of resilience, requires collaborative local and cross-scale action. Some of the ways such collaborative, cross scale decision-making and action are organized at the pan-Arctic level are discussed further in chapters 5 and 6.

Furthermore, the likely existence of unknown regime shifts in the Arctic means that surprises can be expected. However, the risks that accompany those surprises can be reduced by identifying and monitoring key social-ecological processes that connect people to nature, maintaining a diversity of response options, and identifying and tracking changes in key, slowly changing ecological processes. Keeping track of slow changes over large areas requires coordination, cooperation and sharing of monitoring processes and data that connect nations and local communities.

4.5 Implications of the resilience assessment

4.5.1 Summary of analysis

We analysed social-ecological resilience across a diverse set of Arctic case studies to examine the extent to which four behavioural responses (nurturing diversity, capacity for self-organization, combining different types of knowledge, and learning to deal with uncertainty) contributed to resilience. We found that societal capacity for self-organization is a key ingredient of resilience in Arctic social-ecological systems. Nurturing diversity and learning to live with change and uncertainty combine with self-organization as strong contributors to Arctic systems' resilience and capacity for transformation.

This analysis aligns with findings from the established field of common-pool resource research (Armitage 2007; Ostrom 2007; Liu et al. 2007). Perhaps even more importantly, it fits with the perspectives of many Arctic indigenous peoples that national governments' actions over the past several centuries have generally reduced the resilience of the social-ecological systems they are part of (Kawagley 2006).

4.5.2 Implications of analysis

The cases illustrate that there are generic strategies to deal with change – context matters, but there is potential for drawing conclusions across cases regardless of sector, country, or combination of drivers, keeping in mind that conditions continue to evolve. The case studies also provide rich examples of how Arctic people have adapted and transformed the ways in which they live and connect to other areas of the world, including new forms of art, food production and tourism.

National and sub-national governments, international organizations, and other actors in the Arctic all have a role to play in building resilience in the Arctic, particularly by fostering self-organization.

Arctic peoples have shown a high capacity to adapt to local conditions and continually develop their livelihoods, economies, and infrastructure. This capacity has often been undermined by externally imposed measures (policy, legislation, new activities and actors), and there is a great variation in how well local communities have been able to adjust to these interventions. This means that the local context and self-organization matter, and that there are no universal solutions or panaceas that will work across the Arctic.

National policies clearly play a defining role in shaping the ways in which local communities can prosper. This role is increasingly important as the greater accessibility of minerals attracts more actors to the Arctic. As highlighted by the mining case in northern Finland, national policies can play a decisive role in structuring these activities in a way that supports these communities rather than reducing their resilience.

The Arctic Council has established a range of assessments that individually are excellent sources of material and synthesize crucial information about the Arctic. Important gaps in these assessments relate to the various types of social-ecological behaviour response strategies that this chapter demonstrates are critical for resilience. These gaps could be reduced by conducting integrated social-ecological synthesis studies that build knowledge about connections, global to local structures, dynamics, and monitoring. Such assessments could also identify and propose alternative strategies for building Arctic resilience.

Other stakeholders could act to support the maintenance and enhancement of local and Indigenous Knowledge in ways that enhance ever more crucial local adaptation and resilience-building efforts. The multiple evidence base approach (Tengö et al. 2014), for example, is being developed to support other international assessment processes. This approach is discussed further below.

4.6 Lessons for supporting Arctic resilience

The novel approach to resilience assessment developed for this report has identified key factors that support resilience in the Arctic. The cross-case comparison has allowed us to gauge the importance of key factors that have been identified in individual or a small number of cases, furthering the understanding of resilience and particularly in an Arctic context.

4.6.1 Reflections on the methods and impact on our conclusions

The approach to resilience assessment taken in this chapter applied a well-established theoretical framework (Berkes et al. 2003), to enable comparison across cases and identify factors supporting resilience. The reported outcomes and factors supporting resilience in the case studies were independent of location or sector, which supports the general importance of these four proposed behavioural responses for building social-ecological resilience. Furthermore, the use of an established theoretical framework for this assessment allowed us to more easily develop and apply our case comparison framework to analyse cases across the Arctic (Quinlan et al. 2016).

Data collection was time-consuming. It took on average 40 hours to complete one case template, once relevant sources had been identified. All cases were based on places where social-ecological research had been conducted and published, but even in these relatively well-researched cases, as we expected, many lower-tier variables were not known. While our coding and analysis were designed for incomplete data, the results emphasize that more integrated social-ecological research and monitoring would improve scientific understanding of factors enhancing and degrading Arctic resilience.

In particular, cultural factors were underrepresented across the case studies. Understanding how culture shapes people's ability to learn and use, respond to and manage places across the Arctic is a topic that would benefit from increased attention, particularly for local-level assessments and planning. As Chapter 3 demonstrates, Arctic regime shifts will have large and not well-understood impacts on local cultural practices. This assessment was designed to use secondary data rather than original research, but these gaps indicate that there are huge opportunities to generate these types of knowledge from collaborative research or citizen science done with Arctic communities. Such research has substantial potential to create more robust understanding and better monitor resilience. Such approaches are further discussed below; it should be noted, however, that they would require substantially more time and resources than this assessment, but could be integrated with existing Arctic monitoring and management activities.

4.6.2 Resilience framework for case comparison

The approach, and its results, has relevance at different scales. At the local scale, the resilience assessment provides a useful framework for understanding connections between people and ecosystems. It can also help clarify how the other levels of decision-making and monitoring can enhance or degrade local resilience. In addition, the resilience approach can identify potential drivers of change, their interactions, and potential for mitigating negative impacts. Furthermore, the collection of case studies forms a library of examples that can provide useful insights to other places in the Arctic, as there are many shared themes, such as responses to relocation, responding to ecological change, and responding to changes in demand for goods. Finally, analysing cases using a shared framework enables them to be compared and contrasted with other assessments of Arctic resilience found in the other chapters of this assessment, as well as in scientific publications, reports and plans.

4.6.3 Increasing the diversity strategies for resilience

Given the diverse set of drivers of change that Arctic communities face, strategies to strengthen resilience in the Arctic should address this diversity. One straightforward approach to enhancing diversity for Arctic resilience would be for external actors to actively seek to identify policies or practices that are eroding or destroying local diversity and make the changes needed to changes. A more positive approach would be to build upon the diversity of Arctic that is demonstrated in these case studies, and invest in ways to enhance social learning within and across places.

Given the potential for learning across cases, and given the cross-scale aspects of the case studies, a useful way to enable diversity would be to encourage the development of Arctic learning networks. This could be done by building upon, interconnecting, and strengthening of existing networks, to allow innovations and challenges to be shared among communities with similar conditions. Learning networks can help build resilience and identify opportunities for positive transformation. Such an approach could help facilitate "safe-fail" experimentation to take place, creating further diversity in the strategies for resilience – a central aspect of institutional diversity and polycentric governance. In turn, these pockets of innovation will allow locally relevant solutions to be developed and tested, and learning networks will allow the diffusing and adapting of knowledge gained from these experiences (Brunner and Lynch 2010).

While such social learning may be straightforward in principle, its translation into practice has been daunting (Berkes and Folke 1998). As community-based and participatory research paradigms become more prominent across the Arctic, there has been a proliferation of place-based documentation and innovation (Wolfe et al. 2011), yet functional networks to scale-up or transpose that hard-won knowledge by sharing relevant experience remain few and nascent. The internet provides unique opportunities for learning from others' experiences; in the Arctic, however, there is unequal access to the internet due to bandwidth, technology, and literacy. Despite the explosion of social media use among Arctic residents, cyberspace alone will not be a sufficient setting for those networks and this must be recognized and addressed.

4.6.4 Need for new forms of monitoring, research, and networks

Our analysis of resilience across the Arctic indicates that social-ecological connections are essential to enable people and places to be resilient: to adapt or transform. However, our analysis indicates that many aspects of people's connections with ecosystems, the maintenance and creation of knowledge, as well as the ability to learn and make decisions are poorly documented in the scientific literature. This can stem from two types of gaps: the first is that they are "unknown unknowns"; the second is that researchers have not yet addressed these in their work. Both of these gaps are important to address by taking advantage of all the diverse forms of knowledge available in the region and beyond – and not only with conventional scientific approaches. Assessing and promoting resilience requires an understanding of social-ecological system functioning, and therefore building resilience will require more in-depth monitoring and research of these in socially acceptable and constructive ways.

As many social-ecological connections are strongly shaped by local people and places, the development of locally based ways of assessing these connections is likely to be more accurate, fair and useful than systems of measurement that are developed independently of local people and places. For many researchers trained in Western academia, the holistic approach of social-ecological systems and resilience is new and challenging. For many people in the Arctic, however, this model remains a simplistic understanding of the integration of the people in their environments, a reminder that developing learning and co-learning strategies requires dialogue (Tengö et al. 2014).

The strength of social-ecological knowledge in the Arctic suggests that that the resilience of the Arctic and of places within the Arctic would be improved by programmes that enhance the capacity of local people to develop their own ways of monitoring and – perhaps more urgently – sharing these capacities. Such local efforts could be joined together across regions or even the entire Arctic through citizen-science collaborations between researchers, organizations and citizens. Arctic inhabitants are already monitoring changes in their environment and sharing knowledge. However, enhancing resilience in the Arctic requires both locally informed and locally relevant knowledge co-production in combination with cross-scale and cross-cultural sharing of that knowledge.

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PART III

The Policy Context: Shaping Change

As the Arctic's sole circumpolar high-level policy forum, the Arctic Council plays an increasingly important role in issues that have major social and environmental implications. Institutions such as the Arctic Council help guide human activities, and they are especially important where the alignment of goals between individuals, communities, and societies is vital, such as with long-term sustainability.

The human capacity for deliberate action (i.e. agency) is central to the humans-in-nature perspective reflected in the social-ecological systems framework of resilience. Agency can be manifested by both individuals and collectively through different kinds of organizations, and the shared deliberation and decision-making role of governance institutions plays a critical role in steering that capacity by defining common problems, assembling the required knowledge, creating rules and norms to guide responses, and marshalling needed resources and facilitating concerted action.

Chapter 5 reviews how the Arctic Council has managed its own evolution over its 20-year history. It has played a central role in identifying issues of common concern in the Arctic. It has facilitated the development of knowledge necessary to tackle those issues, devising novel ways to foster pan-Arctic collaboration, and bridging and brokering between different levels of decision-making. It has continually evolved to grow its effectiveness, and will need to continue to address these challenges going forward.

Chapter 6 examines how the Arctic Council has engaged with three very different global drivers of change that are especially important in the Arctic: transboundary pollution, climate change, and demand for natural resources and its link to extractive industries. The chapter examines the fit of these issues for the Arctic Council in terms of substance and scale, and how each has offered very different kinds of opportunities and challenges.

In its constantly changing context, the Arctic Council has dealt with new challenges by modifying how it works: incorporating new types and forms of knowledge, opening up to observers, and setting in motion new activities – especially to address policy problems that cannot be managed within national borders. Maintaining this ongoing process of organizational evolution will remain vital in the future.

CHAPTER 5

Shared decision-making in a changing Arctic political landscape

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Key Messages

- Arctic policy is part of a dynamic global policy landscape, where decisions and norms from outside the Arctic increasingly shape Arctic policy.
- Negotiation, shared decision-making and policy development – often referred to as governance – play a central role in shaping change in social-ecological systems by shaping how people access, use and modify parts of the Arctic.
- The Arctic Council faces three major challenges in a crowded and increasingly globalized Arctic policy landscape: to define its specific place and role; to strengthen its capacity to effectively engage with a multitude of other relevant policy processes; and to navigate the questions of how decision-making authority is allocated among different potential policy processes.

Arctic Council Secretariat/Linnea Nordström

Arctic Council delegates at the SAO meeting in March 2016 in Fairbanks, Alaska. In September 2016 the Council celebrated its 20th Anniversary.

5.1 Introduction and aim of the chapter

Actors across the Arctic are already responding to the new environmental, social, and economic geography that is emerging in the region. As elaborated in the Arctic Resilience Interim Report 2013 and many other discussions of the Arctic, this new situation creates an imperative for a more integrative understanding of the dynamics of Arctic change that can take into account the cumulative impacts of diverse sets of interconnected drivers (Larsen et al. 2014). In addition to addressing immediate risks, such as those related to current impacts of climate change and increasing commercial activities, the need to build capacity to prepare for further environmental and social changes and unknown future challenges is increasingly clear. As outlined in more detail in Chapter 1, resilience is becoming increasingly established as an important concept to capture the capacity of social-ecological systems to effectively respond to disturbances. This chapter further explores the uniquely social aspects of resilience, the ways in which resilience encompasses the human capacity to learn and employ knowledge, to set goals, and to make joint decisions that chart a course into the future.

The future of the Arctic is being created by actors both within and outside the region. This means that different and sometimes conflicting priorities are inevitable and that decision-makers at all levels will face difficult choices (Arctic Council 2013b, key message 7; Larsen et al. 2014). What is useful adaptation for some people or groups can be maladaptive when viewed from a different angle. Socio-economic transformation can be desirable for some but not for others, depending on the perspective from which one views the "multiple Arctics" described in Chapter 2. Political decisions that shape the future inevitably include choices about what is deemed to be a desirable development. There is thus a need to understand the societal processes within which decisions relating to the Arctic are made.

This chapter focuses on shared decision-making and the role it plays in shaping the relationship between people, as well as between people and their environment, in ways that are relevant for the Arctic. It pays particular attention to the Arctic Council and the shifting landscape it operates within – a landscape characterized by increasing connections between local and global processes.

5.2 Deliberately shaping change: "governance" in social-ecological systems

Chapter 1 emphasizes the importance of agency in social-ecological systems as a quality unique to the social component of these systems. The capacity for making deliberate choices, revising and employing knowledge for making those choices, and for organizing collectively

Mark Byzewski/Flickr

Chief Shakes Tribal House in Wrangell, Alaska: Decision-makers at all levels will face difficult choices to respond to socio-ecological change in the Arctic.


Alexander Kutskiy/International Centre for Reindeer Husbandry

Reindeer herders in Chukotka, Russia: Formal and informal rules, norms and decision-making processes define how communities relate to the environment.

to navigate challenges and opportunities are core aspects of social systems and therefore also core aspects of social-ecological systems. Taken together, these processes are broadly referred to as "governance". In contrast to "government", which typically refers to a decision-making structure or a particular government, governance speaks to a shared process of shaping change, whether applied to local or national political entities, or, for example, to NGOs or corporations. While the term has become increasingly common over the past two decades in the English speaking social sciences, it is not directly translatable in all Arctic languages and is therefore sometimes a source of confusion. We therefore want to spell out clearly what the term encompasses in order to work from a common understanding of the concept.

A broad term with many different definitions, governance relates to both decision-making power and the norms and rules that govern behaviour. Not only does it include the collective efforts of a society to define and achieve common goals (Young et al. 2008; Ostrom 2009), but also the myriad processes by which citizen groups, governments, agencies, corporate actors, individuals and communities interact in decision-making processes that may or may not involve the formal institutions of government (Cornell et al. 2013; Burns 1999).

Social-ecological systems are comprised of human communities and the ecological systems in which they are embedded. This includes ecosystems as well as the social actors, structures, and processes that guide how we value ecosystems and how we behave in relation to them. In the past, many ecosystem processes were largely driven by physical environmental factors beyond significant human influence. Today they are increasingly affected by human activities, both at the local scale and via global pathways and processes (see section 5.4). At the global scale, the essence of this close interrelationship is captured in the notion of the "Anthropocene" (Crutzen and Stoermer 2000; Williams and Crutzen 2013).

As characterized throughout the chapters of this report, ecosystems and the social world are interwoven: not only does human activity have direct and indirect impacts on the biophysical environment, people also depend on the environment in which they live.

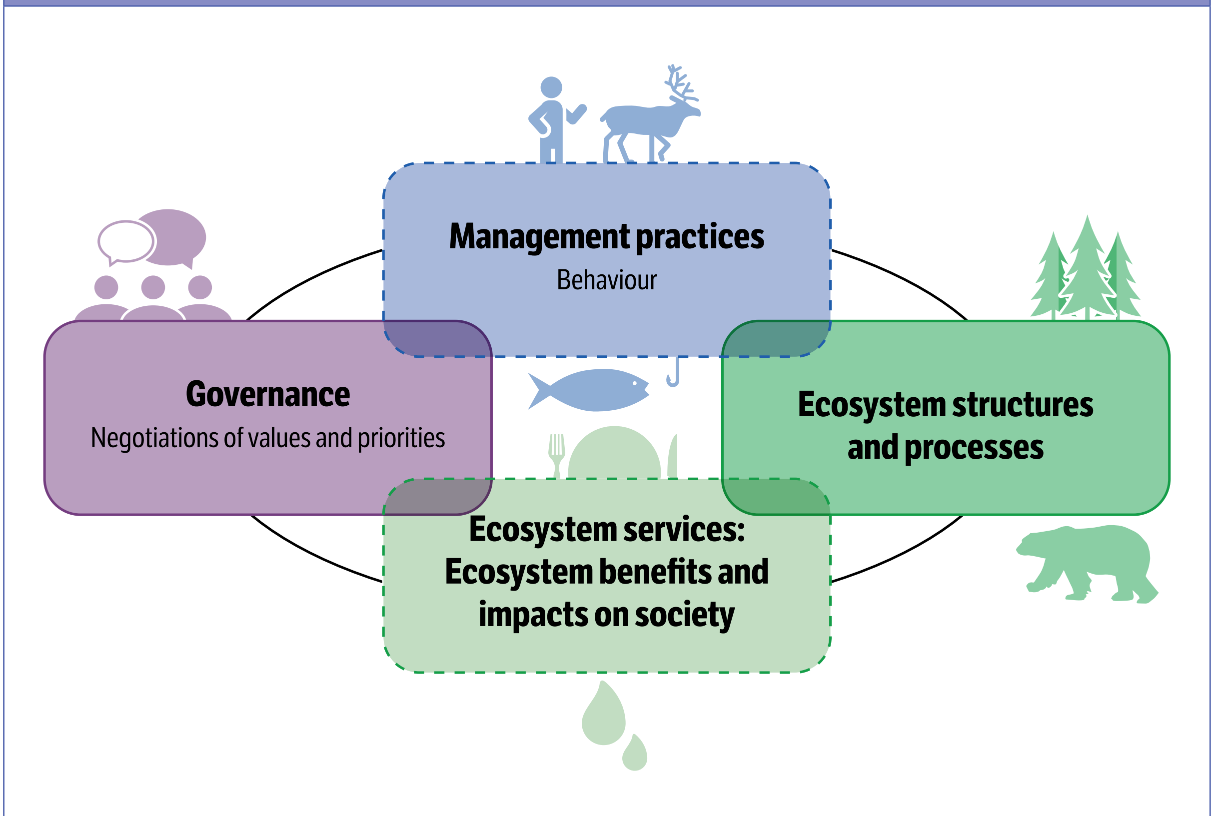
Rules, regulations, norms, and decision-making processes – which, taken together, make up governance – play a central part in guiding how various actors behave towards the environment. While the most explicit example of this is the formal political processes by which we collectively decide on regulations and taxes aimed at individuals, organizations and businesses, many processes outside formal government structures also play a role. In some cases it might be environmental protection that motivates policy (e.g. local harvesting regulations and practices, or efforts to reduce emissions of greenhouse gases). However, policies and decisions stimulated by other concerns also affect people's interactions with the environment. For example, decisions that increase the standard of living often indirectly contribute to lifestyles that use more resources and generate more waste, while policies on science and education can increase expert and public knowledge about the role of ecosystems, which indirectly affects behaviour.

Governance processes also play a role in determining how societies ascribe value to various aspects of the environment. This includes what is often called ecosystem services. While this role is less direct than the one described above, it is significant because it indirectly guides behaviour. While major efforts are under way to capture the value of ecosystem processes in economic terms (Kumar 2012), this is notoriously difficult when it comes to how ecosystems relate to cultural and spiritual practices, not least in the Arctic (CAFF 2015). Moreover, the value of ecosystem services is subject to social negotiations among actors with different priorities and power relationships (Ernstson and Sörlin 2013). The point here is that governance plays a central role in moderating these relationships, and it is within a society's governance processes that the rules of the game are set for *how* societies negotiate over values, and how values should be translated to collective actions.

The result of explicit negotiations about the value of ecosystems can, for example, be protection policies or mechanisms that ensure that a specific ecosystem service becomes integrated into the formal economy. However, not all negotiations are as explicit and in practice, how we often assign low "default" values to ecosystems because the links between ecosystems and human well-being are poorly understood, not articulated, or not recognized in all relevant decision-making processes. Knowledge and cultural processes for ensuring the production and transfer of knowledge are thus essential for how societies define and value ecosystems.

Governance processes, including the weighing of priorities, negotiation of differences, and pursuit of diverse goals can thus be seen as critical to the process of defining relationships between societies and ecosystems. Often the term "resource governance" is used to describe the collective efforts of society to define and achieve goals linked to human-environment interactions (Forbes and Kofinas 2015). Resource governance is a component of a broader set of rules and relationships between different social actors, which include who has the right, as well as the opportunity, to take part in the formal and informal social negotiations that define the values of ecosystem services, and also set the rules for conduct in relation to the environment and among different actors.

FIGURE 5.1 **Governance as a part of social-ecological systems**



The depiction of governance as a part of social-ecological systems in Figure 5.1 is an attempt to explicitly bring governance of social and ecosystem processes into a common conceptual framework. While such a division between the social and ecological spheres is foreign to many indigenous cultures that have a more holistic understanding of the world, it is worth noting that this link exists because science and other western knowledge traditions have treated them as separate entities.

5.3 The changing context for governing in the Arctic

Governance arrangements in the Arctic range from local management of natural resources to formal international cooperation, such as in the functions of the Arctic Council. The complex governance landscape in which the Arctic is situated includes formal governmental and inter-governmental processes, global environmental and economic regimes, trans-national collaboration among indigenous peoples, trans-national scientific organizations, and business platforms (Arctic Governance Project 2010).

The global scene for governing has changed considerably over the past 25 years, with new interdependencies across spatial scales and issues (Young et al. 2008; Biermann and Pattberg 2012a). Just as the Arctic is integrated into the governance structures of specific countries, it is now integrated into a variety of governance structures at the international level, including international environmental treaties as well as sector-specific agreements and trade regimes. There are also many bilateral agreements for managing cross-boundary resources issues (Arctic Governance Project 2010; Young 2011).

Jean-Pierre Dalbéra/Flickr

An exhibition on mineral mining in Greenland and linked urban development and migration was held at the Venice Architecture Biennale in 2012.

The dynamic change in the governance landscape of the Arctic not only creates challenges for understanding the role of different actors and political institutions but also opportunities for building the capacity needed for sound decision-making. The declining sea-ice in combination with expectations of increased shipping is already compelling existing political structures to take on new issues, such as coordination of search and rescue. There have also been calls for broader reforms of Arctic governance (Koivurova 2008; Koivurova and Molenaar 2009; Berkman and Young 2009; Berkman and Vylegzhanin 2013; Arctic Governance Project 2010). This is to be expected in a period of turbulence in the region and uncertainty about the future. Change has also offered an opportunity to think in new ways about governance, which may not have happened without the current need for initiative (Young 2012). During the past 25 years, the Arctic has served as a space for innovation in modes of governance, including new forms of co-management. The Arctic Council is itself an example of that innovation as a forum for cooperation between eight national governments and organizations representing indigenous peoples (Arctic Governance Project 2010; Forbes and Kofinas 2015). New and useful modes of governance in the Arctic are not only relevant for the region; they can also serve as examples for other parts of the world.

Many of the drivers of Arctic change are global, but most decisions about adaptation are taken at the local or sub-national levels within specific countries, thus, the regional international cooperation embodied by the Arctic Council has the potential to connect the local and the global scales. However, there are challenges to realizing this potential – in particular the council's legal status: because the council is a soft-law body rather than a formal treaty, the agreements it makes, such as ambitions stated in the Ministerial Declarations or the negotiated recommendations from its many scientific assessments (Koivurova 2010), are not legally binding, and it depends on the commitment of Member States to follow up on and implement its policy intentions. But given that none of the challenges facing the Arctic can be addressed solely within national boundaries, or at sub-national levels, or by relying solely on binding global agreements and ambitions for continued cooperation are also clear from national Arctic strategies that have been issued by the eight Member States (Heininen 2012), as well as Arctic Council Ministerial Declarations (Arctic Council 2013c; Arctic Council 2015). Given the combination of necessity and commitment, a first step towards understanding the new opportunities and challenges for circumpolar governance is to look at its history.

Joint Arctic search and rescue exercise in Alaska, 2015. The Arctic Council was instrumental in negotiating the Arctic Search and Rescue Agreement.

5.3.1 A short history of international cooperation in the Arctic

Before the end of the Cold War, the circumpolar Arctic was generally not seen as a politically defined region or a place for international cooperation (Heininen 2004; Koivurova 2010). However, the situation had changed by the early 1990s as a result of the end of the Cold War, as well as growing interest in its natural resources, an emerging international indigenous movement, and the signing of the UN Convention on the Law of the Seas (United Nations 1982). Following intensive diplomatic activity, the Arctic Environmental Protection Strategy (AEPS) was signed in 1991, setting the stage for defining the Arctic as a region of political cooperation among the eight Arctic states: Canada, Denmark (with Greenland and the Faroe Islands), Finland, Iceland, Norway, Sweden, the Union of Soviet Socialist Republics (now Russia) and the U.S. (Young 1998; Tennberg 1998; Keskitalo 2004).

Building on the AEPS, the Arctic Council was created in 1996. In addition to environmental protection, its mandate includes a broader commitment to "sustainable development in the Arctic region, including economic and social development, improved health conditions and cultural well-being" (Arctic Council 1996). The Arctic Council is made up of eight Arctic Member States and six Permanent Participants, which represent indigenous peoples. These are the Aleut International Association (AIA), Arctic Athabaskan Council (AAC), Gwich'in Council International (GCI), Inuit Circumpolar Council (ICC), Russian Association of Indigenous Peoples of the North (RAIPON), and Saami Council (SC).

The Arctic Council also includes organizations and states that hold the status of Observers, which follow the work of the Council and contribute at the Working Group level, but which have no formal role in decision-making (Arctic Council 2013a).

A large part of the Council's work takes place in the Working Groups, including scientific assessments of issues such as pollution, impacts of climate change, biodiversity and human development, and review of the policy landscape in relation to key issues. Several Arctic Council assessments have influenced global discussions on environmental policy (most notably for the governance of persistent organic pollutants, see Downie and Fenge 2003; Nilsson 2012; Molenaar 2012). The terms "cognitive niche" and "cognitive forerunner" have been used for describing the role of the Arctic Council as a fact-finder and consensus builder on Arctic environmental challenges (Stokke 2007; Nilsson 2012; Molenaar 2012). The view of respondents to a 2012 survey (Kankaanpää and Young 2012) was that the role of identifying emerging issues, carrying out scientific assessments, and using assessment results to structure the policy agenda was the Arctic Council's primary field of success.

The Arctic Council assessments have in more recent years been important for creating a learning space across knowledge traditions, by highlighting the relevance and role of traditional knowledge (Nilsson 2007; Kankaanpää and Young 2012). There is now also an increasing recognition within the Arctic Council of the importance of bringing together the natural and social sciences, not least for analysing issues related to adaptation and resilience to climate change. There are still challenges

FIGURE 5.2 **A montage of Arctic Council assessments**

to doing so, however, which are partly due to different academic knowledge traditions, while the division of responsibilities between different Working Groups has also tended to create separate communities of practice. Understanding the interlinked dynamics of social and biophysical processes are integral to the overarching goals of sustainable development, which is about the need for seeing the whole picture and discussing policies with a long-term perspective. However, the Sustainable Development Working Group has not played such an integrative role between the different Working Groups and knowledge traditions, leading to suggestions that it should be restructured so that it can more effectively carry out this function (Kankaanpää and Young 2012). While current efforts to develop more encompassing analysis, such as the Arctic Resilience Assessment and the initiative on Adaptation Action for a Changing Arctic, have no single institutional home within the Arctic Council, they are a recognition of the need integrate knowledge across issue areas in ways that are also relevant for local and sub-national actors in the Arctic.

The Council's scientific assessments often result in recommendations with policy relevance, some of which are influential enough to find their way into high-level policy statements such as the Ministerial Declarations.

In recent years, the Arctic Council has evolved from being a high-level policy forum towards becoming an established international organization. The founding of a permanent secretariat in Tromsø is a sign of this development. The Arctic Council has also started to shift its efforts from policy-shaping towards policy-making (Nord 2013; Kankaanpää and Young 2012), a change most evident in the negotiations of two legal agreements under the Arctic Council auspices, one about search and rescue and one about tackling oil-spill emergencies, both of which aim to coordinate national activities. As the Arctic has moved into the global limelight, the Arctic Council has become an attractive club to which a range of new actors want to belong. At the Kiruna ministerial meeting in May 2013, the Council admitted several new observer states.

5.3.2 Changing perceptions

There has been a tradition of exceptionalism in Arctic research, emphasizing the special character of the region rather than its place in a larger global context (Young 1992). In principle, national and international governance systems have long applied in the Arctic, and many global concerns have also been high on the Arctic agenda. However, there has only been limited explicit discussion about how norms from multilateral environmental agreements and inter-governmental regimes should carry over from the global to the regional. And, while sub-national entities with varying powers did inevitably influence their respective regions, their work was studied without much connection to the broader levels of governance or to the work of the Arctic Council.

In the past decade, perceptions of Arctic governance have started to change. In 2004 the publication of the Arctic Climate Impact Assessment (ACIA 2004; ACIA 2005) made clear that the Arctic was facing the impacts of global climate change. This report and other assessments have demonstrated that Arctic change is driven by biophysical processes that are global in character, but also that Arctic climate change has far-reaching global consequences (AMAP 2011; Larsen et al. 2014). The UN Framework Convention on Climate Change (UNFCCC) is thus critically relevant for the Arctic.

The Arctic Climate Impact Assessment carried out some preliminary evaluations of the impacts of climate change on offshore economic activities in the Arctic Ocean and adjacent seas, including fisheries, maritime transport, cruise vessel tourism and offshore oil and gas. The follow-up report, the Arctic Marine Shipping Assessment, tried to predict how shipping would evolve and how governance would need to respond (Arctic Council 2009). However, the record-low 2007 Arctic Ocean sea-ice minimum brought the world's attention to the prospect of an ice-free Arctic Ocean that was much sooner than previous assessment had projected (AMAP 2011; Christensen et al. 2013). The flurry of new political and commercial interest precipitated a need to both define and understand the rules for governing the Arctic Ocean.

5.3.3 Governance of the Arctic Ocean

Central features of internationally established context for governance in the Arctic are the Law of the Sea and the UN Convention on the Law of the Sea (United Nations 1982) including its Article 76, which regulates the delineation of the outermost limits of continental shelves.[1,2] This article is central for defining the sovereign rights of states for the purpose of exploring and exploiting natural resources beyond territorial waters and the exclusive economic zone. In recent years, several Arctic states have made submissions to the Commission on the Limits of the Continental Shelf and some long-standing border issues have been resolved following UNCLOS procedures (see Bankes and Koivurova 2014 for review). There is currently no indication that the peaceful resolution of potential conflicts will not continue in the Arctic.

While all Arctic states, in both their national strategies and through Arctic Council Ministerial Declarations, place UNCLOS as the legitimate legal arrangement for regulating Arctic Ocean activities, the years immediately after the 2007 sea-ice minimum featured a lively debate about the potential need for an Arctic treaty to govern the region (e.g. Carpenter 2009; Young 2011; Koivurova 2010). There was also discussion on the shortcomings of the existing governance structure and ways to strengthen Arctic governance without necessarily suggesting an Arctic treaty (Koivurova 2008; Koivurova and Molenaar 2009; Koivurova 2013; Berkman and Vylegzhanin 2013; Berkman and Young 2009; Arctic Governance Project 2010; Young 2012). Within the Arctic Council, the Working Group on the Protection of the Arctic Marine Environment (PAME) carried out the Arctic Ocean Review, which makes several specific recommendations about how Arctic Ocean governance can be reinforced (PAME 2013). Recurring themes in the more general discussion have included calls for strengthening the Arctic Council, a need to maintain peace and stability, needs for effective management of new economic activities, and calls for more integrated ecosystem-based management. Stewardship has appeared as a prominent term, suggesting a more active engagement in managing Arctic change, but also an increasing focus on environmental security (e.g. Griffiths et al. 2011; Chapin et al. 2015). These discussions have no doubt provided incentive for some of the changes that have strengthened the Council in recent years. They also highlight the central role of existing governance structures for providing a context within which relevant actors can discuss the relationship between resilience and ideas about policies and management.

The relationship between the work of the Arctic Council and the UNCLOS will remain an important issue and indeed become even more important as the impacts of projected climate change become increasingly apparent in Arctic waters. Issues include the need for various types of regulation where Arctic-specific conditions intersect with the domain of global regimes. Maritime transport and fisheries are intensely regulated by global instruments. For example, shipping is regulated via the International Maritime Organization treaties, such as the mandatory Polar Code, which is expected to enter into force in 2017 (International Maritime Organization 2014). New and legally binding treaties are now being developed to tackle environmental and civil security challenges posed by increasing economic activity in the region, including the recently adopted Agreement on Cooperation on Marine Oil Pollution, Preparedness and Response in the Arctic, which is yet to enter into force (Rottem 2015).

UNCLOS may also have implications for protection of the Arctic marine environment at a more general level. While the main obligation for signatory states to UNCLOS is to implement protection through their

1 All other Arctic states are parties to the UNCLOS, except the U.S. Yet the U.S. has confirmed that it accepts most of the rules of UNCLOS as legally binding as customary international law.

2 As stated in UNCLOS article 76, "The continental shelf of a coastal State comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance." See: www.un.org/depts/los/convention_agreements/texts/unclos/part6.htm

Arctic Council/Flickr

Arctic Council delegates at the Senior Arctic Officials meeting in Whitehorse, Canada, in March 2015. The participation of Indigenous Peoples in the membership of the Arctic Council boosts awareness of indigenous rights in the region and round the world.

national jurisdiction, there is also language that provides an imperative for cooperation on a regional basis. Part XII Article 197 asserts that "States shall cooperate on a global basis and, as appropriate, *on a regional basis*, directly or through competent international organizations, in formulating and elaborating international rules, standards and recommended practices and procedures consistent with this Convention, for the protection and preservation of the marine environment, taking into account characteristic regional features" (emphasis added).[3] While it is an open question whether a formal regional seas agreement will be seen as relevant for the Arctic, the Arctic Council has established a Task Force for Marine Cooperation to "assess future needs for a regional seas program or other mechanism, as appropriate, for increased cooperation in Arctic marine areas" (Arctic Council 2015).

5.3.4 Indigenous rights and greater self-determination

Another important trend in the Arctic and globally is the increasing recognition of indigenous rights, along with attention the importance of traditional governance arrangements. In the Arctic this development has been accompanied by an increasing devolution of governmental powers. An example is the increasing number of local regimes for co-management of resources that aim to include traditional and local knowledge rather than relying solely on outside scientific advice (Caulfield 2004; Kofinas et al. 2013). There are also cases of political authority being transferred to new governments. The 2009 Act on Greenland Self-Government gives Greenland considerable self-governing power. The creation of the territory of Nunavut in 1999, where the majority of the population is Inuit, was a result of long negotiations between the Inuit and the Canadian government. And the 2005 Finnmark Act in Norway transferred 95% of the territory of the northernmost county of Norway to an estate that governs on behalf of all population groups of Finnmark, with the Sámi Parliament in Norway appointing three of its six directors. While the Act gives Sámi the opportunity to assert their immemorial rights in special land rights procedures, it has been suggested that it does not fully implement the Indigenous and Tribal Peoples Convention, 1989, of the International Labour Organization (ILO-convention 169),[4] a legally binding international instrument that deals specifically with the rights of indigenous and tribal peoples. In addition to providing protection against discrimination, the convention calls for measures to safeguard the persons, institutions, property, labour, cultures and environment of indigenous and tribal peoples, and requires that they be consulted on issues that affect them.

Globally, the evolving norms of indigenous rights reached a milestone with the non-legally binding 2007 UN Declaration on the Rights of Indigenous Peoples (UNDRIP). This move has helped to include indigenous rights within the broader international human rights frameworks (Bankes and Koivurova 2014). While indigenous rights have only to a limited extent been implemented through legal instruments – national or international – there is nevertheless a clear trend of increasing recognition, which has implications for the division of responsibilities between different types of government bodies and international regimes, including the Arctic Council. Indigenous rights are likely to become increasingly relevant for ensuring resilience for communities in situations of increasing industrial activity and competition for land (Stepien et al. 2014).

3 UNCLOS article 197 Cooperation on a global and regional basis

4 See: www.ilo.org/indigenous/Conventions/no169/lang--en/index.htm

5.3.5 The increasing complexity of environmental governance on a global scale

Various multilateral environmental agreements (MEAs) are applicable in the Arctic, and some work within the Arctic Council is directly aimed at influencing them. One example is how Arctic Council actors joined forces to combat persistent organic pollutants at the regional and global levels (Downie and Fenge 2003; Nilsson 2012) and how data from AMAP continues to inform the global regime on these pollutants. Another is the role of AMAP's assessments in forging a new international treaty on mercury (Koivurova et al. 2015). A third is how the Conservation of Arctic Flora and Fauna Working Group (CAFF) communicates important region-specific biodiversity information to the Secretariat of the Convention on Biological Diversity[5]. Other global agreements that are not directly related to the Arctic Council agenda also apply to the Arctic. Even free trade law applies in full in the entire Arctic, given that now all the Arctic states are members of the World Trade Organization (WTO).

Even though there might already have been awareness of governance links between the Arctic and the rest of the planet when Arctic inter-governmental cooperation began in the 1990s, since the 2000s these connections have become real enough to act upon. So it is increasingly important for the Arctic Council to discuss how to relate to other international governance regimes and the legal contexts they represent. This might include influencing other regimes, but also creating customized regional regulations. One example of the latter is the work of the Arctic Council that catalysed the negotiations for the 2011 Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic and the Agreement on Cooperation on Marine Oil Pollution, Preparedness and Response in the Arctic. Even if these agreements are regional, and concluded among the eight Arctic Council states, they derive most of their content from the already existing global treaties.

Meanwhile, the governance architecture is becoming both more global and more complex, with an increasing number of intersecting regimes and transnational actors (Biermann and Pattberg 2012b). On some issues, such as climate change, it is also becoming fragmented, multi-scalar and increasingly poly-centric, and calls have been made to connect the dots (van Asselt 2014).

This increasing complexity creates new challenges for the Arctic Council, and will likely create new demands to find ways to effectively engage with various regimes and governance actors.

5 See: http://www.caff.is/global-linkages2

Denis Caviglia, Sámediggi Sametinget/Flickr

Plenary Room of the Sámi Parliament, Norway, The Sámi Parliament appoints three of the six directors of the estate that governs 95% of Norway's northernmost county.

5.4 Connectivity across scales and space

Developments elsewhere often influence the Arctic and vice versa. This is clearly the case with biophysical changes such as warming Arctic temperatures and ocean acidification, both driven by global emission of carbon dioxide mostly elsewhere on the planet (see Chapter 3). It is also the case with social activities or developments that influence the flows of economic or natural resources, flows of people, and flows of waste or pollutants. This connectivity – across geographic space, between different social contexts, and between the social and biophysical realms – has always been characteristic of the Arctic. However, with globalization and global environmental change, the connectivity has grown dramatically in importance (Heininen and Southcott 2010; Keskitalo and Southscott 2014). The pace of change at both local and global scales – and the human response to it – has major implications for governance. Local communities, in the Arctic and elsewhere, cannot steer all the processes that affect their immediate environment and their daily lives, no matter how sophisticated the local governance system (Brondizio et al. 2009). In practice, communities and local environments are closely linked to both global and national decision-making processes, both physically and politically.

The resilience of local communities is thus a function of decisions made at many levels, including the international, national, sub-national and local level. These decisions may be made by individual actors or in collective governance processes. At the international level, many decisions are made through formal intergovernmental processes. Transnational networks not directly linked to intergovernmental processes also play an increasingly important role (Biermann and Pattberg 2012b), and can influence local resilience. Environmental certification schemes are an example of such a mechanism, and could make local Arctic products more (or less) attractive for consumers elsewhere. International certification schemes exist for both forestry products and fish, which are important export products from the Arctic. Other examples include voluntary codes of conduct that apply to specific types of activities, and efforts to develop more generic standards or corporate social responsibility. When backed by economic power, such codes can have profound implications for local communities (see examples in Section 5.4.1 below). The Arctic Investment Protocol[6] illustrates this type of private sector activity even if so far it is a stated intention rather than established procedure.

6 See: http://www3.weforum.org/docs/WEF_Arctic_Investment_Protocol.pdf

Seal hunter on the shore, Greenland 2016: The crash of the sealskin market illustrates how formal government mechanisms can impact local livelihoods.

The initiative is driven by the Global Agenda Council on Arctic under the World Economic Forum (Minerd 2015). In addition, individual decisions and actions outside the Arctic, when they become part of larger shifts in public perceptions or market behaviour, can have major impacts on local Arctic communities. Media often play a major role in such shifts, as do campaigns run by non-governmental organizations, often without any clearly defined process for collective decision-making.

5.4.1 Two examples of global-local connectivity

The crash of the sealskin market is a case in point of how non-governmental activities can interact with formal government mechanisms and, via market mechanisms and changes in trade patterns, affect local livelihoods. In 2009, based on concerns for animal welfare, the European Union (EU) banned trade in all seal products in the EU (with some exceptions for indigenous communities and sustainable management of marine resources). The ban followed narratives that environmental organizations have cultivated over many decades focusing on the "commercial" seal hunt being inherently cruel and contributing little to economic well-being. These narratives can be contrasted with a Canadian perspective, which views the seal hunt being subject to a tight web of regulations and being both economically and culturally important. As early as during the drafting process of the EU trade ban the markets for seal products collapsed: the lack of a labelling system led many potential customers to abstain from buying any seal products. Moreover, the EU ban sparked bans in the Russian, Belarusian and Kazakh customs union in 2011, as well as in Taiwan in 2012, while China was hesitant to open its markets. The ban is currently being amended in order to comply with a WTO ruling about its discriminatory effects. While the Arctic Council has no direct role in relation to the EU or the WTO, it has been affected by the politics surrounding the sealskin issue. The Arctic Council has served as a platform from which Inuit and Canadian perspectives on the issue have been able to influence and partly shift the narrative to a more nuanced position, compared to early anti-sealing sentiments. Moreover, the EU's seal hunt ban has been a significant factor in Canada's opposition to the EU's application to observer status in the Arctic Council (European Commission 2015; Wegge 2013; Sellheim 2013; Sellheim 2015).

Mining provides another example of the close connectivity between local livelihoods and global markets, transnational actors, and policies decided elsewhere. Decisions about mining in the Arctic are taken by a range of different actors and at different levels of governance. At the front line are the companies – often transnational – making business decisions about operations and prospecting. They, in turn, depend on their investors and other ways of raising the capital necessary to operate a mine. Government authorities are involved by providing permits to prospect and making decisions on acceptable environmental impacts. Mining booms are a reflection of expected demand as well as expected supply in a global context. Geopolitical considerations can also affect the market (Jürisoo and Nilsson 2015). However, decisions made by mining companies and investors are also based on national mining legislation and a range of other factors relating to the legal and social context of the country in which the mine would be located. Several Arctic countries have created policies at the national level explicitly to attract foreign investments in mining. At the local level all these decisions translate into both benefits, such as employment opportunities and investment in new infrastructure, and negative impacts, including pollution, effects on biodiversity, nature recreation and cultural values. Moreover, mining often competes with other uses of the same land, which has been the case in Sweden, Finland, Norway and Russia where mining occurs in reindeer-herding areas (van Dam et al. 2016).

Connectivity across scales also applies when mining is not booming. The downturn of metals markets since 2014 has led to economic difficulties for several mines in the Arctic, including bankruptcy (e.g. Northland mine in Pajala, Sweden) and lay-offs. Although global connectivity is inevitable in businesses such as mining that cater to global markets, there have been calls for increased local influence in decisions about prospecting and opening new mines, for example the recent Declaration from reindeer herding youth at the Gávnnadeapmi 2015 (Gávnnadeapmi 2015).

Victor Svensson/Flickr

Boliden Aitik copper mine, Sweden: Mining in the Arctic is one example of how global markets and actors affect local livelihoods.

TABLE 5.1 **Interactions across scales and space, and related tools for policy influence**

	Tools for Policy Influence					
Pathways for Interactions across Scales and Space	Trans-national networks (non-governmental)	International cooperation, including formal agreements	Bilateral and regional cooperation	National policies	Sub-national capacity/ regional processes	Local capacity and processes
Environment						
Physical pathways (e.g. winds, oceans, rivers)	Environmental certification schemes	Stockholm Convention on Persistent Organic Pollutants; Minamata Mercury Convention; UNFCCC, Vienna Ozone Convention	E.g. EU Water Directive	Land-use regulations and planning	Land-use planning	Spatial planning
Biological pathways (migratory species, biomagnification processes)	Environmental certification schemes Media messaging	Convention on Biological Diversity, CITES	Bilateral and regional species and natural resource management arrangements, e.g. Polar Bear Treaty, NAMMCO	Land-use planning Nature reserves Regulation aimed at specific species and (protected or pests) and other national wildlife management schemes	Land-use planning	Spatial planning
Money						
Trade		WTO	Bilateral trade agreements EU	Trade protection measures Direct or indirect support to specific sectors (mining, fossil, forestry)	Flexible labour market Diversification of economy	Flexible labour market Diversification of economy
Investments		World Bank		National incentive structures	Regional capacities, infrastructure and incentives	Local capacity to communicate with investors
Transfer payments		Global adaptation fund		Policies towards regions Welfare policies Tax systems		

Ninara/Flickr

TABLE 5.1 **Interactions across scales and space, and related tools for policy influence**

Pathways for Interactions across Scales and Space

	Tools for Policy Influence					
People						
Refugee migration	Trans-national volunteer networks	UNHCR	Border capacities Regional policy coherence	Economic incentive structures Job market policies Education system Refugee policies	Regional coordination of refugee reception	Local capacity for welcoming refugees
Work migration	Trans-national labour union cooperation		VISA rules and other cross-border agreements	Economic incentive structures Job market policies		
Travel (tourism, social networks, work)			VISA rules and other cross-border agreements Infrastructures	Infrastructure investments	Tourism investments and marketing	Tourism investments and marketing
Ideas and Knowledge						
Social media and internet			Capacity for social media communication	Investments in internet infrastructure and skills	Investments in internet infrastructure and skills	Investments in internet infrastructure Support for local skills and capacity
Traditional media and its messages		Scientific assessments (e.g. IPCC)	Scientific assessments Capacity for media communication	Outreach/PR activities Policy statements	Outreach activities Capacity building Subnational media channels (incl. web)	Capacity building
Education			Regional collaboration and exchange programs (UArctic)	Education policies Funding schemes		
Communication of scientific knowledge		Scientific assessments	Scientific collaboration Observation networks Exchange support Research infrastructure (virtual and physical)	Research funding Research infrastructure (virtual and physical)	Regional capacity to take part in scientific assessment and/or arrange spaces for co-learning	Local capacity to engage with scientific research and in participating in opportunities for co-learning
Sharing of Indigenous Knowledge and local knowledge (IK and LK)		Scientific assessments that include IK and LK	Scientific assessments that include IK and LK	Policies that support IK and LK and communication of IK and LK beyond the local	Activities that support communication of TEK beyond local	Activities and social networks that support communication of IK and LK
Sharing of spiritual beliefs and world views					Support for cultural activities	Support for cultural activities

As discussed further in Chapter 6, mining issues have largely remained within the purview of Arctic states. The Arctic Council has not engaged specifically with mining issues; the complexity of the decision-making landscape illustrates some of the challenges in addressing issues when the circumpolar level has its place among many other potential governance regimes.

In media reporting on the Arctic, connectivity is illustrated by a tendency to include both local and global issues in the same articles, linking diverse topics to each other (Christensen 2013). As Arctic communities and individuals become more and more connected to global markets and to global media flows, these interactions create challenges for communities with limited capacity to influence processes beyond their own local context. At the same time, the changing media landscape enabled by the Internet has also provided new opportunities to communicate globally in ways that were not conceivable a few decades ago.

Given the increasing connections between the local and the global it is especially important to identify ways in which Arctic governance processes may influence drivers of change that are external to the Arctic. Table 5.1 highlights some key mechanisms of cross-scale interactions and identifies governance tools that can play a role in influencing their impacts. The mechanisms of connectivity include physical pathways, money flows, mobility of people, as well as exchange of knowledge and ideas. The mechanisms of intervention range from specific policies to internationally coordinated exchange of knowledge that enables co-learning and framing of the public debate through media. Organizations that can provide venues for knowledge exchange across scales – so-called bridging organizations – are also an important mechanism (Hahn et al. 2006). The role of the Arctic Council in this context is discussed further in Chapter 6.

5.4.2 Features of connectivity

The increasing density of links among different decision-making processes has inspired a growing literature on the structure of connections among different decision-making contexts. One key characteristic of governance structures is "nestedness" (Boyer and Hollingsworth 1997), in which each successively larger scale encompasses multiple bodies at the smaller scale,

Alexander Kutskiy/International Centre for Reindeer Husbandry

Reindeer herder with sledge, Chukotka, Russia.

and in which the larger scale often establishes the norms and rules within which the smaller scales operate. In the case of formal decision-making, this relationship has been described in terms of levels – for example (e.g. "multi-level governance": see Hooghe and Marks 2001). The relationships between different scales (levels) are then often formally defined in terms of levels of governance, with lower levels operating under the authority of higher levels in which they are located. They also tend to be hierarchical; the national level typically represents highest level of political authority, although such authority may be pooled with other states through mutual agreement. Within multi-level governance systems, there is often some tension between governance levels, with certain kinds of decisions considered the domain of local or other subnational level bodies. This dynamic relationship between higher and lower levels of authority is important not only in federal or quasi-federal systems such as the U.S. or Canada, but also in countries where the formal state or province structure is absent. For the Arctic countries that are members of the EU, some policy areas are heavily influenced by European politics, such as environmental policy, while other areas remain under the purview of states.

Another type of connectivity important to resilience in the Arctic can be characterized as "horizontal" or "lateral" interplay. This type of connection is less likely to play out as a set of hierarchical relationships and more likely to entail participation of at least formally equal partners, although some may enjoy more resources than others. Examples of this type of connection include formal and informal collaboration among municipalities, villages, and communities; collaboration and learning among indigenous organizations; or networks of researchers, commercial actors, or environmental or other civil society organizations. The mechanisms involved in horizontal interplay include information exchange and sharing of best practices. Using notions of governance structures as hierarchies, networks or markets is useful for highlighting the highly diverse types of connectivity (Powell 1990).

Ostrom emphasized the "polycentric" nature of decision-making processes – with different kinds of authority, capacity and interest distributed across both scale and space (Ostrom 2010). Further attention to poly-centricity is sometimes hailed as the best way forward for issues where it is difficult to reach international agreement, and because diversity contributes to resilience. However, the down side is fragmentation of governance that may make policies less effective in relation to an overarching goal, such as mitigation of climate change (van Asselt 2014).

Connectivity means that while specific issues may manifest themselves at a particular location (e.g. disappearance of ice, migration of food sources, increase in ship traffic) the underlying causes may lie elsewhere. This is a crucial concern in making decisions that influence resilience where the challenge is to determine where the capacity to make meaningful decisions and take meaningful action resides. For the Arctic Council it becomes a matter of identifying when it has opportunity to take meaningful action that other potential venues for negotiations may lack.

5.5 Deliberate choices: summary and conclusions

"Governance" is a fundamental element in the "feedbacks" that produce continuity and change in social-ecological systems. As such it plays a central role in shaping social-ecological systems, and therefore in enhancing or eroding resilience. The Arctic is part of a dynamic governance landscape that is being globalized, and in which there is an increasingly dense and increasingly connected web of decision-making contexts, which include both formal governments at different levels as well as non-governmental actors and networks of actors, ranging from indigenous organizations to corporations.

At the same time as global political developments and legal regimes are having a growing influence in the Arctic, various Arctic actors including the Arctic Council have the potential to influence global policy. For example, global environmental agreements are relevant for decisions at the local, national and circumpolar level, and vice versa. Moreover, governance bodies and political actors in the Arctic are both influenced by and can influence overarching norms, such as the recognition of indigenous rights.

The current context poses three challenges for the Arctic Council as a circumpolar body for political cooperation. One is to define its specific place within the emerging landscape. The second is to develop capacity to engage with a wide range of other relevant policy processes. The third is to navigate the politics of how decision-making power is allocated among different institutions, ranging from the local to the global as well as from formal governments to non-governmental actors and organizations.

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CHAPTER 6

Learning to live with change

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Key Messages

- The need to be responsive to evolving conditions places constantly changing demands on policy and decision-making structures. Maintaining effectiveness requires an ongoing effort to facilitate and accelerate learning, and to build capacity to put that learning into practice.
- The Arctic Council has been successful in learning and adapting to new knowledge regarding many issues, yet the need for integration of new knowledge across the expertise of the individual Working Groups remains a difficult challenge, particularly where issues are closely linked to political goals.
- For dealing with environmental challenges that extend across scales, it is increasingly important that governance bodies develop the capacity to continually reassess their own role in engaging with the challenges and opportunities at hand and the activities of other governance bodies and actors.

Mike Beauregard/Flickr

Marble quarry near Arctic Bay hamlet, Nunavut, Canada.

Claudia Strambo

Diamond mine in Mirnyi, Russia. Global demand for natural resources is a key driver of socio-ecological change in the Arctic.

6.1 Introduction

Learning is a central aspect of the social response to social-ecological change and thus to resilience. This chapter[1] emphasizes organizational learning at the level of the Arctic Council, using three separate case studies to better understand how some policy problems may "fit" its mandate and structure, while others may not. Specifically, we analyze how the Arctic Council has taken on three global drivers of change that are especially important in the Arctic: pollution, climate change, and demand for natural resources and its link to extractive industries.

As the Arctic's sole circumpolar high-level policy forum, the Arctic Council has potential to connect decision-making at the local and international levels. While the Arctic Council has played this kind of bridging role on some issues, it has been less active on others that can also have major social and environmental consequences. After examining the three examples, we discuss how the notion of "adaptive governance" might be useful to the Arctic Council in making itself more nimble in responding to rapid environmental and social change.

1 This chapter is an abbreviated version of Nilsson, A.E. and Meek, C.L. (forthcoming). *Organizational Learning in Regional Governance: A Study of the Arctic Council.* SEI Working Paper. Stockholm Environment Institute, Stockholm. To be available at http://www.sei-international.org.

We specifically focus on learning as a central aspect of governance and examine the question: when and how has the Arctic Council changed its position or its way of working in response to new information? The purpose of this analysis is to identify how the Arctic Council could become more effective as a learning organization in ways that builds on its achievements.

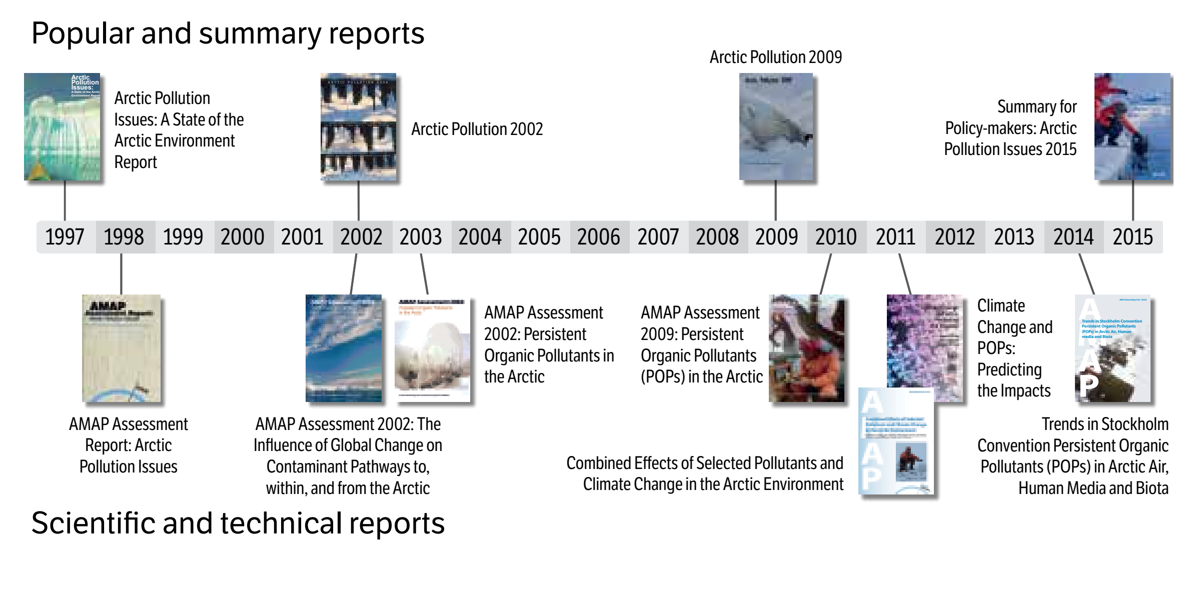
6.2 Case examples

6.2.1 Persistent organic pollutants

Pollution has been a central issue for Arctic circumpolar political cooperation since the early 1990s. It was a core part of the Arctic Environmental Protection Strategy (AEPS), and, together with sustainable development, is also central for the Arctic Council. Pollution has a clear organizational home in the Arctic Monitoring and Assessment Programme (AMAP) Working Group, which has the mandate to "propose actions to reduce associated threat for consideration by governments". The pollution issue that has received the most attention is persistent organic pollutants (POPs). The story of the science and policy of POPs in the Arctic has been documented by several people who were active in the policy processes (Downie and Fenge 2003; Stone 2015), but also as part of the cognitive work that circumpolar cooperation has enabled (Schram Stokke 2006; Nilsson 2012). It is often heralded as an example of successful Arctic cooperation, and is therefore a useful example for analyzing whether there are particular features of Arctic cooperation that have facilitated this success.

The international politics of chemicals contributed to the success of circumpolar work on POPs through the creation of networks that, while not set up for work on POPs in the Arctic, were easily integrated into the new international cooperation of the Arctic Environmental Protection Strategy. For example, Canada had been running its Northern Contaminants Programme since the 1980s with well-established routines for communication not only between scientists and the policy sphere, but also with indigenous representatives. Internationally, negotiations were already under way to include POPs in the UN Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP). Some of the same people took part in the negotiations to establish the Arctic Environmental Protection Strategy. It is therefore not a coincidence that there was a good fit between the POPs issue and the structure of the Arctic cooperation. And when AMAP published its first major assessment in 1997 (AMAP 1997), some of the findings presented in the chapter on POPs had already become part of the international negotiations under way through CLRTAP. Arctic cooperation

FIGURE 6.1 **AMAP's POPs assessments on a timeline**



through AMAP helped focus the world's attention on the heightened susceptibility of the Arctic to the accumulation of POPs in both people and the environment, as evidenced by the preamble in the 2001 Stockholm Convention on Persistent Organic Pollutants (2001).

Since then, AMAP has published several assessments (see Figure 6.1) that have focused on different chemicals, as well as new knowledge about the impacts of chemicals, signs of the effects of policy action, and how levels of POPs in the environment may be affected by climate change (AMAP 2002; Macdonald et al. 2002; AMAP 2009b). From the perspective of understanding the role of the Arctic Council in the continued work on chemicals policy, it is important to realize that some of AMAP's ideas on monitoring were exported to international conventions, which gave the Arctic Council and AMAP a specific role in providing updated information on both old and new chemicals in the Arctic environment. In spite of the fact that some of the specific individuals have since been replaced by others, the institutional links between AMAP and the POPs convention, and the related epistemic community, have remained and even expanded. Through AMAP, the Arctic Council thus served as a bridging organization, bridging between a global problem with local consequences, and making local Arctic issues a global concern.

Given the success of the Arctic Council in influencing global policy processes, the need for organizational learning may not seem acute: the working model has been a success. However, the details of how the POPs issue has developed in the Arctic Council show that policy learning has taken place. One of the most important ways it has done so relates to a finding in the first AMAP report: that there were also substantial local sources of POPs *within* the Arctic. The major initial framing of the POPs issue was that these chemicals were transported *to* the Arctic by air and water and accumulated in the Arctic because of the cold conditions and the nature of the marine ecosystems, which have many trophic levels in the food web and fat as a key source of energy (AMAP 1997). These characteristics contribute to bio-magnification of POPs and high levels in top predators. With this understanding of the problem, international regulation was a necessity because emissions from anywhere in the world can eventually reach the Arctic. However, it soon became clear that POPs levels in some places were higher than could be easily explained by long-range transport, and scientists started to turn their attention to local sources. These included emissions from burning trash, but also from dumped toxic material and continued use of some POPs, especially in Russia. While these sources would be covered by the global convention, the Arctic Council also concluded that the circumpolar cooperation had a special role to play in taking care of them. In 2000 the Council endorsed and adopted the Arctic Council Action Plan to Eliminate Pollution of the Arctic (Arctic Council 2000a). In addition to POPs, the work would focus on heavy metals and radioactive pollution, which had also been a focus of the first AMAP assessment. In 2006 this plan was institutionalized in the form of a new working group and renamed the Arctic Contaminants Action Program (ACAP). Its mission is to act "as a strengthening and supporting mechanism to encourage national actions to reduce emissions and other releases of pollutants", and has a budget to back up this mission.

In summary, the co-evolution of the Arctic cooperation and the emergence of POPs as an environmental and health concern in the Arctic, both scientifically and politically, created a good fit between the organizational structure of the Arctic Council, exemplified by AMAP, and the actions needed to meet the challenge. Moreover, when new knowledge revealed local and regional sources of POPs in the Arctic and a complementary *modus operandus* was needed, an action plan was formulated and later successfully turned into a separate policy initiative and working group. On one level, the conditions and degree of success are unique, but AMAP's assessment and Arctic Council initiatives have served a similar role in relation to the Minamata Convention on Mercury (Koivurova, Kankaanpää and Stępień 2015). This suggests that there is organizational learning across issue areas on how to navigate global environmental politics in a way that focuses attention on Arctic concerns.

6.2.2 Climate change

How attention to climate change has evolved in Arctic circumpolar cooperation has been described in some detail (Nilsson 2007; Koivurova et al. 2009; Nilsson 2012). Climate change was mentioned as a potential concern when the circumpolar political cooperation was first formalized in the Arctic Environmental Protection Strategy. It was not prioritized, however, because it was seen as a global issue that should primarily be handled through cooperative mechanisms operating at a global scale, such as the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (UNFCCC). The first major AMAP assessment gave some attention to climate change (Weatherhead 1998), but its executive summary and recommendations did not highlight specific policy action on climate change, only stating that Arctic countries should support the UNFCCC process. For the scientific community, however, Arctic climate change was already a major issue (Nilsson 2007; Wormbs et al. forthcoming). By the end of the 1990s, climate science had advanced far enough that it was reasonable to assume that the impacts in the Arctic would be more severe than elsewhere, but the knowledge about regional climate dynamics and their potential impacts was limited. Moreover, concerns were growing both in the scientific community and among the Arctic's Indigenous Peoples about the slow progress in international negotiations, creating strong incentives for a thorough assessment of the impacts of climate change in the Arctic. These interests merged with AMAP's effort to follow up on its first major assessment, and in 2000 the Arctic Climate Impact Assessment (ACIA) was launched. Four years later its plain language summary report was released (ACIA 2004), followed by the full assessment report (ACIA 2005).

The ACIA process included two important innovative features. First, the assessment process was set up differently from previous assessments in that it included collaboration between two working groups, AMAP and Conservation of Arctic Flora and Fauna (CAFF), as well as with a separate organization, the International Arctic

Alaska DOT&PF/Flickr

Rapid coastal erosion is one of the many impacts of climate change in the Arctic that damage infrastructure. In Kotzebue, Alaska, Shore Avenue was rebuilt because erosion had reduced it to less than two lanes and was forcing traffic onto adjacent property.

Science Committee (IASC), which brought in broader expertise than there would have been had ACIA been set within one single working group. Moreover, the Arctic Council recognized the need for social and economic expertise and requested that this be included in the assessment. The assessment was also the first within the Arctic Council to integrate Indigenous Knowledge in a systematic manner. As a result of the new knowledge from the assessment process, the Arctic Council, in the 2002 Inari Declaration, recognized climate change as a new issue of concern and expressed its intent to "reinforce dialogue on climate policy and help deal with vulnerability and adaptability" (Arctic Council 2000b). This new policy stance did not immediately translate into policy action, however. Instead the framing remained in which policy responsibility for responding to climate change should mainly lie with global institutions.

Because the ACIA was not a standard working group activity, and because its policy implications were politically controversial for some Member States, it was not self-evident how it should be followed up. Impacts of climate change were also relevant across the different working groups. In practice, immediate follow-up action was limited to launching the Arctic Marine Shipping Assessment (AMSA), which examines the need for new regulations of marine shipping as a consequence of the receding ice cover. AMSA is led by the Working Group for the Protection of Arctic Marine Environment (PAME), where it has a natural fit with its mandate. AMSA's first report was issued in 2009 (Arctic Council 2009a) and since then several follow-up reports have been published. AMSA is an example of an Arctic Council assessment that has had its recommendations followed up in a structured manner, including direct engagement with the International Maritime Organization's Polar Code for vessels standards.

The Salekhard Declaration, adopted at the 2006 Ministerial in Salekhard, Russia, provides a window into the Arctic Council's growing engagement with climate change as an Arctic Council issue. While it reaffirmed the commitment to support IPCC and the UNFCCC as the principal international forums for organizing both science and policy response, it also called for "the SAOs [Senior Arctic Officials] and the Arctic Council working groups to implement activities, as appropriate, to follow-up the Arctic Climate Impact Assessment (ACIA) and the ACIA Policy Document". For example, it directed the Sustainable Development Working Group to draw on expertise from the other working groups and other stakeholders to learn about best practices and potential adaptation action (Arctic Council 2006). However, this initial effort to link activities across the working groups failed to get much traction. The concrete work that emerged was a compilation of findings and recommendations developed by past Arctic Council assessments that could inform adaptation strategies, and

Western Arctic National Parklands/Flickr

A scientist adjusts weather station equipment near Mount Noat, Alaska, to gather climate data.

information about existing adaptation efforts in Arctic states and regions. The next steps to develop knowledge on climate change and its impacts were the Snow, Water, Ice, Permafrost in the Arctic assessment (SWIPA), and an update of the ACIA with modest ambitions that resulted in the 2009 report Update on Selected Climate Issues of Concern (AMAP 2009a), both led by AMAP.

Following the publication of Update on Selected Climate Issues of Concern and a report on the Greenland ice sheet as part of the SWIPA project (AMAP 2009c), the 2009 Tromsø Declaration spoke about the urgency of action on climate change and called for states to commit to climate-change action through the UNFCCC and to recognize the need for adaptation actions (Arctic Council 2009b). Mitigation of climate change was, however, still seen as a task to be organized at the global scale rather than one in which the Arctic Council should collectively take a lead. The Arctic Council did, however, identify one aspect of climate mitigation where it could engage, deciding to take on the issue of short-lived climate forcers by setting up a task force in 2009 "to identify existing and new measures to reduce emissions of these forcers and recommend further immediate actions that can be taken". This can be seen as the first attempt to start addressing the pressures that contribute to climate change in the Arctic. This task force has since delivered several reports that clearly show that while short-lived climate forcers are important for Arctic warming and must be addressed to slow down the rate of change, they represent only a fraction of the warming potential from carbon dioxide (Arctic Council 2011; Arctic Council 2013).

euno/Flickr

The container ship *Arctic Express* gliding through Kola Bay to the Barents Sea. The Arctic Marine Shipping Assessment is an example of how the Arctic Council has adapted over time to tackle new issues.

When SWIPA presented its report in 2011 the results confirmed earlier assessments of rapid climate change with major impacts in the Arctic (AMAP 2011). By this time, the 2007 record low sea-ice minimum had turned the world's attention to climate impacts in the Arctic, and the 2007/2008 International Polar Year had brought a wealth of new knowledge about climate change, including studies on vulnerability and adaptation. Within the Arctic Council, however, it remained difficult to identify a suitable locus of responsibility for this issue. Instead, activities were initiated and carried out in several different contexts, including the Arctic Marine Shipping Assessment (Arctic Council 2009a), attention to the impacts of climate change on biodiversity in the Arctic Biodiversity Assessment (CAFF 2013), ongoing work on climate modeling within AMAP, and some efforts to support sharing of information on adaptation.

Other important climate-change related efforts directly relevant for the Arctic Council include SDWG's EALAT and EALLIN projects, run by the Association of World Reindeer Herders, which focus on the impacts of climate change on reindeer herding. Moreover, two Arctic Human Development Reports have been published, in 2004 and 2014 (AHDR 2004; Larsen and Fondahl 2015). Neither AHDR report focuses on climate change directly; rather they focus on social and cultural issues, where climate change is an increasingly important part of the context. In AHDR-II, climate change appears as one of three common threads, together with gender and globalization, and there is no question that it is part of the social realities of the region. There are no systematic links between the AHDR process and the work on climate change carried out in the Arctic Council working groups but these efforts, together with lessons from research during the International Polar Year 2007-2008, would be a base for better integrating social, cultural and biophysical aspects in assessments of climate change and its consequences.

While a once proposed overarching assessment of Arctic change has not been initiated, a project called Adaptation Actions for a Changing Arctic (AACA) is currently ongoing. A major forthcoming output of the AACA is a set of pilot sub-regional assessments focusing on the Barents region, Davis Strait-Baffin Bay, and the Bering-Beaufort-Chukchi region.[2] The new focus on sub-regions rather than the circumpolar scale is especially relevant for adaptation issues. The shift in focal scale creates a new setting for bringing different types of expertise together, including a broader set of stakeholders, such as local decision makers and businesses. It is too early to judge the impacts of the new focus, but the ambitions of engaging more broadly with regional actors may in the longer run lead to an improved and more nuanced understanding of climate change challenges across the Arctic. Assessing and responding to the need for adaptation to rapid social and environmental change still present challenges for the existing working group structure, however, as the organizational structure of the working groups was established to address less cross-cutting issues. Issues involving complex links between environmental and social change, of which climate change is only one, may require a more thorough analysis of how the organizational structure of the Arctic Council can best meet the needs of decision-makers at the circumpolar level as well as at the national and sub-national levels.

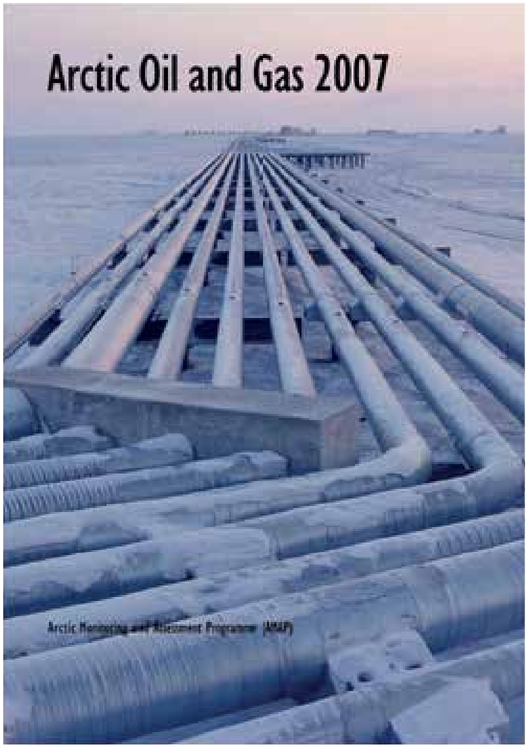
2 See: www.amap.no/adaptation-actions-for-a-changing-arctic-part-c

FIGURE 6.2 **Locations of mines in the Arctic**

6.2.3 Global resource demand and extractive industries

Extractive industries have played a major role in shaping social development in many parts of the Arctic. This includes industrial development and infrastructure related to oil and gas, as well as mining and other activities related to mineral resources. AMAP's first assessment on Arctic pollution issues (1997) addressed impacts of some extractive industries in the chapters on heavy metals and hydrocarbons. The assessment focused on environmental impacts from pollution, but not social or economic issues related to extractive industries. The assessment of environmental impacts from oil and gas activities was followed by AMAP's 2007 Oil and Gas Assessment, which provided a thorough background on such activities, as well as a discussion of the social effects and governance responses (AMAP 2008; AMAP 2010). It recommended that the consequences of oil and gas activities should be given increased priority through research, assessment, and guidelines for improved management. With reference to the transboundary nature of pollution from oil and gas activities, the recommendations also called for bilateral and multilateral coordination on preparedness and response to oil spills. This was followed up in the 2008 Tromsø Ministerial Declaration, in which the Arctic Council Member States decided "to strengthen cooperation related to the prevention of, and response to, accidental spills of oil and hazardous substances in the Arctic" (Arctic Council 2009b). Later on, this decision became the basis for negotiations on the Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic, which is the second legally binding agreement negotiated under the auspices of the Arctic Council. Moreover, in the Tromsø Declaration the Arctic Council members "encourage future national, bi-national and multinational contingency plans, training and exercises, to develop effective response measures".

FIGURE 6.3 **Cover of AMAP's Arctic Oil and Gas Assessment 2007**



Without a doubt, oil and gas issues are one area where Arctic Council members have indeed moved from knowledge and assessment to action aimed at preventing pollution, framed as part of protecting the Arctic environment. By contrast, the social aspects of oil and gas industrial development have not been specifically addressed. The most prominent consideration of social impacts can be found in a few case studies presented in AHDR-II, one focusing on indigenous-industrial relations in Russia (Forbes in Forbes and Kofinas 2014), the other discussing Greenland's legal framework for non-renewable resource exploitation (Lennert in Forbes and Kofinas 2014). However, because the AHDR-II was not an Arctic Council report it does not require follow up. The limited discussion of the social impacts of extractive industries suggests that Arctic Council Member States see these issues as falling outside the purview of the Arctic Council. Young and Kankaanpää make note of this likelihood in their broader discussion of resource governance, suggesting that the cooperation "is not designed to address domestic concerns like establishing and operating co-management regimes governing human-environmental interactions on a local or sub-regional scale" (Young and Kankaanpää in Forbes and Kofinas 2014). Young and Kankaanpää do note that SDWG could potentially play a much stronger role in incorporating social issues related to resource management than it has done to date, and while such a role could result in "requiring the Council to take an interest in activities occurring within the jurisdiction of individual states", it would not require adjustment to existing structures of authority (p. 284–5).

Mining issues have been treated within the Arctic Council context mainly as a potential source of heavy metals in the environment (AMAP 1997; AMAP 1998; AMAP 2002). Mining also has major social impacts and is an engine for infrastructure development, but this aspect has not been addressed by a major Arctic Council assessment. It is mentioned many times in the Arctic Human Development Report-II, for example, in discussions about demography, impacts on subsistence activities, the Arctic economy, and the path-dependent nature of northern development (Larsen and Fondahl 2015), but without specific recommendations. During the Swedish Chairmanship (2011–2013) the Arctic Council initiated work on corporate social responsibility, and during the Canadian Chairmanship (2013–2015) the Arctic Economic Council was formed for discussion of best practice among economic actors in the Arctic, which may provide a context where the Arctic Council could engage more deeply in pollution and social issues associated with mining, but this will also depend on the relationship between the Arctic Council and the Arctic Economic Council, which is an independent organization.

The challenges in understanding extractive industries as part of social-ecological systems is thus partly related to how the Arctic Council organizes its assessment, but also to political priorities about the Council's role vis-à-vis other levels of governance. It is nevertheless relevant to also assess the extent to which organizational structures may create additional obstacles for bringing important concerns to the fore.

6.3 Discussion

All three cases in this chapter highlight how global drivers of change and associated impacts directly affect people living in the Arctic. Such cross-scale issues present a challenge for any regional governance body, including the Arctic Council, and there is an additional challenge in negotiating where policy authority should lie in relation to different levels of governance. Scale is central to how particular policy problems are structured. For the Arctic Council, the issue of defining the problem has been most apparent in climate change mitigation, which has been historically defined as requiring global responses, and the social impacts of resource extraction, which remain within the purview of national authority. Another element of this complexity is that both the structure of these policy problems and how they are understood in scientific and policy circles changes with time. Continuous adaptation to new circumstances (sometimes discussed

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Nickel mine on the Kola Peninsula, Russia: Extractive industries have played a major role in shaping social development in many parts of the Arctic.

as "adaptive governance") is thus a central aspect of governance in the "Anthropocene" (Kofinas et al. 2013).

Wyborn (2015) summarizes adaptive governance as "decision-making that anticipates, learns from and responds to change", and discusses adaptive *co-management* as an important extension of the concept. Co-management has been developed in several contexts of resource management within the Arctic, and it requires that different knowledge systems and perspectives be shared through partnership and inclusive decision-making. So, adaptive co-management is an approach that merges the goal of continued learning with the partnerships that are central for co-management regimes. However, while this kind of learning aims to make the current mode of management more effective, it does not necessarily shift any of its underlying assumptions. As a means to do so, Wyborn therefore sets out the idea of "*co-productive* governance", which demands attention to the dynamic interplay among context, knowledge, process, and visions of governance. It includes a readiness to re-evaluate not only specific policies, but also overarching assumptions and mental models, including *how* and for *what* goals we make joint decisions in society. Co-productive governance highlights the normative (what we morally should do) and cognitive (what we know and think) elements of governance, and also addresses how these elements emerge in specific contexts.

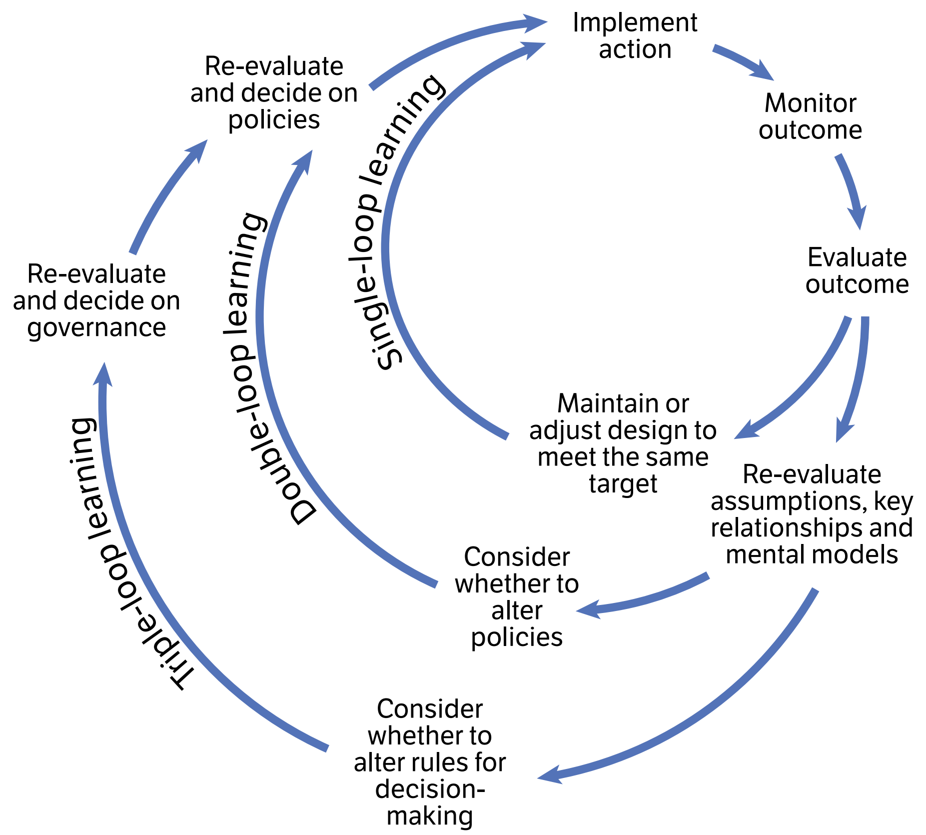
Historically, shifts in the overarching logic of norms and goals in international decision-making have taken place in reaction to new major challenges combined with the space for a wider range of voices in the discussion. One example is the focus on sustainable development as a framework for international environmental governance that has its roots in the 1980s and became institutionalized at the 1992 UN Conference on Environment and Development in Rio de Janeiro. This focus highlighted tensions and links between environmental, social and economic development, and also brought a new normative emphasis on responsibility for future generations (World Commission on Environment and Development 1987). Moreover, new knowledge and new mental models affected how environmental issues were viewed in society, including the notion that many environmental processes are *global* in nature, requiring international cooperation.

Another example is the birth of circumpolar cooperation (see Chapter 5), which was a response to a combination of new challenges, including new knowledge about the impacts of pollution in the Arctic and an increasing need for cross-border collaboration.

In hindsight it is easy to understand how political structures and decision-making develop in response to change. However, with rapid social and environmental change creating new pressures on policy-making every day, and with scientific consensus on anticipated change, there is a need to look critically at the capacity for learning within current structures, and how that capacity could be improved.

FIGURE 6.4 **In single loop learning, new knowledge is added within an existing conceptual framing, whereas double- and triple-loop learning require reassessing old beliefs, norms and objectives.**

Source: Adapted from Chapin et al. (2009)



There are many definitions of learning. One of the more relevant ones for the study of governance is Sabatier's notion of policy learning as "relatively enduring alterations of thought or behavioural intentions that result from experience and that are concerned with the attainment or revision of the precepts of one's belief system" (Sabatier 1987, p.673). In this definition, learning goes beyond acquiring new factual knowledge and includes using it to revise basic premises or beliefs.

Others have categorized learning as either single, double, or triple-loop learning (see Figure 6.4). Single-loop learning includes new knowledge within existing ways of framing an issue, while double-loop learning is more fundamental in that it includes a reassessment of the operational framework of beliefs, norms and objectives (Siebenhüner 2002). Siebenhüner goes on to describe triple-loop learning as "learning to learn", that is, when an organization reflects on the procedures by which it collects, evaluates and takes action on new knowledge. Chapin et al. (2009) also suggest that altering the rules of decision-making is part of triple-loop learning.

What types of learning are evident within the Arctic Council? What structures and practices within it can facilitate different types of learning? Koivurova et al. (2015) describe a shift in emphasis from early efforts to create normative frameworks to scientific assessments as an example of learning and adaptation. Efforts to create guidelines for activities in the Arctic had limited influence, including those on environmental impact assessments that were never put into practice. More recently, the Arctic Council has had to adapt to increasing attention on the Arctic and has responded by strengthening its organizational structure. Koivurova et al. (2015) argue that these developments illustrate how the soft-law character of Arctic cooperation has allowed enough flexibility for the Arctic Council to successfully navigate its role in complex governance landscape, where due attention is needed to both international and national processes. Another important factor is that the Arctic Council has created a platform for building epistemic communities that include scientists, government officials and Indigenous Peoples.

Within this overall success as an adaptive governance regime, the picture is more mixed. As the case studies in this chapter illustrate, the Arctic Council's organizational structure has been quite effective in accommodating some new issues that were not prominent when that structure was first created (e.g. climate change and the increasing need to understand social dimensions of environmental challenges). Yet with others, new issues and perspectives have pressed the structural bounds of the working groups. For example, in spite of the increasing impacts of mining in the Arctic, this issue has not been a focus of any scientific assessment. For climate change, the initial response of the Arctic Council was limited, as was the follow-up after the ACIA. One example of a successful path for more assertive engagement is the Arctic Marine Shipping Assessment, with its clear organizational home in PAME.

Moving from scientific assessment to addressing the source of the pressure on the environment and social development is also fraught with challenges, because it raises questions about who should be responsible for taking action. While there are clear successes, such as the role that the Council has played and continues to play in international chemicals management and the emerging cooperation on preventing oil spills, purposeful, coordinated action by Arctic Council Member States to address emission of greenhouse gases has been far more modest. It is clear that, so far, the Arctic Council has found it a challenge to overcome the political constraints that spill over from global climate politics, even if climate change is often described as one of the major pressures facing the region.

Some of the challenges of effectively engaging in these kinds of complex policy problems can be understood in light of insights from policy learning in other settings. Studies of social learning and environmental governance have identified several organizational features that increase the capacity for social learning. They include openness and transparency in decision-making processes, participation, dialogue, trust, and social networks that cut across various communities of practice. Studies of mechanisms of social learning highlight issues of participation (e.g. who is present and who has the power to decide), the process (e.g. the nature of participation and facilitation), the horizontal and vertical links to processes in other organizations or at other governance levels, and how different norms shape social interactions in specific institutional contexts (Mostert et al. 2007; Pelling et al. 2008; Siebenhüner 2002). Such norms can influence how the boundaries between policy and science are organized and negotiated, a process sometimes called boundary management (Guston 2001; Miller 2001). Another feature is the extent to which the norms allow for so-called shadow systems, which are informal channels of communication

U.S. Coast Guard photo, Petty Officer 2nd Class Grant DeVuys/Flickr

Oil spill exercise in Kotzebue, Alaska, in 2015: The Arctic Council has played a key role in building cooperation to prevent oil spills in the Arctic.

where issues can move forward even if they are difficult to handle within the formal decision-making processes (Pelling et al. 2008). Last, but not least, is the issue of how the institutional context contributes to trust (Pahl-Wostl et al. 2007; Mostert et al. 2007). How have these features played out in the Arctic Council in the three case studies?

Broad participation appears central to the Arctic Council's success on the issue of persistent organic pollutants, where actors with influence and knowledge about ongoing policy processes appear to be key to making the scientific assessment directly useful in creating new policy. Moreover, the early participation of Indigenous Peoples in this dialogue was also important, helping to create a cross-scale link in which Arctic Council activities served as a connecting point between national and, to some extent, local concerns and global processes. This participation appears to have made the new knowledge from the assessment salient to key policy actors, a feature that, together with credibility and legitimacy, is crucial for environmental assessment to be successfully incorporated into policy (Mitchell et al. 2006).

It would seem that the Arctic Council could serve a similar role on climate change, in terms of generating knowledge that directly influenced policy, and providing a forum for coordinating actions taken by Arctic Council members. However, while the ACIA and later Arctic Council assessments focusing on climate change have informed the IPCC, they have not yet had substantial impacts on climate policy. Because links to the global policy processes were present in the ACIA policy negotiation (e.g. through the participation of people who also acted as national negotiators in the UNFCCC) the bottleneck would seem to lie elsewhere, or rather, the same bottlenecks that were present at the global level also applied in the Arctic Council. Based on studies of the ACIA process and its immediate follow-up, one of the major issues was a lack of confidence on the part of some in the integrity of the scientific process, which added to the challenges caused by strong national interests and different perspectives among the Arctic Council member states. Scientific credibility as such was not in question; the challenges were related more to the process of how scientific insights are transformed into policy recommendations (Nilsson 2012).

Arctic Council Secretariat/Linnea Nordström

Flags of the Member States and Permanent Participants of the Arctic Council.

The Arctic Council has grown, with the addition of new observers making it more challenging to create an informal atmosphere of trust. Together with the fact that the Arctic Council faces more contentious issues, it cannot be taken for granted that Arctic actors have shared interests and shared perspectives to the same extent as has been the case earlier through its development. Arctic international cooperation has in a sense become more like international cooperation in general, where the building of trust and transparency requires concerted effort. The legitimacy of the assessment processes and their links to policy processes are crucial, pointing to the central role of reflecting on how the relationships between basic knowledge production, assessments and policy processes are managed.

While in many ways the Arctic Council has been successful in adapting to new challenges by taking on innovative activities, especially in the realm of knowledge production, there have also been limits to its capacity to redress some of the real problems facing people living in the Arctic. Given the increasing need for action and the growing number of interested actors, some of these problems are likely to be exacerbated in the future. Some of the limitations of the Arctic Council have to do with the appropriate scale of governance in relation to the issues to be tackled. This is often termed the "fit" of governance (Folke et al. 2007; Young 2002; Galaz et al. 2008). It is inevitable that regional organizations face challenges in addressing problems that stem from global processes. Likewise, circumpolar cooperation is not likely to be able to provide an adequate setting for addressing community concerns that requires knowledge about the local social and environmental context and engagement from local actors. Also, when national interests are central, some issues are more likely to be perceived as national rather than international concerns, making Arctic Council members unwilling to engage with them in the Arctic council setting. Moreover, the Arctic Council is a soft-law body and is thus dependent on its member states for translating normative goals to national policies and also for pushing agreed priorities in international negotiations.

One way to overcome this inevitable challenge for political decision-making at the circumpolar level is to create conditions that favour vertical links and communication across political levels. The literature on resilience has identified "bridging organizations" as key features of successful management at the local level because they

Arctic Council Secretariat/Linnea Nordström

Senior Arctic Officials meeting in Yellowknife, Canada, in 2014.

can facilitate communication across levels (Olsson et al. 2007). In the case of persistent organic pollutants, participation by actors engaged at different levels of governance, from national to international, contributed to the success, while for the politically more contentious issue of climate change the lack of perceived fit created challenges. For oil and gas, it appears that the Arctic Council has been able to carve out a niche of international cooperation where the fit is fairly good because of a need to collaborate across national jurisdictions without it being useful to frame the practical collaboration as a global concern. For mineral resources and mining, one could argue that the issue does not fit within the mandate of the Arctic Council based on the fact that there has been no articulated need for international collaboration in addressing potential social and environmental challenges related to mining. The extent to which the Arctic Council should engage in the issue would depend on the extent to which it should engage in broader issues of sustainable development within the member states, and thus the issue of mineral resources and mining would be part of a much broader discussion of the role of the Arctic Council for sustainable development across the circumpolar North.

In spite of some issues appearing to have a better fit than others, whether an issue is indeed taken up by the Arctic Council is a matter of political negotiation, in which knowledge and learning is only one aspect to take into account and where the issue of fit becomes part of a social negotiation (Lebel et al. 2005; Brenner 2001). However, in a world where interactions across scales and connectivity is the norm rather than the exception, and when rapid change creates a need for adaptive governance, it could be useful to think about the notion of fit as the capacity for an organization to learn and be adaptive to new challenges, instead of focusing on how its mandate fits within the specific scale or scope of an issue. Thus, in order to assess fit and to support the Council's organizational development, it may be relevant to explicitly examine the structures that bridge across scales and issue areas, as well as those that provide space for innovation and reframing of issues, and also help the Council pick up on new developments that do not fall into the fields of expertise and interests of the current working groups. Moreover, there appears to be a need for more ways to create links between the expert communities associated with the different working groups, especially between the natural and the social sciences.

6.4 Summary and conclusions

Rapid change and uncertainty create new demands on governance structures, especially to accommodate new knowledge and take action to respond to new priority issues. While the Arctic Council has been able to accommodate some issues that were not prominent when the working group structure was first created, including climate change, the current organizational structure has not encouraged the inclusion of new issues and perspectives. Therefore there is an opportunity for the Arctic Council to think about ways in which learning can be facilitated, especially for issues requiring a broad range of expertise or which may be politically contentious. As challenges extend across spatial scales, there is a risk that responsibility will be placed elsewhere simply because the Arctic Council is not seen as the ideal policy venue in scope and scale for the challenges at hand. As an alternative, the notion of governance fit is better applied to the organizational capacity for learning than to identifying the best scale and scope of governance arrangements.

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PART IV

Building Resilience for Responding to Change

Mads Pihl/Destination Arctic Circle

Resilience can be cultivated and strengthened – a process that entails understanding the components of resilience and how they interact with one another, and then facilitating activities that enhance these individual components and their interactions, and monitoring and evaluating results through ongoing assessment.

Knowledge and other factors influence how communities and societies prepare for change through adaptation, enhancing their capacity to adjust, adapt, and actively navigate change. Many of the reports commissioned by the Arctic Council influence resilience by increasing the knowledge base on challenges faced by Arctic communities and societies.

A variety of other Arctic Council initiatives have already strengthened aspects of Arctic resilience. For example, the Arctic Climate Impact Assessment, published in 2004, helped set the stage for action, with its attention to impacts of climate change for peoples and communities in the north, and by including local and Indigenous Knowledge.

Chapter 7 reviews initial efforts to assess and measure components of resilience, and identifies promising approaches to monitoring these components. Natural, social, human, cultural, knowledge, financial and infrastructural capital, in combination, are essential to support human well-being and development. They also support the types of adaptive and transformative capacity that are expressions of resilience.

Navigating change effectively requires different combinations of these capitals. Individuals, communities and organizations may possess some of the prerequisites for change, yet still be unable to activate them due to a lack of other prerequisites, or inadequate interactions among these components of resilience.

Chapter 8 points to overall principles that can guide activities that build resilience: working to establish clear shared goals; organizing to ensure that learning occurs and that insights from integrating diverse bodies of knowledge are organized and used; and linking across scales to support place-based partnerships that can respond to global and regional dynamics while taking local culture into account.

Finally, the chapter examines resilience building activities that are already being implemented in the Arctic and beyond. These include knowledge-building processes such as assessment and monitoring to strengthen knowledge, and policy evaluation processes such as exploring alternative futures using simulation models and participatory scenarios, in addition to developing concrete actions informed by these insights.

CHAPTER 7

Building capacity to adapt to and shape change

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Key messages

- The key characteristics of resilience and the capacity to effectively respond to change – adaptive and transformative capacity – can be identified, evaluated and measured. Monitoring these elements is an important strategy for monitoring resilience, and how policy choices may strengthen or undermine it.
- Individuals, communities and organizations may possess some of the prerequisites for adaptive capacity, yet still not be able to activate them due to critical gaps in others. These gaps become the "weak links" in the chain.
- The Arctic Council already plays an important role in enhancing some elements of adaptive and transformative capacity, and there are additional areas where it could play an important role, thus building resilience of communities and peoples of the North.

Kitty Terwolbeck/Flickr

Svalbard Airport near Longyearbyen, Norway.

7.1 Resilience, adaptive capacity, and the Arctic Council

Environmental and social changes in the Arctic are happening so fast and on such a large scale that to successfully adapt, local communities need support from all levels of governance, including circumpolar political cooperation. Communities' capacity to achieve transformational change also needs to be enhanced to ensure continued improvements in human well-being.

This chapter examines the roles that the Arctic Council, as a circumpolar body for cooperation, might be able to play in strengthening adaptive and transformative capacity in the region. We discuss efforts already under way, and consider what else is possible. The chapter dovetails with ongoing work in the project Adaptation Action for a Changing Arctic (AACA), which assesses current and future changes and the adaptation actions needed to address them.

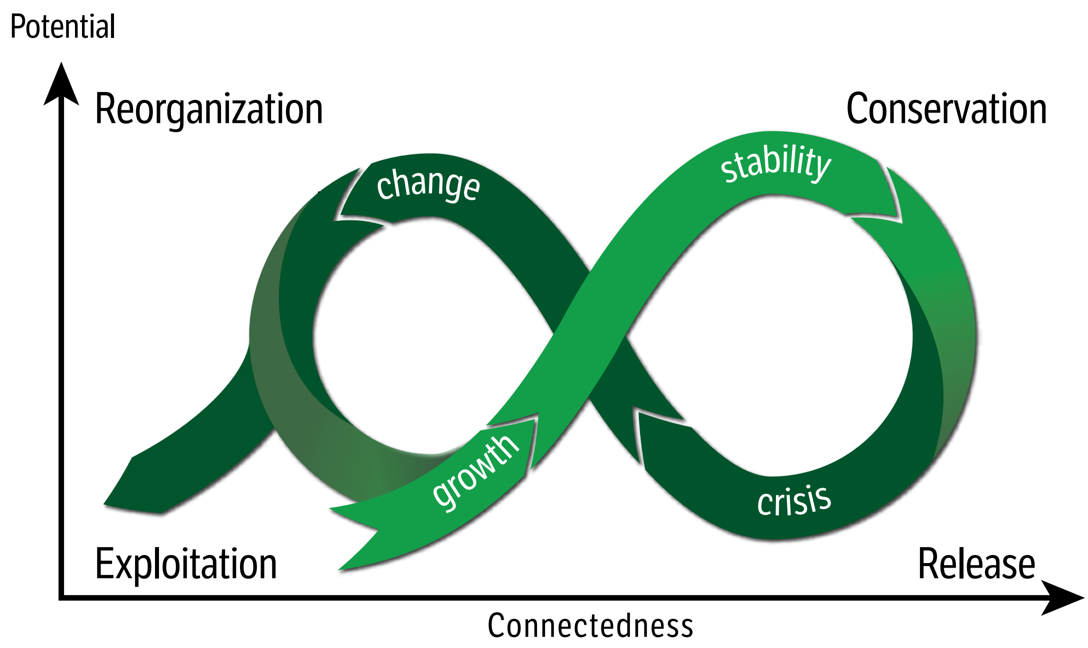
As outlined in Chapter 1, adaptation is the process by which a social-ecological system "copes with, manages or adjusts" to change, with change entailing both risk and opportunity (Smit and Wandel 2006, p.282). Transformation implies a more fundamental change, rather than adjustments within a social-ecological system as it functions today. We refer to "intentional transformation" as making deliberate choices to fundamentally alter some activities in order to maintain core identities. Chapter 4 provides examples of such transformation.

As shown in Figure 7.1, both adaptation and transformation involve change-shaping processes within the adaptive cycles of social-ecological systems. Societies may seek to control drivers of unwelcome change, yet change itself is an inevitable and natural part of both societies and ecosystems. While resilience represents the capacity to effectively navigate change – contributing to both adaptive and transformative capacity (see Chapter 1) – the elements that contribute to resilience can be identified and examined further to better understand how a given set of actions or activities might contribute to, or weaken, resilience (see also Chapter 4).

Our knowledge and understanding of the processes that drive change and shape societal adaptive responses and adaptive capacity have increased in recent years. This includes more scientific attention to the interlinkages between societal and environmental drivers and the broad range of consequences and adaptive responses.

FIGURE 7.1 **The adaptive cycle in social-ecological system dynamics**

Change is a natural part of social-ecological systems. It can be part of an adaptive cycle where some sort of crisis leads to a major reorganization, followed by a move towards greater stability of the new system structure, until the next crisis. This figure is adapted from Figure 2.5 in the Interim Report.



Derrick Midwinter/Flickr

Natural capital is crucial to people's capacity to adapt and transform in the face of environmental change.

The Arctic Resilience Interim Report 2013 synthesized some aspects of this knowledge base, in an attempt to explicitly link insights from adaptation and vulnerability research with resilience thinking (Kofinas et al. 2013). Drawing on the adaptation and development literature, the synthesis identified seven key aspects of adaptive and transformative capacity in need of attention: natural capital, social capital, human capital, infrastructure, financial capital, knowledge assets, and cultural capital. This chapter relates those categories to other conceptualizations of conditions that are likely to influence how society responds to change, as a background for discussion of what role the Arctic Council has played and might play in strengthening adaptive capacity in the Arctic.

With that analysis as its starting point, this chapter asks three core questions: a) What ongoing efforts under the auspices of the Arctic Council speak to these categories? b) How might those efforts and activities contribute in different ways to resilience, and subsequently to adaptive and transformative capacity? and c) How can we better ensure that societies and communities can navigate change and shape it along a trajectory that enables continued human well-being?

Reports commissioned by the Arctic Council have increased the knowledge base for how society can better prepare for change through adaptation, and by enhancing adaptive and transformative capacity. The first report to address the impacts of climate change in the Arctic in depth was the Arctic Climate Impact Assessment (ACIA 2005). In addition to the scientific assessment, the report paid special attention to traditional knowledge and observations by Indigenous Peoples as critically important for assessing change and impacts in the Arctic. The ACIA also represents the Arctic Council's initial attempts to address multiple stressors, as well as the concept of resilience within a vulnerability framework (McCarthy et al. 2005). Roughly at the same time, the first Arctic Human Development Report was published, providing baseline knowledge about the social, political and economic aspects of human development in the region (AHDR 2004). It concluded that, although Arctic societies have historically been relatively resilient in the face of change, the combination of rapid social and environmental changes poses new challenges.

The ACIA was followed up by the Snow, Water, Ice and Permafrost in the Arctic (SWIPA) report (AMAP 2011). Its main focus was on impacts of climate change on the cryosphere, but it also dedicated a chapter to assessing the impacts of those changes on Arctic societies. In 2011, the Arctic Council decided to review the need for an integrated assessment of multiple drivers of Arctic change as a tool for governments, Indigenous Peoples, industry and Arctic residents to prepare for the future. The result is the assessment process Adaptation Actions for a Changing Arctic, which will produce three regionally focused assessment reports due to be published in 2017.

7.2 Facets of adaptive and transformative capacity

There are many ways of categorizing or describing the factors, determinants, dimensions or aspects that are important for adaptive capacity. Smit and Pilifosova (2001) have identified economic resources, technology, information and skills, infrastructure, institutions and equity as key determinants of adaptive capacity. Wesche and Armitage (2010) distinguish between "endogenous" factors that are important for adaptive capacity at the local, household or individual level, and "exogenous" factors which are beyond their control. They also expand on the determinants of adaptive capacity identified by Smit and Pilifosova, to include knowledge and skills, access to resources and technology, institutional support, and social networks. Empirical studies on adaptive capacity have refined, deepened and contextualized these dimensions. They have also emphasized that adaptive capacity is context-dependent and varies with time and in different locations (Adger et al. 2009; Hovelsrud and Smit 2010; Vulturius and Keskitalo 2013).

In the Interim Report, Kofinas et al. (2013) assess the current literature on adaptive capacity. They bundle the different aspects, assets or determinants into seven facets or sources of adaptive capacity in the Arctic context: natural capital, social capital, human capital, infrastructure, financial capital, knowledge assets, and cultural capital (see Figure 7.2). Each source is a bundle of interlinked qualities with implications for adaptive capacity. Each also plays a different role in creating a supporting context for any adaptation activity. These seven sources can be thought of as bundles of resources that are not directly interchangeable, but are linked and interact in various ways.

While the bundles of resources serve as important preconditions for successful adaptation, studies point to the importance of being able to activate these capacities (Bay-Larsen et al. forthcoming). The following elaborates on the definition of these bundles of resources, potential barriers to their activation in the Arctic, and how they might be strengthened.

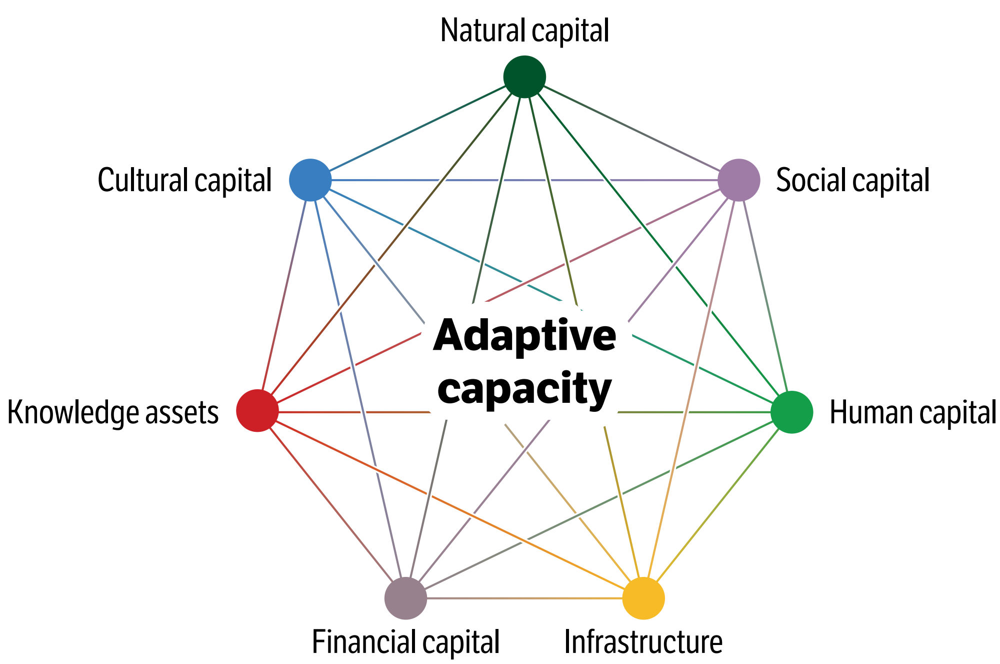
The Arctic encompasses many local communities, sub-regions, and sectors that differ in both adaptation needs and adaptive capacity. For example, in natural resource-driven economies in the Nordic countries, the most important factors for adaptive capacity have been found to be "economic resources in a market-based system, technological competition, and infrastructure" (Keskitalo et al. 2011). The factors that facilitate or hinder the activation of these aspects of adaptive capacity may be different than in communities with other institutional, cultural and historical contexts, such as a stronger reliance on the land for livelihoods.

Systemic barriers can prevent adaptive capacity from being realized. The capacity as such is thus a latent property of a social-ecological system (Engle 2011; Nelson et al. 2007), which some characteristics may hinder from being activated, while others may facilitate its activation. Two critically important factors for activating adaptive capacity are enabling institutions and a social and environmental space that allows for flexibility (Hovelsrud et al. 2010).

While a variety of studies have found high levels of adaptive capacity in the Arctic (Tyler et al. 2007; Forbes et al. 2009), some changes in the social-ecological system, such as economic development processes and environmental changes, may decrease the adaptive capacity of some groups (Bay-Larsen et al. forthcoming). When grazing areas are bad in one location, for instance, reindeer herders need to have the flexibility to move across large areas for migration between summer and winter pastures. Climate change increases the need for flexibility,

FIGURE 7.2 **The capitals that underpin adaptive capacity**

Adaptive capacity in the Arctic context can be described as a bundle of interlinked resources or "capitals", each of which is itself a bundle of interlinked qualities with implications for adaptive capacity.



Arctic natural capital provides a range of ecosystem services, including food, materials, regulation of climate, and availability and purification of freshwater for people living in the Arctic and beyond.

but infrastructure and industrial development in these areas often limit the mobility of reindeer herders (Tyler et al. 2007; Forbes et al. 2009). For example, demand for natural resources is driving industrial development on the Yamal Peninsula, the world's largest area of reindeer herding; this means that grazing lands will likely shrink as the anticipated development occurs (Forbes et al. 2011; Larsen and Fondahl 2015).

A study from Finnmark, in northern Norway, shows that Indigenous Knowledge is important for adaptive capacity, but institutional and other structural issues can create barriers for applying Indigenous Knowledge in local policy processes and implementation (Turi and Keskitalo 2014). The case illustrates the need to better understand the structure of the systems that prevent the activation of Indigenous Knowledge as a source of adaptive capacity. Another example is the Inuit Circumpolar Council-Alaska's recent food security report, which highlights several barriers to the application of Indigenous Knowledge, including a lack of information-sharing both between natural and social scientists and between scientists and Inuit communities (ICC-Alaska 2015).

7.2.1 Natural capital

Natural capital refers to the world's diverse stock of natural resources, which includes minerals, soil, air, water, and all living things, as well as the flows of ecosystem services that support livelihoods and human well-being (Millennium Ecosystem Assessment 2005). Arctic natural capital provides a range of ecosystem services, including food, materials, regulation of climate, and availability and purification of freshwater for people living in the Arctic and beyond. It also provides spiritual and cultural identity and sustenance, inspiration and health (CAFF 2015). The case studies in Chapter 4 provide some examples of the interaction between ecosystem services and social changes.

While the term natural capital implies economic value, most ecosystem services should not and arguably cannot be valued only in monetary terms (CAFF 2015). Cultural ecosystem services are especially difficult to value in economic terms, as illustrated by a study of perceived changes in ecosystem services and their impact on communities in northern Norway and Sweden. The study highlights that even when ecosystem services are critical for rural livelihoods, such as the provision of pasture and recreational land, losses due to environmental changes may relate more to lifestyles than to incomes, as these livelihoods are often part-time (Dannevig et al. 2015). It is also difficult to assess the potential value of ecosystem services for future generations, who will live in a different environmental and social setting.

Still, highlighting the value of ecosystem services can be useful for understanding how to evaluate alternative management strategies. A critical first step for understanding the importance of natural capital is to recognize the different types of value that people attribute to ecosystem services. To the extent that natural capital underpins a community's adaptive capacity, such recognition may be a critical first step in crafting policies to activate that capacity.

Sometimes individual features of nature are critical for supporting ecosystem services, but more often services are the result of complex adaptive interactions between certain climates, ecosystems, and natural or cultural landscapes. Ecosystem services originate from fundamental ecosystem processes such as maintenance of productivity and biological diversity. Disturbance regimes, ecological connectivity and integrity are particularly important for resilience.

Diversity is also important, because it broadens the options to respond to changing conditions and increases the range of available development trajectories (Enfors 2013). This can help to avoid social-ecological traps – situations in which people make choices that are immediately appealing but are ultimately harmful (a closely related concept is maladaptation). Diversity can be seen as a form of insurance: when changing conditions lead to the failure of one set of options, other sets are available. Looking at biodiversity in particular, the diversity of species' responses to environmental change can contribute to maintaining a given ecosystem function (Rosenfeld 2002) and associated services. Response diversity is also particularly important for ecosystem self-organization and reorganization when ecosystems need to renew themselves following rapid change (Elmqvist et al. 2003).

Overall, management of most natural capital in the Arctic is under the purview of states, though national political structures are guided by international and bilateral agreements, such as fisheries agreements focused on straddling fish stocks and migratory fish species. There are also various local and subnational resource governance regimes, and in some regions, specific natural resources are co-managed by entities composed of local and national stakeholders.

Flexibility in natural resources management has been found to be a critical component of adaptive capacity, in particular in local communities relying on renewable natural resources for their livelihoods (Tyler et al. 2007; Wesche and Armitage 2010; Hovelsrud et al. 2010). This highlights the links between natural and social capital, especially the role of institutions in enabling the activation of adaptive capacity. Institutional gaps in the governing of ecosystems, or poorly functioning institutions, can easily lead to the erosion of natural capital. Examples range from overharvesting to pollution and physical disturbances that threaten the integrity of ecosystems. Management, in turn, depends on continual updating of knowledge of the system and is thus related to knowledge assets as a feature of adaptive and transformative capacity.

7.2.2 Social capital

Social capital is the capacity of people to work together to address and solve problems (Coleman 1990; Putnam 2000; Kofinas et al. 2013). It is embodied in social networks, activities and processes that enhance collaboration. Social capital reflects continually evolving relationships among individuals and groups that emerge from and are governed by mutual trust, expectations, obligations, and shared norms. High levels of social capital can increase the capacity of communities or societies to collectively respond to challenges. It is important for sharing resources, including information, and is thus potentially critical in the context of rapid environmental and social change (Kofinas and Chapin 2009)

Social capital goes beyond local networks; in fact, in an interconnected world, broader networks are increasingly important. In the Arctic, a continued focus on international cooperation has been important in strengthening social capital on a circumpolar scale, and has enabled the peaceful development of the region.

Some social networks are relatively formal, supported by international arrangements such as the Arctic Council, Indigenous Peoples' organizations, and forums for scientific collaboration. Other, more informal networks range from friendships to trade-related connections. In recent decades, new transportation infrastructure and the spread of communication technologies have played a major role in connecting remote Arctic areas to one another and to the rest of the world. While local impacts are likely context-dependent and varied, both transportation infrastructure and communication technology have potentially increased social capital at the circumpolar scale.

The institutions that make up formal governance structures can also be included under the general heading of social capital. As discussed in Chapter 5, the complexity and density of the international governance landscape has increased in the past 20 years (see also Poelzer and Wilson 2015). In addition, at the subnational level, there is an increasing institutional complexity, including new

International Centre for Reindeer Husbandry

The International Centre for Reindeer Husbandry is a formal social network. Such networks are a form of social capital.

David Stanley/Flickr

Inuit street art in Nuuk, Greenland: Human capital includes qualities such as leadership and creativity, which are critical for navigating unknown terrain.

forms of governance with Indigenous Peoples' participation. As a simple quantifiable measure, it would therefore appear that social capital has increased. However, further analysis is needed of how different types of relationships contribute, in practice, to communication and trust among the relevant actors. Moreover, the literature on social capital has highlighted that it is unevenly distributed, and it does not automatically benefit everyone or society as whole.

7.2.3 Human capital

Human capital refers to human resources and competencies, including skills, knowledge, education and vocational skills, leadership and creativity. Education plays a central role in supporting human capital (Hirschberg and Petrov 2015). When education is defined broadly and in ways that are sensitive to local needs and cultures, it can increase the capacity to navigate change by increasing knowledge about the broader context of the change and expanding the skills needed to address the situation.

Similar to the notions of natural capital and social capital, human capital originally refers to assets that generate economic value. Used in this narrow sense, a major shortcoming of the concept of human capital is that it hides diversity and different perspectives. For example, gender, indigenous issues and identities are often subsumed in the language of economic rationality (Oksala 2013), and enveloped into universal concepts in economic projects, including social investment in human capital (Kuokkanen 2012; Jenson 2009). However, human capital, understood in a broader sense, emphasizes the role that individuals can play in society's capacity to adapt to and shape change (Burch 2010; Galaz 2005). For example, the term human capital includes qualities such as leadership and creativity, which are critical for navigating unknown terrain, yet are impossible to quantify in monetary terms.

7.2.4 Infrastructure

Infrastructure includes the basic facilities and services needed for a functioning society, such as roads, railroads, airports, and digital networks, as well as the basic structures needed to supply people with energy, water, food and shelter. In many parts of the Arctic, infrastructure is not sufficient to meet basic needs. Moreover, as shown in the ACIA and SWIPA reports, some infrastructure is vulnerable to the impacts of climate change, such as thawing permafrost and coastal erosion (ACIA 2005; AMAP 2011).

Industrial development often comes with investments in infrastructure, as a necessary pre-condition for bringing resources to markets outside the Arctic. One can thus foresee major development of infrastructure in the Arctic in the coming decades. Whether these changes will also benefit people in the region will depend to a large extent on where and how infrastructure is built. While it can create new opportunities for interconnectivity and economic activities (including industrial development and tourism), new infrastructure can also be a threat to biodiversity, traditional herding and harvesting activities, and public access to land and resources, especially when development contributes to fragmentation of the landscape (CAFF 2010).

7.2.5 Financial capital

Financial capital – money – plays a key role in adaptive and transformative capacity. Based on assessments such as the Arctic Human Development Report (AHDR 2004; Larsen and Fondahl 2015), and The Economy of the North (Glomsrød and Aslaksen 2006; 2009), it is possible to make some general comments about financial capital in the Arctic. First, the Arctic region generates substantial financial capital, because of extraction of natural resources. This economic activity does not necessarily translate into high household incomes, however, because resources and their ownership are unevenly distributed, and a substantial amount of revenue goes to owners outside the region. Second, in many parts of the Arctic, mixed economies play a major role, with subsistence and sharing economies interacting with the more formal monetary economy. Money is needed for the purchase of fuel and equipment, while food and other resources secured from nature may help buffer the impacts of conventional markets.

Lack of money at the local and individual levels is a major barrier to adaptation, especially when there is a need for investments. However, economic growth at a general level is not sufficient for supporting individual and community capacity to navigate change; there is also a need to address issues related to power over and distribution of financial resources.

7.2.6 Knowledge as a social process

Knowledge as a social process, including the capacity to learn, is essential for navigating change. This applies to knowledge about ecosystems, about social processes, and about the linkages between them. Knowledge, together with preferences and power relationships, provides the basis for decisions that affect adaptation and any attempt to transform a social-ecological system. As elaborated in Chapter 1, Carson et al. (forthcoming) suggest that the capacity to learn, share and use knowledge is at the heart of the capacity to respond to disturbances, stave off unwanted changes, and pursue more desirable arrangements.

As reviewed by Kofinas et al. (2013) in the Interim Report, there has been considerable attention in the Arctic to the need for new practices for creating knowledge, with a focus on co-production of knowledge as an essential part of co-management of natural resources. It is useful to think about knowledge as part of an ongoing and highly dynamic social process by which we shape our understanding of the world, not least in relation to political decision-making (Jasanoff and Wynne 1998). Knowledge goes beyond gathering facts and information, and also includes monitoring, analysing and synthesizing observations, and critiquing various framings of the challenges to be addressed. Framing knowledge as a social process also highlights the close links between knowledge assets and social capital.

Knowledge serves two major functions in relation to adaptive and transformative capacity. One is to support an understanding of the systems in which change is taking place: What major systems changes can be expected, and when? How do drivers of change interact? What are the social and ecological features that make people and ecosystems vulnerable to change? The second is to provide and continuously update understanding of the changes by, for example, monitoring drivers and impacts of change and factors that may strengthen adaptive and transformative capacity.

7.2.7 Cultural capital

Cultural capital is accumulated cultural knowledge, including Indigenous Peoples' traditional knowledge. In the Arctic context, it is closely linked to social networks (social capital), to the environment (natural capital), and to the ordinary practices and norms that are transmitted via formal and informal education and through language (knowledge assets).

Alaska Region U.S. Fish & Wildlife Service/Flickr

Alaska's National Wildlife Refuges organizes summer camps with local communities. Young people can explore the landscape with teachers, mentors and elders to better understand natural resource issues that affect their lives and practice cultural traditions.

The Interim Report defines culture as "encompassing virtually all aspects of human life including language, knowledge, world views, beliefs, norms, values, social relationships, perceptions of risk, power relations, and understanding of and responses to the world" (Kofinas et al. 2013). It also concludes that the rich cultural diversity found across the Arctic is potentially an important resource for maintaining human well-being and enhancing resilience and viability in an uncertain future. Individuals and communities are guided from within by these socially transmitted frameworks that include the knowledge, belief systems, and ways of creating meaning that constitute their culture (Blumer 1969).

Cultural capital includes shared beliefs and practices; culturally expressive objects and other cultural "goods" that are aspects of the physical manifestation of culture; and institutions or rules, which may be expressed either in the form of established norms or formal qualifications (Bourdieu 2010). As these individual forms of cultural capital help provide structure and meaning in their own particular ways, they can help evaluate the overall level of available cultural capital.

7.3 The Arctic Council's role in strengthening adaptive capacity

A review of the work produced under the auspices of the Arctic Council reveals that it is already deeply involved in activities that strengthen some aspects of adaptive capacity (often in combination), has modestly contributed in other areas, and has been largely absent in others. As the preceding two chapters illustrate, this is to some extent a product of the origins and evolution of the Arctic Council as a high-level forum for international cooperation. Over time there has been an evolution in the level of engagement in activities that speak to the different aspects of adaptive capacity.

Amanda Graham/Flickr

Legislative Building of Nunavut in Iqaluit: The Arctic Council can further strengthen the underlying capacity of Arctic societies to respond to and shape change.

The rapid changes occurring and projected in the Arctic raise important questions about how the Arctic Council could best strengthen the underlying capacity to effectively respond to and shape change. Two of the most obvious pathways are to find ways to expand work that is already serving this function, and to pursue new ways to systematically monitor and assess the state of the various aspects of adaptive capacity, how they are changing, and how they might be understood and strengthened.

7.3.1 Extensive record of involvement and contribution

The Arctic Council, with its mandate on environmental issues, is playing an important role in building knowledge of the Arctic's ***natural capital*** and shaping policies that affect it. For example, AMAP has produced the ACIA and SWIPA assessments, compiling information on status and trends of Arctic natural capital in the context of current and anticipated climate change.

The Arctic Biodiversity Assessment (CAFF 2013) reviewed the status of and trends in Arctic species and ecosystems in light of human activities and climate change, while the Life Linked to Ice report (Eamer et al. 2013) highlighted the significance of ice for the region's unique species, ecosystems and cultures. The importance of sea ice as a platform for human activities and as a habitat for species and food-webs is also shown in the SWIPA report (AMAP 2011), which includes an explicit list of the range of services that flow from the sea ice system to people.

To demonstrate Arctic Council stewardship of Arctic marine natural capital, PAME (2015) produced the Arctic Ocean Review, a comprehensive analysis of the status and adequacy of agreements and standards for the conservation and sustainable use of the Arctic Ocean. In its section on adaptation to change, the review concludes that most attention to Arctic development to date "has not considered the long-term, cumulative effects of development on the Arctic marine environment and Arctic peoples".

AMAP's ongoing Adaptation Actions for a Changing Arctic project is investigating regional adaptation options in response to the anticipated consequences of a range of change drivers, including climate change and industrial development.

Ville Miettinen/Flickr

University of Lapland, Faculty of Arts and Design: The Arctic Council enables initiatives that underpin new social networks, such as the University of the Arctic.

The Arctic Council is also involved in programmes monitoring natural capital. The CAFF Circumpolar Biodiversity Monitoring Program focused on species and processes that are indicative for the integrity of their respective ecosystems. The resulting insights can improve understanding of the status and trends of bundles of ecosystem services. Moreover, the Arctic Council has initiated the Sustaining Arctic Observing Networks to monitor processes of change and thus better understand the effects on ecosystem services.

While these Arctic Council initiatives advance the general knowledge on the physical and biological environment and include perspectives on its role for people's well-being, they generally fall short of recognizing, demonstrating or evaluating the specific benefits that natural capital has for continued human development, including the capacity to adapt to Arctic change. Nevertheless, there is awareness of the need to put more emphasis on these aspects. The Arctic Council's 2015–2025 Arctic Marine Strategic Plan (PAME 2015) includes the goal to "enhance the economic, social and cultural well-being of Arctic inhabitants, including Arctic Indigenous Peoples and strengthen their capacity to adapt to changes in the Arctic marine environment." Over the coming years this goal provides a frame for activities within Arctic Council working groups. Demonstrating the values that Arctic inhabitants hold about natural capital and ecosystem services, and finding ways to capture them in marine planning and coastal development policies and governance, may be a way for the Arctic Council to activate this aspect of adaptive capacity.

A recent scoping study for The Economics of Ecosystems and Biodiversity (TEEB) in the Arctic (CAFF 2015) recommended recognition of the diversity of values that people hold for Arctic natural capital and ecosystem services, and identification of ways to capture them in decision-making. While the report highlighted this as an opportunity to improve policies affecting resilience and adaptation, it also pointed out the scarcity of tools to do so. Particular emphasis was placed on the need for capacity-building in the Arctic through partnerships between scientific disciplines and across communities with different world views and knowledge systems. The report identified a particular role for the Arctic Council in facilitating this knowledge exchange.

Regarding ***social capital***, the Arctic Council plays a crucial role by providing a forum for international political cooperation, and by enabling new knowledge networks in connection with producing scientific assessments. More indirectly, it enables other initiatives that underpin new social networks, such as University of the Arctic.

The Arctic Council has not yet played a substantial role in supporting social capital at the local level. Assessments and other activities have had difficulties connecting to the local level (Hasanat 2012). Permanent participants of the Arctic Council play a key role in connecting local Indigenous Peoples' concerns with Arctic Council priorities. However, local-level decision-makers with the responsibility to translate national decisions into local practices do not have a direct link into the Arctic Council. The current AACA initiative is an attempt to connect with sub-national decision-makers, including sub-national governments.

Regarding ***knowledge assets***, improving knowledge about the circumpolar region has been at the heart of Arctic Council activities. This is reflected in the Council's being credited as being a cognitive forerunner (Nilsson 2012), as well as having carved out a cognitive niche (Schram Stokke 2006) in governance, as discussed in Chapter 5. The Council's activities include all scientific assessments and the coordination of monitoring activities across different countries, as well as its role as a platform for dialogue between scientific and traditional knowledge. So far the focus has been on mapping drivers of change and their direct impacts, as well as on providing an understanding of Arctic biophysical, ecological and social structures and processes.

A future task of the Council could be to monitor features that strengthen societal capacity to adapt to and shape change. There is no off-the-shelf set of indicators to use for such monitoring, but previous efforts to develop new indicators could provide a starting point. These include the Arctic Social Indicators Project (Larsen et al. 2010; Larsen et al. 2015), as well as the environmental indicators used by AMAP and CAFF, such as levels of contaminants and number and distribution of key species. A chapter in the forthcoming AACA report from the Barents region proposes "resilience indicators" that would illustrate the ability of Arctic social-ecological systems to deal with uncertainty and rapid change, with special attention to diversity, awareness of change, livelihoods, knowledge and self-organization. Together with other work towards identifying indicators, these efforts could serve as a starting point for a more coherent effort to develop Arctic-relevant indicators for adaptive and transformative capacity.

Another key issue regarding knowledge assets and the Arctic Council is how Indigenous Knowledge is used and included in assessments of change and to better understand adaptive and transformative capacities. In addition to Indigenous Knowledge, there is a need for further attention to the local knowledge held by other communities. The Arctic Climate Impact Assessment (ACIA 2005) paved the way for Indigenous Peoples' voices to be included in Arctic Council assessments. It focused on climate change in the Arctic, with an increased knowledge of the consequences of climate change for Arctic communities, livelihoods, and industries. On a global scale, the assessment significantly contributed to the 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), a scientific body operating under the auspices of the United Nations (Asinimov et al. 2007).

The 2002 Arctic Pollution report (AMAP 2002) combined scientific data and traditional ecological knowledge to provide evidence of negative exposure to the effects of persistent organic pollutants experienced by both Arctic indigenous and non-indigenous communities (Prior 2013; Selin and Eckley Selin 2008), as discussed in Chapter 6. Traditional ecological knowledge is also documented in the report Arctic Traditional Knowledge and Wisdom: Changes in the North American Arctic (CAFF forthcoming), in the context of the Arctic Biodiversity Assessment.

Yet despite past efforts to be inclusive of traditional ecological knowledge, there is room for improving how it is integrated into Arctic Council decision-making processes and knowledge assessments (Turi and Keskitalo 2014; Eira et al. 2013). The task can be challenging, however, as exemplified by efforts to monitor, measure and understand snow cover in northern Norway. Understanding of snow cover is more accurate when the knowledge of "local users", in this case reindeer herders, is included in the scientific data collections (Eira et al. 2013). However, there is a danger of mistranslation in exchanges between local and scientific experts. For example, while numbers-based scientific observations seek to ensure continuity and translatability across countries, reindeer herders take a more holistic approach. They use a rich and very specialized vocabulary that helps them understand factors affecting the complex ecosystem of reindeer, such as the physical processes leading up to particular snow conditions (Fierz et al. 2009; Eira et al. 2013). It is thus crucial to not only ensure the participation of both knowledge systems, but to also appropriately compare observations when developing adaptation strategies.

7.3.2 Moderate involvement and contribution

A key aspect of social capacity to collectively address problems is the role of gender in the Arctic. Men and women are affected in different ways by change, and therefore respond and adapt differently to that change. However, the depth of focus given to gender-related issues depends heavily on the agendas set by each Council chair. While the Swedish Chairmanship (2011–2013) did focus on gender, the two most recent chairs, Canada

Alanah Heffez/Flickr

Inuktituk street signs: Language diversity is a component of cultural capital in the Arctic.

(2013–2015) and the United States (2015–2017), have not prioritized it. Consequently, most recent work on gender in the Arctic has taken place outside the Council.

Contributions from the Arctic Council on gender-related issues include the report on Gender Equality in the Arctic (Sigurðsson et al. 2015) from the Sustainable Development Working Group. It highlights differences in political participation and representation in decision-making, as well as the gendered impacts of socio-economic development, natural resource development, and climate and environmental change. It also highlights several other issues where gender plays a role, including identity, human security, migration, mobility and education.

Both Arctic Human Development Reports (AHDR 2004; 2014) also noted issues of gendered violence and political representation in the context of social capital (AHDR 2004, Chapter 11). The Arctic Social Indicators project (Larsen et al. 2010), following the publication of the 2004 ADHR, called for gender-disaggregated data. It noted that "breakdowns of indicators by age and gender would add much to our ability to read" the indicators.

A lack of gender-disaggregated data makes it challenging to develop, implement and monitor policies targeted at northern women, especially indigenous women (Lahey et al. 2014). These include environmental, economic, and human development policies that shape social capital in the Arctic. Analysis that includes the better integration of such data, a knowledge asset, into Arctic Council assessments would provide a better understanding of adaptive and transformative capacity in the circumpolar North. Linking this data to existing UN-level gender data would also help establish more comprehensive baselines (Lahey et al. 2014; Larsen et al. 2010).

Regarding ***human capital***, it is difficult to identify Arctic Council activities that have contributed directly, though it has contributed indirectly by supporting several relevant activities. One example is the project Assessing, Monitoring, & Promoting the Vitality of Arctic Indigenous Languages, led by the Arctic Council's Permanent Participants. Another is the support to the University of the Arctic, with its focus on providing access to education. A third example is the production of material that can be used in education, such as popular-science versions of scientific assessments, and collaboration between Arctic Council activities and education efforts. For example, the first AHDR report (AHDR 2004) has been used extensively by the University of the Arctic and in other post-secondary course curricula. The Arctic Resilience Assessment also played a role in developing a course on resilience for the University of the Arctic.

The level of formal education is lower in the Arctic than farther south in the Arctic countries, but new virtual communication possibilities increase the range of opportunities for young people to take part in formal education beyond secondary school. The links that are being created between Western science and Indigenous Knowledge (Krupnik 2010; Krupnik et al. 2011) also make it easier for young people to build their competence in both Western and Indigenous Knowledge, with better appreciation of their different qualities. Supporting further dialogue between science and Indigenous Knowledge may thus be a way for the Arctic Council to strengthen human capital in the Arctic, even if it is not directly engaged in education as such. However, as noted by several reports (AHDR 2004; Larsen and Fondahl 2015), the loss of traditional knowledge and particularly the lack of transferral of traditional knowledge between generations is a concern in many communities, indigenous and non-indigenous alike. Supporting Indigenous Knowledge and other traditional knowledge by encouraging knowledge dissemination is one way in which the Arctic Council might reverse this trend. The inclusion of science and traditional/local knowledge as equally valid in Arctic Council reports could also be helpful.

7.3.4 Preliminary involvement and contribution

Regarding ***infrastructure***, as a follow-up to the Arctic Marine Shipping Assessment, the Arctic Council has taken initiatives to strengthen infrastructure in relation to search and rescue and oil spills, but has otherwise not played a significant role in this aspect of adaptive and transformative capacity. While many decisions lie with local and national authorities, the cross-border nature of some infrastructure suggests that this is an area for the Arctic Council to play a stronger role, not least in mapping needs and potential impacts of current developments to ensure that they benefit people in the region. It would also be relevant to investigate what role the Arctic Council could play as a knowledge-sharing node for infrastructure issues in a changing climate and in remote areas. Topical issue areas include housing, sanitation and energy supply.

As to ***financial capital***, one of the priorities for further work listed by the authors of the ECONOR-II report (Glomsrød and Aslaksen 2009) was to improve statistical indicators of well-being, to look beyond GDP. They also proposed establishing a permanent institution for a statistical network that can provide information on the economy, environment and livelihoods in the circumpolar Arctic. With climate change, rapid industrialization, and increasing connections to the global economy, Arctic economies and access to financial capital are likely to change. Moreover, economic returns with the potential to support local economic sustainability are used as a rationale for many industrial projects. Further work on the relationship between the formal economy and household incomes and well-being is thus urgently needed. Moreover, there is a need to better understand the links not only between financial capital and household incomes, but also between financial capital and capacity for adaptation at the municipal and regional or county levels. Becoming a node for such analysis could be within the scope of Arctic Council responsibilities.

gerogeri/Flickr

Berries, Saxha Republic, Russia: The Arctic Council is playing an important role in building knowledge of the Arctic's natural capital.

Concerning ***cultural capital*** as an asset for adaptive and transformative capacity, the main roles of the Arctic Council have involved looking at culture as an important way to understand human well-being (e.g. AHDR); gathering knowledge and observations about the environment and environmental change (e.g. ACIA, CAFF), and considering culture as an important aspect of resource management (Nuttall et al. 2005; CAFF 2013; Forbes and Kofinas 2015). Another example is political support for including local/Indigenous Knowledge as part of scientific assessments, even if this is seldom adequately backed by financial support for the work. A third example is the attempt to assess language diversity in the Arctic Biodiversity Assessment (CAFF 2013).

7.4 Conclusion and knowledge gaps

This chapter has reviewed possible ways for the Arctic Council to contribute to strengthening adaptive and transformative capacity, and consequently resilience, in the Arctic. Using the categorizations of sources for adaptive and transformative capacity developed for the Interim Report (natural capital, social capital, human capital, infrastructure, financial capital, knowledge assets and cultural capital) as a starting point, the chapter highlights how different facets of adaptive capacity are interlinked and should be viewed as bundles of resources that complement one another. It also shows that adaptive capacity is a latent property of a social-ecological system that requires supporting structures to ensure it can be activated. An example of such supporting structures are well-functioning institutions.

The chapter also reviewed how various reports commissioned by the Arctic Council relate to the need to strengthen adaptive and transformative capacity, given the rapid ongoing social and environmental changes in the region. One conclusion is that major efforts have been made to increase knowledge about both environmental and social processes in the Arctic. However, little is known about the practical implications of Arctic Council activities for building adaptive capacity on the ground.

In addition, our analysis highlights the need to create indicators that could be used to monitor and assess the status of different aspects of adaptive and transformative capacity and how they are developing over time. Such a system could be used for evaluating different policy options and their outcomes as they relate to resilience.

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CHAPTER 8

Building resilience in the Arctic: From theory to practice

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Key Messages

- The Arctic Council can build upon its activities that strengthen resilience, and ensure that resilience monitoring, policies and practices take an integrated social-ecological approach. Deeper and more frequent integration of social and ecological knowledge and practices would improve the ability of the Arctic Council and other Arctic actors to build resilience.
- The Arctic Council is already engaged in a variety of activities that strengthen resilience, but many are segregated by discipline. It is critical to build on and integrate existing programmes to provide a more holistic perspective on change. That requires monitoring and studying coupled social-ecological system dynamics, and making findings from that work available in ways that inform policy-making.
- Building Arctic resilience requires goal-oriented collaboration, using regional processes to bring people together to tackle well-defined problems. These collaborations need to link global, national and local activities in ways that bridge across the diversity of practices, knowledge and cultures in the Arctic.
- Successful collaboration requires innovation and meaningful engagement of the full range of Arctic stakeholders. Participatory scenarios analysis, use of simulation modelling, and self-assessments of resilience are examples of useful approaches. Putting resilience thinking into practice requires clearly linking those activities to policy-making.

8.1 Introduction

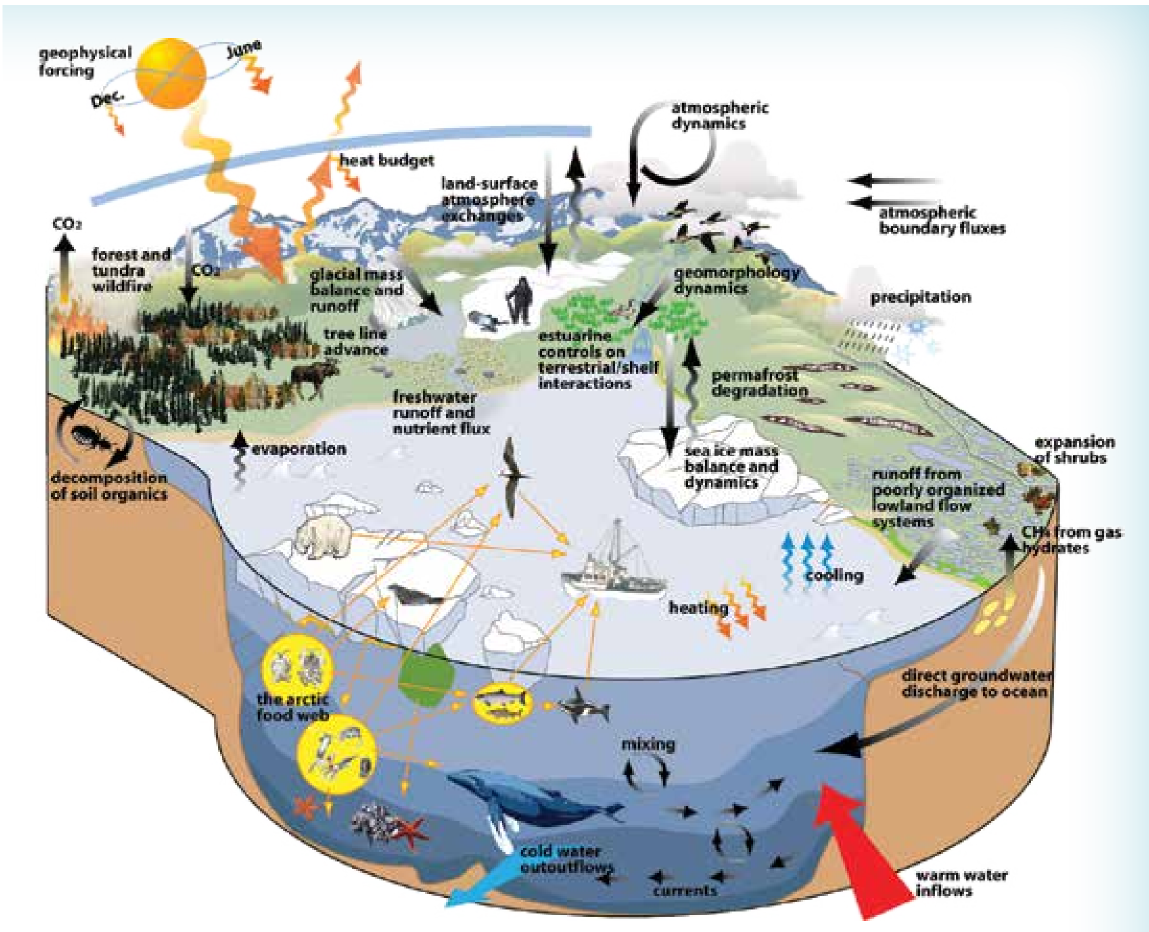
Previous chapters of this report have described how resilience theory and its application in Arctic studies have provided novel insights into the dynamics of Arctic change. While resilience research has improved understanding of how Arctic systems behave and react, moving from resilience theory to practice remains a formidable frontier of Arctic science and governance. This chapter takes the concepts, frameworks and insights of resilience thinking and applies them more concretely to management and governance, providing examples of specific activities that are well suited to fostering resilience in the Arctic.

A recurring theme of this report is that building resilience requires viewing the Arctic as a set of highly dynamic relationships between human and environmental components. This approach, in turn, requires a nuanced appreciation of sustainability – one that acknowledges system dynamics and the coupled interrelationships between humans and environment (see Chapter 1).

As noted, social-ecological systems are affected by both external (exogenous) and internal (endogenous) drivers that interact within and across scales. This means that change in the Arctic (and in most systems) is a complex and often unpredictable process (see Figure 8.1). Scientists can make broad projections on the trajectories of Arctic change, but when researchers and policy-makers seek to determine how change will unfold in specific contexts, the task is more challenging. Adding to this complexity and unpredictability are differences between the ecological systems and social systems, and the potential for human agency to shape responses through the use of knowledge, creativity and innovation. For these reasons, approaches to decision-making that assume system equilibrium and practice top-down management are ill-suited for addressing Arctic change (Chapin et al. 2010; Lovecraft and Eicken 2011). Today, approaches are

FIGURE 8.1 **Illustration of social-ecological system complexity**

Source: World Resources Institute



needed that improve societal readiness, facilitate adaptation and transformation under conditions of uncertainty, and result in action.

How then can resilience thinking and our evolving understanding of rapid change in the North contribute to stewardship and transformation of the Arctic? Is a new kind of knowledge production needed – what Funtowicz and Ravetz (1994) called a "post-normal science", for when "facts are uncertain, values are in dispute, stakes are high, and decisions urgent"? How can actors, organizations, and institutions enhance social learning and human adaptation and, where needed, facilitate transformative change? How are these objectives achieved within and across scales?

In this chapter we build on the findings of previous chapters of the report to provide concrete examples of how to link the principles of resilience with action. We first present basic principles of building resilience from the literature and the implications of their translation into practice. This background information is followed by a listing of key heuristics – or rules of thumb – that are especially useful for the Arctic. These cross-cutting heuristics are followed by specific practices or activity areas that are consistent with resilience thinking and have been shown to contribute toward resilience-building. We provide examples where possible.

The examples, discussion and suggestions of this chapter are offered to inspire action through experimentation and innovation by the organizations, policy-makers, agency managers, communities, scholars, public leaders and the Arctic Council. We hope these ideas will lead to continued experimentation to explore ways of benefiting from resilience assessments with new and effective approaches to research, problem solving and planning. Writing about institutional arrangements for sustaining common-pool resources, Ostrom et al. (2007) noted that there are no panaceas. Accordingly, there is no single recipe for building resilience; there are no silver-bullet solutions to translating resilience thinking to action. The application of general principles for resilience-building depends on diagnosing the appropriateness of principles to each local context (Ostrom et al. 2007; Young et al. 2008). Moving from principles to application, in turn, is best achieved through engagement of a diverse set of actors through several decision-making processes. Thus, activities for resilience-building should be implemented on several fronts, ideally with good communication for shared learning.

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Institutions of higher education in the Arctic, such as the University Centre of Svalbard, contribute to social learning and human adaptation.

8.2 Resilience definitions and their implications

How resilience thinking is applied to action follows, in part, from how it is defined – and the underlying assumptions of the definition. Chapter 1 presented a number of definitions of "resilience", noting the considerable ambiguity in the literature (Gunderson et al. 1995; Gunderson and Holling 2001). Some authors assume that systems are perilously fragile, while others see them as highly stable, or as transitional through multiple stable states of evolution. An engineering view of resilience (measured by the system's capacity to return to its original condition) contrasts with the structural view commonly taken by ecologists, and with the social-ecological systems perspective, which sees ecosystems and social systems interacting in a dynamic and evolving process (Gunderson and Holling 2001). These differences can lead to public debates about the potential impacts of perturbations to the system. For example, a "fragile Arctic" perspective can support anti-development policies, while a highly stable view can support significant changes to landscapes.

Whether resilience is defined as an attribute of a system or as value-based is also important. Ecologists tend to use a systems approach in which resilience is neither inherently good nor bad (Walker and Salt 2006). From this perspective, high resilience can in some cases constitute an undesirable state in need of significant change – i.e. transformation (Ludwig et al. 1997). For example, poverty traps and persistent institutional inertia may require transformation in order to move to a state conducive to greater human well-being (Carpenter and Brock 2008). From this perspective, resilience is simply a condition, and adaptation and human-navigated transformation are responses to it.

Resilience has also been defined as a desirable characteristic, somewhat synonymous with adaptive and transformative capacity (see Chapter 1). In integrating these two orientations, several scholars have suggested that successfully navigating change is a complex process of identifying the desirable features of a system and strengthening them, while weakening other features to allow for transformational change (Walker et al. 2004; Olsson et al. 2006; Chapin, Kofinas, Folke, et al. 2009; Folke et al. 2010). The process of making assessments, making active choices, and implementing them forms the basis for emphasizing the important role of human agency.

Another distinction relevant to linking theory with practice is the difference between "specific resilience" and "general resilience". The first refers to a system's capacity to maintain its structure, function and identity in the face of a specific driver of change, such as a system's resilience to wildfires; the second refers to the overall capacity of the system to adjust in response to any conceivable driver or set of drivers (Walker and Salt 2006; Carpenter et al. 2012). Both types of resilience have import to policymaking. Prescriptive strategies for achieving general resilience typically come as broad goals or principles, such as maintaining diversity (see next section). Actions for building and maintaining resilience to specific forces of change (e.g. flooding events, wildfires, thawing permafrost) can be prescribed more precisely. For example, Bronen (2015) proposes a resilience framework for governance specifically to maintain and build the resilience of Arctic coastal communities that require relocation because of coastal erosion.

Terry Chapin

A greenhouse built by the community of Igiugig, Alaska, provides fresh vegetables to community residents and their school for much of the year.

As already noted in earlier chapters, it is important to clarify the focus of resilience when evaluating a situation and implementing ideas: resilience *of what? to what? for whom?* These questions help avoid problems such as analysing one scale while ignoring the implications for another. For example, a focus on achieving resilience at the scale of the nation state may overlook the implications for local communities at the margin (Carpenter et al. 2001).

8.3 Principles for applying resilience theory

The social-ecological resilience literature is replete with principles and frameworks for moving from theory to action. They are generally stated as objectives, goals,

BOX 8.1 Examples of stewardship strategies to prepare for, and shape, uncertain change

Chapin et al. (2010) identified a series of strategies for building resilience and helping communities to navigate change, in three broad categories:

Maintain a diversity of options

- Subsidize innovations that foster socio-economic novelty and diversity;
- Renew the functional diversity of degraded systems;
- Prioritize conservation of biodiversity hot spots and pathways that enable species to adjust to rapid environmental change;
- Sustain a diversity of cultures, languages and knowledge systems that provide multiple approaches to meeting societal goals.

Enhance societal learning to facilitate adaptation

- Broaden the problem definition and knowledge co-production by engaging multiple disciplinary perspectives and knowledge systems;
- Use scenarios and simulations to explore the consequences of alternative policy options;
- Develop transparent information systems and mapping tools that contribute to developing trust among decision-makers and stakeholders, and build support for action;
- Test understanding through comparative analysis, experimentation and adaptive management;
- Exercise extreme caution in experiments that perturb a system larger than the jurisdiction of management.

Adapt governance to implement potential solutions

- Provide an environment for leadership and respect to develop;
- Foster social networking that builds trust and bridges communication and accountability among existing organizations;
- Enable sufficient overlap in responsibility among organizations to allow redundancy in policy implementation.

Source: Adapted from Chapin et al. (2010).

Terry Chapin

Elders like these women in Newtok, Alaska, are the living library of cultural knowledge and wisdom. Their input is crucial for preparing their community to move to higher ground to escape climate-induced coastal erosion.

TABLE 8.1 **Methods of preparing for social and ecological surprises: Insights from transition to ecosystem-based management in the Great Barrier Reef Marine Park**

Strategies	Actions	Examples of barriers to change
Making internal organizational changes	• Establishing Senior Managers' Forum and regional teams • Clear and transparent leadership at all relevant levels • Communicating vision and goals	• Resource constraints • Lack of innovation, direction, shared vision, engagement, trust, leadership, cross-sector cooperation and communication
Bridging science and policy	• Drawing on existing networks of scientists, managers and industry to promote dialogue • Forums for synthesizing knowledge • Communicating vision and goals	• Science is fragmented • Scientific uncertainty • Different perceptions of scientists and managers and resulting lack of trust
Changing public perceptions	• Clear, simple, tailored information from a communication professional • Visualizing the entire Great Barrier Reef as an interconnected ecosystem • Communicating an urgent need for conservation	• Different levels of knowledge and interests among stakeholder groups • Low awareness and understanding of problems, threats and ecological interactions
Facilitating community participation and public consultation	• Building trust with communities through personal interactions and regional teams • Community information sessions • Recasting problems as opportunities • Regular updates	• Conflicting views among key actor groups, misinformation • Outreach to local communities difficult • Lack of leadership and trust
Gaining political support	• Preparing for change: staff expertise, timing actions, information availability • Briefing key players and allying with other key actor groups • Polling to leverage and monitor public opinion	• Change of people in power • Lack of support from key politicians • Zoning plans can be stopped • Opposing views

Source: Adapted from Resilience Alliance (2010), Table 5, a synthesis of Table 1 in Olsson et al. (2008).

directives or desired conditions (see, e.g., Berkes and Folke 1998; Walker and Salt 2006; Chapin, Kofinas and Folke 2009; Biggs et al. 2012). In most cases they relate to building general resilience.

Berkes et al. (2003), which informed the analysis in Chapter 4, identified four key conditions for building resilience: learning to live with uncertainty; nurturing diversity; combining different types of knowledge; and supporting the capacity for self-organization to ensure social-ecological sustainability. (See Box 8.1 for an example of general strategies for dealing with uncertainty, and Table 8.1 for methods of preparing for surprise.) Biggs et al. (2012) expanded on that list to reflect more recent thinking, noting ways in which governance structures can contribute or detract from resilience. These frameworks and principles, while fairly general, can help guide decision-makers as they evaluate specific options or try to identify potential actions to build resilience.

8.4 Cross-cutting heuristics

Building on the principles and frameworks in the literature, in this section we identify a set of heuristics for evaluating activities, programmes, practices and/or strategies in terms of their likely support of resilience-building. These ideas are basic "rules of thumb" and questions that decision-makers can use as a starting point.

8.4.1 Are the goals clear?

A common, major barrier to achieving coordinated action to build resilience is lack of clarity about the nature of the problem and the desired outcome. Different actors may see the problem differently and have conflicting goals or priorities that have to be understood and addressed in order to achieve a mutually agreeable solution. Clark et al. (2008), for example, found Canada's polar bear conservation programme was falling short of its goals because decision-making processes were not facilitating discussion of different actors' perspectives. Several laudable efforts, such as implementation of adaptive management approaches for natural resources, have failed because stakeholders launched programmes without first agreeing on the objectives (Lee 1999; Beratan 2014).

Various processes are useful in guiding groups as they seek to clarify differences and find common ground. In practice, this kind of clarification and consensus-building is one of the important roles played by the Arctic Council (see Chapters 5 and 6). In some cases, the practices listed in Section 8.5 can help groups identify actions on which they can all agree. When perspectives on end-goals remain divergent, there is a high likelihood of protracted conflict, decision paralysis, and a possible erosion of resilience.

8.4.2 Are multiple kinds of knowledge being integrated?

As discussed in Chapter 1, framing and solving problems in social-ecological systems requires an interdisciplinary orientation. Extensive experience shows how working within a single disciplinary lens (or knowledge system) carries the risk of generating solutions that are blind to other dimensions, potentially resulting in unintended consequences (Chapin, Kofinas and Folke 2009; Berkes 2012). Where possible, it is best to examine problems through a transdisciplinary framework, rather than try to cobble together perspectives from different disciplines. For example, building ecological resilience may reduce social resilience by constraining a community's livelihood, such as when individual harvest quota systems are imposed without regard for communal systems of harvesting and sharing. This means a range of dimensions and, where possible, knowledge co-production processes should be applied to arrive at robust, holistic solutions.

None of this is simple or likely to happen automatically. Despite considerable progress in the last decade, achieving true integration of disciplines and perspectives often requires transformations in organizational structure, personnel and culture. In the North, the challenges of interdisciplinarity have at least two dimensions, and perhaps three. The first is the integration of social and natural sciences. The second is the integration of science with the knowledge of local and Indigenous Peoples (Armitage et al. 2011; Berkes 2012). Achieving integration across both of these dimensions can challenge groups' fundamental beliefs on legitimacy and truth, and requires rethinking what are acceptable methods of collecting data, undertaking analyses, and identifying solutions. For example, often local knowledge is used as a source of information (empirical observations), while local people's alternative ideas on causality and the underlying worldview are dismissed. These challenges are apparent in monitoring and research, but also have implications for management, policy-making and overall governance.

A third dimension is that efforts aimed at bridging and integration can be taken a step further, to encompass policy processes. These processes are broadly informed by knowledge, not least in the definition of policy problems and preferred remedies (Carson et al. 2009), constituting a body of knowledge in their own right. And while it is essential to remain alert to cautions that the scientific and policy worlds are guided by different sets of rules and values (Schneider 2009; Weber 1946), the benefits of bridging science and policy have been identified both by the research community and by practitioners. (For a selection of published discussions of these topics, see http://www.unesco.org/new/en/social-and-human-sciences/themes/most-programme/bridging-research-and-policy/.) Such efforts can be approached from the perspective of policy-makers as part of a larger community of stakeholders (Forrester et al. 2008), or in an effort to achieve policy impact around issues of great concern (Forrester et al. 2009).

Today there is much talk about the need to bridge knowledge systems, yet there are also many misunderstandings about what it entails. Realizing the potential of integrating knowledge systems will take significant investments in education and a rethinking of the way institutions function, including the roles and responsibilities of key players. Organizing around problem areas, instead of disciplines, is an important first step, in part because problem areas are inherently interdisciplinary and directly related to public policy. As knowledge is more divergent, the challenges of bridging become more significant. Recognizing the utility of various approaches for bridging is helpful, such as the multiple-evidence approach developed by Tengö et al. (2014).

Several institutions of higher education with connections to the Arctic have been at the forefront of realizing interdisciplinarity in graduate studies on social-ecological systems, and thus preparing a new generation of scholars and analysts skilled at working in this environment. However, institutional rigidity can be an obstacle, and transformation may be required, starting with a change in reward systems, among other things. Exemplary efforts of interdisciplinary higher education include the research and graduate programmes at the Arctic Centre University of Lapland; the Resilience and Adaptation Program at the University of Alaska Fairbanks; and the Stockholm Resilience Centre.

Funding for educational programmes at all levels and for research that encourages and supports interdisciplinarity can be a powerful force for shifting the activities and culture of institutions. The US National Science Foundation's Natural-Human Systems programme and several of the European Union's large-scale funding programmes have been successful in this regard. Similarly, there are numerous independent research institutes whose mission it is to bridge between policy-making and problem-focused, interdisciplinary research. Several house Arctic-specific

US Navy photo by Chief Yeoman Alphonso Braggs

Polar bears on the sea ice of the Arctic Ocean, near the North Pole, as photographed from the bridge of the US Navy submarine USS Honolulu. The complex interactions of human and natural systems, and the diverse types of knowledge relevant to the region, make interdisciplinarity essential.

research, including the Brookings Institution, the Finnish Environment Institute, the Alaska Center for Climate Assessment and Policy, and the Stockholm Environment Institute, to name only a few. Still, the lion's share of funding for research and education support continues to be allocated to disciplinary-based programmes, which perpetuates the fragmentation of knowledge and the conventional organization of institutions that support it.

8.4.3 Are place-based community partnerships being supported?

Adaptation to climate change to a great extent involves actions by individuals, households or local communities. Building resilience at the local level is thus crucial. Adaptation requires exploring local problems, identifying potential solutions, and implementing appropriate policies and programmes. Yet in too many cases, top-down approaches guide the work of government agencies, NGOs, universities and research institutes.

Community partnerships put community concerns at the centre of efforts to plan and implement actions to build resilience and adapt to Arctic change. For example, while climate change is a concern at all levels, the narratives about change at the community level in the Arctic typically emphasize the need to address economic and social conditions. Most funding agencies that support studies in the North, meanwhile, are more concerned with changes in the climate system and their physical effects. The large share of International Polar Year funding that went to climate research is a case in point (Krupnik and Hik 2011). From that perspective, the extent to which organizations are attentive to community needs is a measure of a system's adaptive capacity. One positive example is agencies' approach to wildfire protection in Alaska, which was informed by community priorities, such as the need to protect historical sites and access routes (see https://www.frames.gov/partner-sites/afsc/home/). In short, a strong focus on and attentiveness to community is needed to build resilience.

Another positive example is the project Community Partnership for Self-Reliance (CPS), which builds partnerships between communities and university researchers to address the priorities of Alaska Native communities, rather than the priorities of university researchers. Four communities have participated through a facilitated process that identified top local priorities (Chapin et al. 2016). Interestingly, the focus on "self-reliance" emerged in response to a proposal to focus on community resilience, with community leaders stating that self-reliance was locally relevant and a better strategy for achieving sustainability and resilience.

Communities in the CPS project have elected to focus on energy security, clean water, language retention, cultural integrity, and rights and access to harvested resources. Issues related to climate change were referenced indirectly (e.g. flood protection, village relocation), but were not primary research priorities. The biggest barriers to success have been the lack of facilitating institutions, funding, social relationships, and trust among participants. The project's greatest success was its role in matching community needs with appropriate researchers, finding ways to diffuse lessons and strategies among communities and to higher scales, and creating a venue for learning through action research. Many past "outreach" initiatives by agencies, universities and NGOs have involved a one-way delivery of services to communities. Partnerships such as CPS move beyond outreach to collaboration. Community partnerships in research to support community adaptation are not suggested as a replacement to traditional systems science, but they are needed to actually build resilience among people who are often just the subjects of research and not its beneficiaries.

8.4.4 Are linkages being made across scales?

Many have noted the importance of cross-scale institutional linkages in resilience-building (see Chapter 5 and Young 2002b; Berkes 2002; Adger et al. 2005; Folke et al. 2007; Armitage et al. 2009). Young (1996; 2002a; 2013) pointed out that linkages can be vertical and horizontal, noting interregional, inter-community and international interactions. Cross-scale linkages can be achieved using boundary-spanning organizations (Guston 2001), "shadow" networks – informal networks that work both within and outside the dominant system (Westley et al. 2011) – and other approaches (see Berkes 2002; Kofinas et al. 2013).

The need for cross-scale linkages is particularly important in the Arctic, given that most of the region is part of larger nation-states whose governments are based well to the south of the Arctic. The actions of distant entities can directly affect the resilience of Arctic communities and ecosystems – even more if one considers the role of climate and energy policies around the world in shaping the Arctic's future. Linkages between the Arctic and non-Arctic entities, through informal networks and more formal institutions, can contribute new information, approaches and actions that increase resilience within the Arctic and around the world.

Ostrom (1961) and Biggs et al. (2012) noted the contributions of polycentric systems to resilience, and thus, question the effectiveness of rigidly hierarchical systems when there is need for rapid response (e.g. rapid disaster relief). In practice, polycentric systems are more the norm, as highlighted in the Chapter 5 discussion of the complex and dynamic political landscape in which the Arctic Council operates. Polycentric systems have multiple centres of decision-making that are formally independent of one another, or at least have high levels of autonomy. The extent of their interconnectivity is one measure of adaptive capacity. Experience suggests that the best approach for fostering resilience is to have a mix of strong and weak linkages, to provide sufficient local autonomy, but also ensure dialogue and connect communities to knowledge and resources at larger scales. For example, the Saami Council's and Alaska North Slope Borough's informal "inter-local" ties with other Indigenous Peoples' groups internationally, along with formal ties with governments, have enhanced their communications, influence, and potentially their authority in decision-making (e.g. Meek et al. 2008).

8.4.5 Is social learning being facilitated?

Change in Arctic systems is likely to produce novel situations that require an enhanced ability at all levels to keep learning, so as to be able to respond effectively. This is where social learning comes in – the process by which people within a society learn together and from one another, and thus adapt to changing conditions. But how is social learning actually achieved, at and across various scales? While the concept is widely appealing, putting it into practice can be complex (Lee 1999; Diduck et al. 2005; Beratan 2014). Social learning is demanding, requires time, effort and experimentation, and can sometimes fail, but also can lead to robust decisions that leave society better prepared for the future. By contrast, when decision-makers fall back on what is familiar and comfortable, the result can be "muddling through" (Lindblom 1959), repeatedly applying solutions that are familiar but have also proven unsuccessful in the past, and dismissing viable alternatives.

A resilience-based approach to decision-making that facilitates social learning requires both informal and formal processes for reflection within and across scales. Being reflexive in decision-making includes operating in a culture (community, organizational or greater) where it is the norm to reflect on and even question underlying assumptions and explanations, and test novel solutions. Social learning occurs when groups systematically observe social-ecological conditions and draw on those observations to improve their understanding of system behaviour. They then need to evaluate the implications of emergent conditions and the various options for action, and respond to support the resilience of the system.

Social learning requires meaningful participation of stakeholders, face-to-face deliberations, and the time and space needed to reflect on past experience and carefully evaluate options. This is where bridging organizations and shadow networks can play a valuable role, by connecting actors and facilitating interactions in a management setting (such as a working group). As discussed in Chapter 6, the Arctic Council itself can be considered a bridging organization that in many cases fosters social learning.

Bridging organizations typically lower transaction costs through the coordination of tasks, trust-building and social learning, and help establish communities of practice and function as central nodes of cross-scale network interactions (Folke et al. 2005; Olsson et al. 2006; Berkes 2009; Kowalski and Jenkins 2015). Broader societal-level social learning can also occur through a more diffuse process of "communities of practice" or learning networks.

The CircumArctic Rangifer Monitoring and Assessment Network (CARMA; see http://carma.caff.is) was an exemplary community of practice that evolved into a highly functioning shadow network and created international cross-scale linkages on the important relationship between caribou, people, and their mutual sustainability (Gunn et al. 2013). CARMA facilitated international data-sharing, created protocols for monitoring, and developed methods for involving hunters in research and new methods for documenting traditional knowledge. The programme, now housed at Conservation of Arctic Flora and Fauna (CAFF), was very active while funded through the International Polar Year programme, but has become dormant because of limited funding and lack of succession planning in leadership. The limited activity without ongoing funding demonstrates that secure resources are needed to sustain and develop these programmes; these types of interactions cannot continue simply through voluntary efforts.

8.4.6 Is culture taken into account?

The great diversity of cultures in the Arctic – indigenous, non-indigenous, European, Russian, North American, corporate and others – presents challenges, but this diversity also represents a unique strength. The challenge is how to account for this diversity in the effort to build resilience, as worldviews, values and preferences can differ in ways that greatly hinder communication and mutual understanding. Culture can also explain the diversity of human responses to social-ecological change. For example, while most reindeer husbandry decreased in the post-Soviet period, there was an increase in herders and reindeer among the Nenets of the Yamal region of Russia. To a great extent, this increase is explained by the high value placed by the Nenet culture on herding traditions, and by the desire of younger generations to continue that traditional way of life (Forbes et al. 2009; Forbes 2013).

There are countless examples in the North of how disregard for cultural diversity has resulted in problems – locally and on larger scales. Conversely, there are good examples of how cultural awareness has resulted in more effective solutions to problems. Ultimately, accounting for culture in practice requires respectful acknowledgement of different perspectives, non-judgmental understanding, and functioning within a plurality of decision-making processes. It also requires adopted pluralistic modes of collaboration and consideration of multiple values and ways of working (see also Chapters 4 and 6).

8.5 Practices for building resilience

This section presents a set of practices or activity areas that demonstrate how resilience thinking can be applied to governance. Essentially, all the practices here are decision support systems that can potentially inform the processes by which societies cope with change, navigate its challenges, and pursue goals (i.e., governance). The practices fall into one or more of three categories – observing, understanding, and responding to change – which are the focal areas of the US National Science Foundation-funded Study of Arctic Environmental Change, SEARCH (Lee et al. 2015). To be effective, activities in each of the categories should parallel the social learning loops of adaptive governance (Folke et al. 2005; Brunner and Lynch 2010) and more operationally, adaptive co-management (Armitage et al. 2007; Berkes 2009; Kofinas 2009; see also Section 8.4.5 and discussions of "triple-loop learning" in Chapter 6).

Alaska Region U.S. Fish and Wildlife Service/Flickr

Alaska's National Wildlife Refuges work alongside local communities to provide science and culture summer camps for rural youth such as these children from the Iñupiaq village of Selawik in northwest Alaska.

In some areas we describe exemplary efforts of practice. Again, it is important to remember that the appropriateness of any practice and its respective implementation design depends on context: Who are the subjects? What are the issues of concern? What is the state of knowledge? What resources are available for implementation? What are the restrictions? What are the goals? There are no panaceas or one-size-fits-all solutions.

8.5.1 Monitoring social-ecological system status and change

Observation systems for tracking the state and trajectories of social, ecological and economic conditions are accepted as necessary and indeed common in the Arctic. Examples include CAFF, the Arctic Monitoring and Assessment Programme (AMAP), and the International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT), among many others. With the increasing focus on climate change, governments are investing significant funds to support and create new observation system infrastructure. Efforts to track social conditions are limited and typically occur only at the regional level. Comprehensive and systematic observations programmes focused on interactions and feedbacks in Arctic social-ecological systems are even more limited. Systematic monitoring of such interactions with an eye on resilience and thresholds of change is limited to non-existent. When these efforts do occur, the focus is too often on fast variables of change, without attention to more slowly changing variables that govern system dynamics.

Monitoring social-ecological systems in any biome requires knowing enough of what to measure, and then relating observations to ecological health and human well-being. Knowing what to monitor requires understanding how elements of the system relate and which measurable variables are most sensitive to change. Thus, there is an underlying and critical link between observing and understanding, with each informing the other (Lee et al. 2015). In the ideal programme, these two activities are both related and iterative, with ongoing questioning of the assumptions of knowledge (Armitage et al. 2009; Kofinas 2009). Active engagement of local stakeholders adds another dimension to this process, often broadening the range of considered goals, the observations relevant to those goals, and the ultimate assessment of health and well-being of people.

Monitoring for resilience raises the bar by requiring attention to the system as a whole, including the *interactions* of ecological dynamics, ecosystem services, human well-being and human activity, and how feedbacks among them affect ecosystem health (Collins et al. 2011). The challenges in meeting this objective are doubled in the Arctic because of the tremendously high cost of collecting data and the many incomplete or limited datasets, in terms of time depth, geographic extent and social-ecological breadth. Moreover, while there is often funding for ground-breaking new programmes, long-term commitments to monitoring are uncommon (as happened with CARMA, discussed above). There are a few exceptions, such as several programmes of the Arctic Council, as well as the US Long Term Ecological Research Network (LTER; see https://lternet.edu), which has committed to supporting monitoring and research in key areas for up to 35 years. LTER includes two currently funded projects in northern Alaska.

A common problem is that observation systems are often "siloed" within a particular discipline (see Section 8.4.2). Few holistic efforts to measure social-ecological interactions exist, though some noteworthy efforts are under way at various scales. At the pan-Arctic level, the Circumpolar Biodiversity Monitoring Programme (CBMP; see http://www.caff.is/monitoring), sponsored by the Arctic Council, documents the status of species and habitat. While the CBMP largely focuses on ecosystems and keystone species, its efforts have extended to include some elements of the human dimension, shifting the focus from purely on biodiversity to include considerations of bio-cultural diversity (e.g. implications to livelihoods such as subsistence and measures of language loss).

The US National Oceanic and Atmospheric Administration (NOAA)'s Arctic Report Card, a concise, annual summary of the state of the Arctic environment, is another example of interdisciplinary observations, but its attention is focused primarily on the biophysical, noting implications to humans. The Arctic Adaptation Exchange Portal (see http://arcticadaptationexchange.com), a programme initiated by the Arctic Council's Sustainable Development Working Group, is a comprehensive collection of Arctic data and information. It shows promise, but is only at an early stage of development.

Local sources have demonstrated great potential in providing a historical view of change where no other data exist, a fine scale of granularity not available from remotely sensed and field-based studies, and a view of change through the lens of a different worldview. Methodologically, there have been considerable advances in the use of technology for the monitoring of change using local knowledge. Examples include camera-equipped GPS units and personal digital assistants, group interviewing, participatory mapping, web postings and videography (Gearheard et al. 2011; Mustonen 2013; Mustonen 2015). In Alaska, the Local Environmental Observer (LEO) network allows local observers to enter anomalous environmental observations using a phone application or directly online, which automatically posts the information, spatially tagged, for public access.

Over the past two decades, there has been much discussion about how to realize the potential of local communities and Indigenous Knowledge to contribute to monitoring ecological change (Krupnik and Jolly 2002; Gearheard et al. 2011; Johnson et al. 2015). However, the collection, analysis, access to and archiving of local and Indigenous Knowledge can be fraught with challenges. As noted in Section 8.4.3, some relate to the tendency by some scientists to see local residents only as data sources, not knowledge holders or, much less, partners in research. There can also be a lack of appreciation of the multiple dimensions of Indigenous Knowledge, which goes well beyond pure observations (Krupnik and Jolly 2002; Berkes 2012). Houde (2007) has noted that this type of knowledge has six "faces": factual observations, systems of management, information about past and current uses of the environment, ethics and values, the role of places in culture and identity, and cosmology (see Table 8.2).

Potential obstacles related to the use of Indigenous Knowledge also include approval processes, intellectual property rights issues, loss of datasets, and formatting of data to allow for comparability between datasets. While there are challenges, the recognized value of local and traditional knowledge is now accepted by many

TABLE 8.2 **Characteristics of the six faces of traditional ecological knowledge (Indigenous Knowledge)**

Face	Key components	Challenges	Opportunities
Factual observations	• Empirical observations • Classifications • Naming of places • Descriptions of ecosystem components • Understanding of interconnections • Spatial and population patterns • Ecosystems dynamics and changes	• Open to misinterpretation • Equitable sharing of monetary benefits of knowledge	• Enhancement of scientific knowledge • Added information for monitoring of environmental changes • Criteria and indicators for environmental impact assessments and management of species at risk • Preparedness for social or ecological surprises
Management systems	• Practices adapted to context • Methods for conservation • Methods for sustainable resource use • Methods for adapting to change • Appropriate and effective technologies	• Diversification of management regimes and methods • Transfer of responsibilities by central administrations to develop context-specific management models	• Decentralized, appropriate management regimes • Novel sustainable approaches
Past and current uses of environment	• Land use patterns • Occupancy • Harvest levels • History of the cultural group • Location of cultural and historical sites • Location of medicinal plants	• Misinterpretation of oral history • Misinterpretation of occupancy patterns • Equitable sharing of monetary benefits of knowledge	• Re-appropriation of aboriginal geographies • Increased aboriginal negotiation power • Identification of medicinal plants
Ethics and values	• Correct attitudes to adopt	• Values often incompatible with dominant discourse • Values not explicit in current management processes • Abstract dimension for non-aboriginals	• Inspiration for new environmental ethics • Socially acceptable resource management systems
Cultural identity	• Links life on the land, language, identity, and cultural survival	• Acceptance of aboriginal societies as vibrant and multifaceted • Conciliation of multiple meanings	• Rich cultural diversity • Restorative benefits of appropriate cultural landscapes
Cosmology	• Assumptions about how things work • Beliefs • Spiritual relationship to the environment	• Mistrust of alternative narratives • Structural and methodological problems for knowledge-holders in working with government bureaucrats	• Re-evaluation of long-lasting assumptions • Preparedness for social and ecological surprises

Source: Adapted from Houde et al. (2007), Table 1.

policy-makers in the North. In some cases, the recognition of knowledge is formally stated in law, as is the case of the Yukon claim agreements (e.g. the Yukon Umbrella Agreement). Providing international leadership in this area is the Exchange for Local Observations and Knowledge of the Arctic (ELOKA; see https://eloka-Arctic.org), which facilitates and supports the many efforts to collect, preserve, exchange and use local observations and knowledge. Through data management, user support and accessibility, ELOKA has also helped to span different scales by supporting the interaction of researchers and local knowledge-holders.

The monitoring of social systems differs from documentation of local observations of ecological change. (In some researchers' view, the inclusion of Indigenous Knowledge constitutes monitoring and research of social factors, but it does not.) Social dynamics in the Arctic are in many respects unique because of ongoing traditional activities of Indigenous Peoples (e.g. subsistence food harvesting), the remoteness and rural qualities of many northern communities, and their marginal position in power structures (Larsen and Fondahl 2015). Thus, monitoring of social systems needs to examine the extent to which Arctic residents are engaged in the cash and subsistence sectors of their economy, how traditional sharing of harvest occurs through time, patterns of in- and out-migration in rural areas, the extent to which conventional and Indigenous Knowledge are available and utilized, and communities' capacity for self-organization. To have a resilience orientation, they also must consider how changes in ecosystem services affect human livelihoods and to what extent people succeed or face barriers in their efforts to adapt and transform.

Sven Skaltje/International Centre for Reindeer Husbandry

Since the 1960s, Sámi reindeer herders have adopted modern technologies, such as snowmobiles, somewhat changing their relationship with the animals.

Paralleling the CBMP, but with a strong focus on social systems, is the Arctic Social Indicators (ASI) programme (Larsen et al. 2010; Larsen et al. 2015), which has identified key measurable social indicators and compiled available empirical data related to human well-being and human development. Key ASI indicator areas of monitoring social systems include fate control – guiding one's destiny; cultural vitality – belonging to a viable local culture; and contact with nature – interacting closely with the natural world, which are all relevant to Arctic residents (AHDR 2004). Subsequent efforts have re-evaluated and then elaborated on these areas, redefining the categories as health and population, material well-being, education, cultural well-being, contact with nature, and fate control (Larsen et al. 2015).

The selection, testing and eventual use of resilience indicators for social-ecological systems over time could potentially offer a set of measures that capture current system status and historical change. Social-ecological resilience indicators differ from single-disciplinary indicators in their focus on critical thresholds, traps, and state changes. If implemented with a focus on resilience to a specific set of shocks, they could provide powerful insights to inform policy.

Monitoring indicators of resilience also potentially offers a cost-effective method of tracking social-ecological system dynamics, based on the assumption that the selected indicators assess system status and capture current and emerging trajectories of change. The strength of indicators, however, ultimately depends on the user's underlying understanding of system behaviour and the qualities of the system that are important to human well-being and human values. What will cause a change in abundance in a key ecosystem service? How might people respond to such a change? What is the ultimate consequence of a particular change to human welfare and development? In short, are the selected variables indicative of social-ecological change? Do they illuminate potential fundamental shifts in the structure, function and identity of the system? And how do they relate to the groups' agreed-upon goals and vision?

In summary, there are many outstanding monitoring initiatives under way in the North, but few that integrate social and ecological systems and even fewer that consider monitoring in the context of social-ecological resilience. There is also a tendency to design and implement monitoring programmes that are disconnected from the process of understanding change (or resilience) and making decisions.

Given the paucity of integrated social-ecological observation systems, there are several ways to start to improve monitoring for a resilience-based approach:

TABLE 8.3 Measurable and testable indicators of adaptive capacity

Capacity domain	Category	Example of community indicator
Ecosystems	Ecological diversity	Main harvested species
	Ecosystem health	Caribou herd population; habitat quality
Geography	Climate	Heating degree days
	Remoteness	Round-trip airfare to urban center
Human capital	Formal education	% of population aged 25+ with a high school diploma
	Traditional knowledge	Number of skilled hunters by age
State of knowledge	Level of uncertainty	Number of long-term studies in area
Physical infrastructure	Housing quality	Median house value
	Water-sewer system	% of homes with indoor plumbing
Social capital	Social ties	Number of ties per household with other households
Cultural capital	Language retention	% of population aged 5+ speaking indigenous language
Institutions	Local government	Main local authority
Financial capital	Local revenue base	Per capita taxable property value

Source: Adapted from Berman et al. (in press).

- Identify attributes (e.g. resources, types of capital) that contribute to the capacity of communities to adapt to change, and measure the status of those attributes (see Chapter 7 and Table 8.3). This task requires a rigorous and systematic indicator identification exercise, a process by which empirical evidence will support the selection of measureable variables, generating testable hypotheses about the conditions contributing to adaptation. It also requires addressing conceptual confusion in discussions about adaptive capacity; often resources for adaptation are confused with outcomes of adaptation.

- Establish stronger linkages among currently implemented programmes, such as CBMP and ASI, to develop coordinated activities and integrated products that inform policy-makers. Monitor activities that build resilience, such as the number of workshops, collaborative and cross-scale studies that consider variables presented in this assessment, and the availability of resources for such (Berman et al. in press). Resilience monitoring should be approached as a process of learning. It is a means of testing hypotheses, and of understanding how context may affect outcomes and how different system responses may lead to different outcomes. This approach is further discussed in the sections on scenario analysis and simulation modelling.

8.5.2 Tracking and learning from regime shifts

Regime shifts, a central concept in resilience theory, are large, persistent changes in the structure and function of social-ecological systems that occur abruptly relative to the time-scales in which those systems operate (see Chapter 3). They have been empirically documented in a variety of terrestrial and aquatic systems and studied with mathematical models. Examples include the shift from forest to savannah (Hirota et al. 2011) and the collapse of ice sheets in the Arctic and Antarctic (Schoof 2007).

Society's ability to anticipate and prepare for regime shifts contributes to resilience, but as discussed in Chapter 3, our understanding of these shifts is limited. Practically, it is difficult to collect long-term monitoring information and combine it with a good understanding of the dynamics of a social-ecological system to identify changes in key feedback processes, even in well-studied ecosystems (see, e.g., Carpenter 2003, focusing on lake ecosystems). The approach to regime shifts taken in Chapter 3 is to identify what regime shifts can occur and their impacts, and then assess what kinds of processes drive these regime shifts. This allows the probability, or risk, of regime shifts to be assessed, and to begin to identify where different types of regime shifts can occur, what forces may trigger the change, and what consequences can be expected.

Kenny Louie/Flickr

The coast of Newfoundland is dotted with abandoned homes, because people were forced to move to find work after the Canadian government imposed a moratorium on the northern cod fishery. A first step in anticipating ecological regime shifts, such as the collapse of the fishery, is documentation and analysis.

Documenting and analysing regime shifts is a first step in anticipating their occurrence. The Regime Shifts Database (http://www.regimeshifts.org), described in Chapter 3, is an open website that documents, codes and analyses examples of regime shifts in social-ecological systems. It focuses on regime shifts that have large impacts on ecosystem services, and therefore on human well-being. In this sense it is a kind of observation system, populated with case studies that are intended for exploratory research.

The Regime Shifts Database is an initiative led by the Stockholm Resilience Centre as an information resource for students, lecturers, ecosystem managers and researchers, and for future assessment activities such as follow-ups to the Millennium Ecosystem Assessment. Whenever possible, each regime shift is reviewed by an expert prior to publishing it online. This approach has also been used to compare global and marine regime shifts (Rocha, Peterson, et al. 2015; Rocha, Yletyinen, et al. 2015). Documented Arctic regime shifts are presented in Chapter 3. The documentation of these regime shifts is one of the few cases in which observers of change view the social-ecological system as the basic unit of analysis.

The development and use of a regime shifts database in the Arctic could be further elaborated in four ways:

1. The existing analysis could be elaborated and refined, updating the details on existing regime shifts based on new scientific research and adding newly identified or proposed regime shifts for the Arctic to the database for further comparative work.

2. Specific examples of the types of regime shifts identified in Chapter 3 could be collected and compared. Such work could help map the occurrence of regime shifts, help assess the range of variation where regime shifts occur, and the relative risk of different types of regime shifts.

3. Invest in detailed research on key large-scale regime shifts to understand how various social-ecological processes and feedbacks control their dynamics.

4. Elaborate on the role of social and economic change in driving regime shifts, to provide a better balance with the database's current primary focus, which is on ecological change and its consequences for ecosystem services and people.

The first approach is probably most useful for assessing the relative importance and connections among multiple regime shifts. The second approach would be helpful for assessing smaller-scale, more frequent regime shifts, such as thermokarst transitions and river channel change. The third approach would aid understanding of important large-scale regime shifts, such as the collapse of the Greenland ice sheet or sea-ice loss. Finally, greater inclusion of cases where social and economic drivers are primary drivers will capture potential regime shifts in the North more completely. Engagement of stakeholders to learn about their thoughts on possible regime shifts would enrich the learning process. In summary, more extensive development of the Regime Shifts Database and its analysis would help decision-makers assess the likely risks, impacts, possible mitigation, and adaptation strategies for regime shifts.

8.5.3 Assessing the resilience of social-ecological systems

Resilience assessments can facilitate the development of management and governance strategies for coping with change, and thus improve a system's (or community's) capacity to respond. To be effective, the assessment must be meaningful to stakeholders and those who make decisions affecting the system. Thus, it should be integrative, participatory, and aimed at supporting social learning. Table 8.4 presents several resilience assessment tools and approaches.

The Resilience Assessment Framework (Resilience Alliance 2010) is an example of a method that engages practitioners and researchers in understanding how integrated social-ecological systems change, in order to inform management practices. Applying the knowledge garnered from a resilience assessment can help provide insight into strategies for buffering or coping with both known and unexpected change.

The first step is to define the scope of the assessment: resilience *of what* (whom), *to what?* The study thus starts by delineating the boundaries of the system, using a set of questions and activities to construct a conceptual model of the social-ecological system. The model represents a place of interest along with its associated resources, stakeholders, institutions and issues (Quinlan et al. 2016). Although the assessment is focused on specific resource issues, it is important to look at the broader context across multiple scales to ensure that management goals and plans do not compromise the integrity of the system as a whole.

The conceptual model also identifies potential thresholds between alternative regimes or system states (e.g. salt marsh to tidal flat, or tundra to forest), as well as drivers of change. Cross-scale interactions among system components are explored, and the potential for cascading change is analysed. Attributes of adaptive governance that exist or are absent in the system are explored, and next steps are considered, including devising stewardship strategies or preparing for transformation. Focusing on specific issues or concerns about a natural resource system can help to focus the resilience assessment and ensure that it is directly relevant to stakeholders. That means, among other things, tailoring the assessment to emphasize the questions and activities that are most relevant to the specific context. It may be necessary, during the process or in subsequent iterations, to adjust the definition of the system's boundaries and/or to fine-tune sections of the assessment in light of new information. To avoid excessive complexity, it is essential to identify the key variables of interest and focus on them. Lastly, because resilience assessments are time-sensitive, it is important to keep updating.

A valuable aspect of resilience assessments is that they can help build a mental model of a system that encourages and works with change, variability and diversity, rather than one focused on how to control system components.

TABLE 8.4 **Approaches and tools for assessing the resilience of social-ecological systems**

Approach/tool	Context	Format	Reference
Assessing Resilience in Social-Ecological Systems: Workbook for Practitioners (Version 2.0)	Natural resource-based issues; environmental change; integrated social-ecological systems; local to regional scales	Multi-method; guided questions and activities; conceptual model development; systems-based, cross-scale analysis	Resilience Alliance (2010)
Designing Projects in a Rapidly Changing World: Guidelines for Embedding Resilience, Adaptation and Transformation into Sustainable Development Projects (Version 1.0)	Development projects; agro-ecosystems; social-ecological systems; climate change adaptation and transformation; local to regional scales	Step-by-step approach; guiding questions and activities; theory of change; system description; pathway development	O'Connell et al. (2016)
Community Based Resilience Analysis (CoBRA) Implementation Guidelines	Human-centred development and risk reduction; vulnerable communities	Participatory, community process; household surveys, focus group discussion and interviews	UNDP (2014)
Toolkit for the Indicators of Resilience in Socio-Ecological Production Landscapes and Seascapes (SEPLS).	Production landscapes and seascapes; social-ecological systems; communities	Stakeholder-led process; participatory community discussion; shared development and ranking of indicators	UNU-IAS et al. (2014)
Rapid Assessment of Circum-Arctic Ecosystem Resilience (RACER)	Arctic regions; landscapes and seascapes	Mapping of biophysical features to identify high conservation-value areas	Christie and Sommerkorn (2012)

Such a shift may involve a re-examination of one's underlying assumptions about how the world works, and being receptive to new ideas. For these reasons, and to be effective, the resilience approach demands the participation and engagement of those who will be involved in making decisions about the system and those who will be affected by those decisions.

A growing number of case studies and applications of the Resilience Assessment Framework are helping to refine the approach and to develop new ways to quantify resilience through indicators (Quinlan et al. 2015; O'Connell et al. 2015). While resilience assessments in the Arctic following this approach have only been applied in a limited way, several researchers have used a resilience lens to address similar questions (Chapin et al. 2006; Forbes et al. 2009; Kofinas et al. 2010; Hovelsrud and Smit 2010; Lovecraft and Eicken 2011; Carmack et al. 2012). Looking ahead, applying this framework in highly participatory assessments of social-ecological resilience in the Arctic could be valuable in closing the gaps between theory and practice. The development of methods for resilience assessment will depend to a great extent on support from Arctic leaders, both by providing resources and through endorsements.

On a broader scale, the comparison of case studies is a helpful approach to resilience assessment that combines a strong basis in theory with the synthesis of existing research and knowledge (see Chapter 4 and Berman et al. in press). This approach allows one to identify traits that appear to contribute to resilience and loss of resilience, as well as gaps in current knowledge of local social-ecological dynamics. This approach could be built upon by collecting more cases, refining the case comparisons, and better linking of published literature to local and Indigenous Knowledge. Such an approach is useful for providing an Arctic-level perspective on resilience, and it can allow for comparison and potentially networking among cases internationally. However, it may be less useful in helping specific communities to identify strategies to improve their local situation.

8.5.4 Simulating social-ecological system dynamics with models

Computer simulation models are simplified representations of the real world that capture the best available knowledge of system dynamics and project possible future conditions. Their utility is best measured by the extent to which the model gives insight, stimulates discussion, inspires innovation, and/or helps to resolve societal problems (Holling and Chambers 1973; Starfield et al. 1990). Because of the degree of uncertainly around the behaviour of social-ecological systems, simulation models typically project (versus predict) future conditions and are only as good as the data used and the understanding represented (i.e. "junk in, junk out").

Simulation models are today commonly developed and used in many areas of Arctic science (Roberts et al. 2010), primarily by the physical disciplines and, to a lesser extent, ecological and biological scientists. Some are used by resource management agencies for making decisions on harvest allocation. However, in the Arctic, modelling is rarely done in a participatory manner to explore social-ecological resilience and inform policy. Simulation models have been shown to be powerful tools in some ecological assessments (Jensen and Bourgeron 2001) and have promising applications for considering the implications of cumulative effects, but the inclusion of simulation modelling in some legally required environmental assessment processes (e.g. environmental impact statements, which are required by the National Environmental Policy Act of the US) is not allowed.

Carpenter et al. (1999) pioneered the use of agent-based social-ecological system models to study critical thresholds in a social-ecological system involving human-produced phosphorus inputs into a lake system. They argued that agent-based models are a better alternative to conventional economic cost-benefit analysis. The latter, they noted, usually omits slow variables and nonlinearities and fails to represent the evolved and evolving nature of ecosystem components, which may be sources of resilience or surprise. Therefore, the analysis always omits potentially important outcomes, simply because they have not yet been observed or cannot be forecast, causing errors in policy choice, potential surprises and impact to stakeholders.

While the use of modelling is common in the Arctic, there are few examples of simulation models used to represent social-ecological systems, with fewer used for decision-making and resilience. Several disciplinary models, however, have been used to contribute to decision-making. For example, a caribou energy protein and population model, coupled with various development proposals, was used to predict the cumulative effects of diamond mine development (Gunn et al. 2011; Russell 2014a; Russell 2014b). The model served as input at a workshop of stakeholders, contributing to the development of required conditions for approval for the Baffinland project in Canada's Northwest Territories. So far that model has not been used to demonstrate trade-offs, such as to offset the effects of development by reducing harvest (or vice versa), although these contributions to management or land use planning are possible.

In the Canadian Arctic, various decision-making bodies are becoming increasingly familiar with the simulation models (e.g. the ALCES model for boreal caribou; see Schneider et al. 2003), and benefiting from their use. The "Caribou Calculator" of the Canadian Porcupine Caribou Management Board, a simple simulation model projecting changes in herd population based on biological monitoring and assumptions on harvesting (i.e., rate, sex, wounding loss), was used by the co-management board to establish harvest levels, risk levels during a period when there were no population census data, and agreed-upon harvest quotas. With the population decreasing for the Western Arctic caribou herd, wildlife managers are initiating a similar effort.

Yet modelling can be problematic. When model outputs are first presented to stakeholders after the model is built, those stakeholders can find it difficult to understand their logic. Failure to represent local knowledge in the model can lead some stakeholders to completely reject the results. Even when such issues are addressed, the representation of outputs in technical terms (e.g. histograms) can result in misunderstandings. The opaque nature of models is part of this problem. Starfield et al. (1990) suggest that highly simplified models are more helpful than detailed models in informing decision-making: By simply presenting the interaction of critical variables, they allow stakeholders to explore complexities through dialogue. Experience working with models also helps. Modelling as a decision support tool for a broad range of stakeholders in the Arctic represents more of an opportunity than a proven method at this time, but it has potential worthy of greater investment.

8.5.5 Participatory scenario analysis

Scenario analysis is a method for analysing the future of social-ecological systems (Peterson et al. 2003; Oteros-Rozas et al. 2015), with participatory scenario analysis involving stakeholders and others in that process. Prior to, but particularly following, the Millennium Ecosystem Assessment (MEA 2005), a wide variety of participatory social-ecological scenarios were developed around the world (Oteros-Rozas et al. 2015). These projects ranged from how wildlife managers can cope with climate change in the Yukon (Beach and Clark 2015), to evaluating investments in dryland agriculture in Tanzania (Enfors et al. 2008). These projects have been used to engage diverse communities, often including Indigenous Peoples, in discussions around the management and governance of landscapes for multiple benefits.

Scenario analysis can be flexible and accessible, and can integrate non-quantitative, partially quantitative, or fully quantitative information (Amer et al. 2013). Social-ecological scenarios have usually analysed how decisions or policies perform in alternative futures in a way that addresses uncertainties (Bennett et al. 2003; Carpenter et al. 2006). As frameworks for integration, scenarios

Terry Chapin

Waterfowl in the off-road community of Nikolai, Alaska. The Community Partnership for Self-Reliance at the University of Alaska–Fairbanks works with communities to explore ways to sustain subsistence hunting and fishing in a time of rapid climatic, socio-economic and regulatory change.

provide a platform for addressing and bridging different approaches to knowledge, views of how the world works, and values (Thompson et al. 2012). They typically explore the implications of change and develop mental pathways for responding to change; thus, they can help build the adaptive capacity of a group or groups (Nakicenovic et al. 2000; Walker et al. 2002; Peterson et al. 2003; Miller 2004).

Scenario analysis is undertaken with one of several approaches or a combination of approaches. Forecasting and backcasting are among the most common. In forecasting, best available knowledge is used to generate one or more outcomes (i.e. futures) of what is likely to occur, such as the seminal use of scenarios by Shell Oil in assessing economic development and changing energy futures conditions (see, e.g., Wack 1985). Backcasting starts by defining a desirable future and addresses what actions are necessary to achieve that future (Robinson 1990). Swart et al. (2004) outline key conditions for effective use of scenario analysis, including:

- Sufficiently large and diverse group of participants;
- Adequate time for problem definition, knowledge base development, iterative scenario analysis, review and outreach;
- Full accounting of available knowledge and rigour of methods;
- Explicit discussions about normative scenario elements;
- Development of coherent, engaging stories about the future;
- Exploring the possibility of surprise events and address possible seeds of change; and
- Placing the problem in a broader context.

While participatory scenarios are often more accessible, integrative and engaging than technical, they are also less rigorous, less comparable and less generalizable than scenarios from technical simulation models. Participatory scenario processes also take significant amounts of time to complete. Still, they have proven effective in engaging a diversity of people in discussions about the state of knowledge, the trade-offs of choices, and alternative actions. There are a number of guidebooks on conducting social-ecological scenario planning projects, but the tools, techniques and guidance can be further improved.

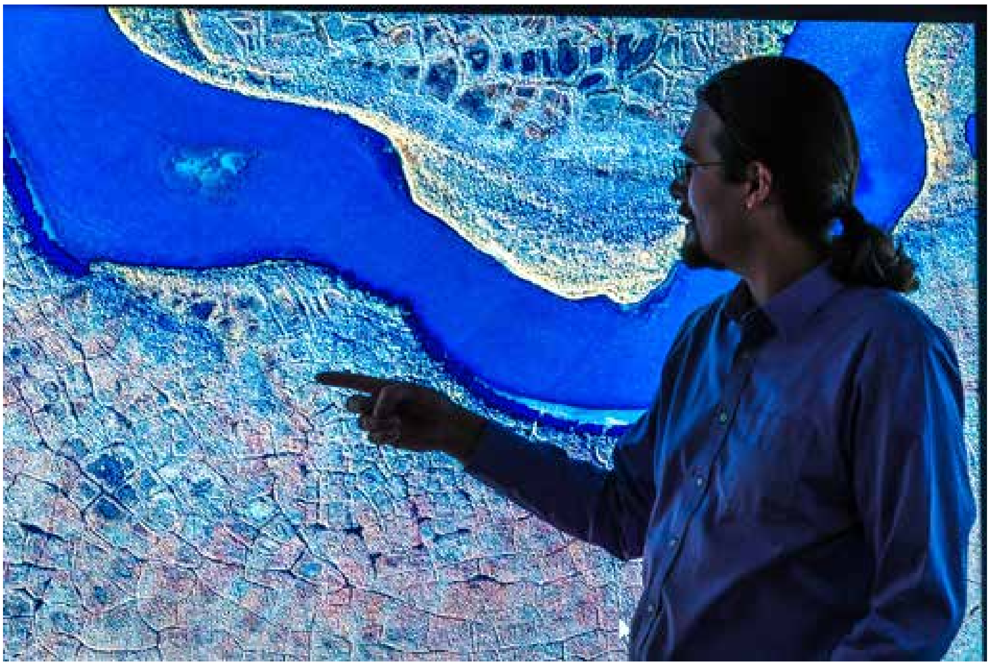
Recent research has focused on combining forecasting and backcasting in scenarios (Kok et al. 2011), evaluating scenario methods, expanding scenarios from narratives, and using different media in scenario planning (Vervoort et al. 2012). A wider use of scenario methods requires making scenario practice more accessible, which requires building a community of practice among scenario practitioners, evaluating scenario processes, and assessing the utility of different tools for different contexts and objectives (Oteros-Rozas et al. 2015).

Several noteworthy participatory scenario analyses with a focus on social-ecological systems have been undertaken in the Arctic. Among them is the US National Park Service "Rehearsing the Future" programme for park units of Alaska, organized as a set of workshops. An evaluation of that process by Ernst and Riemsdijk (2013) found that the diversity of stakeholders who participated broadened decision-making beyond the National Park Service. It also enhanced understanding of participants' attitudes towards climate change and climate change decision-making, and that understanding influenced the decision-making process. The analysis suggests that the programme could be a model for future climate change planning in public land agencies.

The Oil Development Scenarios Project of the North Slope Science Initiative of Alaska used maps in a participatory analysis process, leading to the identification of research needs. With a different emphasis, the Canadian Department of National Defense used scenario analysis to study the national security issues of an ice-free Arctic. Another example of the participatory scenario approach in the Arctic can be found in the Barents region, where scenario workshops have included local and regional actors from public agencies, organizations and the private sector in three different locations (Pajala, Sweden; Kirovsk, Russia; and Bodø, Norway). Another scenario exercise was carried out together with reindeer-herding youth across the Eurasian Arctic (van Oort et al. 2015; Nilsson et al. 2015). These and other applications point to the need to advance methods for using science-stakeholder discussions about society's needs and plausible futures, and the public policy process.

8.5.6 Decision theatres

While data-driven decision-making is critical to producing robust solutions in complex environments, data alone do not make decisions. People make decisions, often in illogical steps and using ineffective methods (Kahneman 2011). Recent research has begun to identify the positive impacts that shared visual spaces may provide. Andrews et al. (2010) showed that presenting information on a large, high-resolution display helps people make sense of data "by becoming part of the distributed cognitive process, providing both external memory and a semantic layer". Creating an immersive visual environment enables a group of people to view a large amount of information at once, organized across multiple screens. The act of organization and manipulation across the physical environment of the screens "can work together to become a



Todd Paris, University of Alaska Fairbanks.

The Decision Theater North provides a focal point for bringing together flexible, adaptive university research teams to address questions across Alaska and the Circumpolar North.

spatial environment, changing the way the user works and thinks", thereby promoting a deeper understanding of the data.

Several "decision theatres" using this approach have been developed as experiments to try to make relevant data available to stakeholders and facilitate decision-making. Examples in North America include the Decision Theater at Arizona State University (ASU; see https://dt.asu.edu), the BC Hydro Theatre at the Centre for Interactive Research on Sustainability at the University of British Columbia (see http://cirs.ubc.ca/booking-room), and the McCain Institute Decision Theater (see https://www.mccaininstitute.org/work/decision-theater/). These are promising efforts that support a collaborative approach to decision-making and team science.

Other research has shown that although shared displays may not increase task efficiency, they can have the advantage of increasing the shared understanding of each person's activity (Wallace et al. 2009), promote communication and collaboration among team members (Stewart et al. 1999), and increase the development of a shared mental model of common goals (Swaab et al. 2002).

A recent study in the ASU Decision Theater concluded that stakeholders who deliberated on local policy issues in the shared visual space showed greater cooperative behaviour in a social dilemma scenario than when they had interacted with individual laptops. A technology-facilitated environment can therefore provide both a context for interaction and deliberation, and a platform for fostering cooperation. This approach may contribute to building shared understandings of problems and a stronger sense of community, and facilitate collective action towards common goals (Hu et al. 2012).

The University of Alaska Fairbanks's Decision Theater North (DTN; see http://www.dtn.alaska.edu) is a nascent-stage effort in implementing and testing the effectiveness of this approach in the North. The DTN is an immersive visual environment designed to facilitate dialogue and collaborative decision-making by agencies, industry, communities and academia, and consists of a bank of high-definition monitors connected to super-computing and storage, allowing users to display the dynamics of a problem through clear and deliberate visualizations of data.

The DTN provides a focal point for bringing together flexible, adaptive university research teams to address questions across Alaska and the Circumpolar North. It also convenes stakeholders from multiple organizations to discuss complex problems facing a particular region and/or the Circumpolar North, and to shape the way people make decisions. Projects undertaken at DTN thus far include tsunami preparedness for coastal Alaska communities, scenario planning for oil development on the North Slope, development of science proposals in interdisciplinary teams, local community planning, and research data analytics, among others. Initial experience suggests that the decision theatre approach has great potential as a means of building resilience.

8.5.7 Regional and global strategies for resilience

Many stakeholders are organizing at the global and regional levels to build resilience to climate change and natural disasters. Global and regional strategies for building resilience serve as a way to convene state and non-state actors under a common umbrella, identify specific priorities, and coordinate efforts. Regional strategies are increasingly being linked to relevant global agreements and platforms, such as the Paris Agreement on climate change and the Sustainable Development Goals. Several global and regional strategies have been adopted or are currently under development. Table 8.5 lists examples of strategies for resilience and the approaches they take.

Recently developed strategies have several common elements. Most have one uniting and overarching outcome or vision statement and identify a specific time frame for accomplishing their goals. Several outline guiding principles for identifying and implementing action items. Specific actions can be organized according to a number of different levels of action (e.g. national, regional, global), with specific parties assigned responsibility for each action. Several of the strategies use "results frameworks" or other project management tools to demonstrate the expected outcomes and indicators of success for each action item. A coordinating body is typically required to ensure that actions are implemented and to evaluate progress.

The coordinating strategies encourage monitoring, evaluation and learning, and use various platforms for

TABLE 8.5 **A sampling of global and regional strategies to build resilience**

Strategy	Description
Sendai Framework for Disaster Risk Reduction 2015–2030[1]	This framework has an overarching goal to substantially reduce disaster risk and losses in lives, livelihoods, health and assets. It also outlines seven specific targets, to be measured at the global level. The framework acknowledges that countries have the primary responsibility to implement the framework, but it also outlines roles for non-state actors. The framework focuses on understanding disaster risk, strengthening governance to manage risk, investing in disaster risk reduction for resilience, and enhancing disaster preparedness for effective response.
EU Strategy on Adaptation to Climate Change[2]	The EU Adaptation Strategy seeks to strengthen the European Union's overall resilience to climate change by promoting action by individual Member States, promoting better informed decision-making, and promoting adaptation in key vulnerable sectors. The strategy lays out specific actions by Member States and the European Commission.
Extended Programme of Action for the Implementation of the Africa Regional Strategy for Disaster Risk Reduction (2006–2015)[3]	This strategy's overall goal was the substantial reduction of social, economic and environmental impacts of disasters on African people and economies. The strategy included several specific objectives, including the mainstreaming of risk reduction and climate change adaptation, the strengthening of long-term capacities, the development and mobilization of resources, and the translation of policies and strategies into practical tools for decision-makers. The strategy also identified specific actions and responsibilities at the regional, sub-regional and national levels.
Strategy for Climate and Disaster Resilient Development in the Pacific (in development)[4]	The draft strategy lays out three strategic goals: strengthened integrated risk management; low-carbon development; and strengthened disaster preparedness, response and recovery. Actions are identified for national/sub-national governments, civil society, the private sector and regional organizations. The strategy also presents a set of 11 guiding principles for resilient development, such as the adoption of integrated approaches to managing risks, the incorporation of traditional information, and the incorporation of processes that reinforce cultural resilience and the knowledge of communities.
African Union Strategy on Climate Change (in development)[5]	The African Union's draft strategy on climate change is intended to increase the adaptive capacities and resilience of Member States and Regional Economic Communities. The strategy is underpinned by four thematic areas, including climate change governance; the promotion of research, education, awareness and advocacy, the mainstreaming of climate change imperatives in planning, budgeting and development processes; and the promotion of national and regional cooperation. The strategy is intended to span 20 years (2015–2035) and will be reviewed every five years.

1 http://www.unisdr.org/we/coordinate/sendai-framework.

2 http://ec.europa.eu/clima/policies/adaptation/what/documentation_en.htm.

3 https://www.unisdr.org/we/inform/publications/19613.

4 http://gsd.spc.int/srdp/.

5 http://www.un.org/en/africa/osaa/pdf/au/cap_draft_auclimatestrategy_2015.pdf.

As the Arctic countries develop and implement their national adaptation strategies, it is important that they draw on the knowledge and insights of Arctic peoples.

sharing case studies and best practices (e.g. the EU ClimateADAPT Platform, http://climate-adapt.eea.europa.eu, and the Global Platform for Disaster Risk Reduction biennial forum, https://www.unisdr.org/we/coordinate/global-platform). Most of the strategies encourage the mainstreaming of adaptation/resilience into various sectors, and most regional strategies indicate support of their member states in developing their own national-level plans for adaptation and resilience. Many strategies either coordinate with donor agencies or request that donor agencies consider the priorities outlined when developing their own donor funding plans.

While most strategies are still in the early stages of implementation, a few earlier strategies have pointed to important good practices. The development of the Sendai Framework for Disaster Risk Reduction 2015–2030, for instance, was largely informed by the implementation of its predecessor, the Hyogo Framework for Action 2005–2015. The Hyogo Framework demonstrated the importance of multi-sectoral, multi-hazard, and widely inclusive approaches to resilience. It also demonstrated the need for a more action-oriented framework, one that includes strong links between policy strategies and financing strategies.

The implementation of national-level strategies has also pointed to successful practices and limiting factors. A study of EU Member States' adaptation strategies, designed to draw insights for the EU strategy, indicated that mainstreaming, effective communication and awareness-raising, and strategies that are flexible and can evolve, are all good practices (European Commission 2013). On the other hand, inadequate funding, monitoring and evaluation, or concrete action plans can inhibit the success of a strategy. An example of a place where local engagement in global strategies is occurring is the Udege Bikin region in the Russian Far East (see http://globalforestcoalition.org/udege-indigenous-forest-russia/). This region, centred on the village of Krasny Yar, has been able to use strong local leadership and global connections to channel benefits from the Kyoto Protocol carbon market to support local resilience. The community used its earnings from trade on the carbon market to rent its harvesting grounds and ensure the preservation of its homeland.

8.6 From resilience theory to practice: Looking ahead

Resilience theory offers important insights on regime shifts, adaptability, and ways of navigating transformation. The theoretical orientation of resilience thinking is especially important in the Arctic, where rapid change is raising concerns about ecosystem health and human well-being. While the application of resilience theory to practice is underdeveloped, there are insights and examples for application in the North. Literature and lessons from the case studies have enabled us to identify a set of general principles for building resilience. We elaborated on six cross-cutting heuristics that have special relevance for the Arctic. We then presented types of practice or activity areas that embody resilience thinking, with examples of their implementation in the Arctic.

Putting resilience principles into practice is neither straightforward nor simple. Social-ecological systems are complex and require careful review of the feedbacks and potential regime shifts associated with change. Knowledge of system dynamics always involves uncertainty. Living with uncertainty inherently requires accepting the fact that in some cases, decisions must be made with imperfect information, and that people do not always act rationally. Assessing levels of uncertainty can be helpful. For example, there is little uncertainty that the Arctic is warming or that the sea ice is shrinking. There is modest uncertainly that the extent of sea ice will affect interests in Arctic ocean shipping prospects, and there is great uncertainty in the long-term rate of loss of ice, the nature of a potential associated regime shift, and its effects on social-ecological systems.

While more monitoring and research are necessary, they are not ends in themselves. They must be systematically related to assessments, preparedness and policies. Living with uncertainty therefore implies building the capacity of governance systems to reflect, evaluate possible actions, and ultimately respond in the event of surprise.

Institutional arrangements (informal and formal rules that guide human behaviour) play a key role. Informal institutions, such as communities of practice, shadow networks, and boundary organizations can be powerful forces of change when there are no formal arrangements to address a problem. Formal institutions are crucial as well, as they give legitimacy to initiatives and can help establish and support resilience-building programmes. Understanding the performance of such institutions, with an eye on their contribution to resilience, is critical. The Arctic Council has been instrumental in developing both formal and informal institutions, both of which are highly important to the Arctic's future development.

The realization of resilience thinking in the Arctic – of moving from theory to practice - will need to be a multi-scale enterprise that draws on the different types of capacities and competencies available at the local, regional and national, pan-Arctic, and even global levels. It will be important to be sensitive to power imbalances, issues of justice (and injustice), and people's local-level needs, because these characteristics influence the levels of resilience. Redundancies within and between levels can be beneficial, but efficiency has value too, as there are limits in time and resources for taking action. And because both bottom-up and top-down efforts are needed, good linkages and information exchanges across scales, well-articulated and coordinated actions, and high responsiveness are very important.

The practices described in this chapter should be viewed as ingredients for problem-solving and decision-making. The appropriate "recipe" in each context will depend to a great extent on local conditions, the groups involved, their goals, interests and available resources, and the nature of the problem being addressed. Applying these resilience-building practices in various contexts offers huge opportunities for innovation, to be creative, mix and match ideas, and experiment.

Putting resilience thinking into practice is a multi-scale enterprise. It needs to be sensitive to power imbalances, issues of justice (and injustice), and people's local-level needs, taking both bottom-up and top-down approaches. Realizing resilience in the Arctic will require a multi-dimensional effort. These dimensions include (but are not limited to):

- Defining and establishing clear, consistent linkages between resilience, adaptation, and transformation, especially in the context of climate change;
- Focusing efforts at the circumpolar regional scale, and regional and local-level scales in the Arctic, and linking these scales where possible;
- Drawing on and recognizing the value of working from a diversity of knowledge systems, including local and Indigenous Knowledge as well as interdisciplinary science;
- Striving towards an integration of disciplines, knowledge, and experience;
- Addressing multiple risks, opportunities, and co-benefits whenever possible;
- Considering risk and resilience on a range of time scales;

- Developing and innovating processes that enhance social learning;
- Recognizing the importance of the capacity for self-organization, especially at the community level;
- Empowering local communities through resources, incentives, and decision-making responsibilities, as appropriate;
- Adopting multi-stakeholder approaches in the range of activities (monitoring, research, decision-making); and
- Pursuing coherence between policies associated with sustainable development, climate change, and disaster risk reduction plans.

Building resilience is crucial in this time of rapid and often surprising change. As shown through the examples in this chapter and throughout the report, a great deal of ground work has already been laid, and multiple practices, tools and strategies are available to move from resilience theory to resilience-based practice. While the challenges of Arctic change are significant, the people of the North have a long history of adaptation. But they cannot navigate these changes alone. The resilience of Arctic social-ecological systems depends not only on the commitment and imagination of Arctic people, but on the support provided by Arctic countries' governments, non-governmental organizations, industry and others. Ultimately, realizing resilience in the Arctic will depend on empowering the people of the North to self-organize, define challenges in their own terms, and find their own solutions, knowing that they have the flexibility and external support to implement their plans.

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APPENDIX 1

Background of the Arctic Resilience Assessment

The Arctic Resilience Assessment (originally called Arctic Resilience Report) is an initiative of the Swedish Arctic Council Chairmanship (2011–2013). Its mandate was set out by the Arctic Council at its meeting in Luleå, Sweden, on 8–9 November 2011. The Senior Arctic Officials report to the Nuuk Ministerial Meeting and the Nuuk Ministerial Declaration in May 2011 identified the need for "an integrated assessment of multiple drivers of Arctic Change as a tool for Indigenous Peoples, Arctic Residents, government and industry to prepare for the future".

The Arctic Resilience Report was charged with the task of identifying potential "cliffs" or tipping points, assessing challenges to the communities in the Arctic, and identifying ways in which the Arctic Council might contribute to preserving and/or strengthening resilience across the Arctic.

Project organization and leadership

This initiative of the Swedish Arctic Council chairmanship was joined by the United States in 2014. The project's final phase is therefore co-chaired by both countries, with Sweden represented by Johan Rockström, Executive Director of Stockholm Resilience Centre, and the United States represented by Joel Clement, Director of the Office of Policy Analysis, US Department of the Interior.

The project has been led by the Stockholm Environment Institute and the Stockholm Resilience Centre in collaboration with the University of Alaska Fairbanks and the Resilience Alliance. Importantly, the project has built on collaboration with other Arctic States and Indigenous Peoples in the region, as well as with several Arctic scientific organizations.

Broad participation is reflected in the Project Steering Committee (PSC), which has included representatives from Arctic States and Permanent Participants, as well as from the Arctic Council Working Groups and collaborating organizations and Arctic Council Observers. At its meeting in June of 2015, the PSC updated the project name to Arctic Resilience Assessment (ARA), while this final report is called the Arctic Resilience Final Report. The PSC also supported a proposal to move the project under the Arctic Monitoring and Assessment Programme (AMAP), both to support further cooperation and to provide a longer-term base within the Arctic Council's working group structure for future resilience assessment.

As part of its assessment, the project has engaged with Arctic Council Working Groups with which there are clear synergies. In addition to consultation with the Working Groups, the project has explored possible links with the work of the Sustainable Development Working Group and has worked closely with AMAP through the AACA-C project. These collaborative efforts are especially important, as a resilience lens provides an interdisciplinary approach that facilitates the integration of relevant knowledge from different traditions.

Workshops

In addition to the extensive ongoing research and analysis of case studies that underpin the assessment, the ARA has organized workshops and participated in several conferences in which ARA work has been presented and input has been sought. Expert workshops were held in conjunction with PSC meetings in late summer and fall 2013 and in spring 2014 to develop the methodology for the final report, agree on a proposed chapter structure, and identify lead and contributing authors.

In January 2015, the ARA project hosted a workshop in Tromsø on the theme *Governance in times of rapid change and unpredictability: What role(s) can the Arctic Council play?* This workshop constituted an opportunity for Arctic Council country representatives, Permanent Participant representatives and Working Group representatives to discuss, under the Chatham House rule, initial insights about the role of circumpolar governance in relation to resilience with a broader group of experts and policy-makers.

In June of 2015, the ARA held another workshop, *One Arctic, Many Possible Futures*, in collaboration with the US Department of the Interior at the House of Sweden in Washington, DC. The workshop explored the "multiple Arctics" that arise from the diversity of perspectives and goals for the Arctic, discussed areas in which these different goals sometimes collide, and shared examples of successful efforts to negotiate workable arrangements. The very valuable input from these workshops has contributed to the project's mandate of identifying ways in which the Arctic Council can support action to strengthen resilience.

Deliverables

The Arctic Resilience Interim Report was published in 2013. It described innovations in resilience assessment methodology, developed specifically for this large and complex regional scale. It provided an assessment of the potential for large shifts in ecosystem services that may affect human well-being, and reviewed the literature on adaptive and transformative capacity, which enables ecosystems and human populations to withstand unexpected and disruptive changes. It also explored the use of pilot case studies to illustrate some of the challenges and opportunities relating to resilience in particular places and for particular issues in the Arctic.

While this final scientific report formally concludes the ARA's work, the project will produce one additional document – a Synthesis for Arctic Leaders – which will include key highlights from the final report along with policy recommendations. The Synthesis will be delivered to the Ministerial at the close of the US Arctic Council Chairmanship. ARA and AACA-C collaborated to share early findings between writing teams in order to ensure a more comprehensive and coordinated set of final products. ARA has collaborated closely with AMAP to contribute a resilience perspective to AACA-C regional reports, and anticipates providing similar support for any eventual pan-Arctic report. We anticipate that the ARR and AACA-C products will combine to provide an important new set of resources for Arctic decision-making.

APPENDIX 2

APPENDIX 2.1 Objectives and remits of Arctic Council Working Groups

TABLE A2.1 **Arctic Council Working Groups**

Name	**Objective and remit**
Arctic Contaminants Action Program (ACAP)	*To prevent adverse effects, reduce, and ultimately eliminate Arctic environmental pollution.* ACAP does this by complementing existing legal arrangements, structures and mechanisms under the Arctic Council; allowing for actions on pollution prevention and remediation; and identifying cooperative activities for implementation.
Arctic Monitoring and Assessment Programme (AMAP)	*To monitor and assess the status of the Arctic region with respect to pollution and climate change issues, and propose actions to reduce associated threats.* AMAP does this by making syntheses of findings from monitoring and research activities, and promoting and harmonizing national and international programmes of activity that can support AMAP assessments.
Conservation of Arctic Flora and Fauna (CAFF)	*To address the conservation of Arctic biodiversity, and to communicate its findings to the governments and residents of the Arctic, helping to promote practices that ensure the sustainability of the Arctic's living resources.* CAFF does this through ecological monitoring, assessment and expert working group activities. These provide data for informed decision-making to resolve challenges arising from trying to conserve the natural environment and permit regional socioeconomic development.
Emergency Prevention, Preparedness and Response (EPPR)	*To contribute to the protection of the Arctic environment from the threat or impact that may result from an accidental release of pollutants or radionuclides.* EPPR does this by exchanging information on best practices, conducting projects to develop guidance and risk assessment methodologies, mobilizing response exercises and training. It also considers issues related to response to the consequences of natural disasters.
Protection of the Arctic Marine Environment (PAME)	*To address policy and non-emergency pollution prevention and control measures related to the protection of the Arctic marine environment from both land and sea-based activities.* PAME does this through coordinated action programmes and guidelines complementing existing legal arrangements.
Sustainable Development Working Group (SDWG)	*To propose and adopt steps to be taken by the Arctic States to advance sustainable development in the Arctic, including opportunities to protect and enhance the environment and the economies, culture and health of Indigenous Peoples and Arctic communities; and to improve the environmental, economic and social conditions of Arctic communities as a whole.* SDWG does this by pursuing initiatives that provide practical knowledge and contribute to building the capacity of Indigenous Peoples and Arctic communities to respond to the challenges and benefit from the opportunities emerging in the Arctic Region.

In addition, the Arctic Council operates several Task Forces, with time-limited remits to report on clearly specified Arctic issues. Current Task Forces are:

- Scientific Cooperation Task Force
- Task Force on Arctic Marine Cooperation
- Task Force on Telecommunications Infrastructure in the Arctic

The Task Forces that have completed their work are:

- Task Force to Facilitate the Circumpolar Business Forum, which led to the formation of the Arctic Economic Council
- Task Force on Arctic Marine Oil Pollution Prevention
- Task Force on Arctic Marine Oil Pollution Preparedness and Response
- Task Force on Black Carbon and Methane
- Task Force for Institutional Issues
- Task Force on Search and Rescue
- Task Force on Short-Lived Climate Forcers

APPENDIX 2.2 Overview of the principal actors in the Arctic Council and their primary objectives relating to Arctic governance

TABLE A2.2.1 **Permanent Participants**

Names	Stated objectives in strategic documents
Arctic Athabaskan Council http://www.arctic-council.org/index.php/en/about-us/permanent-participants/arctic-athabaskan-council-aac	"To foster a greater understanding of the common heritage of all Athabaskan peoples of Arctic North America; and represent Athabaskan peoples of Arctic North America as a permanent participant in the Arctic Council." Treaty of the AAC, 2000. See: http://www.arcticathabaskancouncil.com/aac/?q=node/3
Aleut International Association http://www.arctic-council.org/index.php/en/about-us/permanent-participants/aleut-international-association-aia	"To address environmental and cultural concerns of the extended Aleut family whose well-being has been connected to the rich resources of the Bering Sea for millennia." AIA is an Alaska Native not-for-profit corporation, 501(c)(3). See: aleut-international.org/about
Gwich'in Council International http://www.arctic-council.org/index.php/en/about-us/permanent-participants/gwich-in-council-international	"To ensure all regions of the Gwich'in Nation in the Northwest Territories, Yukon and Alaska are represented at the Arctic Council, as well as to play an active and significant role in the development of policies that relate to the Circumpolar Arctic." GCI is a non-profit organization. See: http://www.gwichin.org
Inuit Circumpolar Council http://www.arctic-council.org/index.php/en/about-us/permanent-participants/inuit-circumpolar-council	"To strengthen unity among the Inuit of the Circumpolar region; to promote Inuit rights and interests on the international level; to ensure Inuit participation in political, economic and social institutions which the Inuit deem relevant; to promote greater self-sufficiency of Inuit in the Circumpolar region; to ensure the endurance and the growth of Inuit culture and societies for both present and future generations; to promote long-term management and protection of arctic and sub-arctic wildlife, environment and biological productivity; and to promote wise management and use of non-renewable resources in the circumpolar region and incorporating such resources in the present and future development of Inuit economies, taking into account other Inuit interests." ICC Charter. See: http://www.inuitcircumpolar.com/charter--bylaws.html
Russian Association of Indigenous Peoples of the North http://www.arctic-council.org/index.php/en/about-us/permanent-participants/russian-association-of-indigenous-peoples-of-the-north-raipon	"[We] desire that: our unique cultures, our ancestral homelands and way of life be protected by the government; our legal rights be observed and that we can participate, as equal partners, in the planning strategies for the sustainable development of the North of our country; our experience, knowledge interests and traditional approaches to the use of the environment be accounted for when decisions are made on how the lands of our ancestors shall be used." Raipon Charter. See: http://www.raipon.info/home/vii-sezd-kmnss-i-dv-rf.html
Saami Council http://www.arctic-council.org/index.php/en/about-us/permanent-participants/saami-council	"We support the sustainable development models presented by the Arctic Council, which incorporate principles of genuine partnership between States and Indigenous Peoples, ecosystem approaches, collaboration between traditional and scientific knowledge and local, national and regional implementation plans." Indigenous Peoples' Plan of Implementation on Sustainable Development, Annex to 2002 Kimberley Declaration. See: http://www.saamicouncil.net/?deptid=2163

Note: There is much diversity in aims and modes of representation among the Permanent Participants. The diverse views and interests *within* each group of Indigenous People also need to be recognized and respected, but still rarely features in high-level assessments.

TABLE A2.2.2 **Members**

	A summary of priority themes as stated in current Arctic strategy documents
Canada	• Exercising our Arctic sovereignty • Protecting our environmental heritage • Promoting social and economic development • Improving and devolving Northern governance See: http://www.northernstrategy.gc.ca/index-eng.asp
The Kingdom of Denmark (including Greenland and the Faroe Islands)	A peaceful, secure and safe Arctic • With self-sustaining growth and development • With respect for the Arctic's fragile climate, environment and nature • In close cooperation with our international partners. See: http://um.dk/en/~/media/UM/English-site/Documents/Politics-and-diplomacy/Greenland-and-The-Faroe-Islands/Arctic%20strategy.pdf
Finland	• Fragile Arctic nature: the environmental perspective must be taken into account in all activities in the region • Economic activities and know-how: Finnish know-how must be utilized and supported • Transport and infrastructure: the increasing traffic in the Arctic region requires common rules, technical aids facilitating traffic, and new infrastructure • Indigenous peoples: Finland continues to work for the rights of Indigenous Peoples • Arctic policy tools: Finland actively participates in multilateral cooperation at global and regional level • The European Union and the Arctic Region – developments in the Arctic region have important consequences for the lives of future generations in the whole of Europe. See: http://www.geopoliticsnorth.org/images/stories/attachments/Finland.pdf
Iceland	• Promote and strengthen Arctic Council • Secure Iceland's position as a coastal State within the Arctic region • Promote understanding of a broader than just geographic definition of the Arctic region, to include ecological, economic, political and security matters • Resolve differences that relate to the Arctic on the basis of the UN Convention on the Law of the Sea • Strengthen and increase cooperation with the Faroe Islands and Greenland • Support the rights of Indigenous Peoples in the Arctic • Build on agreements and promote cooperation with other States and stakeholders on issues relating to Iceland's Arctic interests • Use all available means to prevent human-induced climate change and its effects in order to improve the well-being of Arctic communities. • Safeguard security interests in the Arctic region through civilian means, working against militarization of the Arctic. • Developing further trade relations between States in the Arctic region • Advancing Icelanders' knowledge of Arctic issues and promoting Iceland abroad as a venue for Arctic discussions. • Increasing consultations and cooperation at the domestic level on Arctic issues. See: http://www.mfa.is/media/nordurlandaskrifstofa/A-Parliamentary-Resolution-on-ICE-Arctic-Policy-approved-by-Althingi.pdf
Norway	• International cooperation – strengthening Norway's position as a responsible actor and partner in the north • A knowledge-based business sector – business in the North as potential for growth • Broad-based knowledge development – research and education focusing on the north • More reliable infrastructure – safe traffic and transport • Better preparedness, safety, and environmental protection See: http://www.regjeringen.no/en/dokumenter/report_summary/id2076191

TABLE A2.2.2 **Members**

	A summary of priority themes as stated in current Arctic strategy documents
Russia	• Comprehensive socio-economic development of the Arctic Zone of the Russian Federation, including improvement of quality of life for the indigenous population and of social conditions for economic activity in the Arctic; • Development of science and technology; • Creation of an up-to-date information and telecommunication infrastructure; • Environmental safety; • Accounting for the high vulnerability of ecological systems determining Earth's biological stability and climate, and their sensitivity even to minor anthropogenic influence; • International cooperation in the Arctic. See: http://minec.gov-murman.ru/opencms/export/sites/mineconomy/content/arkticzone/Strategy.pdf and http://minec.gov-murman.ru/activities/strat_plan/arkticzone
Sweden	• Climate and the environment: climate, environmental protection, biodiversity, climate and environmental research • Economic development: free trade in the Arctic, industrial policy interests in the Barents region, economic interests in the rest of the Arctic (including natural resource extraction, land transport and infrastructure, maritime security and environmental impact of shipping, reindeer husbandry, and other activities), and educational and research needs • The human dimension: health, impacts of climate change and hazardous substances, indigenous cultures and their industries (including survival of Sámi languages, and knowledge transfer See: http://www.openaid.se/wp-content/uploads/2014/04/Swedens-Strategy-for-the-Arctic-Region.pdf
United States	• Advance United States security interests, which encompass supporting safe commercial and scientific operations to national defense • Pursue responsible Arctic region stewardship: environmental protection, resource conservation, institutionalised integrated Arctic management, increase understanding of the Arctic using scientific research and traditional knowledge • Strengthen international cooperation: bilateral and multilateral arrangements for shared prosperity, Arctic environmental protection and regional security. (See: http://www.whitehouse.gov/sites/default/files/docs/nat_arctic_strategy.pdf)

Note: There are tensions among the different stated priorities. In particular, economic and security aims have direct consequences on key social, cultural and environmental aims.

APPENDIX 2, *continued*

TABLE A2.2.3 **Non-Arctic nation observers**

	Summary of main themes in current Arctic strategies (where available)
France	• Maintain scientific observation stations, and develop multidisciplinary human/environment observatories of dynamic social-ecological change • Develop an understanding of the mechanisms, from molecule to ecosystem, by which climate variability affects biological processes • Model and predict climate system change impacts on people and environments • Inform and participate in conservation, protection, and harm-prevention measures for ecosystems, and for ethnographic, linguistic and archaeological heritage of peoples in the Arctic Prospective Recherches Polaires (2012), The National Center for Scientific Research
Germany	• Seize economic opportunities • Set exemplary environmental standards • Freedom of navigation • Freedom of scientific research • Security and stability See: http://www.auswaertiges-amt.de
The Netherlands	• The diligent implementation of existing treaties and the development of strict, binding supplementary international norms and agreements – based on the precautionary principle – for enhanced protection of the Arctic environment, and • Sustainable management of fishing, shipping and extractive industries, with a focus on compliance with international norms and the development of supplementary agreements See: http://www.nwo.nl/binaries/content/documents/nwo-en/common/documentation/application/alw/new-netherlands-polar-programme---policy-framework
Poland	No formal strategy yet, but Arctic policy priorities have been identified: • International cooperation and scientific diplomacy • Climate change and Arctic environmental protection • Socioeconomic development of the Arctic • Energy and other resources • Sea transport and shipbuilding opportunities and problems • Fisheries and their cautious management See: http://www.msz.gov.pl/en/foreign_policy/baltic/arctic/poland_in_arctic/
Spain	No formal strategy. Spain's scientific interests are articulated through the Spanish Polar Committee. See: http://www.idi.mineco.gob.es/portal/site/MICINN
United Kingdom	Working from a basis of respect for the sovereign rights of the Arctic States to exercise jurisdiction over their territory; for the views and interests of people who live and work in the Arctic and call it home; and for the environment, its fragility and its central importance to the global climate. UK priorities are to: • Work towards an Arctic that is safe and secure; well governed in conjunction with Indigenous Peoples and in line with international law • Promote an Arctic where policies are developed on the basis of sound science with full regard to the environment • Commercially, promote an Arctic where only responsible development takes place See: http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/251216/Adapting_To_Change_UK_policy_towards_the_Arctic.pdf
People's Republic of China	No formal Arctic strategy. Initiatives for scientific development and cooperation, opening free trade agreements, and "resource diplomacy" for oil, gas and minerals exploration and extraction are all rising in visibility. See, e.g., Lanteigne et al. (2014) http://ams.hi.is/wp-content/uploads/2014/11/ChinasEmergingArcticStrategiesPDF_FIX2.pdf

TABLE A2.2.3 Non-Arctic nation observers

Italy	No formal statement of Arctic strategy
Japan	Beyond scientific cooperation plans, there is no formal Arctic strategy, but a semi-official report was published in 2013 (in Japanese) See: www2.jiia.or.jp/pdf/resarch/H24_Arctic/H24_Arctic.php The report is summarised here: http://www.thearcticinstitute.org/review-arctic-governance-and-japans/ For a comparison of the Arctic policies of China and Japan, see: Tonami (2014). http://dx.doi.org/10.1080/2154896X.2014.913931
Republic of Korea	For an overview of Korea's Arctic Policy Development, see: Jong Deog Kim (2014). http://dx.doi.org/10.1080/09700161.2014.952939
Republic of Singapore	Singapore's role in the maritime and shipping sector and international marine governance, and its wider economic concerns shape an emerging Arctic policy landscape.
Republic of India	No national statement of Arctic policy. India's Arctic science strategy prioritizes: • Study of hypothesized teleconnections between Arctic climate and Indian monsoon, based on empirical field studies in the Arctic • Characterizing sea-ice using earth observation (satellite) data to estimate global warming impacts • Glacier dynamics and mass budgets, focusing on sea-level effects • Study of effects of anthropogenic activities on flora and fauna. See: http://www.maritimeindia.org/pdf/Arctic%20Perspectives.pdf
+ 20 non-governmental, intergovernmental and inter-parliamentary organization observers	

Note: "Shadow objectives" are evident in many non-Arctic state strategies: e.g. science offers a legitimate reason for physical and infrastructure presence in the region, while an overt push for an economic or geopolitical presence would be politically unacceptable.

APPENDIX 4

Comparative methods for assessing resilience across scales

This Appendix describes the methods supporting the results presented in Chapter 4. The purpose of the analysis was to compare different cases across the Arctic in order to better understand attributes or conditions enhance resilience. The theoretical background and justification of variables choices are explained in the main text of the chapter.

The main method used for the analysis is qualitative comparative analysis (QCA), a technique that identifies set-theoretic relationships of sufficiency and necessity to an outcome (Ragin 2008). For the purpose of this study, the causal conditions correspond to variables related to adaptive capacity, and the output is related to resilience, transformation, or loss of resilience, from a livelihoods perspective. This appendix summarizes the data selection, coding process and the technical aspects of the study.

Data selection and sampling

The Arctic Resilience Assessment core team organized workshops with different stakeholders, scientist and experts of different Arctic related issues. The workshops were held in Stockholm (April 2013), Helsinki (April 2014), Bodø (June 2014), Tromsø (January 2015), and Washington (June 2015). In the meetings in Stockholm and Helsinki, a data collection template was presented and co-developed, taking as starting point the original template from the Regime Shifts Database (Biggs et al. 2015).

With input of workshop participants, the template was tailored to the purpose of assessing resilience and adaptive capacity. The template was designed to capture features at the local community level and distinguished features of adaptive capacity from the social and ecological realms. The theoretical background of using components of adaptive capacity is further discussed in the main text of Chapter 4 and in the Arctic Resilience Interim Report. A copy of the final template used by data collectors is available at http://www.stockholmresilience.org/ARA/resilience-template.html.

Case studies

For the purpose of our assessment, a case study typically refers to a place-based community whose main livelihoods heavily rely on natural resources. A preliminary list of case studies was also gathered with workshop participants in Stockholm and Helsinki. Literature searches were conducted based on experts' recommendations, following a snowball sampling strategy. Students and researchers from the Stockholm Resilience Centre primarily filled templates based only on the literature available. Most cases were reviewed by an expert on the topic to ensure quality and completeness of the template. A complete list of the cases included is presented in Table 4.1 in Chapter 4.

Coding

The conceptual framework used to code the case studies was developed by Berkes et al. (2003) as a set of aspects to build adaptive capacity. However, during the workshop in Bodø (2014), it was realized that Berkes' framework was too general, inducing ambiguity on the coding and thereby limiting comparison of the cases. Thus, two coders would have give values of 1 or 0 to the same category based on different interpretations of the literature analysed. In order to increase the robustness and reproducibility of our analysis, a third tier of variables was developed, allowing coders to highlight different nuances of the initial set of variables (see Table 4.2 in Chapter 4).

Once a template had been filled out and reviewed, a coder translated it to a vector of codes that represent the components of adaptive capacity on the third tier of variables (N=76). Thus, for example, if a case study template mentioned that there is "participation of different types of knowledge in management discussions", then the variable was coded as 1; if the template reported that there was not participation of different types of knowledge in management discussions, the variable was coded as -1; and if there was no information available on the literature reviewed, the variable was coded as 0.

Figure 4.3 in Chapter 4 was produced by summing across the variables on the third tier that corresponded to the second (N=13) and first (N=4) tier variables of the original Berkes et al. framework.

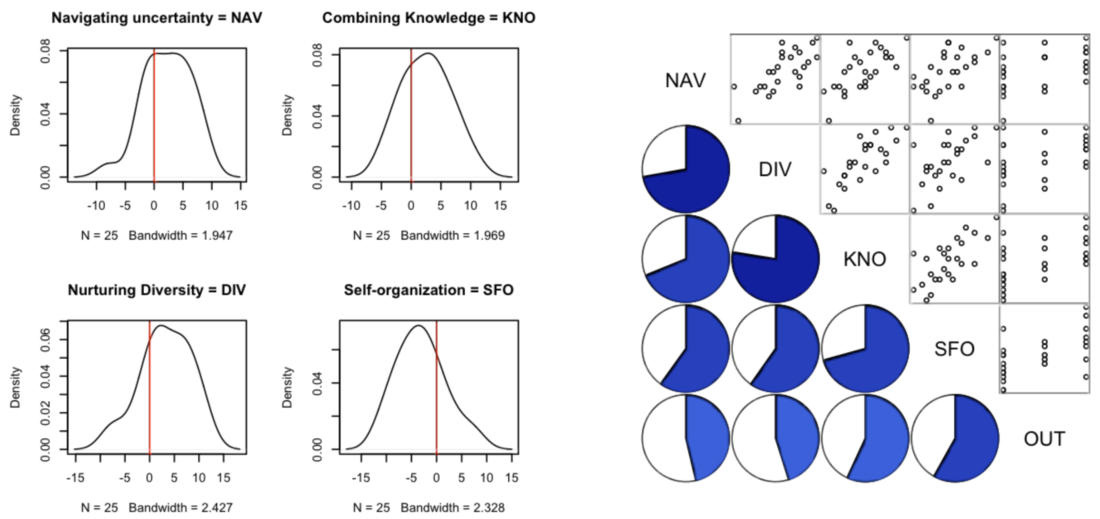
Calibration

QCA relies on Boolean algebra – that is, logical operators between sets such as OR, AND or the negated set. To determine if a case belongs to a set, first the raw data require calibration. In QCA the calibration process denotes the degree of membership of a specified set (Ragin 2008). Figure 1 shows the probability distribution of the first tier of variables: Navigating uncertainty (NAV), combining knowledge (KNO), nurturing diversity (DIV), and self-organization (SFO). Calibration requires the specification of qualitative break points that denote i) full membership, ii) full non-membership or exclusion, and iii) maximum ambiguity.

APPENDIX 4, *continued*

FIGURE A–4.1 Probability distribution of the first-tier variables

(right): Zero values represent maximum ambiguity. Correlation between first-tier variables (left) and outputs coded as resilience = 1, transformations = 0.5 and loss of resilience = 0. Cases with higher scores on all components of adaptive capacity have higher resilience.



Given our coding process, maximum ambiguity is obtained if the aggregated first- or second-tier variables have a value of zero. If the score is positive, it means that there are more variables on the third tier with positive values (presence) than negative; and if the score is negative, it means that there are more variables on the third tier with negative values (absence) than positive. Following this intuition, our calibration thresholds were -0.5 for negative values, 0 for maximum ambiguity, and +0.5 for positive values.

The Boolean minimization algorithm that QCA uses also requires defining the minimal sufficiency inclusion score for a configuration to be coded as true (belonging to a set = 1), which in our case was set as 0.75 as suggested by Ragin (2009). The inclusion cut-off for the coverage was set as 0.5. With these parameters, the analysis of necessity and sufficient conditions was performed (Figures 4.4 and 4.5 in Chapter 4). The analysis was performed in R (R Core Team 2012) with support of the QCA library (Thiem and Dusa 2012).

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